MUDDY RUN STREAM RESTORATION PROJECT
MONITORING REPORT
MONITORING YEAR 4
FINAL

DUPLIN COUNTY, NORTH CAROLINA
PROJECT NO. 95018

Prepared for:

Division of Mitigation Services

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RE: Muddy Run Stream Restoration Site: MY4 Monitoring Report (NCDMS ID 95018)

Listed below are comments provided by DMS on January 17, 2018 regarding the Muddy Run Stream Restoration Site: Year 4 Monitoring Report and RES' responses.

At the 2016 IRT credit release, this project was released as proposed. Be prepared to know and explain any changes in stream credit/footage from as built to mitigation plan. It is suggested that RES provide a brief explanation of any changes as a footnote to the credit table.
Reach 2 was shortened due to landowner negotiations. This has been added as a footnote to Table 1.

For this project, it appears you may need to update your BHR and your ER. ER and BHR does not need to be reported for pools. Cross sections / cross section tables – A couple of methods are currently being utilized to calculate the BHR from year to year. To compare subsequent monitoring years to the As-built condition one can hold the bankfull depth static (denominator) while allowing the Low TOB max depth (numerator) to vary. Another method that has been proposed and is being evaluated is to hold the As-built cross-sectional area static within each years' new cross section and allow that to determine the max bankfull depth for each year. However, if there are large changes in the W/D ratio either method can make for somewhat distorted BHR values depending upon the direction and magnitude of the change in the W/D ratio. Please update calculations to reflect changes observed in the overlays and explain in detail as a table footnote how the calculations were made. Be prepared to defend the method used for credit release and justify through context if any changes observed in a cross section represent an issue.
BHR was calculated on riffles using the baseline bankfull elevation. This method was used because the dimension of the channels has not changed enough to alter the bankfull elevation. None of the riffle cross sections exceeded a 1.2 BHR. This has been added to the report and as a footnote to Table 11.

Stream credit shapefile. The shapefile that DMS has for stream credit doesn't match the lengths shown in the report. Please provide the correct shapefile for the stream asset (divided by reach). This should match credit (within reason) and not include areas of road breaks. Reach 1A is missing from CCPV. Is this valley length credit? Please update to show.
The correct shapefile has been used on CCPV figures and included in the Support Files. The lengths are within reason of the credit and do not include road breaks.

Page 6, please state what monitoring guidance was used for this project (i.e. 2003 IRT stream mitigation guidelines). The report is not specific.
The monitoring guidance used for this project was a combination of the 2003 IRT Stream Mitigation Guidelines and the EEP Monitoring Requirements and Performance Standards Guidance for Stream and-or Wetland Mitigation (11/07/2011). This was approved by the DMS Project Manager and the IRT. This has been added to the report.

Table 13. Are these all the bankfull events or just 2017? It may be helpful to show number by year for your 5 year close out.
These were the bankfull events for just 2017. The table has been redone to show bankfull events from each year.

Muddy Run
Duplin County, North Carolina
DMS Project ID 95018

Cape Fear River Basin
HUC 03030007060010

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EXECUTIVE SUMMARY

The Muddy Run Stream Restoration Project is located within an agricultural watershed in Duplin County, North Carolina, approximately six miles south of Beulaville. The stream channels were heavily impacted by channelization and agricultural practices. The project involved the restoration and protection of streams in the Muddy Creek watershed. The purpose of this restoration project was to restore and enhance a stream/wetland complex located within the Cape Fear River Basin.

The project lies within USGS Hydrologic Unit Code 03030007060010 (USGS, 1998) and within the North Carolina Division of Water Quality (NCDWQ) Cape Fear River Subbasin 03-06-22 (NCDENR, 2002). The project consists of three unnamed tributaries to Muddy Creek, but the project has been divided into five distinct reaches for design purposes. Reach 1A is the upstream-most portion of Reach 1; it begins approximately 50 feet below an agricultural road crossing, and extends to STA17+25. Reach 1B is the middle reach of the main stem; it begins at STA17+25, and runs through a clear-cut area to STA33+67. Reach 1C is the downstream section of Reach 1; it begins at a culvert crossing (STA33+67) and flows westward to STA47+08. Reach 2 starts on the south side of eight hog houses and flows northwest around two hog lagoons before entering Reach 1C. Reach 3 runs north to south, and flows directly into Reach 1C.

The Muddy Run II Mitigation Project is located upstream of Reach 3 and downstream of Reach 1C. Muddy Run II also includes riparian wetland restoration areas directly adjacent to the Muddy Run Easement on Reach 1B, Reach 1C, Reach 2, and Reach 3. Muddy Run II was constructed immediately following Muddy Run.

This Year 4 Annual Monitoring Report presents the data from 20 vegetation monitoring plots, four manual crest gauges, four auto crest gauges, an auto-logging rain gauge, 39 stream cross sections, 10 sets of bank pins, and photo reference locations, as required by the approved Mitigation Plan for the site.

The Year 4 vegetation monitoring observations for Muddy Run Site are summarized in this report. Planted-stem survival for Monitoring Year 4 for all 20 Vegetation Plots (VP) at Muddy Run was well above the interim success criterion of 260 trees per acre at the end of Monitoring Year 4. The average stem density (excluding live stakes) across all vegetation plots was 653 stems per acre. Invasive Chinese privet (*Ligustrum sinense*) was observed along a small portion of Reach 1B in previous monitoring years. Invasive treatment was performed in this area during July 2017. This area will continue to be monitored for invasive species. The Muddy Run Site has met the Year 4 vegetation survival success criterion of 260 trees per acre as specified in the Mitigation Plan.

During the Year 4 monitoring season, the restored stream channel remained stable and continued to provide the intended habitat and hydrologic functions. All monitored cross sections show little adjustment in stream dimension, and the site remains on track to achieve the stream stability success criteria specified in the Mitigation Plan. Monitoring Year 4 activities confirmed the stream reaches are stable and the banks are well vegetated. There was one stream area of concern noted during the MY4 activities. The site is performing as planned and is on track to meeting the stream success criteria.

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1 PROJECT GOALS, BACKGROUND AND ATTRIBUTES

1.1 Location and Setting

The Muddy Run Stream Site ("Site") is located in Duplin County approximately 1.4 miles east of Chinquapin, NC (Figure 1). The project is in the Cape Fear River Basin (8-digit USGS HUC 03030007, 14-digit USGS HUC 03030007060010) (USGS, 1998) and the NCDWQ Cape Fear 03-06-22 sub-basin (NCDWQ, 2002). To access the Site from the town of Chinquapin, travel east on Highway 50, take the first left onto Pickett Bay Road (SR 1819), go 1.1 miles, then turn left onto Kenney Crawley Road. This private road is gravel and will split just past the residential house on the right. Keeping to the left will take you to the downstream portion of Reach 1 and Reaches 2 and 3. Going to the right at the split will take you to the upstream limits of Reach 1 at the Headwater Valley restoration portion.

1.2 Project Goals and Objectives

The Muddy Run stream mitigation project will provide numerous ecological and water quality benefits within the Cape Fear River Basin. While many of these benefits are limited to the project area, others, such as pollutant removal and improved aquatic and terrestrial habitat, have more far-reaching effects. Expected improvements to water quality, hydrology, and habitat are outlined below.

Design Goals and Objectives

Benefits Related to Water Quality	
Nutrient removal	Benefit will be achieved through filtering of runoff from adjacent CAFOs through buffer areas, the conversion of active farm fields to forested buffers, improved denitrification and nutrient uptake through buffer zones, and installation of BMPs at the headwaters of selected reaches and ditch outlets.
Sediment removal	Benefit will be achieved through the stabilization of eroding stream banks and reduction of sediment loss from field areas due to lack of vegetative cover. Channel velocities will also be decreased through a reduction in slope, therefore decreasing erosive forces.
Increase dissolved oxygen concentration	Benefit will be achieved through the construction of instream structures to increase turbulence and dissolved oxygen concentrations and riparian canopy restoration to lower water temperature to increase dissolved oxygen capacity.
Runoff filtration	Benefit will be achieved through the restoration of buffer areas that will receive and filter runoff, thereby reducing nutrients and sediment concentrations reaching water bodies downstream.
Benefits to Flood Attenuation	
Water storage	Benefit will be achieved through the restoration of buffer areas which will infiltrate more water during precipitation events than under current site conditions.
Improved groundwater recharge	Benefit will be achieved through the increased storage of precipitation in buffer areas, ephemeral depressions, and reconnection of existing floodplain. Greater storage of water will lead to improved infiltration and groundwater recharge.
Improved/restored hydrologic connections	Benefit will be achieved by restoring the stream to a natural meandering pattern with an appropriately sized channel, such that the channel's floodplain will be flooded more frequently at flows greater than the bankfull stage.
Benefits Related to Ecological Processes	
Restoration of habitats	Benefit will be achieved by restoring riparian buffer habitat to appropriate bottomland hardwood ecosystem.
Improved substrate and instream cover	Benefit will be achieved through the construction of instream structures designed to improve bedform diversity and to trap detritus. Stream will be designed with the appropriate channel dimension and will prevent aggradation and sedimentation within the channel. Substrate will become coarser as a result of the stabilization of stream banks and an overall decrease in the amount fine materials deposited in the stream.

Addition of large woody debris	Benefit will be achieved through the addition of wood structures as part of the restoration design. Such structures may include log vanes, root wads, and log weirs.
Reduced temperature of water due to shading	Benefit will be achieved through the restoration of canopy tree species to the stream buffer areas.
Restoration of terrestrial habitat	Benefit will be achieved through the restoration of riparian buffer bottomland hardwood habitats.

1.3 Project Structure

Table 1. Muddy Run Project Components

Reach	Mitigation Type	Proposed Stationing	Existing Length (LF)	As-Built Length (LF)	Mitigation Ratio	SMUs
Reach 1A	Headwater Valley	0+66 to 17+87	1,659	1,691	1:1	1,691
Reach 1B	P1 Restoration	17+87 to 33+98	1,597	1,581	1:1	1,581
Reach 1C	P1 Restoration	33+98 to 47+73	1,317	1,345	1:1	1,330
Reach 2	P1 Restoration	2+00 to 17+10	1,448	1,510	1:1	1,493
Reach 3	P1 Restoration	0+94 to 7+01	464	607	1:1	607
		Total	**6,485**	**6,734**		**6,702**

*As-Built length does not include channel in easement breaks.
** SMUs does not include channel in irrigation access areas inside easement.

1.3.1 Restoration Type and Approach

Reach 1A

The principal drainage feature (Reach 1) generally flows northwest to west across the site. It was divided into three reaches (Reach 1A, Reach 1B, and Reach 1C) based on slope, drainage area, and surrounding landscape. Reach 1A flows in a northerly direction adjacent to several hog houses and two large lagoons. The planform of this G-type channel is generally straight and is deeply incised throughout. No large woody debris was observed in the channel. A maintained access path built upon spoil material runs along the channel bank. The channel scored 24 points on the NCDWQ Stream Identification Form (Version 4.11). The natural drainage of this channel was bypassed through a deep, excavated ditch through uplands that connects to Reach 2.

Headwater valley restoration was performed along Reach 1A and continued down to Reach 1B. The existing channel adjacent to the hog houses was backfilled to the extent possible such that cut and fill was balanced along the reach. The existing 18-inch corrugated plastic pipe located under the gravel road was removed and replaced with three 12-inch CMPs at a slightly higher elevation. A sediment trapping pool and level spreader BMP immediately downstream of the road crossing was constructed to provide diffuse flow into the valley and collect sediment from the farm access road. The BMP is located outside the conservation easement to allow for maintenance. The reach was not completely filled so as to prevent hydrologic trespass upstream of the road. Grade control structures were placed along portions of the reach that was filled to provide additional vertical stability. During construction, a drain tile was encountered near STA 7+10. The portion of the tile located within the easement was removed, and a subsurface flow structure was installed.

A forested buffer approximately 115 feet wide was planted throughout this reach. Where the channel was redirected towards Reach 2 near STA 11+31, a channel plug was constructed, and flow has been redirected back in a northerly direction. A channel plug and grade control structure has also been installed where an existing ditch enters the buffer from the east. Flow was directed along the reach such that it follows along the natural valley from STA 11+31 down to Reach 1B. An existing 30-inch CMP culvert located at STA 11+12 has been removed and replaced with three 12-inch CMPs to allow the landowner access to all areas of his property, as the restoration will bisect his land. The terminus of the

headwater valley at STA 17+25 includes a grade control structure at the transition to a stable channel for Reach 1B.

Reach 1B
The middle section (Reach 1B) of this reach was mostly excavated through a forested area. The surrounding riparian forest contains jurisdictional wetlands that are adjacent to Reach 1B. This channel had been dredged to nearly four feet in depth. A farm road that is elevated 0.85 feet above the flood plain was located along the right bank. The planform of this F-type channel was generally straight with occasional bends. The channel was entrenched throughout. The banks were nearly vertical in many locations and had almost no vegetation. No large woody debris was observed in the channel. The channel scored 29 points on the NCDWQ Stream Identification Form (Version 4.11).

Priority Level I restoration was constructed on Reach 1B. For the majority of the reach, the channel has been rerouted to the south of its current location. Relocating the channel did not impact any forested areas because most of the buffer was clear cut in the fall of 2011. However, there is a small, wooded area along the upstream portion of the reach. The restored channel from STA 17+25 to 20+78 meanders along the existing channel footprint in order to minimize impacts to the established buffer to the south. The elevated road bed along the north side of the existing channel has been removed in order to maintain a continuous connection between the proposed channel and its floodplain. A channel plug and grade control structure was installed where an existing ditch entered the buffer from the north near STA 18+08. An existing 42-inch CMP culvert crossing was removed and replaced with two 36-inch CMPs at STA 20+93 to maintain access to all portions of the landowner's property. The downstream section of Reach 1B has been relocated to avoid impacts to two existing wetland areas adjacent to the channel. There are two existing ditches within the proposed easement that cross the wetland to the south. These ditches have been plugged to provide diffuse flow through the wetland and into the restored channel. Structures installed along Reach 1B included log grade controls, root wads, and various woody debris structures to enrich habitat and ensure bank stability and channel integrity.

Reach 1C
The downstream section of Reach 1 (Reach 1C) is located within a cleared hay field. This reach appeared to have been straightened and had been dredged. A farm road that is elevated 0.5 to 1.1 feet above bankfull is located along the right bank. Reach 1C was an F-type channel with a planform that was generally straight with a few minor bends throughout. The entire reach was moderately to severely incised with steep banks due to repeated dredging by the landowner. The dominant bed materials were fine sand and silt. The banks were nearly vertical with sparse vegetation. The channel scored 33 points on the NCDWQ Stream Identification Form (Version 4.11).

Priority Level I restoration was performed on Reach 1C. The restoration approach on this reach included relocating the channel to the north of its current location within the adjacent agricultural field. The relocation also included moving the confluence with Reach 2 to STA 45+27. The existing channel was plugged and filled to prevent continued flow within the ditch. An existing 36-inch CMP culvert crossing located at the upstream end of the reach has been removed and relocated to STA 33+67. Twin 42-inch culverts were placed in-line with the restored stream to maintain access to all portions of the landowner's property.

By rerouting and raising the channel, the restoration will allow the channel frequent access to its floodplain and the opportunity for creating small depressional areas within the buffer to enhance habitat for wildlife and aquatic organisms. Structures along this reach will included log grade controls, root wads, leaf packs, and various woody debris structures that will improve in-stream habitat and bank stability.

The downstream end of Reach 1C terminates at a temporary grade drop structure. The restoration will be continued in a subsequent phase of the project, Muddy Run II.

Reach 2

Flowing into Reach 1C are two smaller tributary reaches (Reach 2 and Reach 3). Reach 2 begins south of Reach 1C at a wetland, and follows a shallow drainage feature to the confluence with Reach 1C. It receives flow through a ditch from Reach 1A. This F-type channel was actively maintained and had been dredged to nearly four feet in depth. The banks were nearly vertical in many locations and had almost no vegetation. No large woody debris was observed in the channel. The channel scored 26.5 points on the NCDWQ Stream Identification Form (Version 4.11).

Priority Level I restoration was performed on Reach 2. The bed elevation at the top of the reach is controlled by a 42-inch CMP culvert. This culvert and the associated farm road were moved approximately 100 feet upstream of its current location. The culvert has been replaced with a 36-inch CMP to maintain access to the adjacent hog houses and lagoons located just north of the upstream end of the reach. The channel now flows in a northwesterly direction to the confluence with Reach 1C.

The majority of the channel has been relocated north and east of the existing ditch towards the lagoons. The lower end meanders through a large spoil area constructed during installation of the lagoons. This area was graded down to match pre-disturbance elevations, and the cut material was used to fill abandoned ditches throughout the project. The restored stream channel can now access its floodplain regularly. Typical in-stream structures along this reach included log grade controls, root wads, leaf packs, and various woody debris structures that will improve habitat and bank stability. All areas within the easement have been planted with native shrub and tree species.

Reach 3

Reach 3, an F-type stream channel, began north of Reach 1C at a wetland ditch and followed a shallow drainage feature to Reach 1C. A hay field is located on the east side, and a scrub community lies to the west. This channel had been dredged and the dominant bed material is fine sand. The banks were nearly vertical in many locations and had almost no vegetation. No large woody debris was observed in the channel. The channel scored 24.5 points on the NCDWQ Stream Identification Form (Version 4.11).

Priority Level I restoration was performed on Reach 3. Its bed elevation was controlled at the top of the reach by a 24-inch CMP culvert. This culvert was removed and replaced with two 42-inch CMPs at a higher elevation to maintain access across the property. The culvert was raised a minimal amount to prevent hydrologic trespass upstream of the project. Restoration began just south of the culvert crossing, and involved relocating the channel to the east of the existing ditch into the adjacent spray field. The reach has been reconnected with the primary channel (Reach 1) approximately 146 feet downstream of the confluence with Reach 1C at STA 5+72. A temporary log ramp has been installed at the downstream end to tie the restored channel into the existing ditch. This structure will be removed when the Muddy Run II Mitigation Project is constructed.

By relocating the channel, the restoration will allow the channel regular access to its floodplain and the opportunity for enhanced wetland habitat throughout the buffer. In-stream structures along this reach included log grade controls, root wads, leaf packs, and various woody debris structures that will provide bed diversity and subsequently improve habitat and bank stability. All areas within the easement were planted with native shrub and tree species.

Reach 3 was designed to reflect a proposed drainage area of 391 acres as opposed to the existing area of 85 acres. This significant increase in watershed size incorporates a drainage area that borders Reach

3 to the north and east, which currently directs flows away from the project site. It appears that the drainage features within this additional area were historically diverted north across a natural divide to promote drainage for agricultural production. The proposed Muddy Run II Stream and Wetland Mitigation Project reconnects this drainage to the Muddy Run project site.

1.4 Project History, Contacts and Attribute Data

1.4.1 Project History

The Site was restored by Resource Environmental Solutions, LLC (RES) through a full-delivery contract awarded by NCDMS in 2011. Tables 2, 3, and 4 in **Appendix A** provide a time sequence and information pertaining to the project activities, history, contacts, and baseline information.

1.4.2 Project Watersheds

The easement totals 19.1 acres and is broken into five reaches. Reach 1A has a drainage area of 0.23 square miles (145 acres); it begins at the start of the restoration project (Sta. 0+62) and extends north and west to Sta.17+25. Reach 1B has a drainage area of 0.28 square miles (177 acres); it begins at Sta.17+25 and extends to Sta. 33+67. Reach 1C is the downstream section (Sta. 33+67 to 47+08) of Reach 1 and has a drainage area of 0.37 square miles (238 acres). Reach 2 has a drainage area of 0.1 square miles (60 acres) and flows northwest directly into Reach 1. Reach 3 has a drainage area of 0.13 square miles (85 acres) extending north to south (**Figure 2**). The land use in the project watershed is approximately 49 percent cultivated, 33 percent southern yellow pine, 9 percent bottomland forest/hardwood swamp, 7 percent wooded and shrubland, and 2 percent managed herbaceous cover.

2 Success Criteria

The success criteria for the Site stream restoration was assembled from a combination of the 2003 IRT Stream Mitigation Guidelines and the EEP Monitoring Requirements and Performance Standards Guidance for Stream and-or Wetland Mitigation (11/07/2011). Specific success criteria components are presented below.

2.1 Stream Restoration

2.1.1 Bankfull Events

Two bankfull flow events must be documented within the five-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. Bankfull events will be documented using crest gauges, auto-logging crest gauges, photographs, and visual assessments for evidence of debris rack lines.

2.1.2 Cross Sections

There should be little change in as-built cross-sections. If changes do take place, they should be evaluated to determine if they represent a movement toward a less stable condition (for example down-cutting or erosion), or are minor changes that represent an increase in stability (for example settling, vegetative changes, deposition along the banks, or decrease in width/depth ratio). Cross-sections are classified using the Rosgen stream classification method, and all monitored cross-sections should fall within the quantitative parameters defined for channels of the design stream type.

2.1.3 Digital Image Stations

Digital images are used to subjectively evaluate channel aggradation or degradation, bank erosion,

success of riparian vegetation, and effectiveness of erosion control measures. Longitudinal images should not indicate the absence of developing bars within the channel or an excessive increase in channel depth. Lateral images should not indicate excessive erosion or continuing degradation of the banks over time. A series of images over time should indicate successional maturation of riparian vegetation.

2.2 Vegetation

Specific and measurable success criteria for plant density within the riparian buffers on the site will follow NCDMS Guidance. Vegetation monitoring plots are 0.02 acres in size, and cover greater than two percent of the planted area. Vegetation monitoring will occur annually in the fall of each year. The interim measures of vegetative success for the site will be the survival of at least 320 three-year-old trees per acre at the end of Year 3, and the final vegetative success criteria will be 260 trees per acre at the end of Year 5. Invasive species on the site will be monitored and controlled if necessary throughout the required vegetation monitoring period.

2.3 Scheduling/Reporting

The monitoring program will be implemented to document system development and progress toward achieving the success criteria. The restored stream morphology is assessed to determine the success of the mitigation. The monitoring program will be undertaken for five years or until the final success criteria are achieved, whichever is longer.

Monitoring reports will be prepared in the fall of each year of monitoring and submitted to NCDMS. The monitoring reports will include all information, and be in the format required by NCDMS in Version 2.0 of the NCDMS Monitoring Report Template (Oct. 2010).

3 MONITORING PLAN

Annual monitoring data will be reported using the DMS monitoring template. Annual monitoring shall be conducted for stream and vegetation monitoring parameters as noted below.

3.1 Stream Restoration

3.1.1 As-Built Survey

An as-built survey was conducted following construction to document channel size, condition, and location. The survey will include a complete profile of thalweg, water surface, bankfull, and top of bank to compare with future geomorphic data. Longitudinal profiles will not be required in annual monitoring reports unless requested by NCDMS or USACE.

3.1.2 Bankfull Events

Four sets of manual and auto-logging crest gauges were installed on the site, one along Reach 1A, one along Reach 1C, one along Reach 2, and one along Reach 3. The auto logging crest gauges were installed within the channel and will continuously record flow conditions at an hourly interval. Manual crest gauges were installed on the bank at bankfull elevation. Crest gauges will be checked during each site visit to determine if a bankfull event has occurred since the last site visit. Crest gauge readings and debris rack lines will be photographed to document evidence of bankfull events.

3.1.3 Cross Sections

A total of 39 permanent cross sections were installed to monitor channel dimensions and stability. Five cross sections were installed along Reach 1A of the headwater valley restoration section. Ten cross

sections (five pools and five shallows) were installed along Reach 1B and four pool and four shallow cross sections were installed along Reach 1C. Reach 2 has a total of 14 cross sections installed throughout its length. Two permanent cross sections were installed along Reach 3. Cross sections were typically located at representative shallow and pool sections along each stream reach. Each cross section was permanently marked with 3/8 rebar pin to establish a monument location at each end. A marker pole was also installed at both ends of each cross section to allow ease locating during monitoring activities. Cross section surveys will be performed once a year during annual monitoring and will include all breaks in slope including top of bank, bottom of bank, streambed, edge of water, and thalweg.

3.1.4 Digital Image Stations

Digital photographs will be taken at least once a year to visually document stream and vegetation conditions. This monitoring practice will continue for five years following construction and planting. Permanent photo point locations at cross sections and vegetation plots have been established so that the same directional view and location may be repeated each monitoring year. Monitoring photographs will also be used to document any stream and vegetation problematic areas such as erosion, stream and bank instability, easement encroachment and vegetation damage.

3.1.5 Bank Pin Arrays

Ten bank pin arrays have been installed at cross sections located on meander pools. These bank pin arrays were installed along the upstream and downstream third of the meander. Bank pins are a minimum of three feet long, and have been installed just above the water surface and every two feet above the lowest pin. Bank pin exposure will be recorded at each monitoring event, and the exposed pin will be driven flush with the bank.

3.1.6 Visual Assessment Monitoring

Visual monitoring of all mitigation areas will be conducted a minimum of twice per monitoring year by qualified individuals. The visual assessments will include vegetation density, vigor, invasive species, and easement encroachments. Visual assessments of stream stability will include a complete stream walk and structure inspection. Digital images will be taken at fixed representative locations to record each monitoring event as well as any noted problem areas or areas of concern. Results of visual monitoring will be presented in a plan view exhibit with a brief description of problem areas and digital images. Photographs will be used to subjectively evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation, and effectiveness of erosion control measures. Longitudinal photos should indicate the absence of developing bars within the channel or an excessive increase in channel depth. Lateral photos should not indicate excessive erosion or continuing degradation of the banks over time. A series of photos over time should indicate successional maturation of riparian vegetation.

3.1.7 Surface Flow

Headwater valley restoration areas will be monitored to document intermittent or seasonal surface flow. This will be accomplished through direct observation, photo documentation of dye tests, and stage recorders. An auto logging stage recorder and crest gauge has been installed within the headwater valley channel and will record stage conditions at hourly intervals. Stage data will be used to determine duration of valley flow. This gauge will be downloaded during each site visit to determine if intermittent or seasonal flow conditions are present.

3.2 Vegetation

A total of 20 vegetation plots were randomly established within the planted stream riparian buffer easement. Each vegetation plot measures 22 feet by 40 feet (0.02 acres) and has all four corners marked with PVC posts. Planted woody vegetation was assessed within each plot to establish a baseline dataset. Within each vegetation plot, each planted stem was identified for species, "X" and "Y" origin located, and measured for height. Reference digital photographs were also captured to document baseline conditions. Species composition, density, growth patterns, damaged stems, and survival ratios will be measured and reported on an annual basis. Vegetation plot data will be reported for each plot as well as an overall site average.

4 MAINTENANCE AND CONTINGENCY PLAN

All identified problematic areas or areas of concern such as stream bank erosion/instability, aggradation/degradation, lack of targeted vegetation, and invasive/exotic species which prevent the site from meeting performance success criteria will be evaluated on a case by case basis. These areas will be documented and remedial actions will be discussed amongst NCDMS staff to determine a plan of action. If it is determined remedial action is required, a plan will be provided.

4.1 Stream

One stream problem was identified during the Year 4 monitoring period and is mapped on the Current Conditions Plan View (CCPV), specifically Figure 3c. The problem was noted at the end of Reach 1C near VP13. This area has had some minor bed and bank erosion. The live stakes are taking and beginning to stabilize the problem. RES plans to continue to monitor this area to ensure it does not get worse.

4.2 Vegetation

Two vegetation problem areas were identified during the Year 4 monitoring period. These vegetation problem areas are mapped on the Current Conditions Plan View (CCPV) as part of the annual monitoring report. The first vegetation problem area (VPA1) consists an area of encroachment on Reach 1B. This problem area is approximately 0.05 acres. The other vegetation problem (VPA2) is a low stem density area that is approximately 0.11 acres on Reach 1C near VP9. This low stem density in this area is due to treatment of Chinese privet that adversely affected the planted trees in this area. RES plans to replant this area with 1-gallon containerized seedlings and will continue to monitor the success.

5 YEAR 4 MONITORING CONDITIONS (MY4)

The Muddy Run Year 4 Monitoring activities were completed in July and November 2017. All Year 4 monitoring data is present below and in the appendices. Data presented shows the site has one stream problem area and two vegetation problem areas; however, the site is on track to meeting stream and vegetation interim success criteria.

5.1 Year 4 Monitoring Data Collection

5.1.1 Morphological State of the Channel

All morphological stream data for the Year 4 survey and dimensions were collected during the annual monitoring survey performed during July 2017. Appendix D includes summary data tables, morphological parameters, and cross section plots.

Profile
The baseline (MY-0) profiles closely matches the proposed design profiles. The plotted longitudinal profiles can be found on the As-Built Drawings. Longitudinal profiles will not be performed in annual monitoring reports unless requested by NCDMS or USACE. Morphological summary data tables can be found in **Appendix D**.

Dimension
The Year 4 (MY-4) cross sectional dimensions closely matches the baseline cross section parameters. Minimal changes were noticed for most Year 4 cross section surveys resulting from stable bed and bank conditions. BHR was calculated on riffles using the baseline bankfull elevation. This method was used because the dimension of the channels has not changed enough to alter the bankfull elevation. None of the riffle cross sections exceeded a 1.2 BHR. All cross section plots and data tables can be found in **Appendix D**.

Sediment Transport
The Year 4 conditions show that shear stress and velocities have been reduced for all three restoration reaches. Pre-construction conditions documented all three reaches as sand bed channels and remain classified as sand bed channels post-construction. Visual assessments (**Appendix B**) show the channels are transporting sediment as designed and will continue to be monitored for aggradation and degradation.

Bank Pin Arrays
Ten bank pin arrays were observed and measured for bank erosion located on the outside meander bends. If bank pin exposure was noticeable, it was measured, recorded, photographed, and then driven flush with the bank at each monitoring location. No bank pin arrays recorded any exposure during the Year 4 monitoring season. Bank pin array data tables can be found in **Table 12, Appendix D**.

5.1.2 Vegetation

The Year 4 monitoring (MY-4) vegetation survey was completed in late October 2017 and resulted in an average of 653 planted stems per acre, well above the interim survival density of 260 stems per acre at the end of Year 4 monitoring. The average stems per vegetation plot was 13 planted stems. The minimum planted stem per plot was 9 stems and the maximum was 20 stems per plot. Sweetgum (*Liquidambar styraciflua*), Loblolly Pine (*Pinus taeda*), Bradford Callery Pear (*Pyrus calleryana*), Persimmon (*Diospyros virginiana*), and Red Maple (*Acer rubrum*) were noted during MY4 activities. Vegetation summary data tables and plot photos can be found in **Appendix C**.

5.1.3 Photo Documentation

Permanent photo point locations have been established at cross sections, and vegetation plots by RES staff. Any additional problem areas or areas of concern will also be documented with a digital photograph during monitoring activities. Stream digital photographs can be found in **Appendix B** and **Appendix C** for vegetation photos.

5.1.4 Stream Hydrology

Four sets of manual and auto-logging crest gauges were installed on the site, one along Reach 1A, one along Reach 1C, one along Reach 2, and one along Reach 3. The auto logging crest gauges were installed within the channel and continuously record flow conditions at hourly intervals. Three crest gauges documented bankfull events during the Year 4 monitoring period. Crest gauge 2, which is located on Reach 1C, documented 18 out of bank events during MY4 with the highest reading of 1.3 feet. Crest gauge 3 (Reach 2) logged 14 bankfull events during monitoring year 4 with a reading with

the highest reading of 1.27 feet. Crest gauge 4 (Reach 3) logged 12 bankfull events during monitoring year 4 with a reading with the highest reading of 2.05 feet. Crest gauge 1 is installed on Reach 1A where headwater valley restoration was performed and documented 53 days of consecutive flow. This stream reach flowed for a total of 197 days during the monitoring Year 4 period. Crest gauge summary data and photo documentation of the bankfull events can be found in **Appendix E**.

6 REFERENCES

Chow, Ven Te. 1959. Open-Channel Hydraulics, McGraw-Hill, New York.

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, Office of Biological Services, FWS/OBS-79/31. U.S. Department of the Interior, Washington, DC.
Environmental Banc & Exchange (2012). Muddy Run Stream Restoration Project Final Mitigation Plan. North Carolina Ecosystems Enhancement Program, Raleigh, NC.

Horton, J. Wright Jr. and Victor A. Zullo. 1991. The Geology of the Carolinas, Carolina Geological Society Fiftieth Anniversary Volume. The University of Tennessee Press. Knoxville, TN.

Johnson PA. 2006. Assessing stream channel stability at bridges in physiographic regions. U.S. Department of Transportation. Federal Highway Administration. Report Number FHWA-HRT-05-072.

Krstolic, J.L., and Chaplin, J.J. 2007. Bankfull regional curves for streams in the non-urban, non-tidal Coastal Plain Physiographic Province, Virginia and Maryland: U.S. Geological Survey Scientific Investigations Report 2007-5162, 48 p.

LeGrand, H.E., Jr. and S.P. Hall, eds. 1999. Natural Heritage Program List of the Rare Animal Species of North Carolina. North Carolina Natural Heritage Program, Division of Parks and Recreation, North Carolina Department of Environment and Natural Resources. Raleigh, North Carolina.

Natural Resources Conservation Service (NRCS). 2007. Stream Restoration Design Handbook (NEH 654), USDA

NCDENR. “Water Quality Stream Classifications for Streams in North Carolina.” Water Quality Section. http://h2o.enr.state.nc.us/wqhome/html (June 2005).

Radford, A.E., H.E. Ahles and F.R. Bell. 1968. Manual of the Vascular Flora of the Carolinas. The University of North Carolina Press, Chapel Hill, North Carolina.

Schafale, M.P. and A.S. Weakley. 1990. Classification of the Natural Communities of North Carolina, Third Approximation. North Carolina Natural Heritage Program, Division of Parks and Recreation, NCDENR, Raleigh, NC.

Sweet, William V. and Jens W. Geratz. 2003. Bankfull Hydraulic Geometry Relationships and Recurrence Intervals for North Carolina’s Coastal Plain. J. of the American Water Resources Association (JAWRA) 39(4):861-871.

Tweedy, K. A Methodology for Predicting Channel Form in Coastal Plain Headwater Systems. Stream Restoration in the Southeast: Advancing the Science and Practice, November 2008, Asheville, NC. Unpublished Conference Paper, 2008.
http://www.bae.ncsu.edu/programs/extension/wqg/srp/2008conference/tweedy_paper.pdf

Appendix A

Project Background Data and Maps

Appendix A. General Tables and Figures
Table 1 Project Components and Mitigation Credits
Monitoring Report Year 4

Table 1. Project Components and Mitigation Credits
Muddy Run Stream Restoration/NCDMS Project # 95018

Mitigation Credits

	Stream		Riparian Wetland		Non-riparian Wetland		Buffer	Nitrogen Nutrient Offset	Phosphorous Nutrient Offset
Type	R	RE	R	RE	R	RE			
Totals	6,702		N/A	N/A	N/A	N/A	N/A	N/A	N/A

Project Components

Project Component -or- Reach ID	As-Built Stationing/Location (LF)	Existing Footage/Acreage	Approach (PI, PII etc.)	Restoration -or- Restoration Equivalent	Restoration Footage or Acreage	Mitigation Ratio
Reach 1A	0+66 to 17+87	1,659	HWV	Restoration	1,691	1 : 1
Reach 1B	17+87 to 33+98	1,597	P1	Restoration	1,581	1 : 1
Reach 1C	33+98 to 47+73	1,317	P1	Restoration	1,330	1 : 1
Reach 2	2+00 to 17+10	1,448	P1	Restoration	1,493	1 : 1
Reach 3	0+94 to 7+01	464	P1	Restoration	607	1 : 1

Component Summation

Restoration Level	Stream (linear feet)	Riparian Wetland (acres)		Non-riparian Wetland (acres)	Buffer (square feet)	Upland (acres)
		Riverine	Non-Riverine			
Restoration	5,011					
Headwater Valley	1,691					
Enhancement						
Enhancement I						
Enhancement II						
Creation						
Preservation						
High Quality Preservation						

BMP Elements

Element	Location	Purpose/Function	Notes
---	---	---	---
---	---	---	---
---	---	---	---

BMP Elements
BR = Bioretention Cell; SF = Sand Filter; SW = Stormwater Wetland; WDP = Wet Detention Pond; DDP = Dry Detention Pond; FS = Filter Strip; S = Grassed Swale; LS = Level Spreader; NI = Natural Infiltration Area; FB = Forested Buffer

Note: The decrease between Mitigation Plan and As-Built SMUs can be attributed to the shortening of Reach 2 due to landowner negotiations.

Table 2. Project Activity and Reporting History

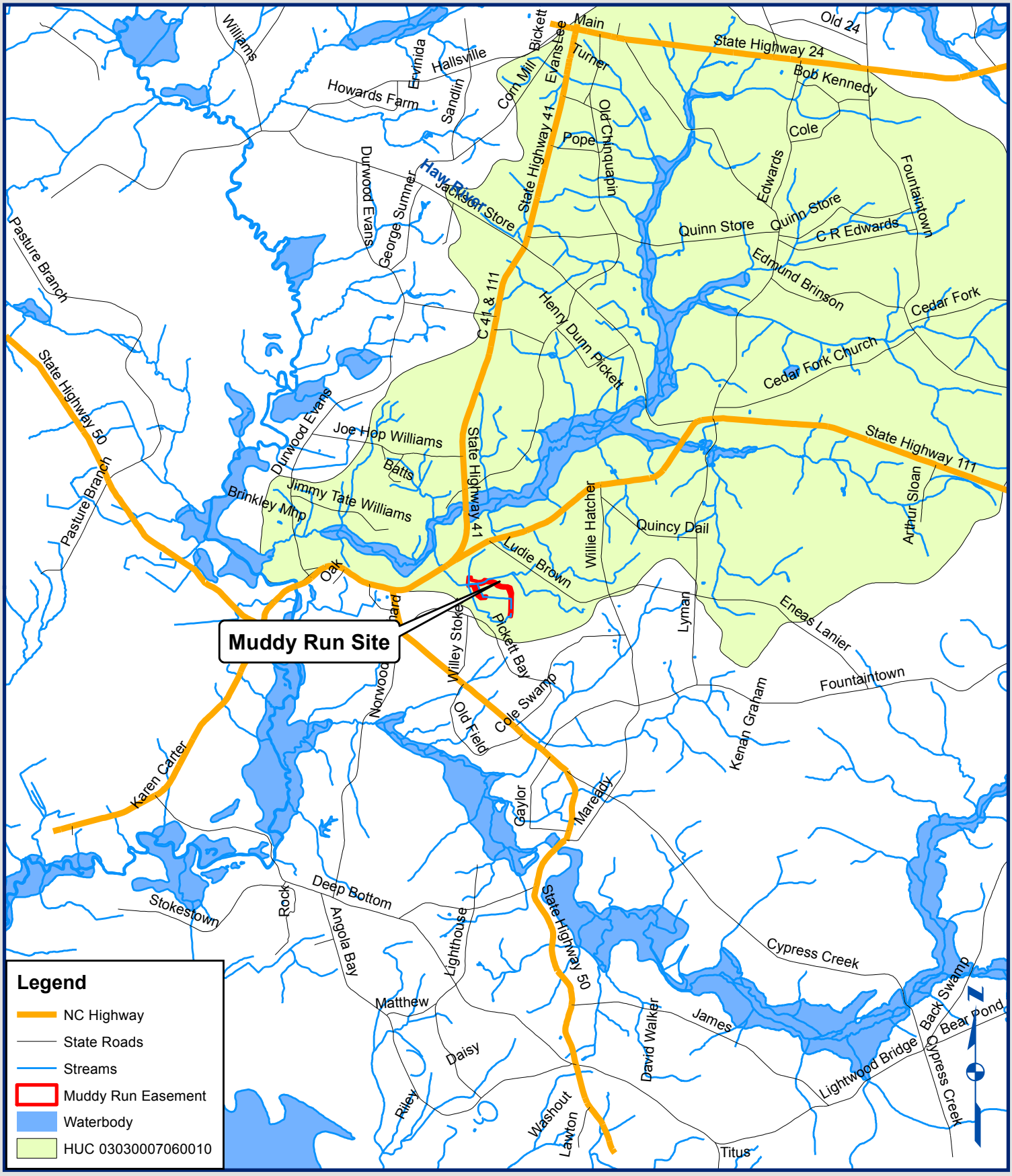
Project Activity and Reporting History Muddy Run Stream Restoration / NCDMS Project #95018		
Activity or Report	**Data Collection Complete**	**Completion or Delivery**
Mitigation Plan	NA	November 2012
Final Design – Construction Plans	NA	August 2013
Construction Completed	NA	April 2014
Site Planting Completed	NA	April 2014
Baseline Monitoring Document (Year 0 Monitoring – baseline)	July 2014	September 2014
Year 1 Monitoring	November 2014	December 2014
Year 2 Monitoring	December 2015	February 2016
Year 3 Monitoring	November 2016	December 2016
Year 3 Invasive Species Management		October 2016
Year 4 Monitoring	Stream: July 2017 Veg: October 2017	February 2018
Year 5 Monitoring		

Table 3. Project Contacts

Project Contacts Table Muddy Run Stream Restoration /NCDMS Project # 95018	
Designer	WK Dickson and Co., Inc. 720 Corporate Center Drive Raleigh, NC 27607 (919) 782-0495 Frasier Mullen, PE
Construction Contractor	GP Jenkins 6566 HWY 55 W Kinston, NC 28504 (252) 569-1222 Gary Jenkins
Planting Contractor	H&J Forestry Matt Hitch
Seeding Contractor	Rain Services, Inc. Lupe Cruz
Seed Mix Sources	Green Resource
Nursery Stock Suppliers	Arbogen
Full Delivery Provider Project Manager:	Resource Environmental Solutions, LLC 302 Jefferson Street. Suite 110 Raleigh, NC 27605 (919) 829-9909 David Godley
Monitoring Performers Project Manager:	Resource Environmental Solutions, LLC 302 Jefferson Street. Suite 110 Raleigh, NC 27605 (919) 741-6268 Ryan Medric

Table 4. Project Information and Attributes

Project Information					
Project Name	Muddy Run Stream Restoration				
County	Duplin				
Project Area (acres)	19.1				
Project Coordinates (latitude and longitude)	34.830843^0 N , -77.792838 ^{0} W				
Project Watershed Summary Information					
Physiographic Province	Coastal Plain				
River Basin	Cape Fear				
USGS Hydrologic Unit 8-digit	03030007	USGS Hydrologic Unit 14-digit	0303007060010		
DWQ Sub-basin	03-06-22				
Project Drainage Area (acres)	391				
Project Drainage Area Percentage of Impervious Area	<1%				
CGIA Land Use Classification					
Reach Summary Information					
Parameters	**Reach 1A**	**Reach 1B**	**Reach 1C**	**Reach 2**	**Reach 3**
Length of Reach (linear feet)	1,691	1,581	1,330	1,510	607
Valley Classification					
Drainage Area (acres)	145	177	238	60	391
NCDWQ Stream Identification Score	24	29	33	26.5	24.5
NCDWQ Water Quality Classification	NA	NA	NA	NA	NA
Morphological Description (stream type)					
Evolutionary Trend					
Underlying Mapped Soils	Foreston / Rains	Goldsboro / Rains	Goldsboro / Rains	Rains	Rains
Drainage Class	---	---	---	---	---
Soil Hydric Status	Hydric	Hydric	Hydric	Hydric	Hydric
Slope	0.0016	0.0022	0.0019	0.0023	0.0010
FEMA Classification	Zone X	Zone X	Zone X	Zone X	Zone X
Native Vegetation Community	Coastal Plain Small Stream Swamp				
Percent Composition of Exotic Invasive Vegetation	0%	0%	0%	0%	0%
Wetland Summary Information					
Parameters	**Wetland 1**	**Wetland 2**	**Wetland 3**		
Size of Wetland (acres)					
Wetland Type (non-riparian, riparian riverine or riparian non-riverine)					
Mapped Soil Series					
Drainage class					
Soil Hydric Status					
Source of Hydrology					
Hydrologic Impairment					
Native vegetation community					
Percent composition of exotic invasive vegetation					
Regulatory Considerations					
Regulation	**Applicable?**	**Resolved?**	**Supporting Documentation**		
Waters of the United States – Section 404	X	X	USACE NWP 27		
Waters of the United States – Section 401	X	X	401 Water Quality Cert.		
Endangered Species Act	X	X	USFWS (Corr. Letter)		
Historic Preservation Act	X	X	SHPO (Corr. Letter)		
Coastal Zone Management Act (CZMA)/ Coastal Area Management Act (CAMA)	N/A	N/A	N/A		
FEMA Floodplain Compliance					
Essential Fisheries Habitat	N/A	N/A	N/A		


Muddy Run Site
Legend
NC Highway
State Roads
Streams
Muddy Run Easement
Waterbody
HUC 03030007060010
Williams
Ervinida
Hallsville
Howards Farm
Sandlin
Corn Mill
Bickett
Evanstee
Main
Turner
Old 24
State Highway 24
Bob Kennedy
State Highway 41
Pope
Old Chinquapin
Cole
Edwards
Fountaintown
Haw River
Jackson Store
Durwood Evans
George Sumner
Pasture Branch
Quinn Store
C R Edwards
Edmund Brinson
Cedar Fork
C 41 & 111
Henry Dunn Pickett
Cedar Fork Church
State Highway 50
Joe Hop Williams
Batts
Jimmy Tate Williams
Brinkley Mnp
State Highway 111
Arthur Sloan
Willie Hatcher
Quincy Dail
Ludie Brown
Oak
Willey Stokes
Pickett Bay
Lyman
Eneas Lanier
Norwood
Cole Swamp
Old Field
Kenan Graham
Karen Carter
Gaylor
Maready
Deep Bottom
Stokestown
Rock
Angola Bay
Lighthouse
State Highway 50
Cypress Creek
Matthew
James
David Walker
Back Swamp
Bear Pond
Lightwood Bridge
Daisy
Riley
Washout
Lawton
Titus
N
Figure 1.
Project Vicinity Map
Muddy Run Site
0
0.75
1.5
3
Miles
1 inch = 1.5 miles
DUPLIN COUNTY
Scale: NTS

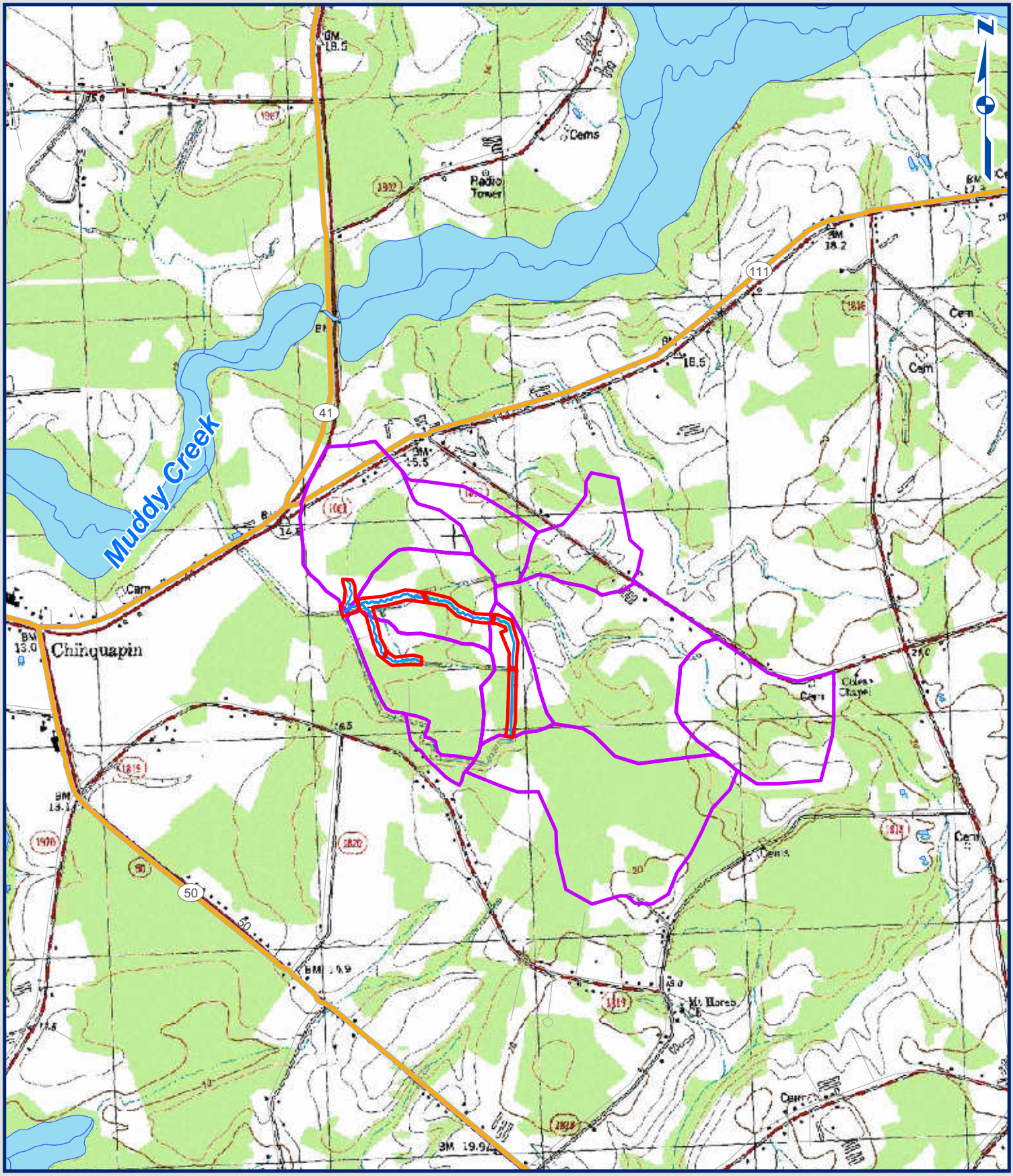


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Figure 2.
USGS/Watershed Map
Muddy Run Site

0 1,000 2,000 4,000 Feet

1 inch = 2,000 feet

Legend

- Muddy Run Streams
- Drainage Areas
- Muddy Run Easement
- Waterbodies

Appendix B

Visual Assessment Data

Reach	Mitigation Type	As-Built Length	Mitigation Ratio	SMUs
Reach 1A	Headwater Valley	1,691	1:1	1,691
Reach 1B	P1 Restoration	1,581	1:1	1,581
Reach 1C	P1 Restoration	1,345	1:1	1,330
Reach 2	P1 Restoration	1,510	1:1	1,493
Reach 3	P1 Restoration	607	1:1	607
		6,734		**6,702**

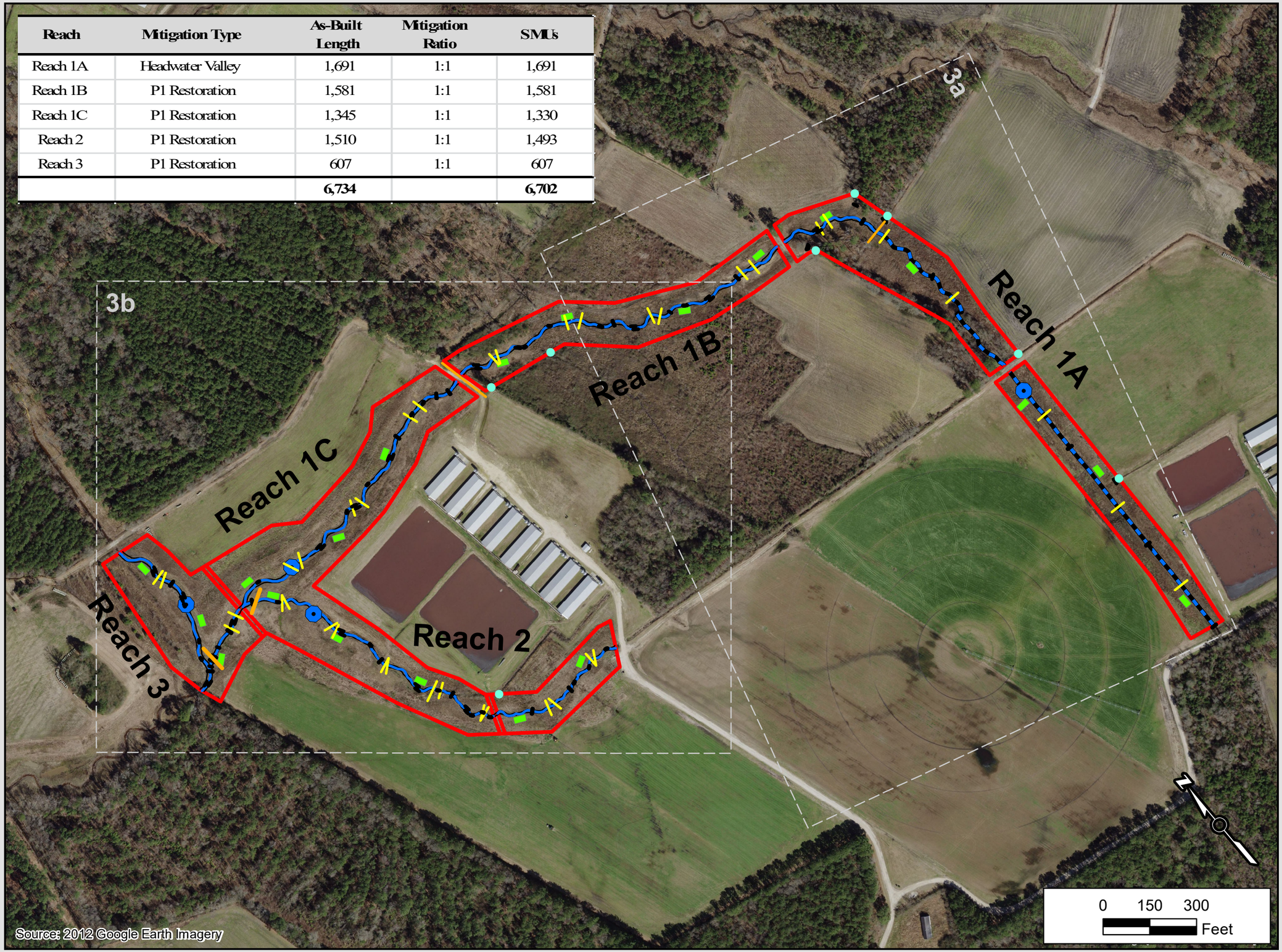


Figure 3a.
Muddy Run Mitigation Site
Current Conditions
Overview Map
MY4 2017

Duplin County, NC

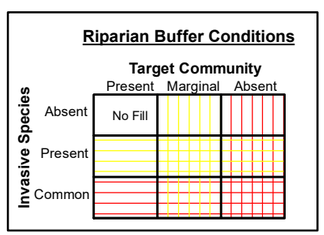
Legend

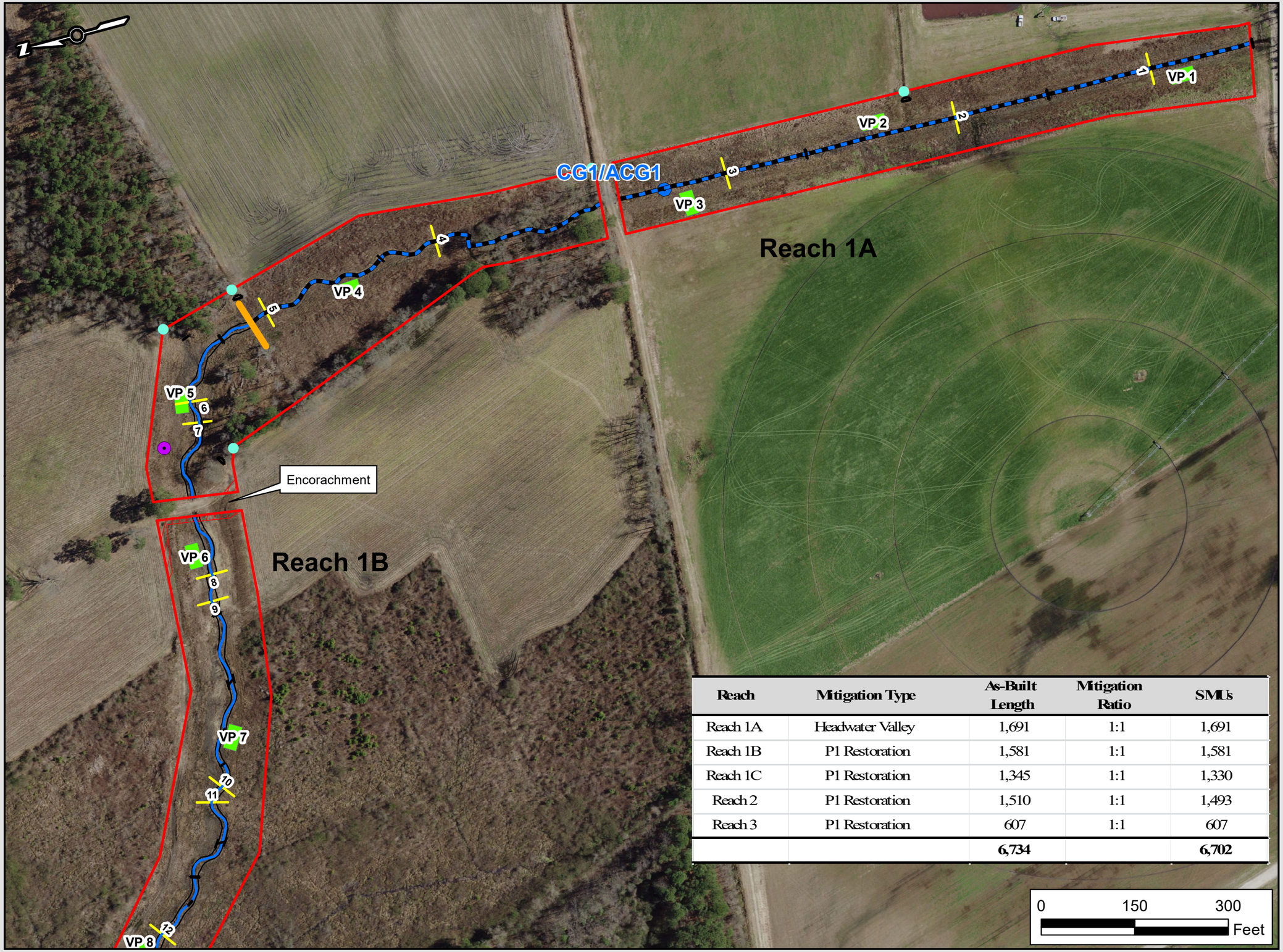
- Easement Boundary
- Restoration
- Reach Breaks
- Stream Structures
- HWV Restoration
- Restoration
- Cross Sections
- Agricultural BMP
- Crest Gauge Locations

Vegetation Plot Success

- Yes

Riparian Buffer Conditions





Reach	Mitigation Type	As-Built Length	Mitigation Ratio	SMUs
Reach 1A	Headwater Valley	1,691	1:1	1,691
Reach 1B	P1 Restoration	1,581	1:1	1,581
Reach 1C	P1 Restoration	1,345	1:1	1,330
Reach 2	P1 Restoration	1,510	1:1	1,493
Reach 3	P1 Restoration	607	1:1	607
		6,734		**6,702**

0 150 300 Feet

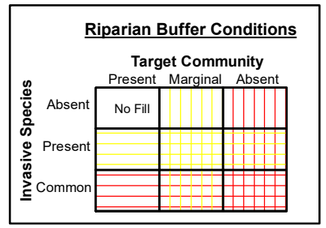
Figure 3b.
Muddy Run Mitigation Site
Current Conditions Map
Duplin County, NC
MY4 2017

Legend

- Easement Boundary
- Restoration
- Agricultural BMP
- Rain Gauge
- Reach Breaks
- HWV
- Restoration
- Stream Structures
- Cross Sections
- Crest Gauge Locations

Vegetation Plot Success

- Yes



Reach	Mitigation Type	As-Built Length	Mitigation Ratio	SMUs
Reach 1A	Headwater Valley	1,691	1:1	1,691
Reach 1B	P1 Restoration	1,581	1:1	1,581
Reach 1C	P1 Restoration	1,345	1:1	1,330
Reach 2	P1 Restoration	1,510	1:1	1,493
Reach 3	P1 Restoration	607	1:1	607
		6,734		**6,702**

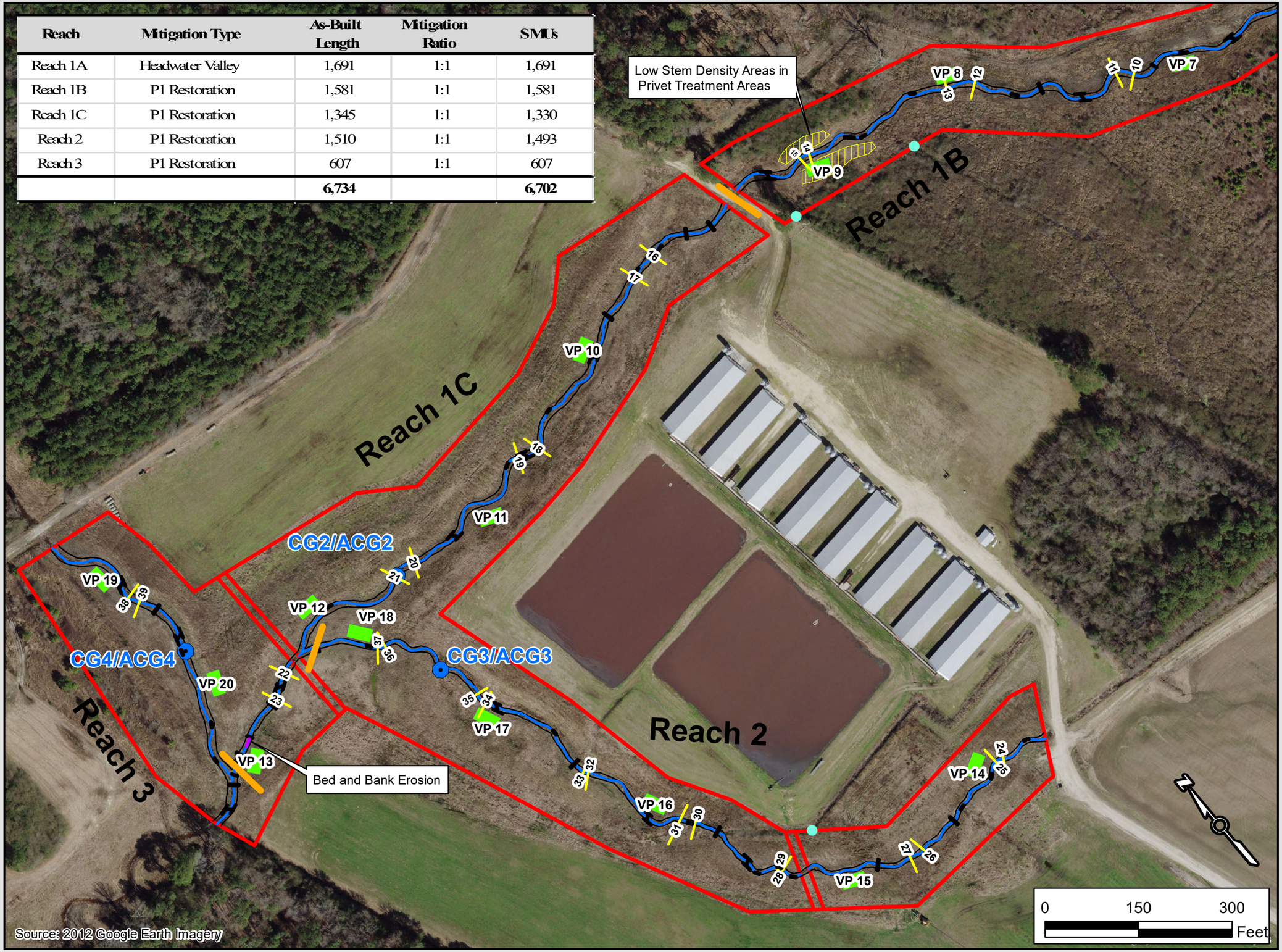


Figure 3c.
Muddy Run Mitigation Site
Current Conditions Map
Duplin County, NC
MY4 2017

res

Legend

- MY4 SPA
- Stream Structures
- Cross Sections

Vegetation Plot Success

- Yes
- Crest Gauge Locations
- HWV Restoration
- Restoration
- Restoration
- Agricultural BMP
- Easement Boundary
- Reach Breaks

Riparian Buffer Conditions

Invasive Species	Target Community: Present	Marginal	Absent
Absent	No Fill		
Present			
Common			

Table 5a **Visual Stream Morphology Stability Assessment**
Reach ID **Reach 1A**
Assessed Length **1691**

Major Channel Category	Channel Sub-Category	Metric	Number [1] Stable, Performing as Intended	Total [1] Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable [2], Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bed	1. **Vertical Stability** (Riffle and Run units)	1. Aggradation - Bar formation/growth sufficient to significantly deflect flow laterally (not to include point bars)			0	0	100%			
		2. Degradation - Evidence of downcutting			0	0	100%			
	2. Riffle Condition	1. Texture/Substrate - Riffle maintains coarser substrate	*NA	*NA			100%			
	3. Meander Pool Condition	1. Depth Sufficient (Max Pool Depth : Mean Bankfull Depth ≥ 1.6)	*NA	*NA			100%			
		2. Length appropriate (>30% of centerline distance between tail of upstream riffle and head of downstrem riffle)	*NA	*NA			100%			
	4.**Thalweg Position**	1. Thalweg centering at upstream of meander bend (Run)	*NA	*NA			100%			
		2. Thalweg centering at downstream of meander (Glide)	*NA	*NA			100%			
2. Bank	**1. Scoured/Eroding**	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	0	0	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does NOT include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
				Totals	0	0	100%	0	0	100%
3. Engineered Structures	**1. Overall Integrity**	Structures physically intact with no dislodged boulders or logs.	4	4			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	4	4			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	4	4			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence does not exceed 15%. (See guidance for this table in EEP monitoring guidance document)	**NA	**NA			*NA			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio ≥ 1.6 Rootwads/logs providing some cover at base-flow.	2	2			100%			

* NA - Headwater Valley Restoration does not have a riffle/pool sequence.
** NA - No bank protection structures were used in this section.
[1] Bed - Coastal plain sand bed channels have a mobile bed along their entire length during geomorphically significant flows. Therefore, the number of shallows and pools, bedform shape, and thalweg position will vary by monitoring event and are not suitable indicators of stability or function.
[2] Percentage based on visual assessment of channel bed condition.

Table 5b **Visual Stream Morphology Stability Assessment**
Reach ID **Reach 1B**
Assessed Length **1581**

Major Channel Category	Channel Sub-Category	Metric	Number [1] Stable, Performing as Intended	Total [1] Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable [2], Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bed	1. **Vertical Stability** (Riffle and Run units)	1. Aggradation - Bar formation/growth sufficient to significantly deflect flow laterally (not to include point bars)			0	0	100%			
		2. Degradation - Evidence of downcutting			0	0	100%			
	2. Riffle Condition	1. Texture/Substrate - Riffle maintains coarser substrate	NA	NA			100%			
	3. Meander Pool Condition	1. Depth Sufficient (Max Pool Depth : Mean Bankfull Depth≥ 1.6)	NA	NA			100%			
		2. Length appropriate (>30% of centerline distance between tail of upstream riffle and head of downstrem riffle)	NA	NA			100%			
	4.**Thalweg Position**	1. Thalweg centering at upstream of meander bend (Run)	NA	NA			100%			
		2. Thalweg centering at downstream of meander (Glide)	NA	NA			100%			
2. Bank	**1. Scoured/Eroding**	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	0	0	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does NOT include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
				Totals	0	0	100%	0	0	100%
3. Engineered Structures	**1. Overall Integrity**	Structures physically intact with no dislodged boulders or logs.	16	16			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	7	7			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	16	16			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence doesnot exceed 15%. (See guidance for this table in EEP monitoring guidance document)	5	5			100%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio ≥ 1.6 Rootwads/logs providing some cover at base-flow.	4	4			100%			

[1] Bed - Coastal plain sand bed channels have a mobile bed along their entire length during geomorphically significant flows. Therefore, the number of shallows and pools, bedform shape, and thalweg position will vary by monitoring event and are not suitable indicators of stability or function.
[2] Percentage based on visual assessment of channel bed condition.

Table 5c **Visual Stream Morphology Stability Assessment**
Reach ID **Reach 1C**
Assessed Length **1330**

Major Channel Category	Channel Sub-Category	Metric	Number [1] Stable, Performing as Intended	Total [1] Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable [2], Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bed	1. **Vertical Stability** (Riffle and Run units)	1. Aggradation - Bar formation/growth sufficient to significantly deflect flow laterally (not to include point bars)			0	0	100%			
		2. Degradation - Evidence of downcutting			1	12	99%			
	2. Riffle Condition	1. Texture/Substrate - Riffle maintains coarser substrate	NA	NA			100%			
	3. Meander Pool Condition	1. Depth Sufficient (Max Pool Depth : Mean Bankfull Depth≥ 1.6)	NA	NA			100%			
		2. Length appropriate (>30% of centerline distance between tail of upstream riffle and head of downstrem riffle)	NA	NA			100%			
	4.**Thalweg Position**	1. Thalweg centering at upstream of meander bend (Run)	NA	NA			100%			
		2. Thalweg centering at downstream of meander (Glide)	NA	NA			100%			
2. Bank	**1. Scoured/Eroding**	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			2	24	99%	2	10	99%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does NOT include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
				Totals	2	24	99%	2	10	99%
3. Engineered Structures	**1. Overall Integrity**	Structures physically intact with no dislodged boulders or logs.	17	17			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	8	8			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	17	17			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence doesnot exceed 15%. (See guidance for this table in EEP monitoring guidance document)	5	5			100%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio ≥ 1.6 Rootwads/logs providing some cover at base-flow.	4	4			100%			

[1] Bed - Coastal plain sand bed channels have a mobile bed along their entire length during geomorphically significant flows. Therefore, the number of shallows and pools, bedform shape, and thalweg position will vary by monitoring event and are not suitable indicators of stability or function.
[2] Percentage based on visual assessment of channel bed condition.

Table 5d **Visual Stream Morphology Stability Assessment**
Reach ID **Reach 2**
Assessed Length **1493**

Major Channel Category	Channel Sub-Category	Metric	Number [1] Stable, Performing as Intended	Total [1] Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable [2], Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bed	1. **Vertical Stability** (Riffle and Run units)	1. Aggradation - Bar formation/growth sufficient to significantly deflect flow laterally (not to include point bars)			0	0	100%			
		2. Degradation - Evidence of downcutting			0	0	100%			
	2. Riffle Condition	1. Texture/Substrate - Riffle maintains coarser substrate	NA	NA			100%			
	3. Meander Pool Condition	1. Depth Sufficient (Max Pool Depth : Mean Bankfull Depth≥ 1.6)	NA	NA			100%			
		2. Length appropriate (>30% of centerline distance between tail of upstream riffle and head of downstrem riffle)	NA	NA			100%			
	4.**Thalweg Position**	1. Thalweg centering at upstream of meander bend (Run)	NA	NA			100%			
		2. Thalweg centering at downstream of meander (Glide)	NA	NA			100%			
2. Bank	**1. Scoured/Eroding**	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	0	0	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does NOT include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
				Totals	0	0	100%	0	0	100%
3. Engineered Structures	**1. Overall Integrity**	Structures physically intact with no dislodged boulders or logs.	17	17			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	5	5			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	17	17			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence doesnot exceed 15%. (See guidance for this table in EEP monitoring guidance document)	9	9			100%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio ≥ 1.6 Rootwads/logs providing some cover at base-flow.	3	3			100%			

[1] Bed - Coastal plain sand bed channels have a mobile bed along their entire length during geomorphically significant flows. Therefore, the number of shallows and pools, bedform shape, and thalweg position will vary by monitoring event and are not suitable indicators of stability or function.
[2] Percentage based on visual assessment of channel bed condition.

Table 5e **Visual Stream Morphology Stability Assessment**
Reach ID **Reach 3**
Assessed Length **607**

Major Channel Category	Channel Sub-Category	Metric	Number [1] Stable, Performing as Intended	Total [1] Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable [2], Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bed	1. **Vertical Stability** (Riffle and Run units)	1. Aggradation - Bar formation/growth sufficient to significantly deflect flow laterally (not to include point bars)			0	0	100%			
		2. Degradation - Evidence of downcutting			0	0	100%			
	2. Riffle Condition	1. Texture/Substrate - Riffle maintains coarser substrate	NA	NA			100%			
	3. Meander Pool Condition	1. Depth Sufficient (Max Pool Depth : Mean Bankfull Depth≥ 1.6)	NA	NA			100%			
		2. Length appropriate (>30% of centerline distance between tail of upstream riffle and head of downstrem riffle)	NA	NA			100%			
	4.**Thalweg Position**	1. Thalweg centering at upstream of meander bend (Run)	NA	NA			100%			
		2. Thalweg centering at downstream of meander (Glide)	NA	NA			100%			
2. Bank	**1. Scoured/Eroding**	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	0	0	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does NOT include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
				Totals	0	0	100%	0	0	100%
3. Engineered Structures	**1. Overall Integrity**	Structures physically intact with no dislodged boulders or logs.	8	8			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	2	2			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	8	8			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence doesnot exceed 15%. (See guidance for this table in EEP monitoring guidance document)	3	3			100%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio ≥ 1.6 Rootwads/logs providing some cover at base-flow.	3	3			100%			

[1] Bed - Coastal plain sand bed channels have a mobile bed along their entire length during geomorphically significant flows. Therefore, the number of shallows and pools, bedform shape, and thalweg position will vary by monitoring event and are not suitable indicators of stability or function.
[2] Percentage based on visual assessment of channel bed condition.

Table 6 Vegetation Condition Assessment

Planted Acreage[1] **17.5**

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	Vertical Red Lines	0	0.00	0.0%
2. Low Stem Density Areas	Woody stem densities clearly below target levels based on MY3, 4, or 5 stem count criteria.	0.1 acres	Vertical Yellow Lines	2	0.11	0.6%
			Total	2	0.11	0.6%
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	Vertical Yellow Lines	0	0.00	0.0%
			Cumulative Total	2	0.11	0.6%

Easement Acreage[2] **19.1**

Vegetation Category	Definitions	Mapping Threshold	CCPV Depiction	Number of Polygons	Combined Acreage	% of Easement Acreage
4. Invasive Areas of Concern[4]	Areas or points (if too small to render as polygons at map scale).	1000 SF	Horizontal Lines	0	0.00	0.0%
5. Easement Encroachment Areas[3]	Areas or points (if too small to render as polygons at map scale).	none	Vertical Red Lines	2	0.05	0.3%

1 = Enter the planted acreage within the easement. This number is calculated as the easement acreage minus any existing mature tree stands that were not subject to supplemental planting of the understory, the channel acreage, crossings or any other elements not directly planted as part of the project effort.

2 = The acreage within the easement boundaries.

3 = Encroachment may occur within or outside of planted areas and will therefore be calculated against the overall easement acreage. In the event a polygon is cataloged into items 1, 2 or 3 in the table and is the result of encroachment, the associated acreage should be tallied in the relevant item (i.e., item 1,2 or 3) as well as a parallel tally in item 5.

4 = Invasives may occur in or out of planted areas, but still within the easement and will therefore be calculated against the overall easement acreage. Invasives of concern/interest are listed below. The list of high concern spcies are those with the potential to directly outcompete native, young, woody stems in the short-term (e.g. monitoring period or shortly thereafter) or affect the community structure for existing, more established tree/shrub stands over timeframes that are slightly longer (e.g. 1-2 decades). The low/moderate concern group are those species that generally do not have this capacity over the timeframes discussed and therefore are not expected to be mapped with regularity, but can be mapped, if in the judgement of the observer their coverage, density or distribution is suppressing the viability, density, or growth of planted woody stems. Decisions as to whether remediation will be needed are based on the integration of risk factors by EEP such as species present, their coverage, distribution relative to native biomass, and the practicality of treatment. For example, even modest amounts of Kudzu or Japanese Knotweed early in the projects history will warrant control, but potentially large coverages of Microstegium in the herb layer will not likley trigger control because of the limited capacities to impact tree/shrub layers within the timeframes discussed and the potential impacts of treating extensive amounts of ground cover. Those species with the "watch list" designator in gray shade are of interest as well, but have yet to be observed across the state with any frequency. Those in *red italics* are of particular interest given their extreme risk/threat level for mapping as points where isolated specimens are found, particularly ealry in a projects monitoring history. However, areas of discreet, dense patches will of course be mapped as polygons. The symbology scheme below was one that was found to be helpful for symbolzing invasives polygons, particulalry for situations where the conditon for an area is somewhere between isolated specimens and dense, discreet patches. In any case, the point or polygon/area feature can be symbolized to describe things like high or low concern and species can be listed as a map inset, in legend items if the number of species are limited or in the narrative section of the executive summary.

Table 7. Stream Problem Areas Muddy Run Stream Restoration Project - Project # 95018			
Feature Issue	**Station # / Range**	**Suspected Cause**	**Photo Number**
Bed and Bank Erosion	Reach 1 at 47+50 to 17+70	Channel adjustment and sparse bank vegetation; but is stable; recommend monitoring	SPA1

Table 8. Vegetation Problem Areas Muddy Run Stream Restoration Project - Project # 95018			
Feature Category	**Station Numbers**	**Suspected Cause**	**Photo Number**
Encroachment	Reach 1B Sta 21+50	Mowing and overspray of crossing	VPA1
Low Stem Density	Reach 1C Sta. 31+60 to 33 + 00	Weed competition and subsequent treatment; continue to monitor	VPA2

Figure 4. MY4 – 2017 Vegetation Plot Photos

Muddy Run - Vegetation Monitoring Plot 1
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 2
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 3
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 4
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 5
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 6
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 7
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 8
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 9
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 10
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 11
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 12
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 13
October 25, 2017

Muddy Run - Vegetation Monitoring Plot 14
October 25, 2017

Muddy Run - Vegetation Monitoring Plot 15
October 25, 2017

Muddy Run - Vegetation Monitoring Plot 16
October 25, 2017

Muddy Run - Vegetation Monitoring Plot 17
October 25, 2017

Muddy Run - Vegetation Monitoring Plot 18
October 24, 2017

Muddy Run - Vegetation Monitoring Plot 19
October 25, 2017

Muddy Run - Vegetation Monitoring Plot 20
October 25, 2017

Appendix B - Stream and Vegetation Problem Area Photos

MY4-VPA1 Encroachment at Reach 1B Sta 21+50

MY4-VPA1 Encroachment at Reach 1B Sta 21+50

Appendix C

Vegetation Plot Data

Table 9a. Planted Stem Total Counts (Species by Plot)
Table 9b. Monitoring Year 4 Stem County Summary (Annual Means)
Table 9c. Planted Species Totals
Table 9d. 2015 Supplemental Planting Species Totals

Table 9a. Planted Total Stem Counts (Species by Plot)
Muddy Run Stream Restoration site

		Current Plot Data (MY4 2017)																			
Species	**Common Name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Taxodium distichum	Bald Cypress	5		6		2	1	1	1	1	5	4	5	5	5		5	3		6	
Fraxinus pennsylvanica	Green Ash	3	1	3	1		1		5	2		2			1	3				1	6
Quercus sp.	Unknown Oak sp.																				
Quercus lyrata	Overcup Oak				2	2			1	1	1	1				2	2	2	1		2
Betula nigra	River birch	5	2	2							1		2			1	3	1		2	1
Quercus michauxii	Swamp Chestnut Oak	1		2	4	1	2	7	1		1	1	5	1		10			5	1	
Nyssa biflora	Swamp Tupelo		1		3	4	1	3	1			1	1	3	2	3		7	1	4	
Plantanus occidentalis	American Sycamore		5	2	2	1	1			6	2	4		3	3				4		1
Quercus laurifolia	Laurel Oak	1		1		2	4		2	2	3	2			3	1	2		2	1	2
Cephalanthus occidentalis	Buttonbush													1							
	Species Count	**5**	**4**	**6**	**5**	**6**	**6**	**3**	**6**	**5**	**6**	**7**	**4**	**5**	**5**	**6**	**4**	**4**	**5**	**6**	**5**
	Stem Count	**15**	**9**	**16**	**12**	**12**	**10**	**11**	**11**	**12**	**13**	**15**	**13**	**13**	**14**	**20**	**12**	**13**	**13**	**15**	**12**
	Stems per Acre	**750**	**450**	**800**	**600**	**600**	**500**	**550**	**550**	**600**	**650**	**750**	**650**	**650**	**700**	**1000**	**600**	**650**	**650**	**750**	**600**

[1]No livestakes or volunteers included in tally

Table 9b. Monitoring Year 4 Stem Count Summary (Annual Means)
Muddy Run Stream Restoration Site

	Baseline		Year 1		Year 2				Year 3				Year 4			
Vegetation Plot	**Stems Planted**	**Stems/Acre Baseline**	**Planted Living Stems**	**Stems/Acre Year 1**	**Planted Living Stems**	**Stems/Acre Year 2**	**Total Living Stems***	**Total Stems/Acre Year 2***	**Planted Living Stems**	**Stems/Acre Year 3**	**Total Living Stems***	**Total Stems/Acre Year 3***	**Planted Living Stems**	**Stems/Acre Year 4**	**Total Living Stems***	**Total Stems/Acre Year 4***
1	16	800	15	750	15	750	15	750	15	750	15	750	15	750	21	1050
2	15	750	9	450	9	450	9	450	9	450	9	450	9	450	11	550
3	17	850	16	800	16	800	18	900	16	800	16	800	16	800	32	1600
4	14	700	14	700	13	650	13	650	11	550	18	900	12	600	43	2150
5	14	700	13	650	11	550	11	550	11	550	11	550	12	600	30	1500
6	15	750	15	750	15	750	22	1100	10	500	10	500	10	500	40	2000
7	17	850	16	800	17	850	17	850	11	550	11	550	11	550	34	1700
8	16	800	15	750	11	550	11	550	11	550	11	550	11	550	14	700
9	13	650	12	600	12	600	18	900	12	600	12	600	12	600	42	2100
10	16	800	14	700	13	650	13	650	13	650	13	650	13	650	13	650
11	17	850	17	850	16	800	16	800	16	800	16	800	15	750	18	900
12	14	700	14	700	12	600	12	600	12	600	12	600	13	650	13	650
13	16	800	15	750	13	650	13	650	13	650	13	650	13	650	14	700
14	17	850	17	850	16	800	16	800	15	750	15	750	14	700	15	750
15	18	900	17	850	22	1100	22	1100	19	950	19	950	20	1000	23	1150
16	16	800	14	700	14	700	14	700	13	650	13	650	12	600	12	600
17	18	900	18	900	15	750	15	750	14	700	14	700	13	650	15	750
18	16	800	16	800	14	700	14	700	13	650	13	650	13	650	14	700
19	14	700	14	700	14	700	14	700	15	750	15	750	15	750	16	800
20	15	750	15	750	12	600	12	600	11	550	11	550	12	600	15	750
Min	**13**	**650**	**9**	**450**	**9**	**450**	**9**	**450**	**9**	**450**	**9**	**450**	**9**	**450**	**11**	**550**
Max	**18**	**900**	**18**	**900**	**22**	**1100**	**22**	**1100**	**19**	**950**	**19**	**950**	**20**	**1000**	**43**	**2150**
Average	**15.7**	**785**	**14.8**	**740**	**14**	**700**	**15**	**738**	**13**	**650**	**13**	**668**	**13**	**653**	**22**	**1088**

* Calculations include volunteer species.
Plot Size = 40 X 22 feet = 0.020 Acres
Number Trees/Acres = # of Trees * 50

Table 9c. Planted Species Totals

Species	Common Name	Total Planted
Trees - Bare Root		
Taxodium distichum	Bald Cypress	2,000
Fraxinus pennsylvanica	Green Ash	1,900
Quercus lyrata	Overcup Oak	1,600
Betula nigra	River birch	1,600
Quercus michauxii	Swamp Chestnut Oak	2,000
Nyssa biflora	Swamp Tupelo	1,800
Plantanus occidentalis	American Sycamore	2,000
Quercus laurifolia	Laurel Oak	1,600
	Total	**14,500**
Live Stakes		
Salix nigra	Black Willow	3,000
	Total	**3,000**

Table 9d. 2015 Supplemental Planting Species Totals

Species	Common Name	Total Planted
Trees - Bare Root		
Quercus lyrata	Overcup Oak	900
Betula nigra	River birch	300
Quercus michauxii	Swamp Chestnut Oak	800
Plantanus occidentalis	American Sycamore	500
	Total	**2,500**

Appendix D

Stream Geomorphology Data

Appendix D. Table 10 - Morphological Parameters Summary Data
Project Name/Number: Muddy Run Mitigation Project/95018

	Reference Reach			Existing[1]					Design				As-Built/Baseline			
				MR1A	MR1B	MR1C	MR2	MR3	MR1B	MR1C	MR2	MR3	MR1B	MR1C	MR2	MR3
Feature	Pool	Run	Shallow	Run	Run	Run	Run	Run	Shallow	Shallow	Shallow	Shallow	Shallow	Shallow	Shallow	Shallow
Drainage Area (ac)	286	286	286	145	177	238	60	85	177	238	60	391	177	238	60	391
NC Regional Curve Discharge (cfs)			9.3	6	7	8	3	4	7	8	3	12	7	8	3	12
Design/Calculated Discharge (cfs)	---	---	13	---	---	---	---	---	9	13	4	19	12.1	13.8	5.4	13.5
Dimension																
BF Width (ft)	10.9	8.9	7.0	6.6	7.3	9.7	6.9	7.2	8.2	9.5	5.6	11.4	11.6	11.5	9.9	11.9
Floodprone Width (ft)	100	100	100	9.9	10.3	15.3	10.3	10.7	> 50	> 50	> 50	> 50	> 50	> 50	> 50	> 50
BF Cross Sectional Area (ft^2)	11.4	8.4	5	5	4.4	5.6	3.6	3.3	6.6	8.9	3.1	13.1	7.4	8.3	4.8	9.3
BF Mean Depth (ft)	1.0	0.9	0.8	0.8	0.6	0.6	0.5	0.5	0.8	0.9	0.6	1.1	0.6	0.7	0.5	0.8
BF Max Depth (ft)	2.1	1.7	1.3	1.1	0.9	1.3	1.0	0.8	1.3	1.5	0.9	1.7	1.4	1.5	1	1.6
Width/Depth Ratio	10.4	9.5	8.8	8.7	12.2	17.1	13.2	15.8	10	10	10	10	18.6	15.7	21.2	15.1
Entrenchment Ratio	9.2	11.2	15.1	1.5	1.4	1.5	1.5	10.5	> 2.2	> 2.2	> 2.2	> 2.2	> 2.2	> 2.2	> 2.2	> 2.2
Wetted Perimeter (ft)	12.8	9.7	7.4	6.9	7.7	10.3	7.2	7.4	8.7	10.1	5.9	12.1	12.2	11.9	10.3	12.4
Hydraulic Radius (ft)	0.9	0.9	0.7	0.7	0.6	0.5	0.5	0.4	0.8	0.9	0.5	1.1	0.6	0.7	0.5	0.8
Substrate																
	Fine Sand			Fine Sand					Fine Sand	Fine Sand	Fine Sand	Fine Sand	Fine Sand	Fine Sand	Fine Sand	Fine Sand
Pattern																
	Min	**Max**	**Med**	---	---	---	---	---	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Channel Beltwidth (ft)	13.6	31.8	23.1	---	---	---	---	---	13.3	40.0	18.0	37.2	10.2	26.8	20.6	40.3	17.9	45.3	14.9	40.3	12.1	27.5	17.3	45.8
Radius of Curvature (ft)	11.0	27.6	17.6	---	---	---	---	---	11.4	40.4	14.8	40.8	8.9	21.7	22.8	46.5	14.5	48.7	16.8	54.9	11.1	29.4	33.8	74.9
Radius of Curvature Ratio	1.5	3.7	2.3						1.4	4.9	1.6	3.5	1.6	3.4	2.0	4.1	1.3	4.2	1.5	4.8	1.1	3.0	2.8	6.3
Meander Wavelength (ft)	34.9	68.3	54.5	---	---	---	---	---	23.2	89.9	33.2	71.2	16.2	48.6	56.5	144	44.9	99.2	37.3	94.9	20.6	44.0	41.88	88.7
Meander Width Ratio	1.8	4.2	3.1	---	---	---	---	---	1.6	4.9	1.9	3.9	1.8	4.8	1.8	3.5	1.5	3.9	1.3	3.5	1.2	2.8	1.5	3.8
Profile																
Shallow Length (ft)	3.1	30.7	12.6	---	---	---	---	---	5	72	10	72	4	62	25.9	39.9	8	27	18	35	7.1	24.3	6.0	27.0
Run Length (ft)	2.2	33.2	11.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Pool Length (ft)	4.2	9.5	5.8	---	---	---	---	---	17	36	20	34	9	20	18.2	49.0	12	28	14	30	11.6	20.2	9.0	28.0
Pool -to-Pool Spacing (ft)	17.5	59.8	36.3	---	---	---	---	---	23	95	25	97	16	78	37.0	90.0	20	82	25	69	22	75	16.0	90.0
Additional Reach Parameters																
Valley Length (ft)	274			---	---	---	---	---	1485		1194		1560		554		1485		1194		1560		554	
Channel Length (ft)	309			1638	1590	1324	1448	464	1652		1386		1533		613		1584		1344		1510		607	
Sinuosity	1.1			1.0	1.0	1.0	1.0	1.0	1.1		1.2		1.0		1.1		1.1		1.1		1.0		1.1	
Water Surface Slope (ft/ft)	0.004			---	---	---	---	---	---		---		---		---		---		---		---		---	
Channel Slope (ft/ft)	0.003			0.0016	0.0033	0.0035	0.0032	0.0055	0.0022		0.0019		0.0023		0.0008		0.0036		0.0031		0.0024		0.0022	
Rosgen Classification	E5			G5c	F5	F5	F5	F5	E5		E5		E5		E5		E5		E5		E5		E5	
*Habitat Index																								

[1] Bankfull stage was estimated using NC Regional Curve equations and existing conditions data

Appendix D. Table 11 - Monitoring Data - Dimensional Morphology Summary (Dimensional Parameters – Cross Sections)

Project Name/Number: Muddy Run Mitigation Project/95018

	Cross Section 1 (HWV)							Cross Section 2 (HWV)							Cross Section 3 (HWV)							Cross Section 4 (HWV)							Cross Section 5 (HWV)						
Based on fixed baseline bankfull elevation[1]	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	(Headwater Valley Restoration) No Morphological Parameters were determined for HWV Reaches.							(Headwater Valley Restoration) No Morphological Parameters were determined for HWV Reaches.							(Headwater Valley Restoration) No Morphological Parameters were determined for HWV Reaches.							(Headwater Valley Restoration) No Morphological Parameters were determined for HWV Reaches.							(Headwater Valley Restoration) No Morphological Parameters were determined for HWV Reaches.						
Bankfull Width (ft)																																			
Floodprone Width (ft)																																			
Bankfull Mean Depth (ft)																																			
Bankfull Max Depth (ft)																																			
Bankfull Cross Sectional Area (ft^2)																																			
Bankfull Width/Depth Ratio																																			
Bankfull Entrenchment Ratio																																			
Bankfull Bank Height Ratio																																			

	Cross Section 6 (Pool)							Cross Section 7 (Shallow)							Cross Section 8 (Shallow)							Cross Section 9 (Pool)							Cross Section 10 (Shallow)						
Based on fixed baseline bankfull elevation[1]	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	49.5	49.5	49.5	49.5	49.5			49.5	49.5	49.5	49.5	49.5			48.5	48.5	48.5	48.5	48.5			48.3	48.3	48.3	48.3	48.3			46.5	46.5	46.5	46.5	46.5		
Bankfull Width (ft)	9.0	8.4	9.4	9.2	9.6			10.7	10.7	11.6	11.5	10.8			9.6	8.9	9.6	8.9	9.3			8.8	8.1	8.8	7.8	7.3			14.3	14.4	15.7	13.5	16.2		
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0		
Bankfull Mean Depth (ft)	1.1	1.0	1.0	1.0	1.0			0.7	0.7	0.7	0.7	0.7			0.7	0.6	0.6	0.5	0.6			0.9	0.8	0.7	0.9	1.0			0.5	0.4	0.4	0.5	0.4		
Bankfull Max Depth (ft)	2.2	2.1	2.0	1.8	1.9			1.7	1.7	1.7	1.6	1.6			1.4	1.4	1.2	1.1	1.2			1.7	1.5	1.5	1.5	1.6			1.3	1.1	1.2	1.2	1.1		
Bankfull Cross Sectional Area (ft^2)	9.4	8.5	9.1	8.9	9.5			8.0	8.0	8.1	7.8	7.5			6.4	5.7	5.8	4.7	5.4			7.5	6.7	6.5	6.9	7.0			6.8	6.1	6.2	6.4	6.4		
Bankfull Width/Depth Ratio	8.5	8.3	9.8	9.5	9.8			14.4	14.4	16.6	17.1	15.5			14.4	14.0	15.9	16.8	16.0			10.3	9.8	11.7	8.9	7.6			29.9	34.2	39.9	28.5	41.2		
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	>2.2		
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	1.1			1.0	1.0	1.0	1.0	1.0			1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	0.9		

	Cross Section 11 (Pool)							Cross Section 12 (Shallow)							Cross Section 13 (Pool)							Cross Section 14 (Shallow)							Cross Section 15 (Pool)						
Based on fixed baseline bankfull elevation[1]	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	46.4	46.4	46.4	46.4	46.4			45.6	45.6	45.6	45.6	45.6			45.5	45.5	45.5	45.5	45.5			45.0	45.0	45.0	45.0	45.0			44.4	44.4	44.4	44.4	44.4		
Bankfull Width (ft)	14.7	14.4	15.4	16.1	16.4			11.4	11.4	11.2	7.7	10.4			13.2	12.3	14.0	12.7	14.7			12.0	12.3	11.4	11.1	13.0			10.0	9.9	11.5	10.9	10.6		
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0		
Bankfull Mean Depth (ft)	0.6	0.6	0.5	0.5	0.5			0.6	0.6	0.5	0.6	0.4			0.6	0.6	0.5	0.5	0.5			0.7	0.7	0.7	0.7	0.6			0.9	0.9	0.8	0.8	0.8		
Bankfull Max Depth (ft)	1.8	1.5	1.4	1.5	1.4			1.2	1.2	1.2	1.1	1.1			1.4	1.3	1.2	1.1	1.1			1.4	1.5	1.4	1.3	1.4			1.9	1.8	1.7	1.7	1.6		
Bankfull Cross Sectional Area (ft^2)	9.1	7.9	7.7	8.2	8.3			7.1	6.3	5.9	4.3	4.5			8.4	7.2	7.6	6.8	7.6			8.7	8.4	7.9	7.4	8.0			9.1	8.8	9.1	8.2	8.3		
Bankfull Width/Depth Ratio	23.9	26.1	30.8	31.7	32.6			18.2	20.7	21.3	13.8	24.1			20.7	21.1	25.8	23.5	28.6			16.4	17.8	16.5	16.7	21.3			11.1	11.1	14.6	14.5	13.5		
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	N/A		
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	0.9			1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	1.0			1.0	1.0	1.0	1.0	N/A		

	Cross Section 16 (Shallow)							Cross Section 17 (Pool)							Cross Section 18 (Pool)							Cross Section 19 (Shallow)							Cross Section 20 (Shallow)						
Based on fixed baseline bankfull elevation[1]	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	44.0	44.0	44.0	44.0	44.0			43.7	43.7	43.7	43.7	43.7			42.8	42.8	42.8	42.8	42.8			43.0	43.0	43.0	43.0	43.0			42.6	42.6	42.6	42.6	42.6		
Bankfull Width (ft)	13.3	14.0	14.8	14.5	15.0			13.0	12.3	12.8	13.0	13.0			8.9	8.7	8.4	8.4	9.1			11.9	11.6	11.4	9.5	9.6			10.8	10.8	15.7	10.2	13.7		
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0		
Bankfull Mean Depth (ft)	0.8	0.7	0.7	0.6	0.6			0.9	0.8	0.8	0.7	0.7			1.1	1.1	1.0	1.0	1.0			0.7	0.7	0.7	0.6	0.6			0.7	0.7	0.5	0.7	0.5		
Bankfull Max Depth (ft)	1.4	1.4	1.3	1.1	1.4			1.5	1.7	1.7	1.5	1.3			2.0	1.9	1.8	1.6	1.7			1.5	1.5	1.4	1.2	1.3			1.6	1.5	1.2	1.4	1.4		
Bankfull Cross Sectional Area (ft^2)	10.0	9.8	10.1	8.2	8.3			11.3	10.4	10.2	9.3	8.8			10.2	9.4	8.8	8.6	9.1			8.1	7.8	7.8	5.4	6.1			8.0	7.3	8.0	7.0	7.0		
Bankfull Width/Depth Ratio	17.6	20.1	21.7	25.8	26.9			15.0	14.5	15.9	18.2	19.3			7.7	8.1	8.1	8.3	9.1			17.4	17.1	16.7	16.7	15.2			14.5	16.1	30.6	14.9	26.8		
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	>2.2		
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	1.0			1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	1.0			1.0	1.0	1.0	1.0	1.0		

1 = Widths and depths for annual measurements will be based on the baseline bankfull datum regardless of dimensional/depositional development. Input the elevation used as the datum, which should be consistent and based on the baseline datum established. If the performer has inherited the project and cannot acquire the datum used for prior years this must be discussed with EEP. If this cannot be resolved in time for a given years report submission a footnote in this should be included that states: "It is uncertain if the monitoring datum has been consistent over the monitoring history, which may influence calculated values. Additional data from a prior performer is being acquired to provide confirmation. Values will be recalculated in a future submission based on a consistent datum if determined to be necessary."

Note: Starting in MY4, BHR was calculated on riffles using the baseline bankfull elevation. This method was used because the dimension of the channels has not changed enough to alter the bankfull elevation.

Appendix D. Table 11 - Monitoring Data - Dimensional Morphology Summary (Dimensional Parameters – Cross Sections)

Project Name/Number: Muddy Run Mitigation Project/95018

	Cross Section 21 (Pool)							Cross Section 22 (Shallow)							Cross Section 23 (Pool)							Cross Section 24 (Shallow)							Cross Section 25 (Pool)						
Based on fixed baseline bankfull elevation[1]	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	42.3	42.3	42.3	42.3	42.3			41.8	41.8	41.8	41.8	41.8			41.5	41.5	41.5	41.5	41.5			45.2	45.2	45.2	45.2	45.2			45.2	45.2	45.2	45.2	45.2		
Bankfull Width (ft)	10.6	10.5	12.3	13.1	10.5			9.8	11.4	10.0	9.4	9.7			10.6	11.7	11.5	10.9	11.2			9.1	9.9	8.9	8.4	8.3			8.6	8.2	8.5	8.4	7.6		
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0		
Bankfull Mean Depth (ft)	1.1	1.1	0.9	0.9	0.9			0.7	0.6	0.6	0.7	0.7			0.7	0.6	0.6	0.6	0.5			0.5	0.5	0.4	0.4	0.4			0.6	0.6	0.6	0.5	0.5		
Bankfull Max Depth (ft)	2.2	2.2	2.1	1.9	1.7			1.4	1.5	1.4	1.3	1.4			1.2	1.3	1.1	1.3	1.2			1.0	0.9	0.7	0.7	0.7			1.3	1.2	1.1	0.9	1.0		
Bankfull Cross Sectional Area (ft^2)	11.5	11.5	11.7	11.7	10.0			7.2	7.1	6.3	6.3	6.4			7.0	7.3	6.8	6.7	6.1			4.6	4.5	3.2	3.3	3.2			5.3	4.9	4.8	3.9	4.0		
Bankfull Width/Depth Ratio	9.8	9.6	13.0	14.6	11.1			13.3	18.2	15.9	14.1	14.9			16.3	18.7	19.5	17.9	20.3			18.2	21.5	24.4	21.6	21.8			13.9	13.8	15.0	18.0	14.4		
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	N/A		
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	1.0			1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	1.1			1.0	1.0	1.0	1.0	N/A		
	Cross Section 26 (Shallow)							**Cross Section 27 (Pool)**							**Cross Section 28 (Shallow)**							**Cross Section 29 (Pool)**							**Cross Section 30 (Pool)**						
Based on fixed baseline bankfull elevation[1]	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	44.6	44.6	44.6	44.6	44.6			44.5	44.5	44.5	44.5	44.5			44.0	44.0	44.0	44.0	44.0			43.6	43.6	43.6	43.6	43.6			42.7	42.7	42.7	42.7	42.7		
Bankfull Width (ft)	7.3	9.1	8.5	7.6	7.7			7.0	7.6	7.3	7.2	7.7			19.6	20.1	20.3	15.9	14.7			9.7	10.1	9.4	9.0	9.8			7.4	7.3	8.5	8.6	6.2		
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0		
Bankfull Mean Depth (ft)	0.6	0.5	0.4	0.5	0.5			0.7	0.6	0.7	0.6	0.6			0.4	0.4	0.4	0.4	0.4			0.7	0.6	0.5	0.5	0.5			0.5	0.5	0.5	0.4	0.4		
Bankfull Max Depth (ft)	1.1	1.1	1.0	1.0	0.9			1.4	1.4	1.3	1.2	1.2			1.2	1.3	1.1	1.1	1.1			1.5	1.3	1.2	1.2	1.3			1.1	0.9	1.0	0.9	0.7		
Bankfull Cross Sectional Area (ft^2)	4.3	4.1	3.4	3.6	3.5			5.1	5.1	4.8	4.4	4.4			8.2	8.7	7.6	6.7	6.6			6.4	6.2	4.5	4.5	4.6			4.0	3.6	3.9	3.6	2.5		
Bankfull Width/Depth Ratio	12.2	20.1	21.2	16.3	17.2			9.5	11.2	10.9	11.9	13.5			47.1	46.3	54.0	38.0	32.6			14.7	16.5	19.4	18.2	21.1			13.6	15.0	18.2	20.1	15.4		
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	N/A		
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	1.0			1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	1.0			1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	N/A		
	Cross Section 31 (Shallow)							**Cross Section 32 (Shallow)**							**Cross Section 33 (Pool)**							**Cross Section 34 (Shallow)**							**Cross Section 35 (Pool)**						
Based on fixed baseline bankfull elevation[1]	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	42.9	42.9	42.9	42.9	42.9			42.6	42.6	42.6	42.6	42.6			42.4	42.4	42.4	42.4	42.4			42.2	42.2	42.2	42.2	42.2			42.1	42.1	42.1	42.1	42.1		
Bankfull Width (ft)	11.3	12.3	13.5	11.3	12.1			6.8	7.2	6.9	6.3	7.4			7.1	7.4	7.8	7.1	7.1			8.4	7.8	6.8	7.1	7.4			7.7	7.8	8.0	7.3	6.7		
Floodprone Width (ft)	70.0	70.0	70.0	70.0	70.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0		
Bankfull Mean Depth (ft)	0.4	0.4	0.3	0.4	0.4			0.5	0.5	0.5	0.5	0.4			0.6	0.6	0.4	0.5	0.5			0.5	0.5	0.5	0.4	0.4			0.7	0.7	0.6	0.7	0.7		
Bankfull Max Depth (ft)	0.9	0.9	1.0	1.0	1.0			1.0	1.0	1.0	1.0	1.0			1.1	1.0	0.8	0.8	0.8			0.9	0.9	0.9	0.8	0.9			1.4	1.4	1.1	1.2	1.2		
Bankfull Cross Sectional Area (ft^2)	4.6	4.5	4.6	4.0	4.3			3.7	3.8	3.5	3.2	3.2			4.3	4.3	3.2	3.5	3.3			3.9	3.6	3.2	3.1	2.8			5.6	5.3	4.7	5.0	4.9		
Bankfull Width/Depth Ratio	28.3	33.7	39.3	31.7	33.9			12.4	13.4	13.6	12.5	17.4			11.5	12.9	19.4	14.5	15.4			18.1	16.5	14.7	16.3	19.7			10.5	11.3	13.8	10.6	9.1		
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	N/A		
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	0.9			1.0	1.0	1.0	1.0	1.0			1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	0.9			1.0	1.0	1.0	1.0	N/A		
	Cross Section 36 (Shallow)							**Cross Section 37 (Pool)**							**Cross Section 38 (Pool)**							**Cross Section 39 (Shallow)**													
Based on fixed baseline bankfull elevation[1]	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+	Base	MY1	MY2	MY3	MY4	MY5	MY+
Record elevation (datum) used	41.8	41.8	41.8	41.8	41.8			41.8	41.8	41.8	41.8	41.8			41.1	41.1	41.1	41.1	41.1			41.1	41.1	41.1	41.1	41.1									
Bankfull Width (ft)	7.4	7.8	9.8	7.8	9.1			9.6	10.0	9.2	9.7	9.4			15.6	15.5	16.7	16.1	16.3			11.9	11.6	12.1	11.9	12.3									
Floodprone Width (ft)	50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0			50.0	50.0	50.0	50.0	50.0									
Bankfull Mean Depth (ft)	0.6	0.6	0.5	0.6	0.4			0.5	0.4	0.5	0.5	0.5			1.2	1.1	1.0	1.0	1.0			0.8	0.7	0.7	0.7	0.6									
Bankfull Max Depth (ft)	1.0	1.0	1.0	1.0	0.8			1.3	1.1	1.1	1.1	1.0			2.5	2.2	2.3	2.0	2.0			1.6	1.5	1.5	1.5	1.4									
Bankfull Cross Sectional Area (ft^2)	4.4	4.3	4.5	4.7	3.7			5.1	4.4	4.2	5.1	4.6			18.6	17.3	17.3	16.4	16.7			9.3	8.1	8.0	8.1	7.9									
Bankfull Width/Depth Ratio	12.2	14.2	21.0	13.0	22.5			18.2	22.9	19.8	18.3	19.1			13.0	14.0	16.1	15.7	15.8			15.1	16.6	18.4	17.5	19.0									
Bankfull Entrenchment Ratio	>2.2	>2.2	>2.2	>2.2	>2.2			>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	N/A			>2.2	>2.2	>2.2	>2.2	>2.2									
Bankfull Bank Height Ratio	1.0	1.0	1.0	1.0	1.0			1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	N/A			1.0	1.0	1.0	1.0	0.9									

1 = Widths and depths for annual measurements will be based on the baseline bankfull datum regardless of dimensional/depositional development. Input the elevation used as the datum, which should be consistent and based on the baseline datum established. If the performer has inherited the project and cannot acquire the datum used for prior years this must be discussed with EEP. If this cannot be resolved in time for a given years report submission a footnote in this should be included that states: "It is uncertain if the monitoring datum has been consistent over the monitoring history, which may influence calculated values. Additional data from a prior performer is being acquired to provide confirmation. Values will be recalculated in a future submission based on a consistent datum if determined to be necessary."

Note: Starting in MY4, BHR was calculated on riffles using the baseline bankfull elevation. This method was used because the dimension of the channels has not changed enough to alter the bankfull elevation.

Table 12.Muddy Run Bank Pin Array Summary

Cross Section	Location	Position	Year 1 Reading (ft)	Year 2 Reading (ft)	Year 3 Reading (ft)	Year 4 Reading (ft)
XS 6 @ Sta. 19+70 Reach 1	US	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
XS 11 @ Sta. 26+70 Reach 1	US	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
XS 15 @ Sta. 32+75 Reach 1	US	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
XS 18 @ Sta. 39+70 Reach 1	US	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
XS 23 @ Sta. 46+30 Reach 1	US	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.1	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
XS 25 @ Sta. 2+90 Reach 2	US	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
XS 29 @ Sta. 7+60 Reach 2	US	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
XS 33 @ Sta. 11+45 Reach 2	US	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
XS 37 @ Sta. 15+80 Reach 2	US	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
XS 38 @ Sta. 2+55 Reach 3	US	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0
	DS	Top	0.0	0.0	0.0	0.0
		Bottom	0.0	0.0	0.0	0.0

Notes:

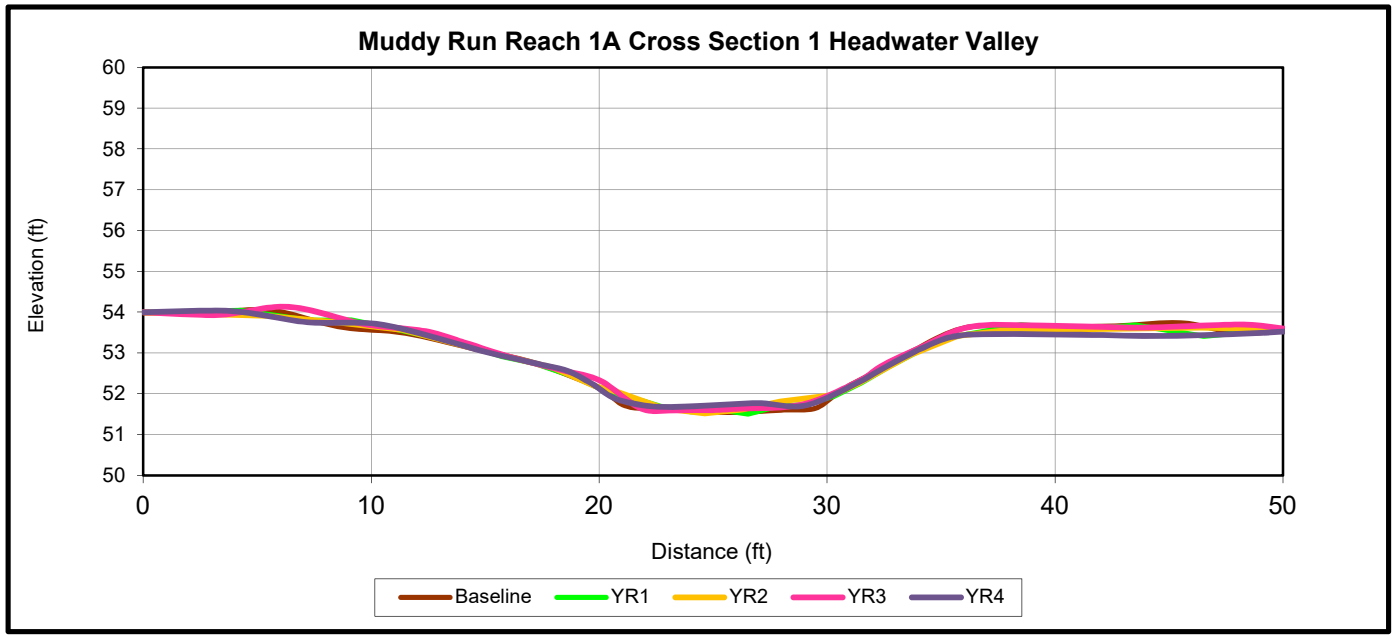
US - Upstream from cross section

DS - Downstream from cross section

Figure 6. Cross Section Plots

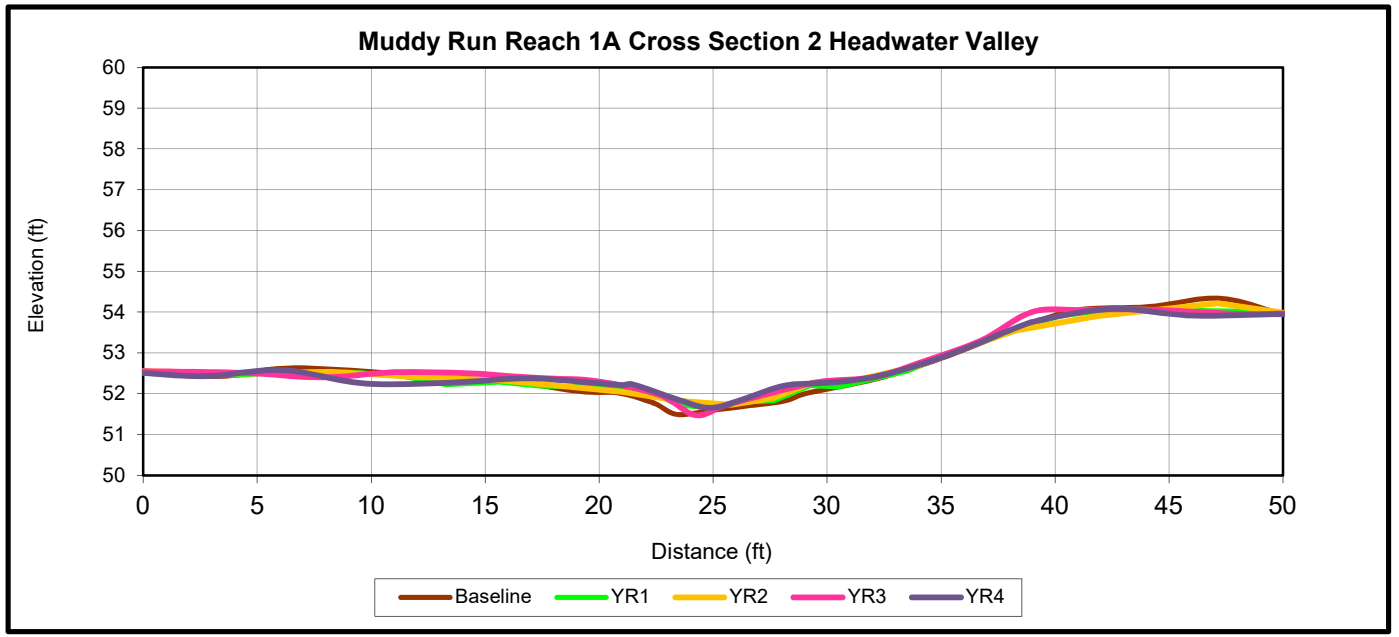
Upstream

Downstream



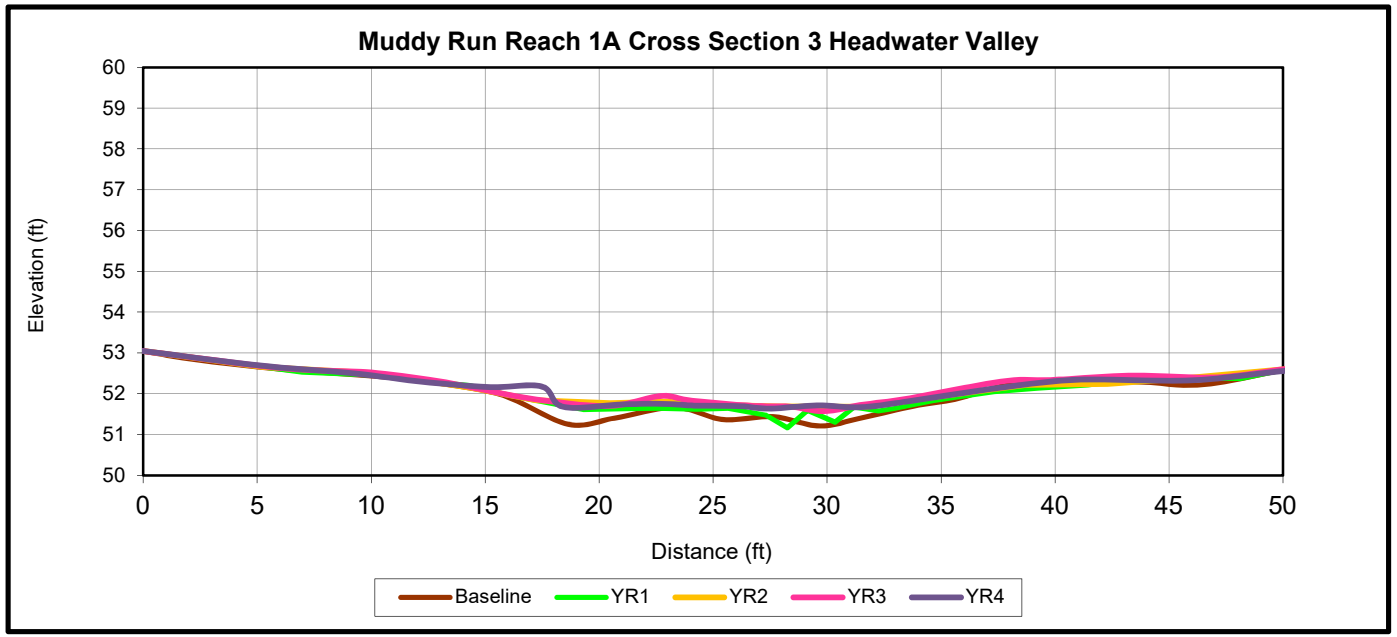
Upstream

Downstream



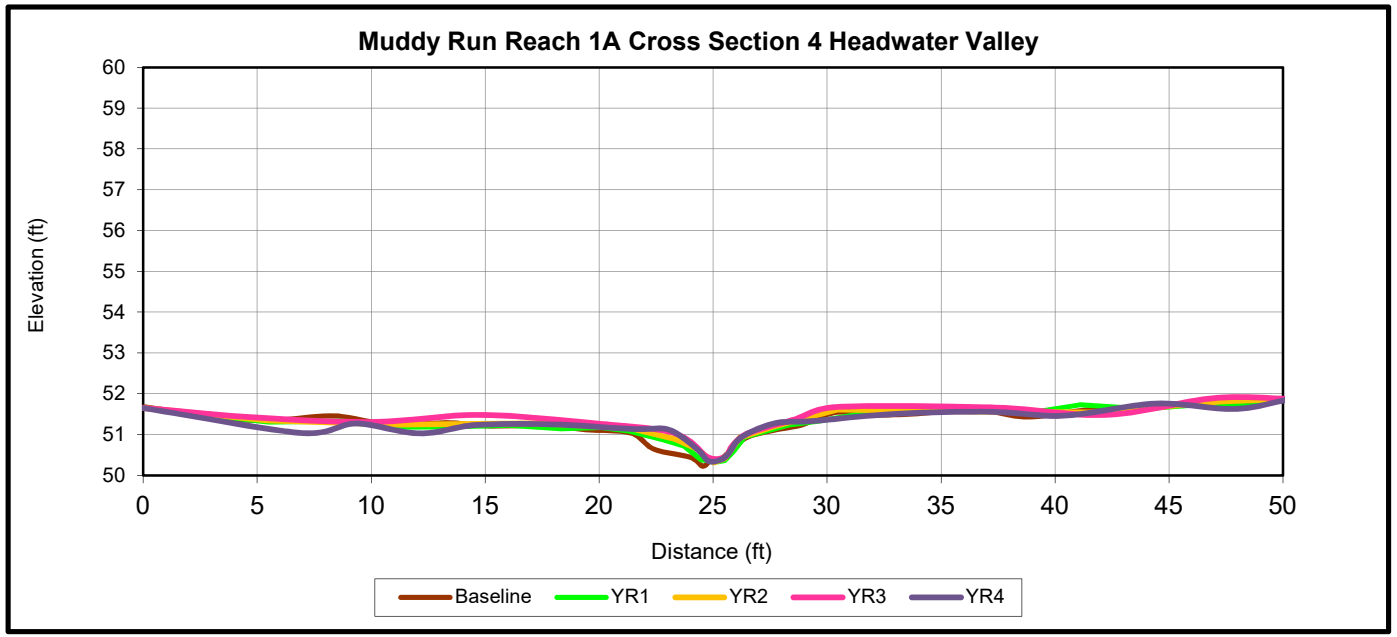
Upstream

Downstream



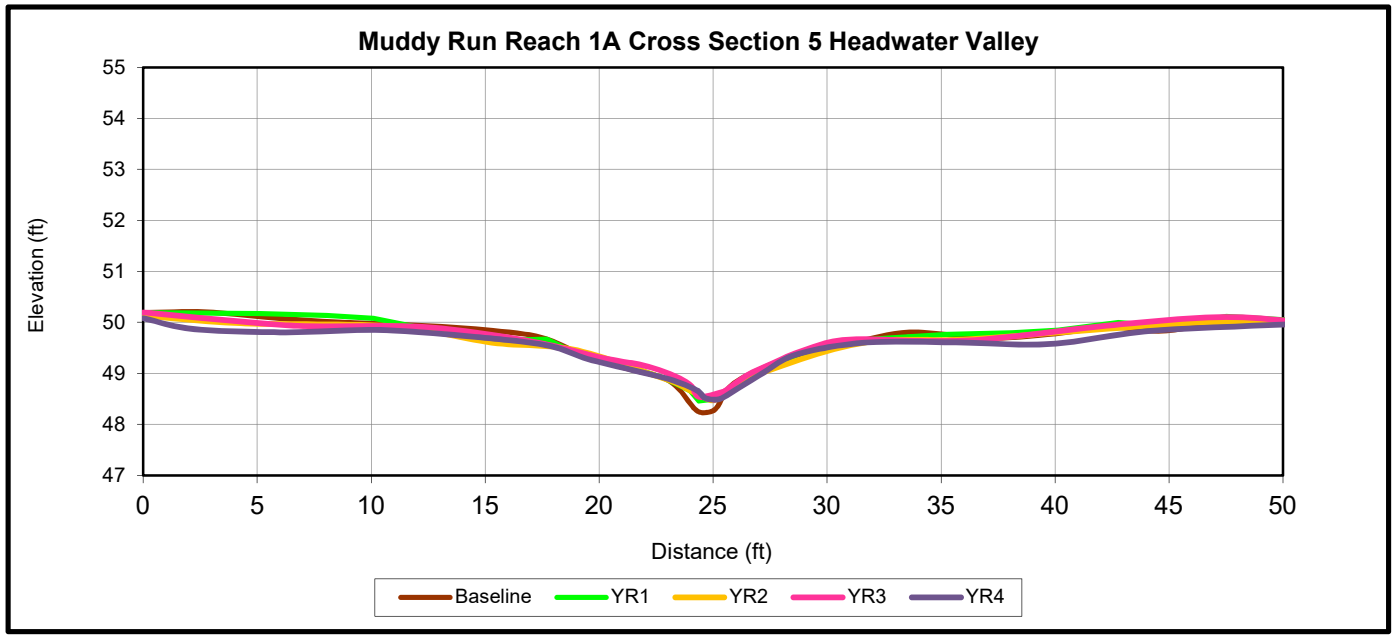
Upstream

Downstream



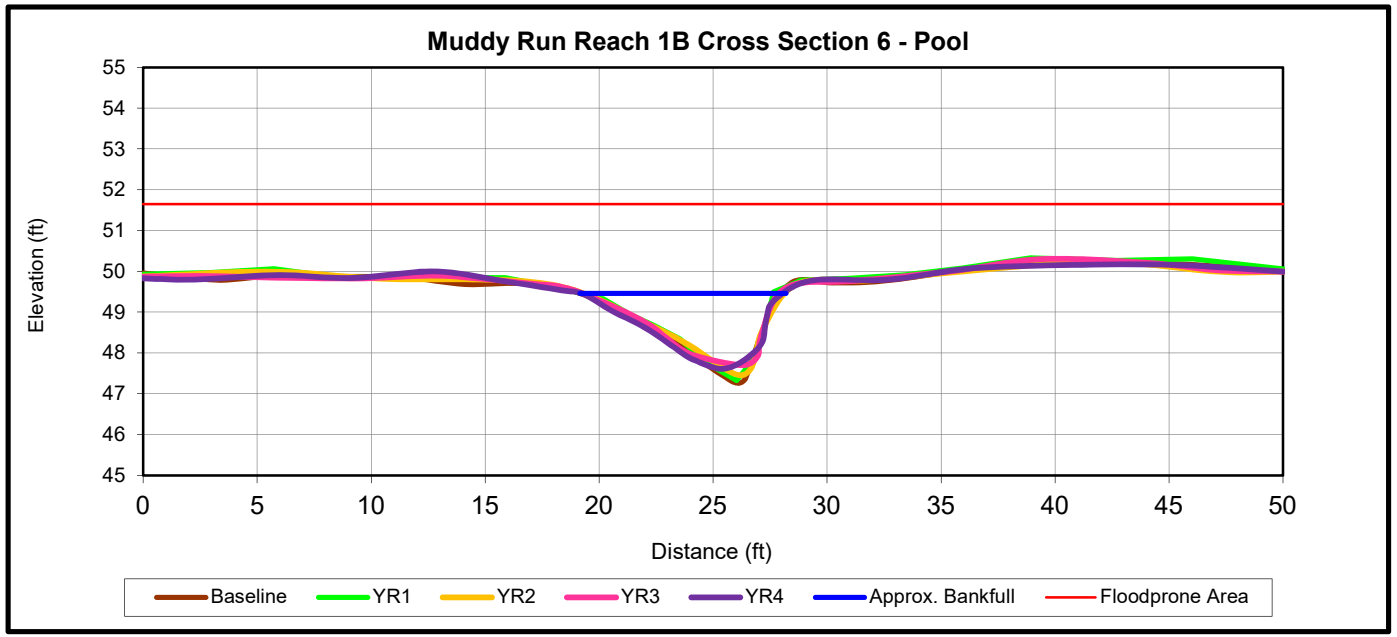
Upstream

Downstream



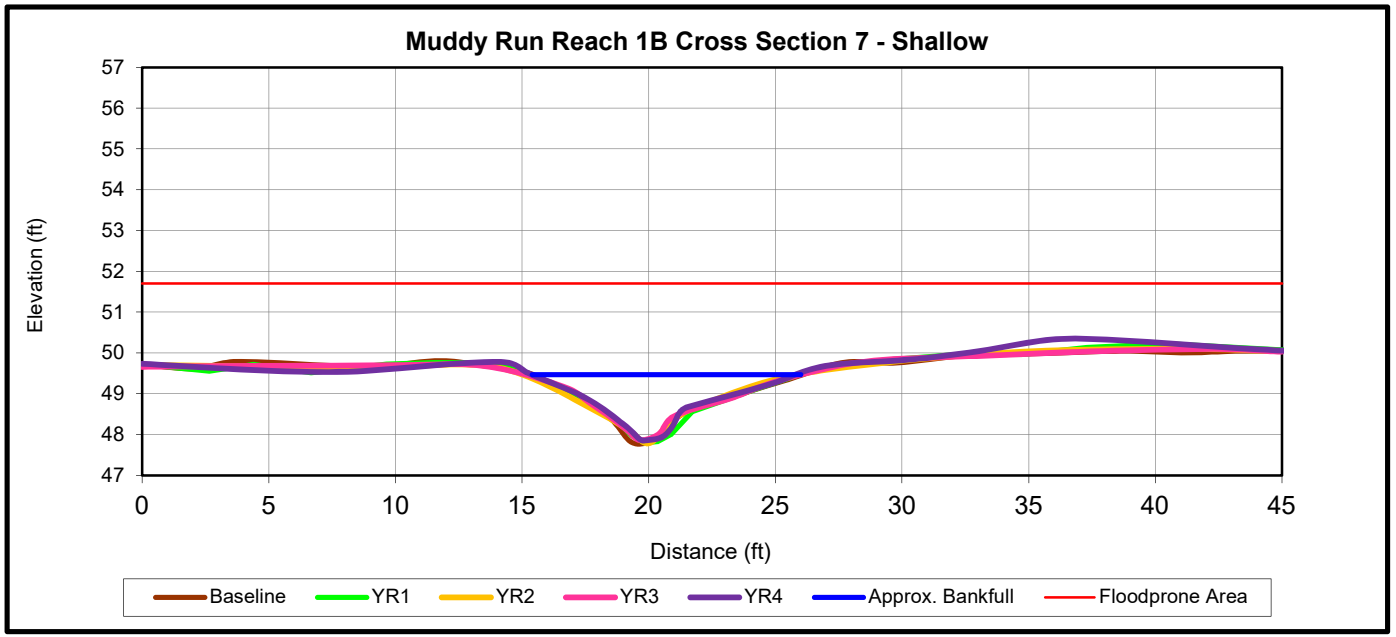
Upstream

Downstream



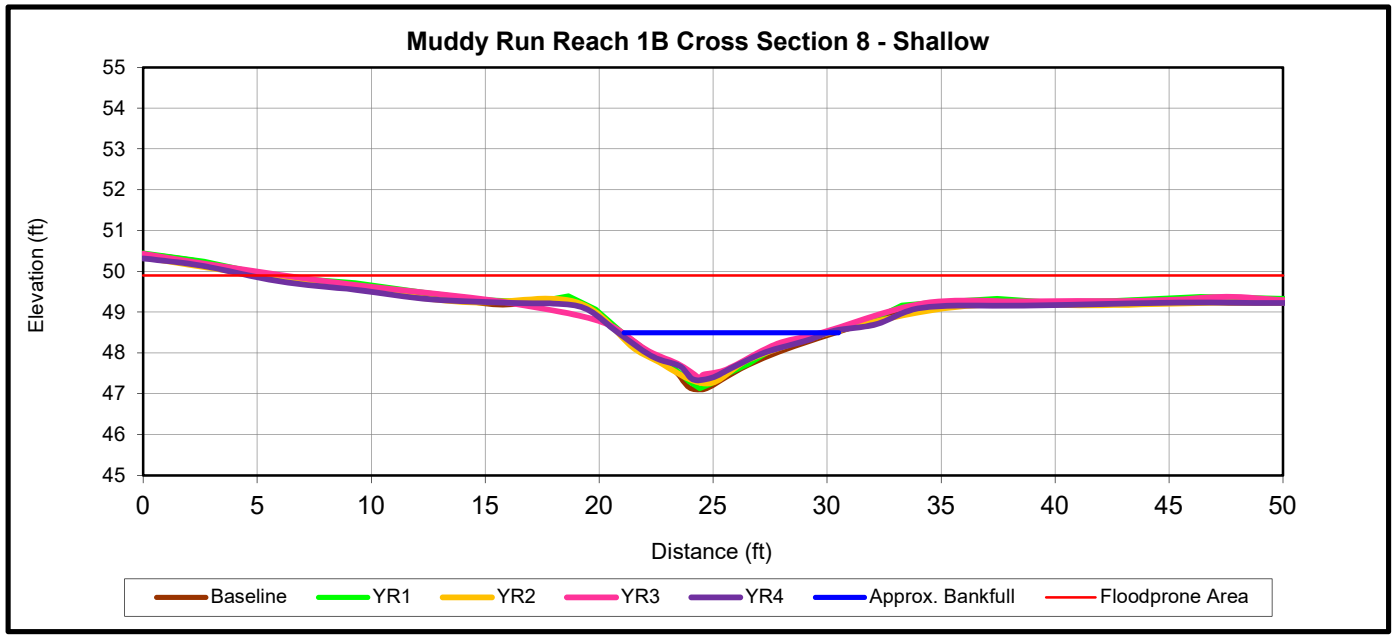
Upstream

Downstream



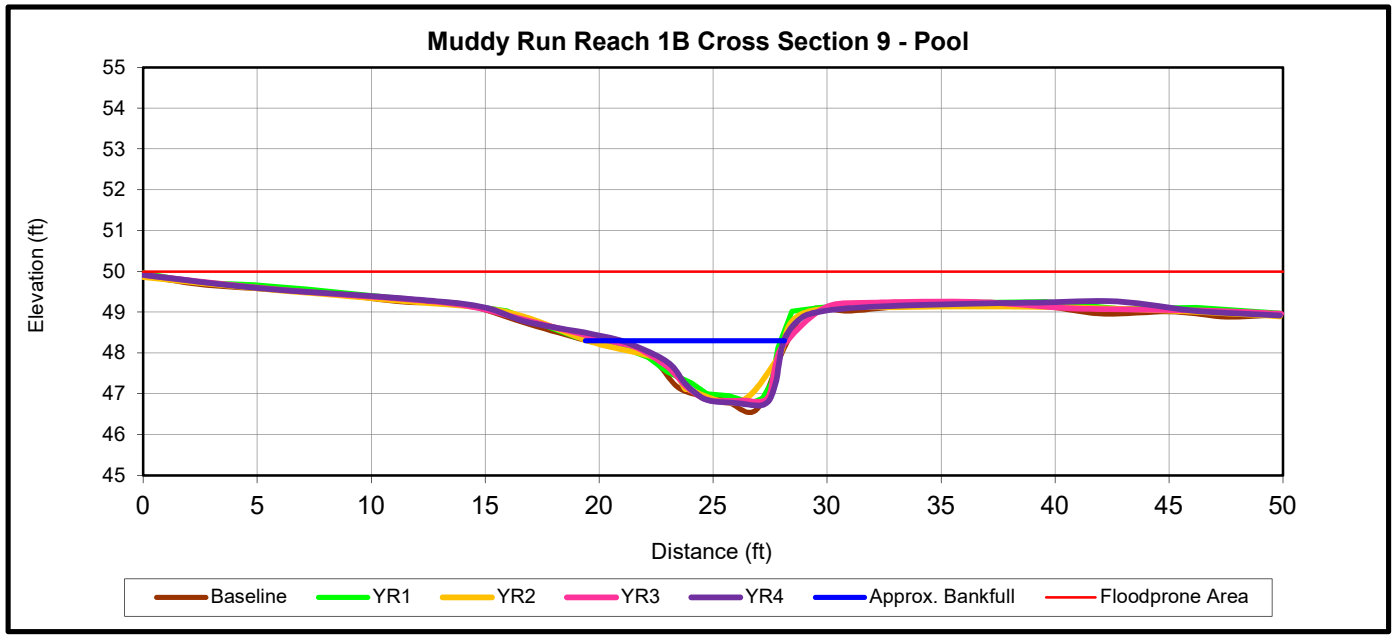
Upstream

Downstream



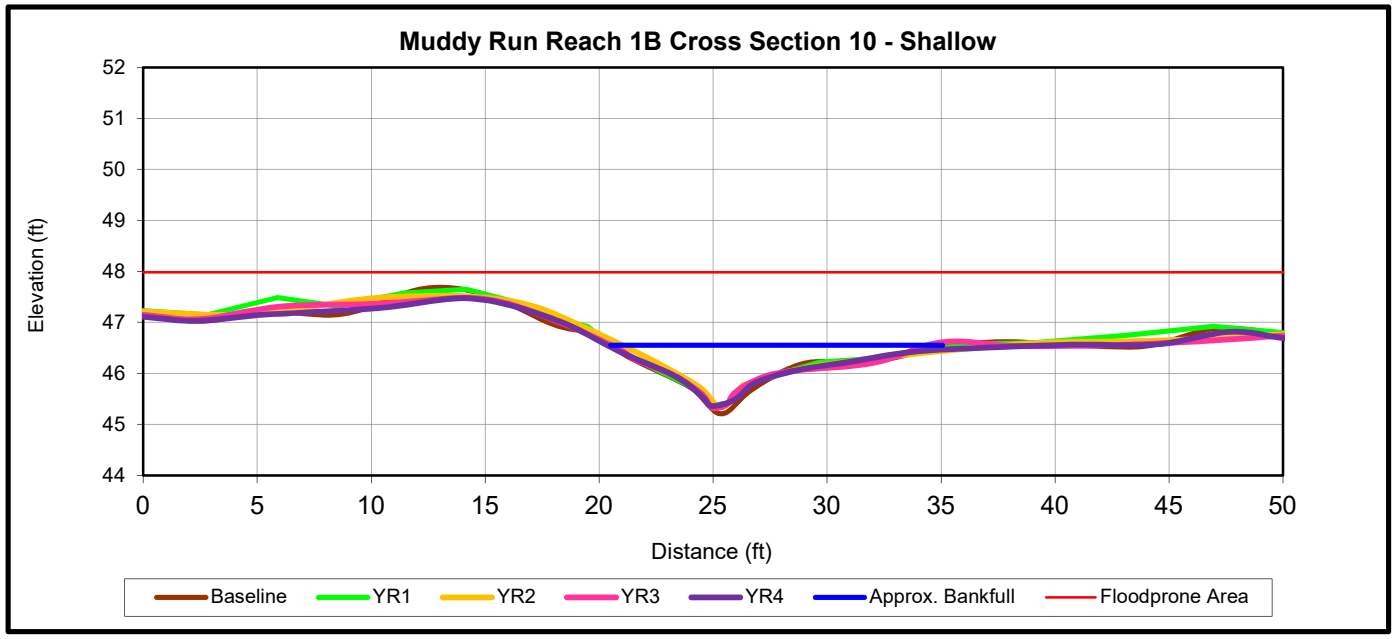
Upstream

Downstream



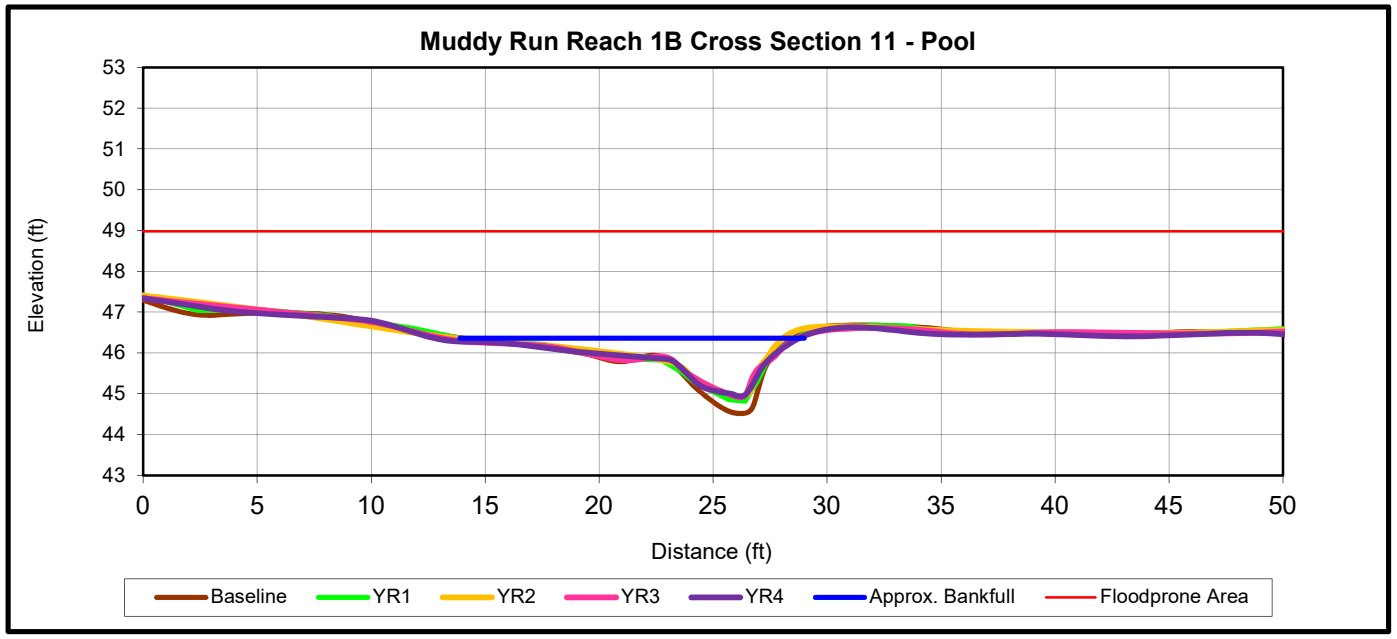
Upstream

Downstream



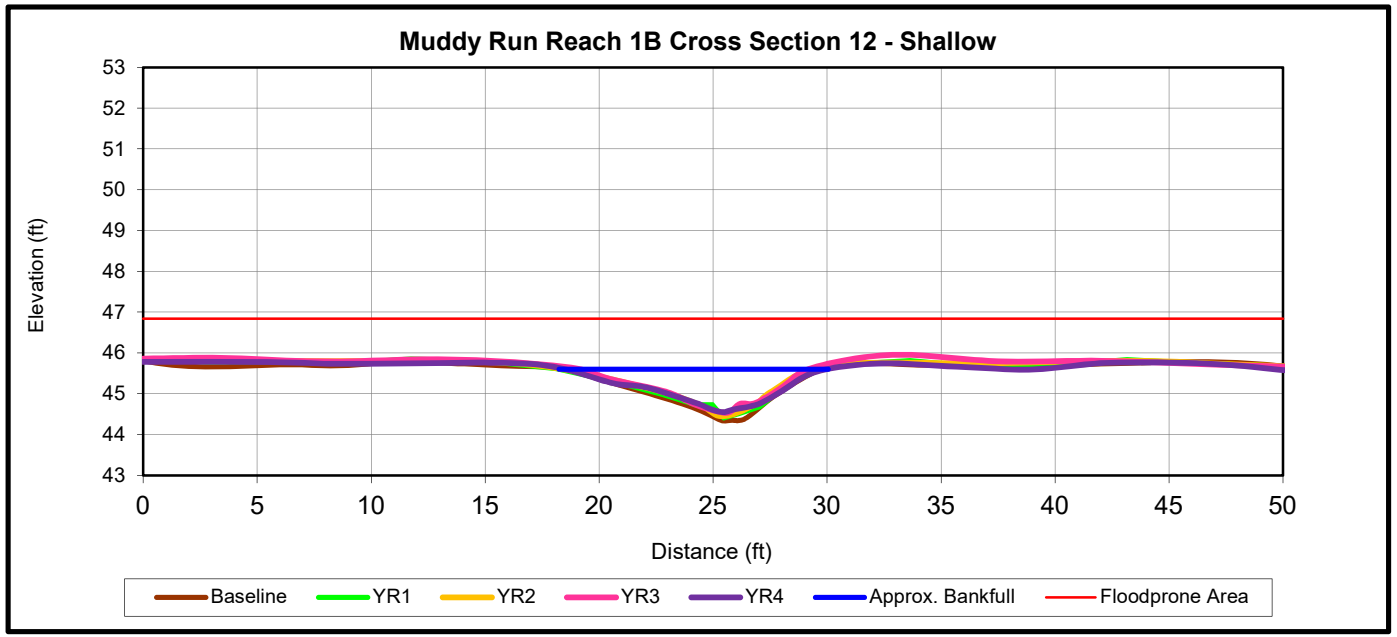
Upstream

Downstream



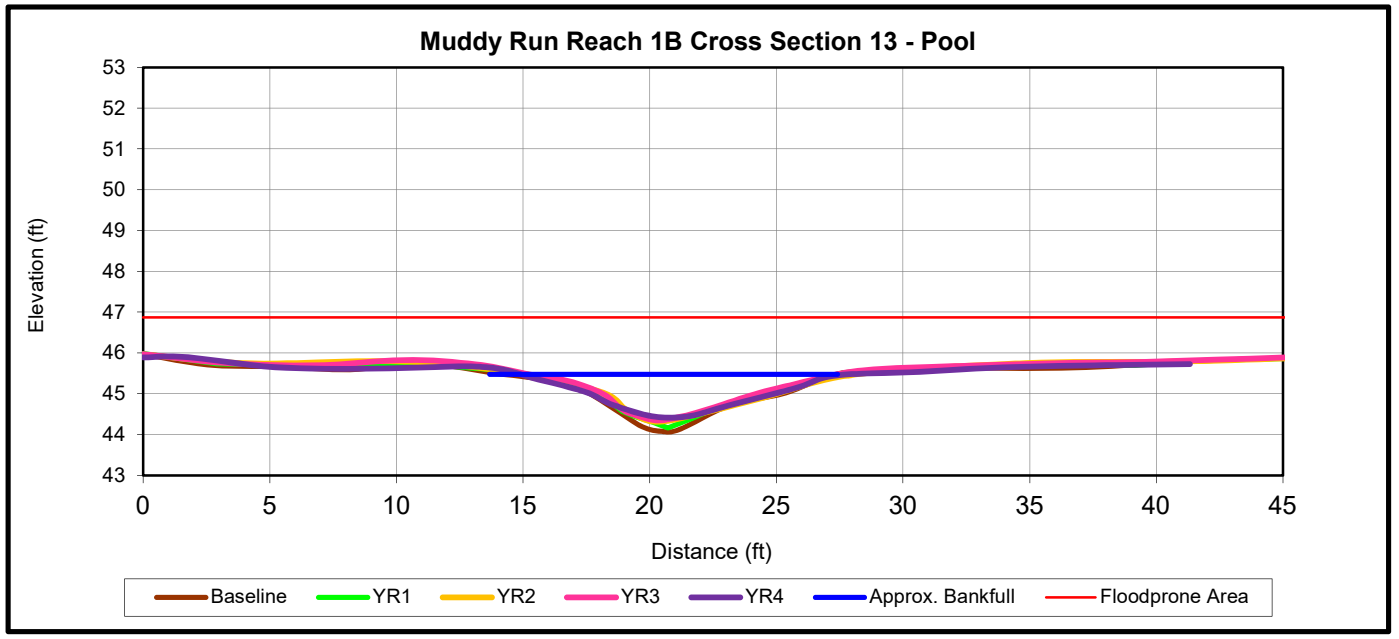
Upstream

Downstream



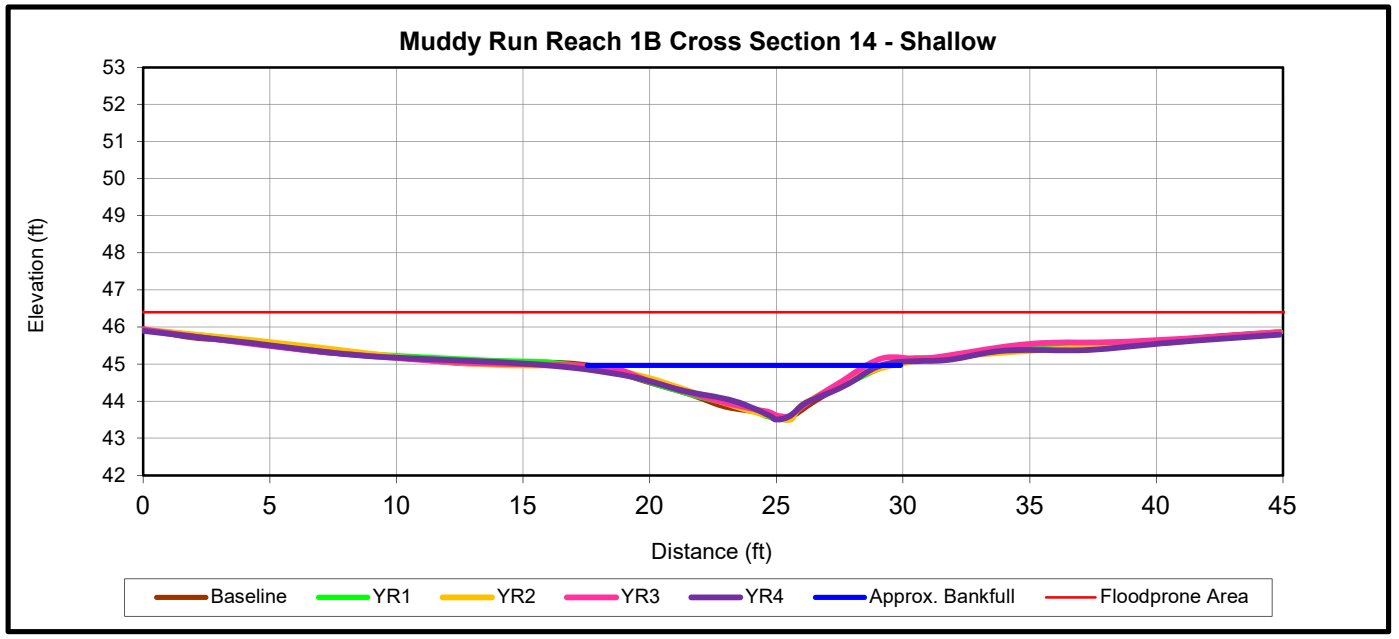
Upstream

Downstream



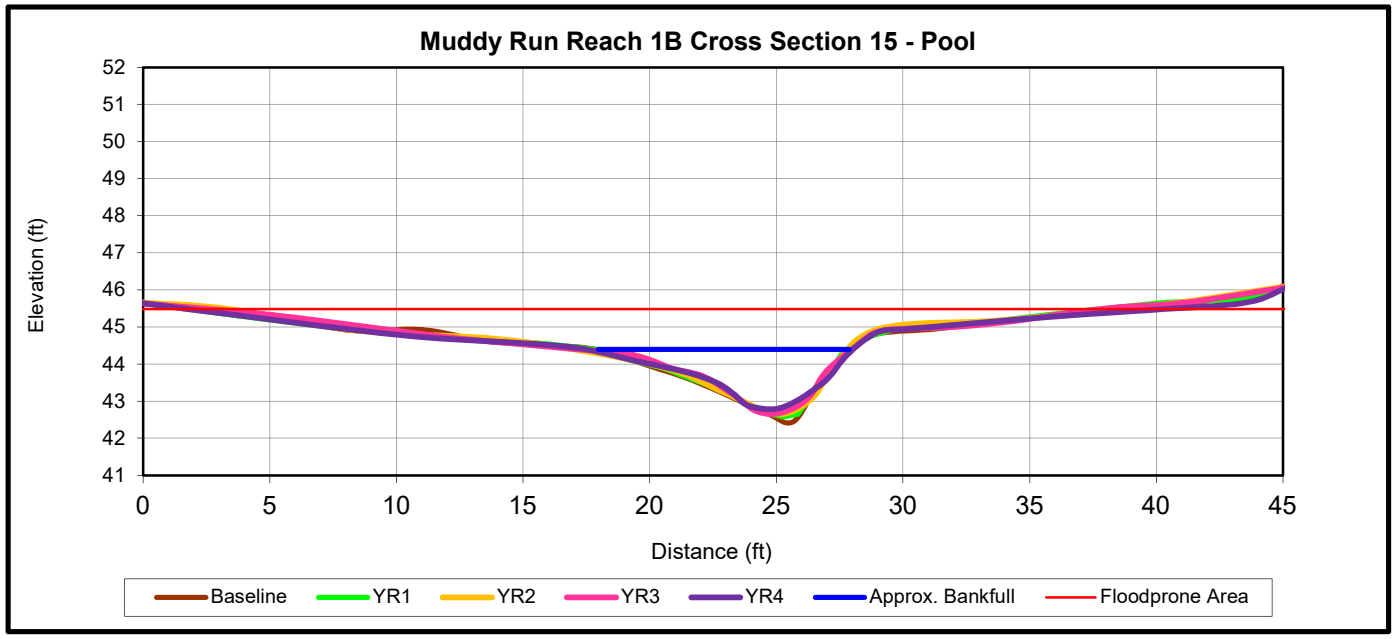
Upstream

Downstream



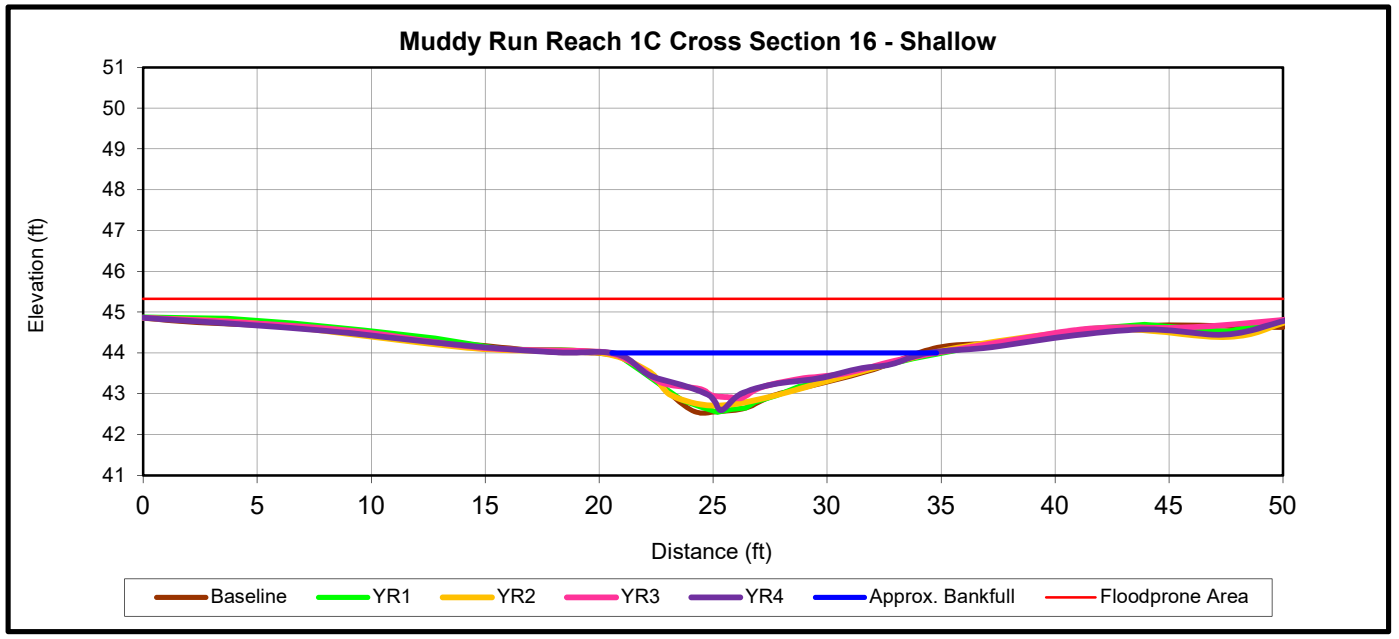
Upstream

Downstream



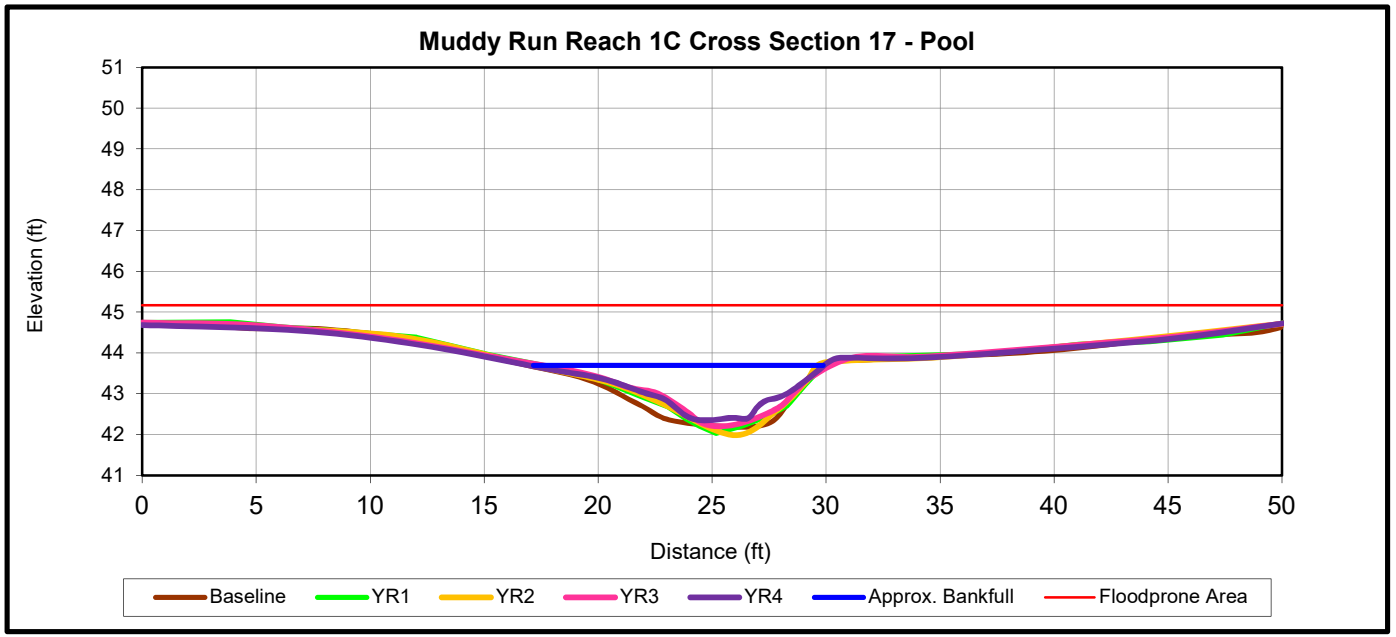
Upstream

Downstream



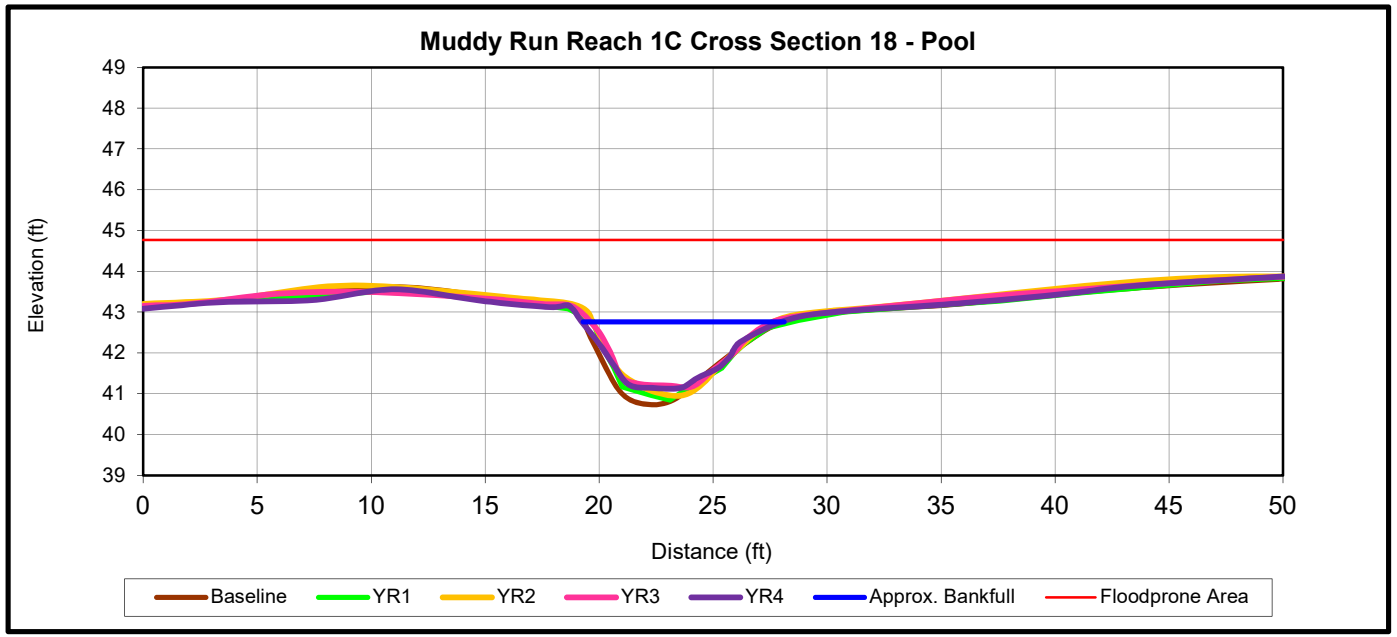
Upstream

Downstream



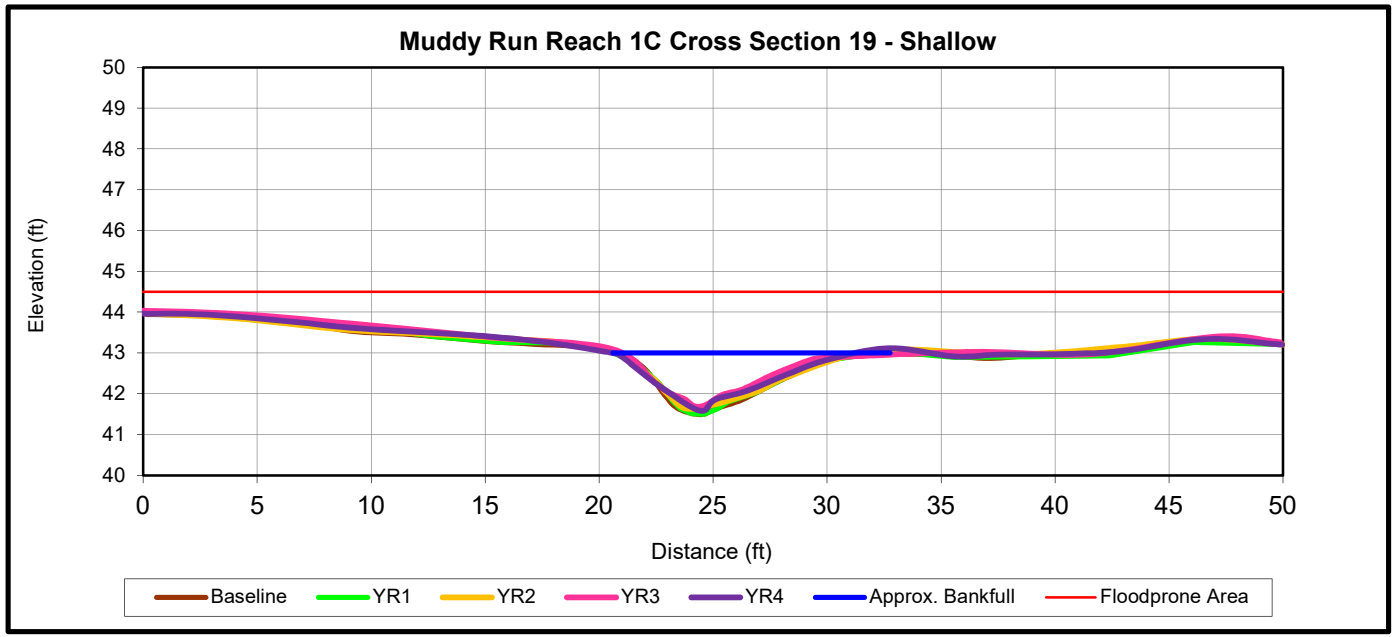
Upstream

Downstream



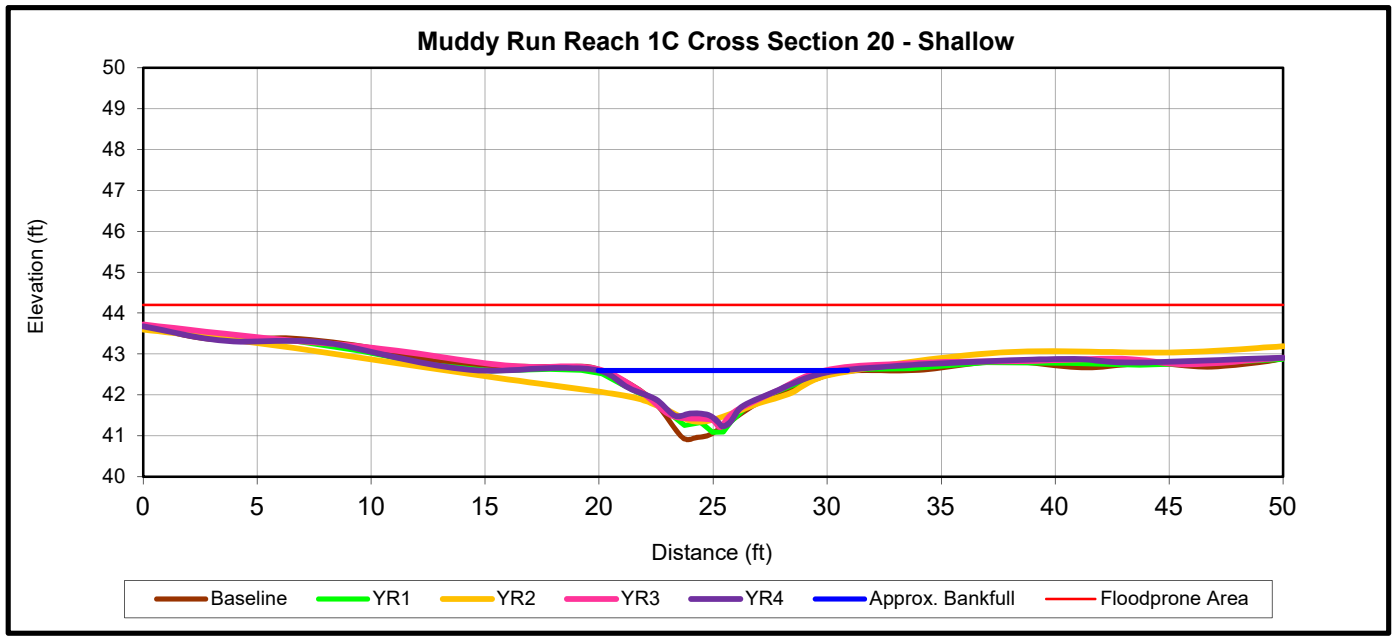
Upstream

Downstream



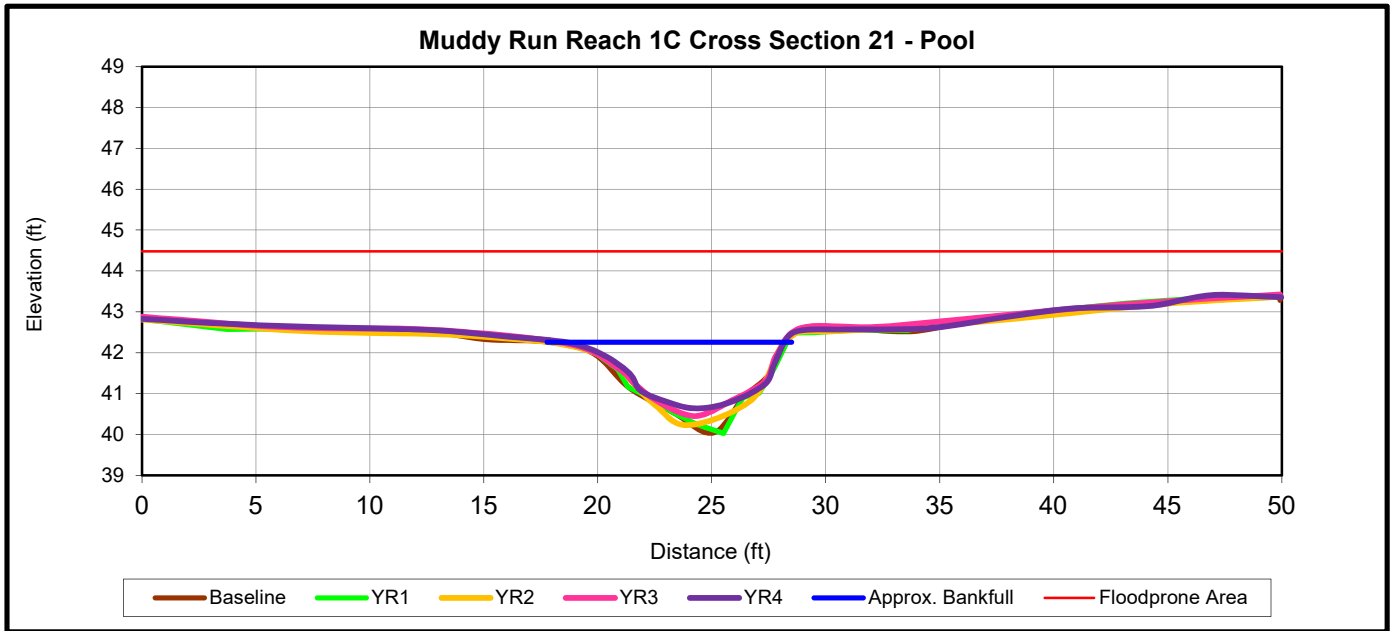
Upstream

Downstream



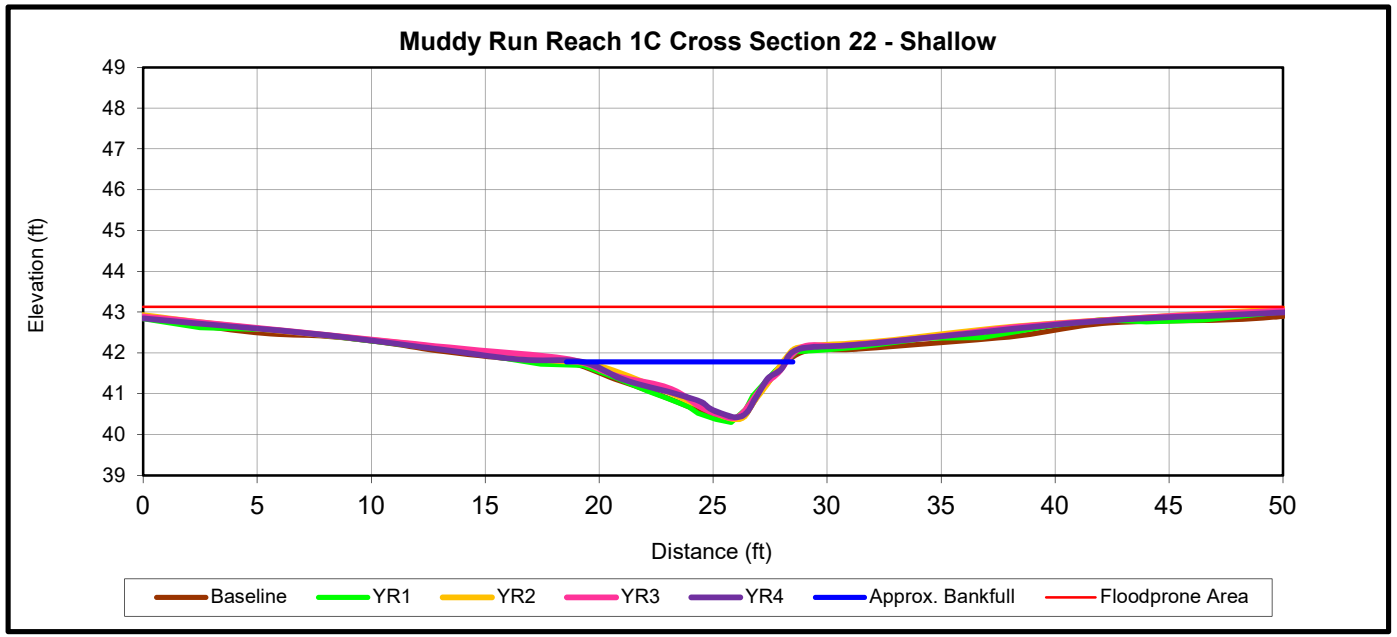
Upstream

Downstream



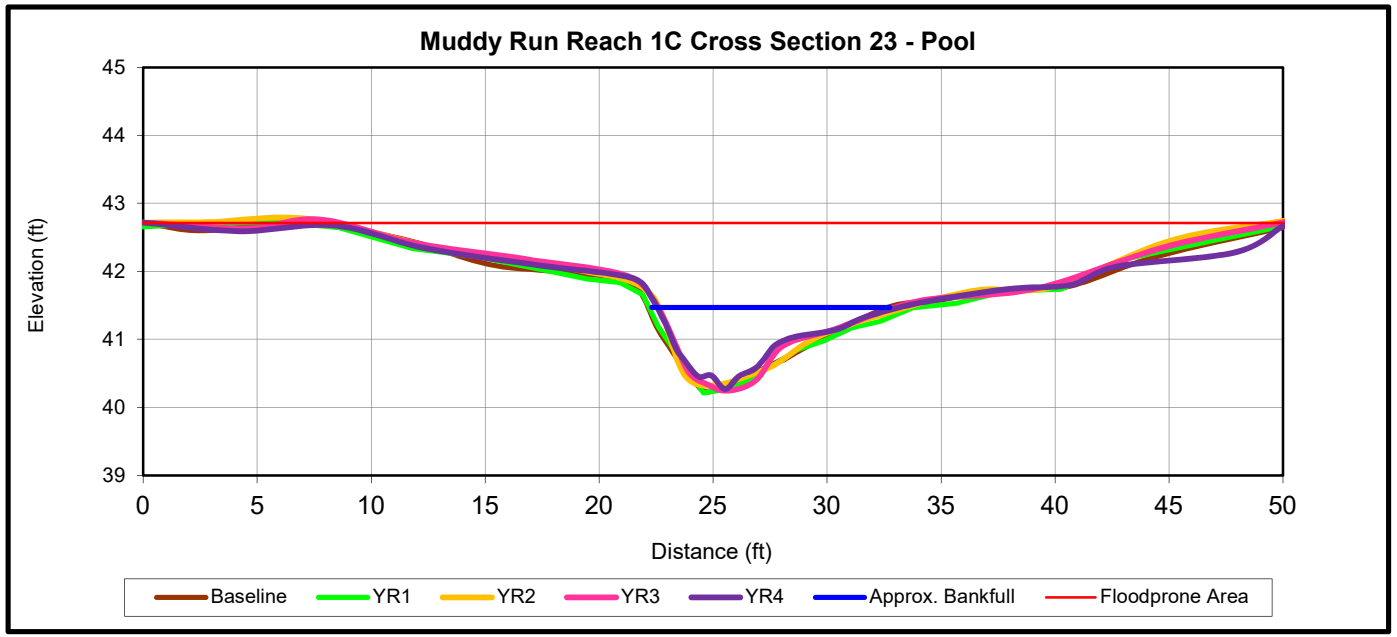
Upstream

Downstream



Upstream

Downstream



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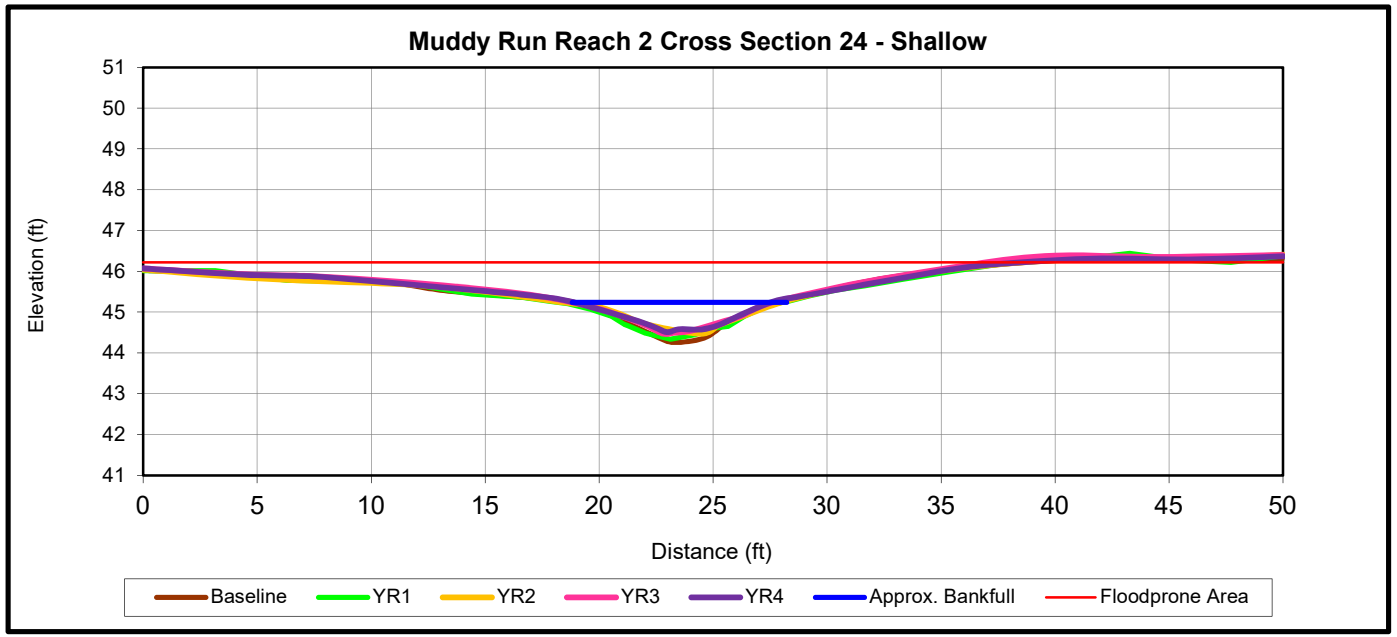
Downstream



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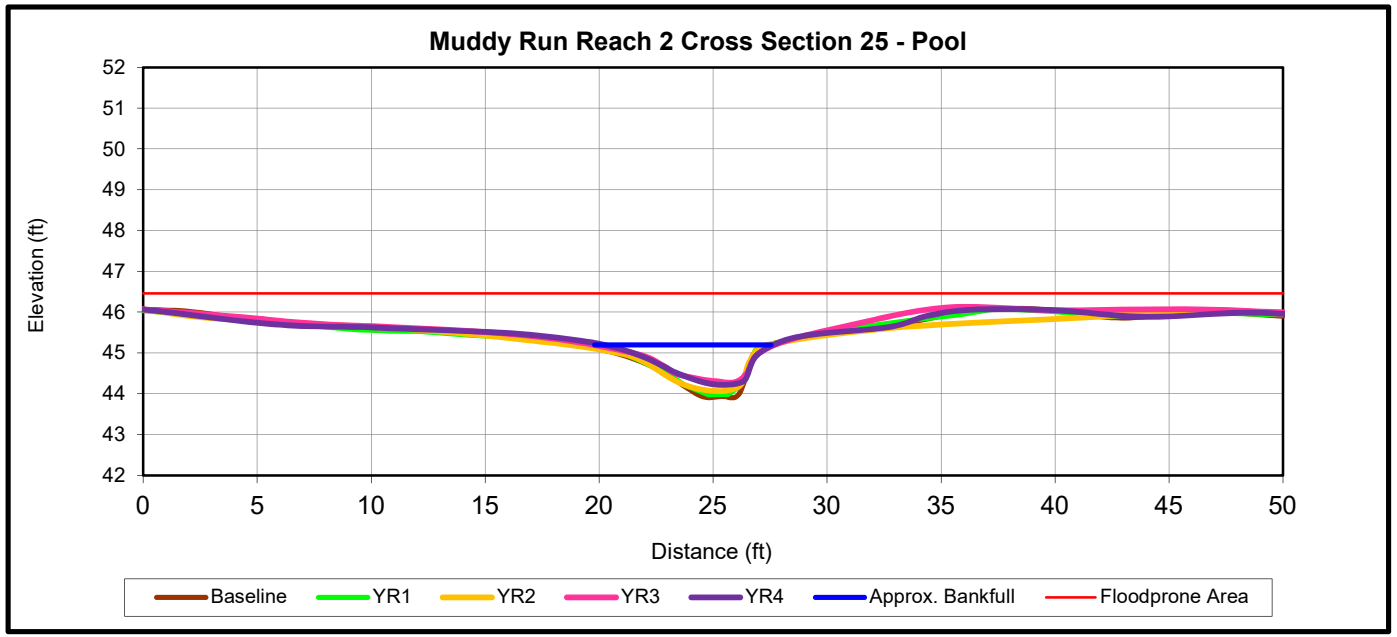
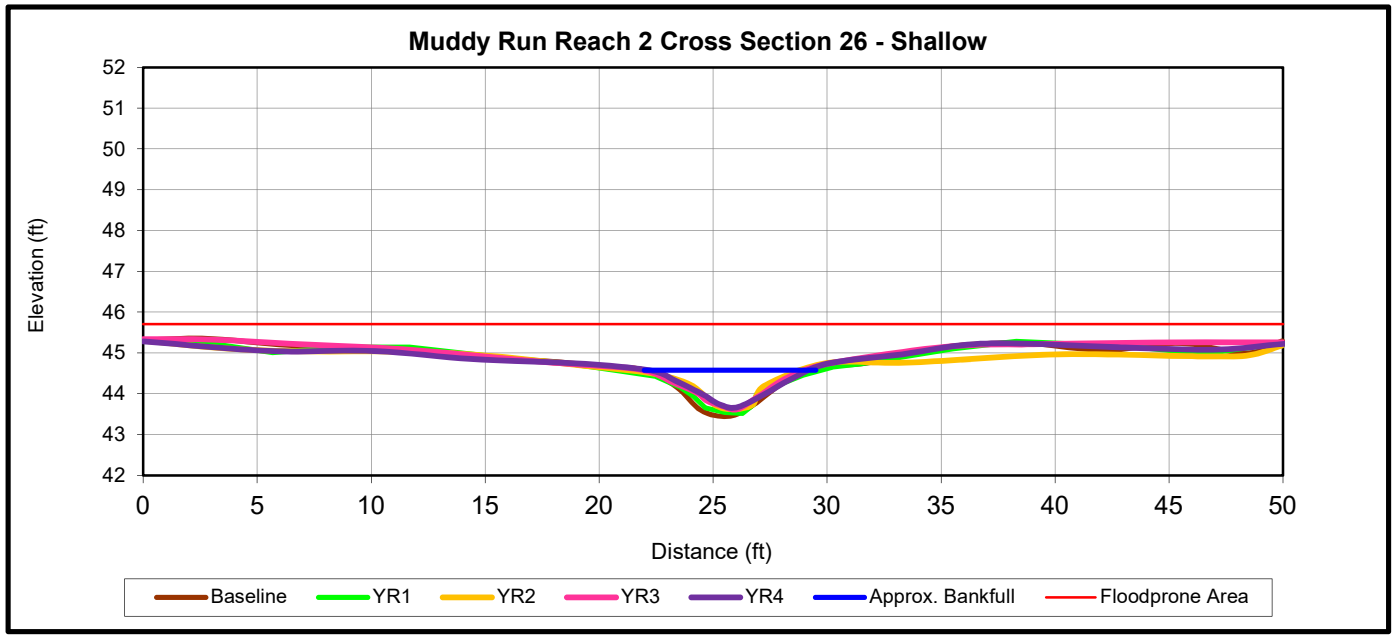


Upstream

Downstream



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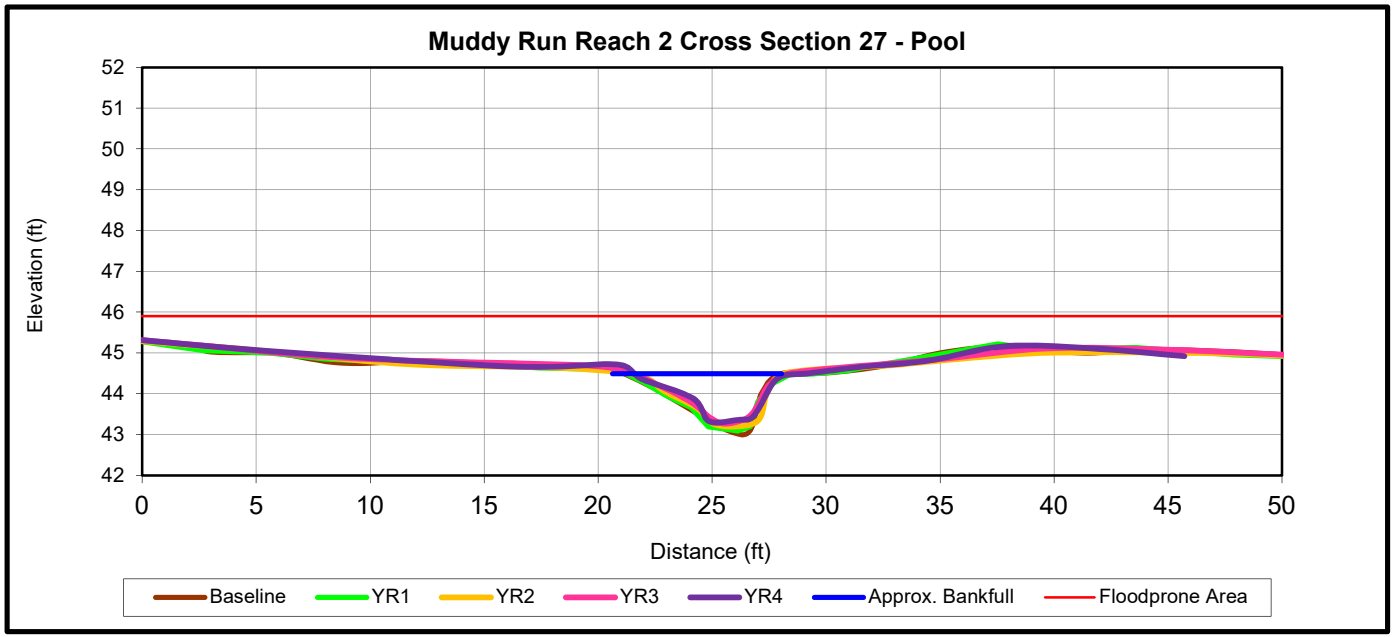

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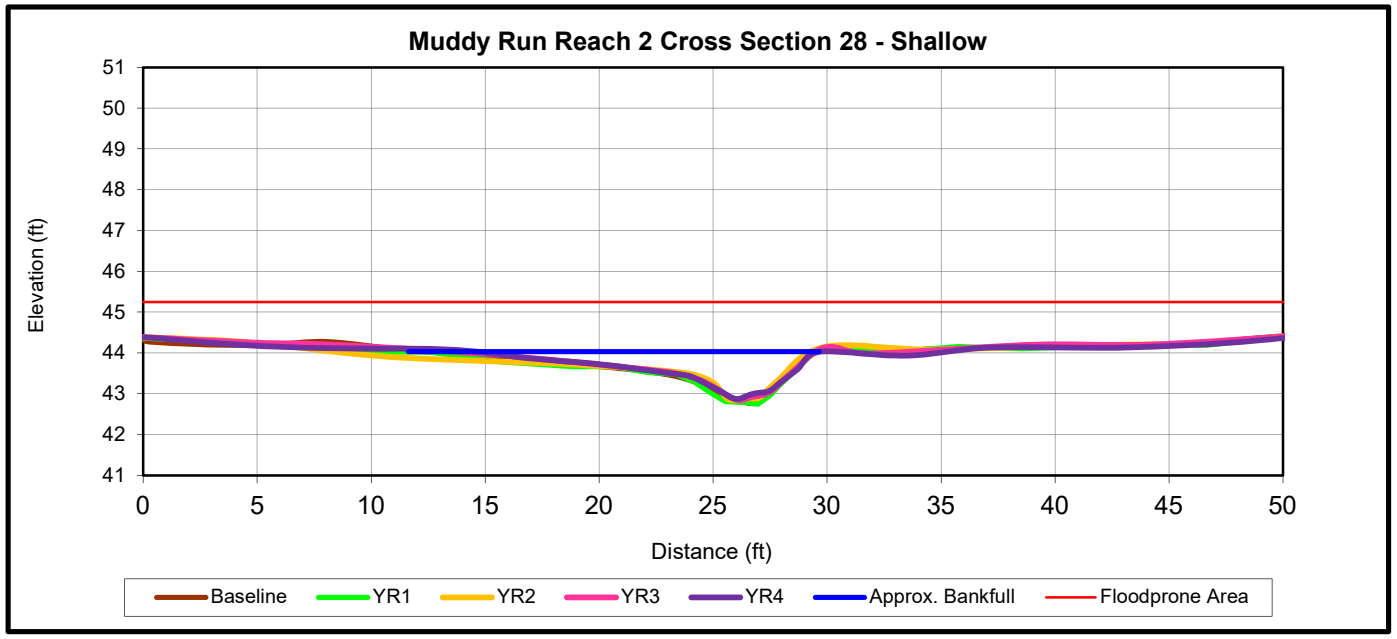

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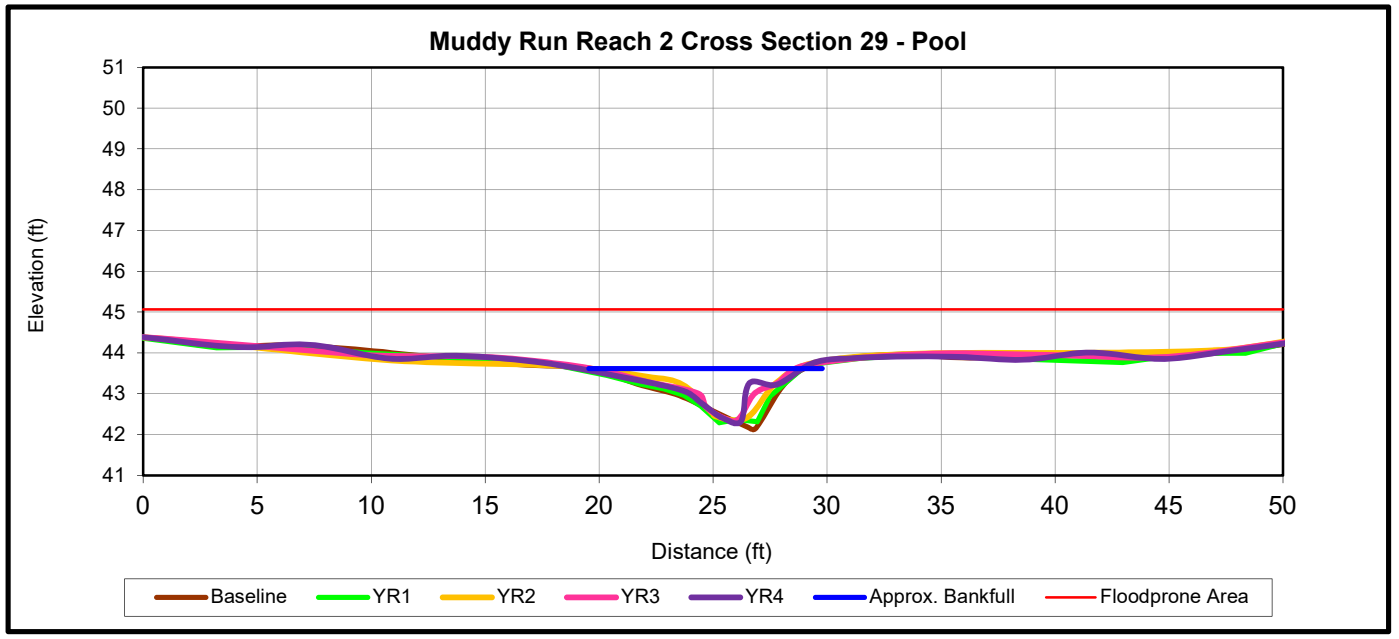

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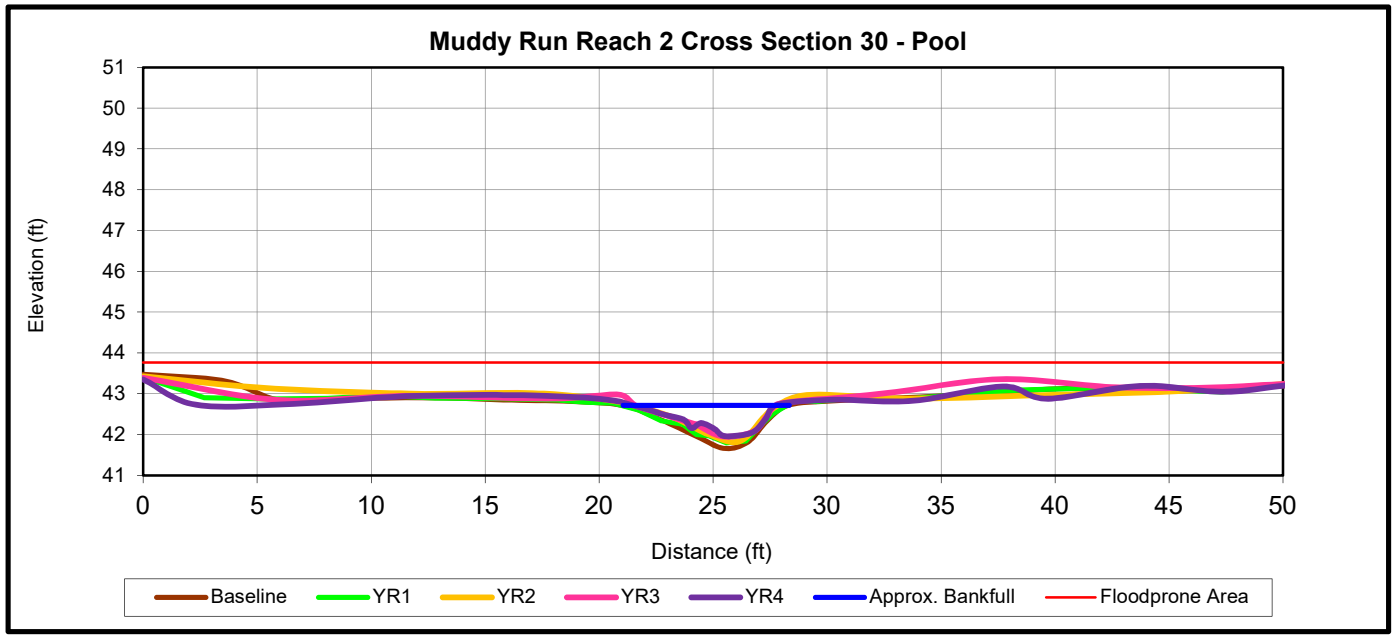

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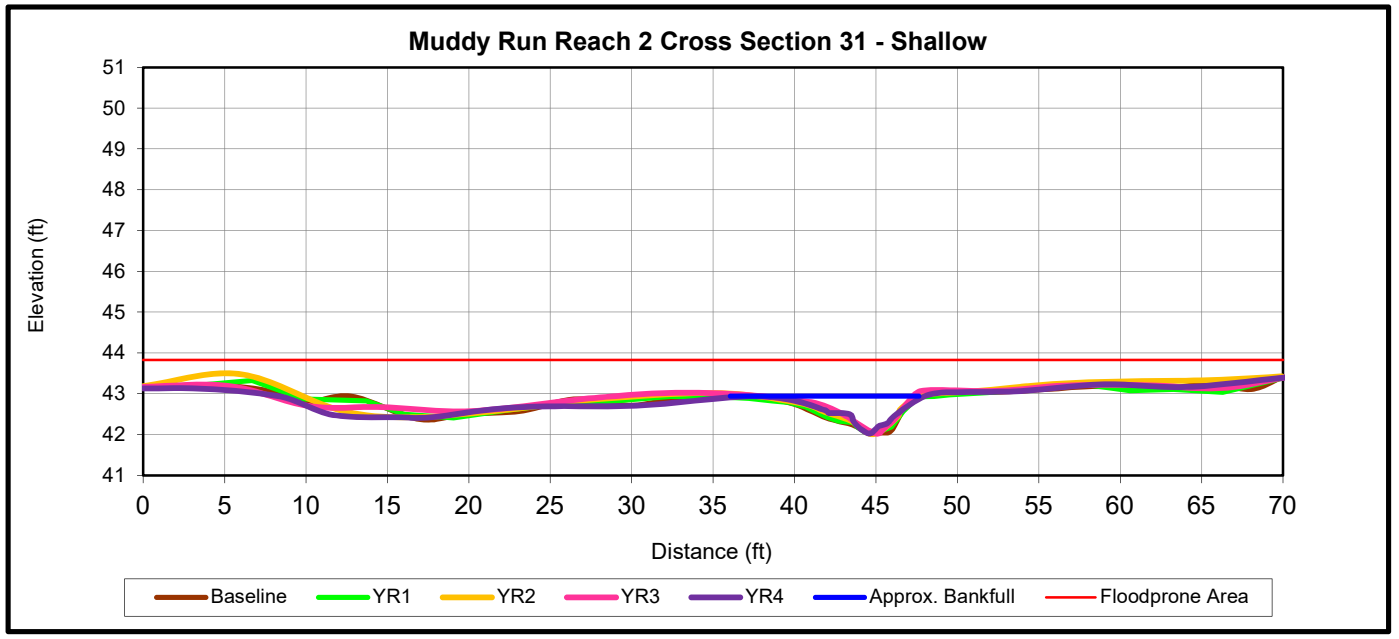
Downstream



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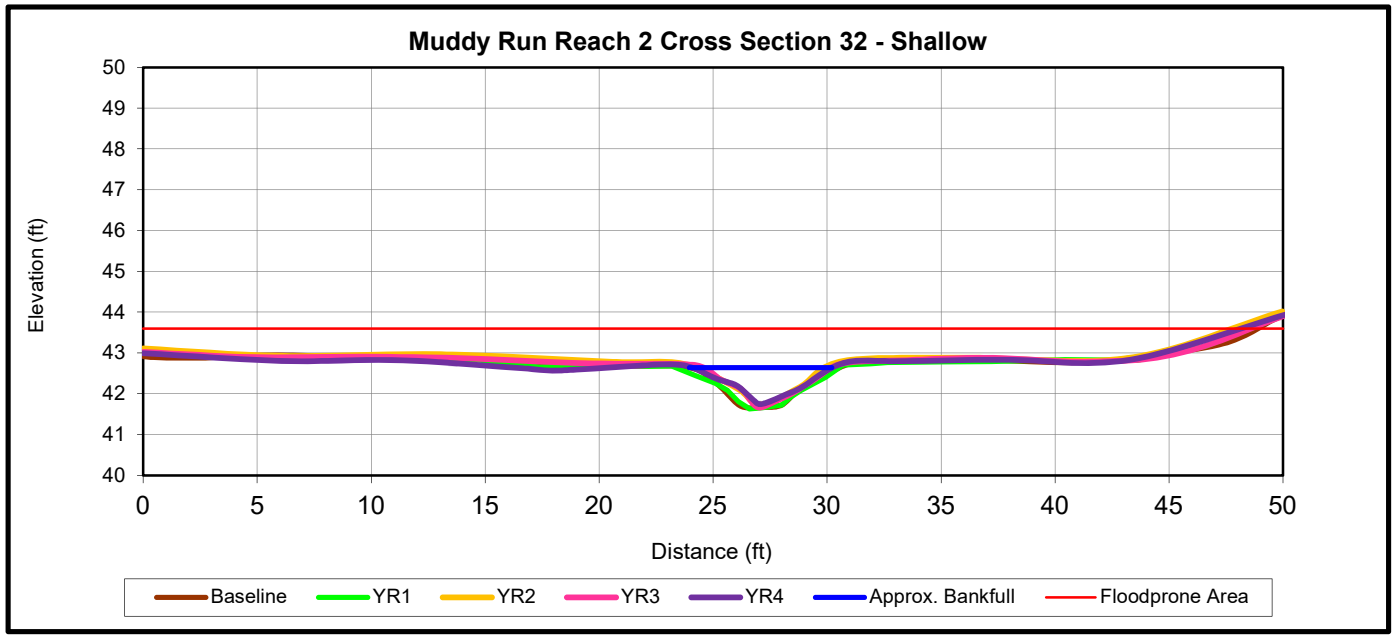
Downstream



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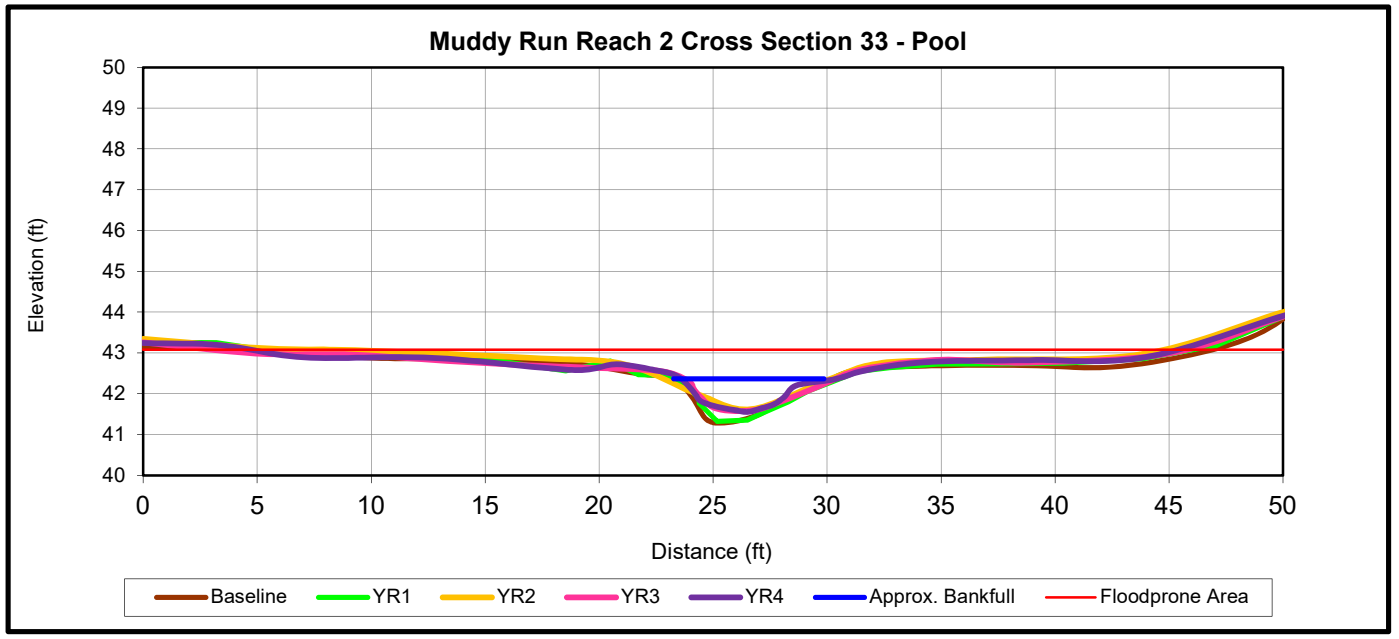
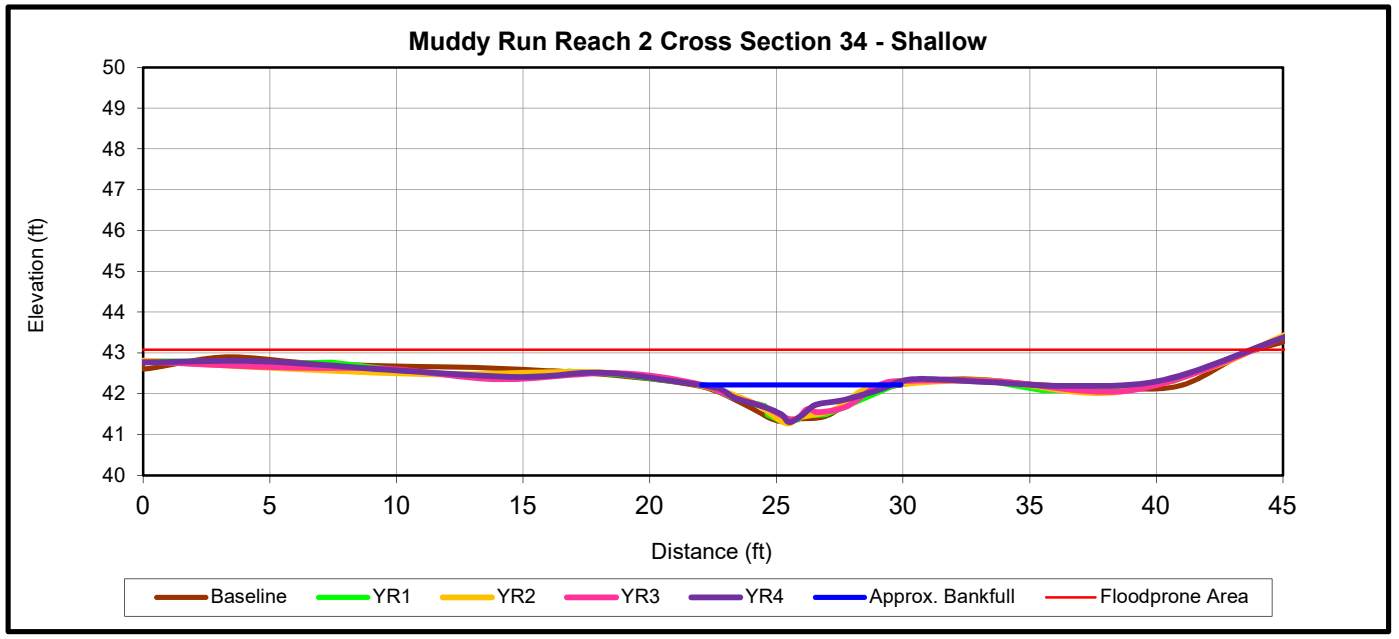
Downstream



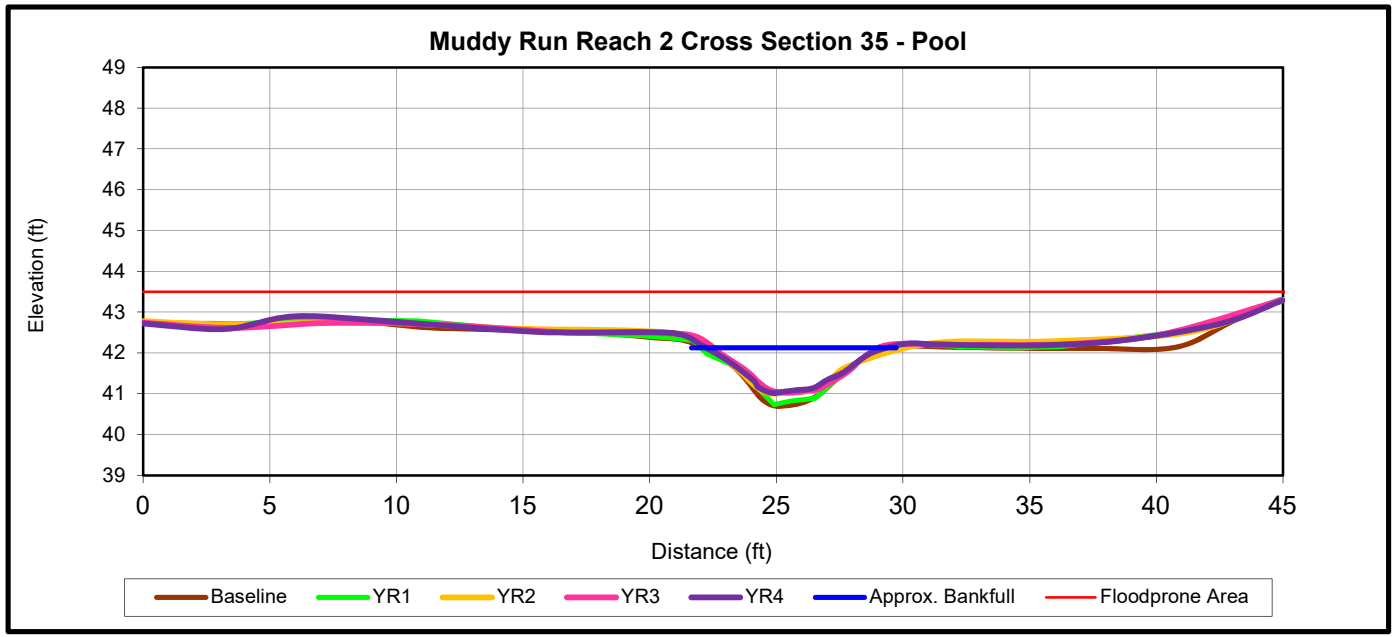
Upstream

Downstream



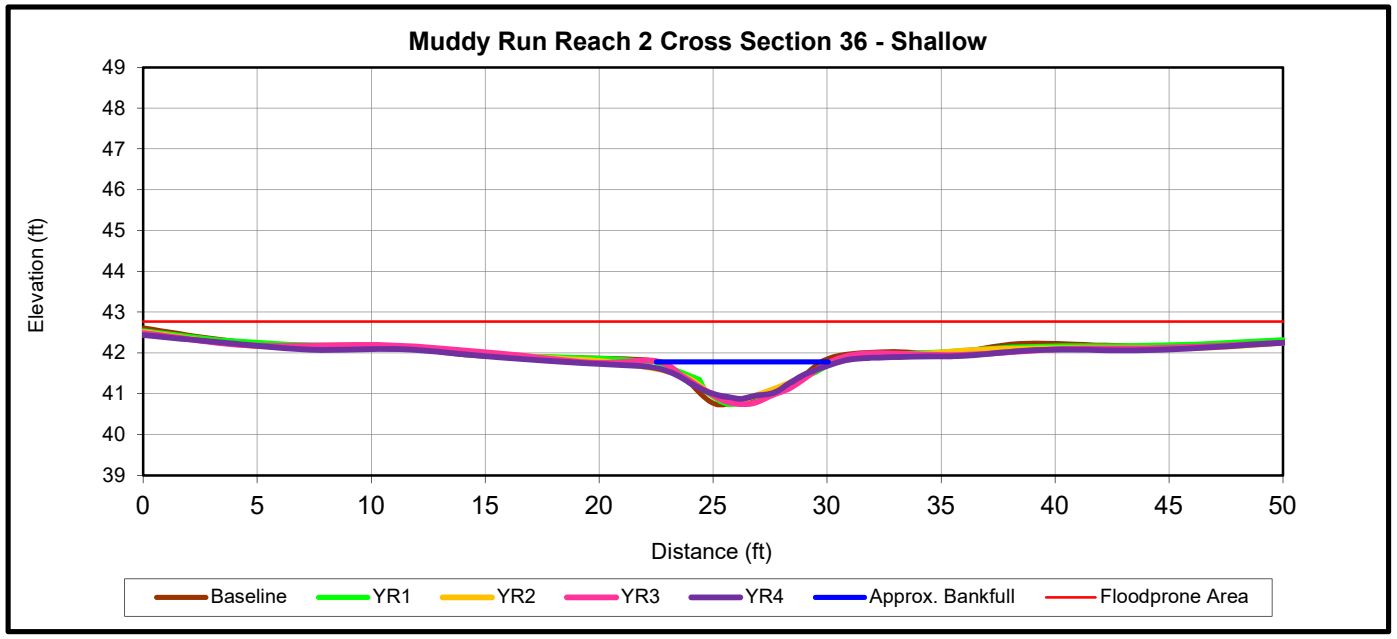
Upstream

Downstream



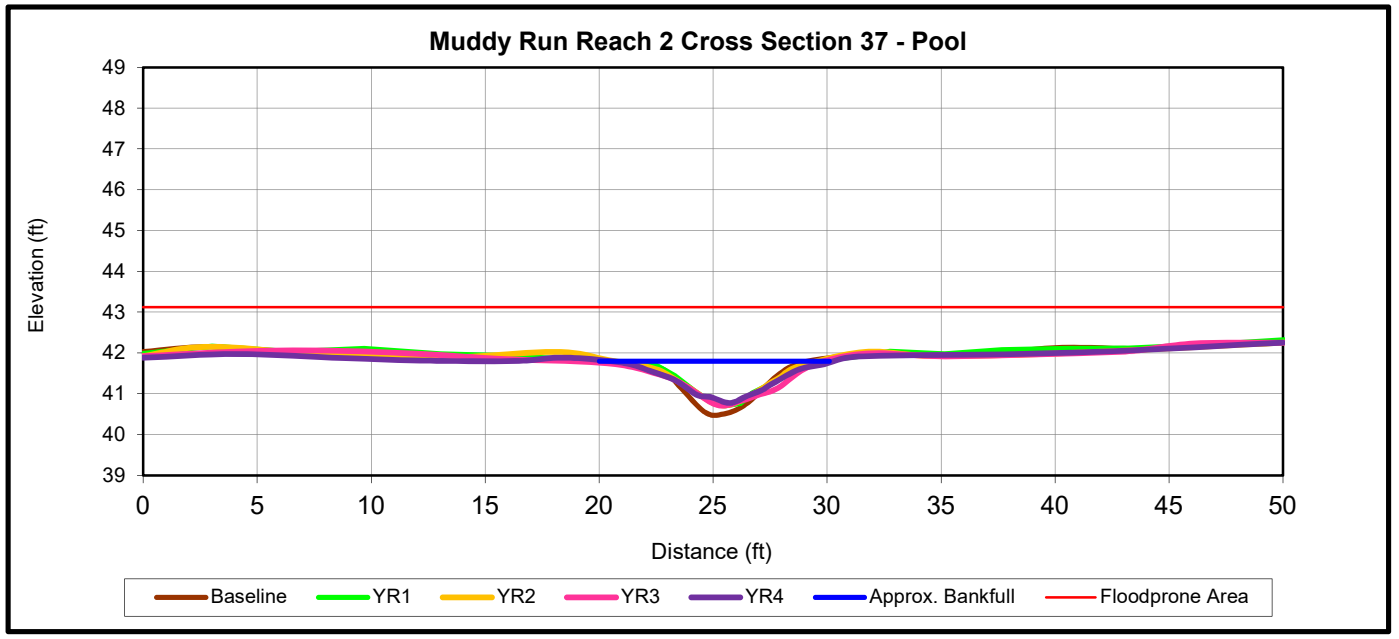
Upstream

Downstream



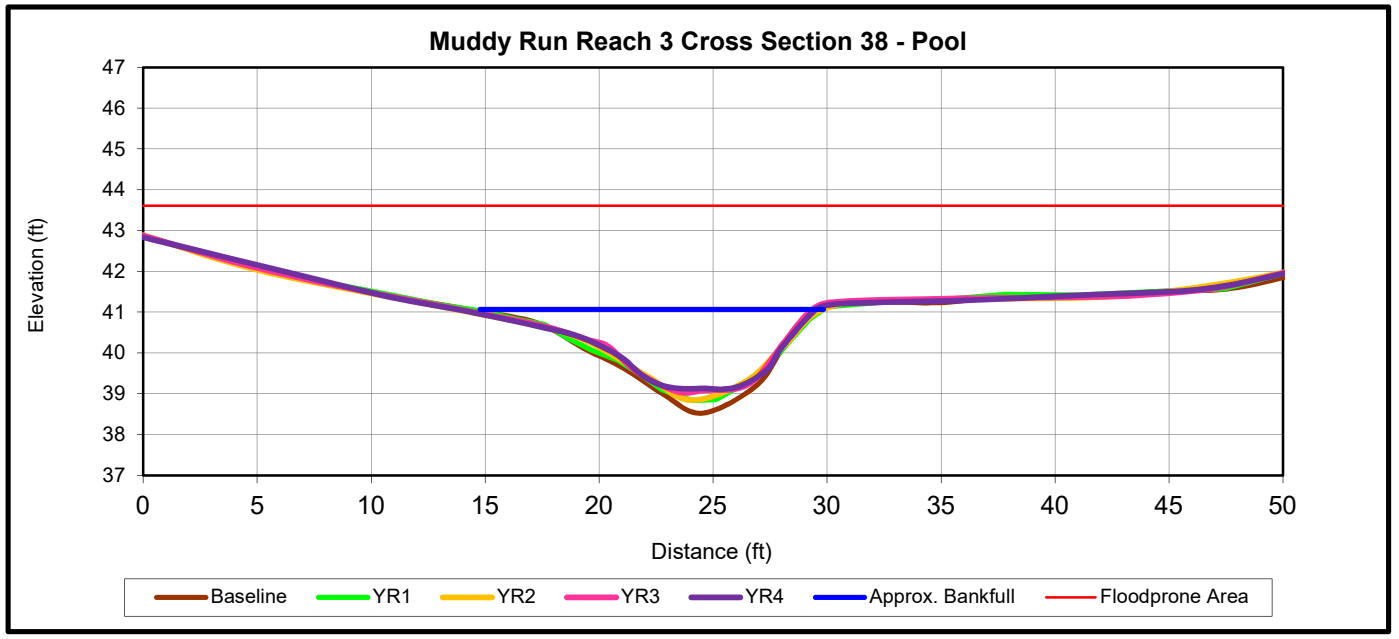
Upstream

Downstream



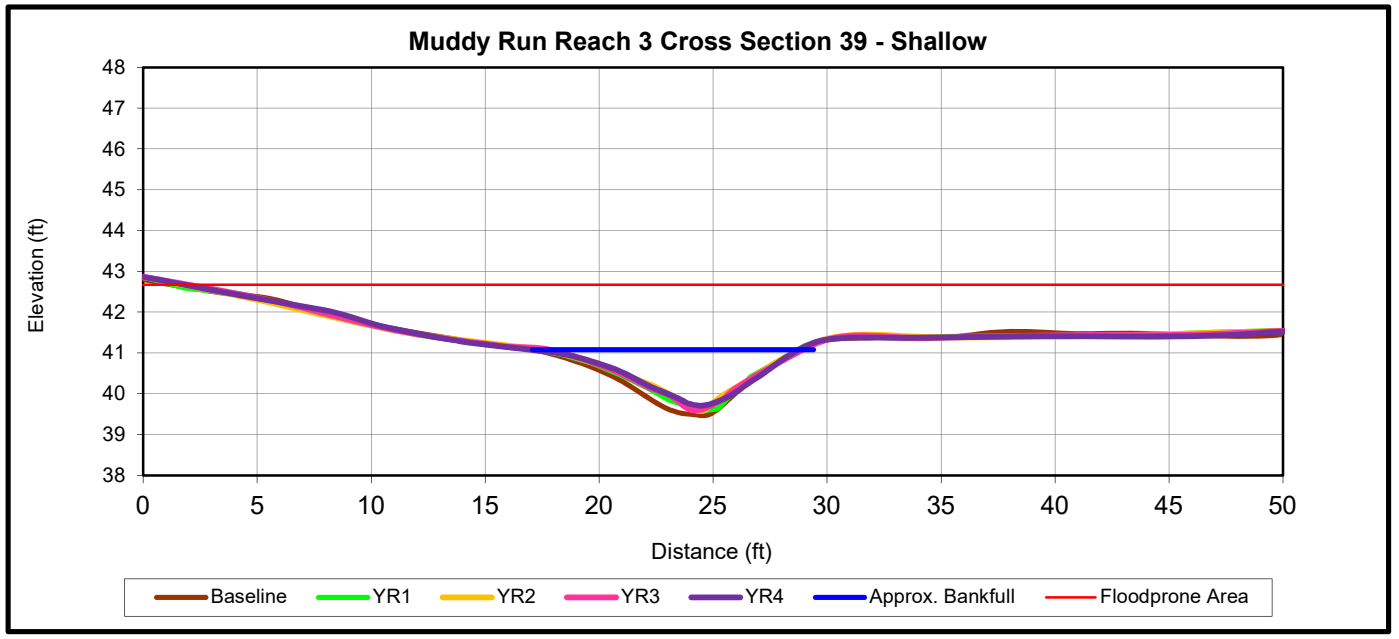
Upstream

Downstream



Upstream

Downstream



Appendix E

Hydrology Data

Table 13. Documentation of Geomorphologically Significant Events

Crest Gauge	Headwater Valley Flow Events	Maximum Consecutive Flow Days	Cumulative Flow Days
Crest Gauge 1 (HWV)			
MY1	16	8	37
MY2	34	96	162
MY3	41	76	168
MY4	34	53	197
Crest Gauge	**Number of Bankfull Events**	**Maximum Bankfull Height (ft.)**	
Crest Gauge 1 (HWV)			
MY1	N/A	1.1	
MY2	N/A	0.95	
MY3	N/A	2.3	
MY4	N/A	1.5	
Crest Gauge 2			
MY1	9	0.85	
MY2	16	1.3	
MY3	13	2.3	
MY4	18	1.3	
Crest Gauge 3			
MY1	10	0.9	
MY2	12	1.1	
MY3	14	1.7	
MY4	14	1.27	
Crest Gauge 4			
MY1	4	1.05	
MY2	9	1.8	
MY3	11	2.7	
MY4	12	2.05	

Table 14. Rainfall Summary

Month	Average	Normal Limits		Wallace Station Precipitation	On-Site Auto Rain Gauage
		30 Percent	70 Percent		
January	4.33	3.32	5.03	4.26	4.21
February	3.23	2.14	3.87	1.82	0.28
March	4.50	3.23	5.32	2.85	0.55
April	3.16	1.70	3.85	7.74	0.55
May	3.68	2.69	4.34	5.47	*
June	4.49	3.11	5.34	5.67	*
July	6.06	4.16	7.22	5.22	1.15
August	5.40	3.12	6.56	8.21	9.24
September	5.00	2.04	6.07	5.86	4.54
October	3.21	1.62	3.92	2.51	2.95
November	2.89	1.83	3.49	0.76	0.32
December	3.24	2.14	3.88	---	---
Total	49.19	31.10	58.89	50.37	23.78

*No data collected during May or June. On-Site Rain Gauge failed and was replaced in July.

Chart 1. 2017 Precipitation Data for Muddy Run Site

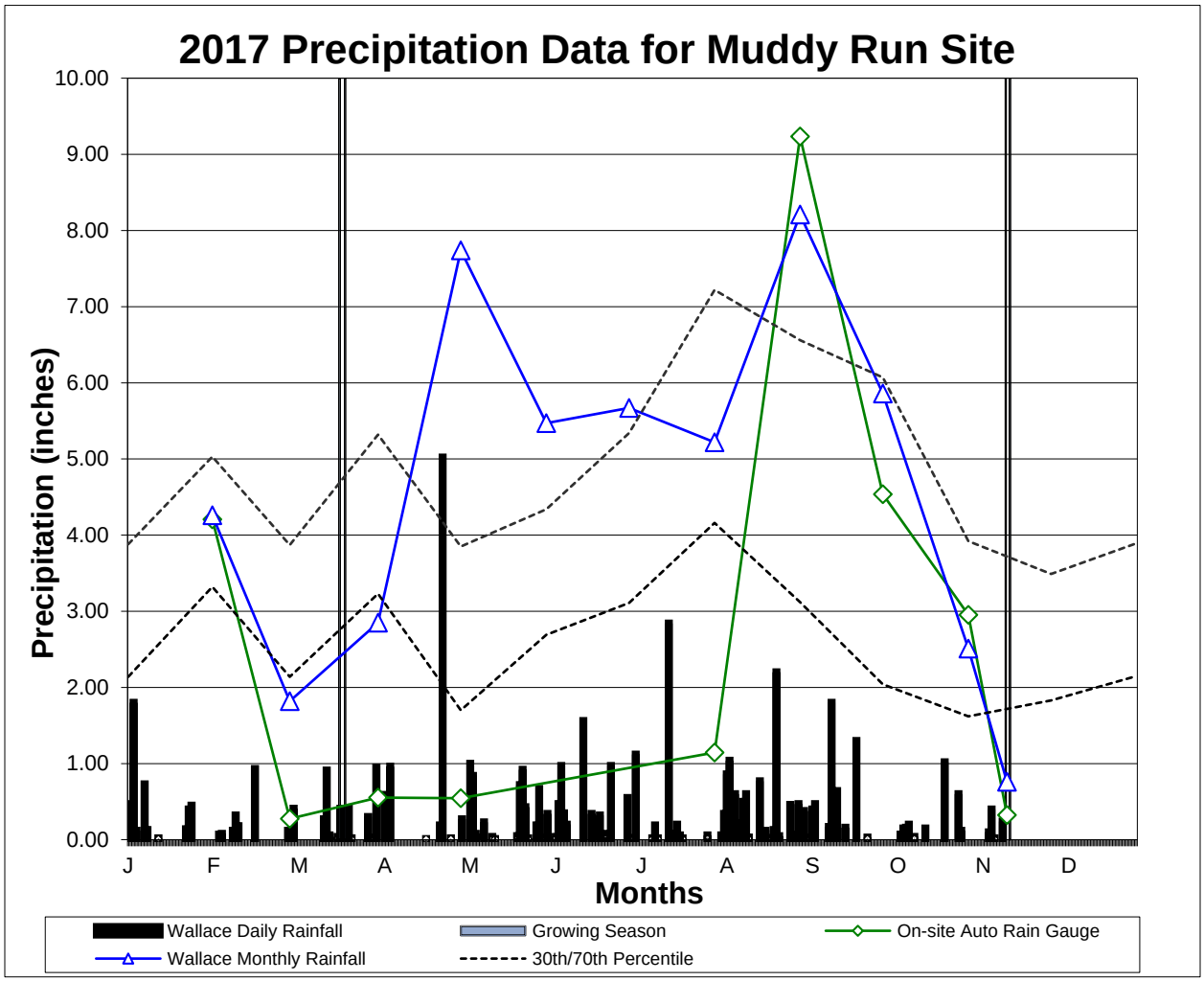


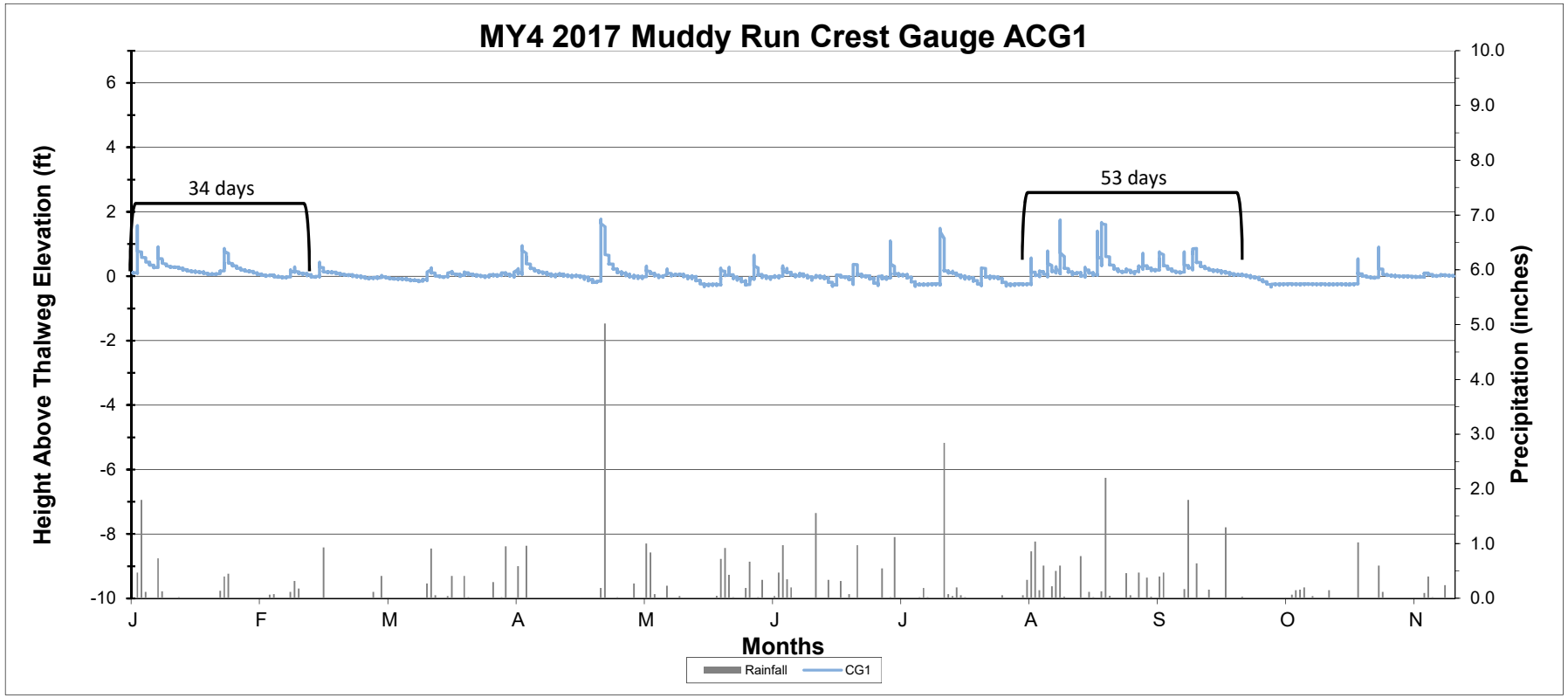
Figure 7 – Crest Gauge Verification Photos

Crest Gauge 1 Reading 1.5’ (4/24/2017)

Crest Gauge 3 Reading 1.27’ (4/24/2017)

Crest Gauge 2 Reading 1.3’ (8/24/2017)

Crest Gauge 4 Reading 2.05’ (4/24/2017)


MY4 2017 Muddy Run Crest Gauge ACG1
Height Above Thalweg Elevation (ft)
Precipitation (inches)
34 days
53 days
6
4
2
0
-2
-4
-6
-8
-10
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
J
F
M
A
M
J
J
A
S
O
N
Months
Rainfall
CG1