

West Fork White River Restoration at Brentwood Mountain Summary Report
Arkansas Department of Agriculture – Natural Resources Division Project 17-0900



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For:

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U.S. Environmental Protection Agency, Region 6

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Introduction

The Watershed Conservation Resource Center (WCRC) in partnership with the Beaver Watershed Alliance and Beaver Water District was selected by the Natural Resources Division of the Arkansas Department of Agriculture (NRD) and U.S. Environmental Protection Agency (EPA) Region 6 for Section 319 grant funding to implement a stream restoration project on the West Fork White River (WFWR) in southern Washington County, AR. The site, referred to as the Brentwood Mountain Restoration site (Figure 1) has experienced severe streambank erosion. The WFWR is listed on the state of Arkansas' 303(d) list for impaired waterways for turbidity. The WFWR further downstream meets the White River and then forms Beaver Lake, the drinking water source for Northwest Arkansas (NWA). Protection of this water resource is critical for the NWA region. Reduction of sediment and nutrients loadings to the watershed by creating channel stability and enhancing terrestrial and aquatic habitat formed the justification for this ecosystem restoration project. Some of the observed instability on site is likely due to floodplain modifications downstream of the site with the construction of a bridge crossing in 2004 that did not adequately convey flows through the floodplain of the WFWR. The loss of stream power created by the floodplain restriction resulted in mid-channel bar formation and the initiation of a downstream meander migration along the left descending river bank. At the upstream extent of the project site, lateral meander migration was causing significant streambank erosion along the left descending bank as well. Figure 1 shows the movement of streambanks at the project site from 2018 through 2021.

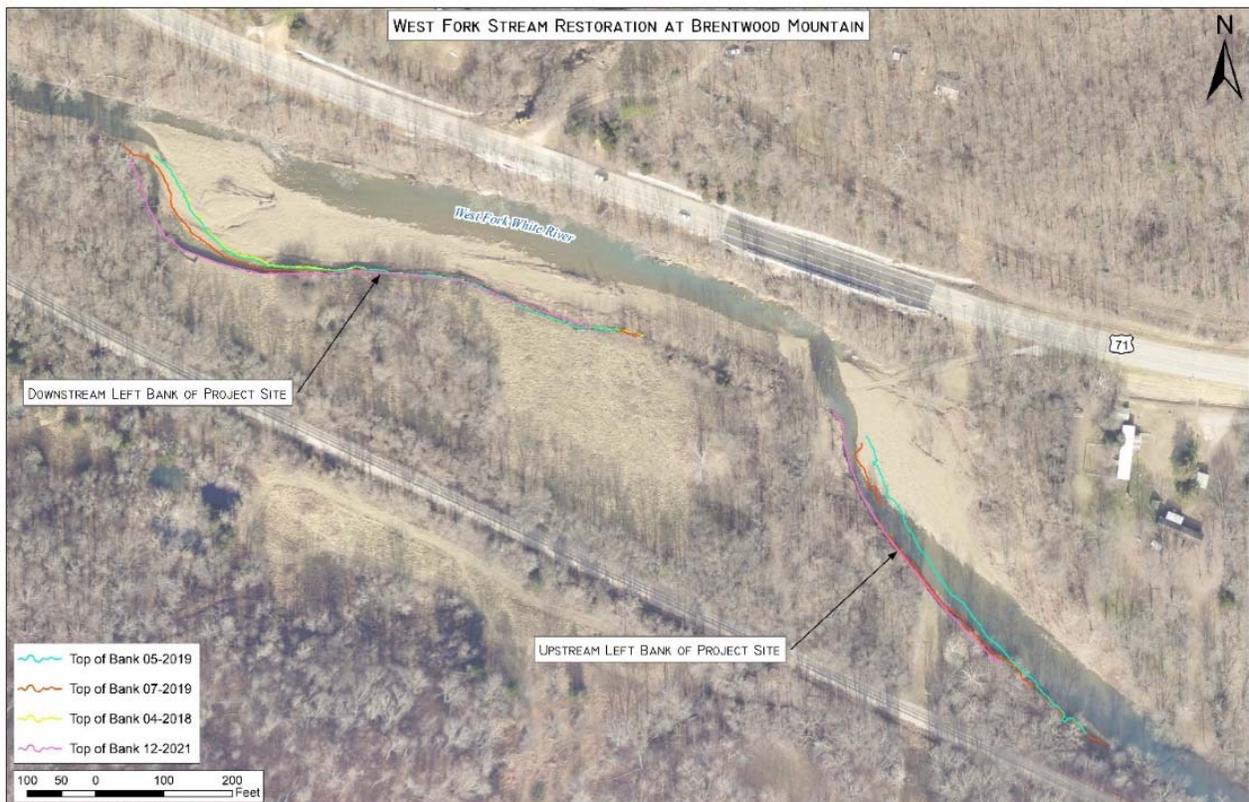


Figure 1. Brentwood Mountain site undergoing erosion and channel instability prior to restoration

Site History

The project site is located in the Boston Mountains physiographic region with a drainage area of 31.3 mi². The geology is the Bloyd shale and Prairie Grove Member of the Hale Formation.¹ Soils present include the Enders-Allegheny complex and Cleora fine sandy loam.² Observations of the site began in 2002 when the site conditions had a healthy riparian area and low width to depth ratios (Figure 2).

Over time, particularly beginning in 2005 as compared to a series of historical aerial photographs dating back to 1942, channel instability began to accelerate. This period of increasing channel instability coincides with construction of a low water bridge crossing immediately downstream of the project site (Figure 3). The bridge failed during a flood event, but not before initiating dramatic channel adjustment with rapid destabilization of the riparian left bank, in channel aggradation, and channel widening. Further information regarding the historic channel alignment and destabilization is available in Attachment 1.



Figure 2. Site prior to destabilization with a healthy riparian and low channel width to depth

The WCRC conducted a survey of stream morphology for the site in April and May of 2018 to provide critical data for the existing stream conditions and to collect relevant data for a restoration design (Attachment 2). They collected data to develop a 6,500 ft longitudinal profile that began 4,000 feet upstream and 600 feet downstream of the site. The channel thalweg, water surface, bankfull depositional features and any other features of interest were captured with a GPS RTK unit. The surveyed reach has an average bankfull slope of 0.0042 ft/ft.

The survey characterized channel substrate by randomly selecting and measuring the B-axis of 100 samples lining the channel bottom for four riffle cross sections and then a representative sample for the entire site based on the weighted length of riffle and pool features. The D₅₀ and D₈₄ of each riffles particle distribution would serve to develop a roughness coefficient for discharge and velocity calculations. Results of the particle sampling is shown in Table 1.

Table 1. Pebble Count Results

Pebble Count Location	D ₅₀	D ₈₄
XS1	49.4	108.5
XS3	41.8	114.2
XS8	51.3	95.2
XS10	48.2	141.0
Representative	49.8	128.0

¹ Haley, B. R. (1993). Geologic Map of Arkansas. Retrieved June 15, 2022, from https://www.geology.arkansas.gov/maps-and-data/geologic_maps/geologic-map-of-arkansas-1993-revised-from-1976-edition.html

² Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Retrieved June 15, 2022, from <http://websoilsurvey.sc.egov.usda.gov/>.



Figure 3. Procession of changes on site. The top image is of 1964, then 2004 prior to installing a low water bridge downstream, then in 2006 where site changes began to initiate coinciding with installation of a bridge, and then in 2020 following a major erosion.

The WCRC surveyed ten channel cross sections at various portions of the channel to obtain critical observations for the existing conditions and departure from stability. The cross sections were located on five riffles, three pools, and two glides along the reach. Transects of the channel were measured recording variations in grade to capture the channel dimensions. They surveyed depositional features and changes in the bank slope at expected elevations at each cross section to establish the bankfull elevations. Bankfull width, cross sectional area, average depth, water surface to bankfull difference, among other features, were determined and the average dimensions for the site for each facet feature were calculated. Some of the data for the riffle cross sections from this survey is presented in Table 2. Longitudinal data further verifies the correct bankfull elevations and slope, and provides dimensions for the variety of depths, slopes and features along the channel. This data was compared with regional curve data developed at USGS stream gage sites within this hydro-physiographic region based on the drainage area. Expected values for this site based on a drainage area of 31.1 mi² include an area of 205 ft² and a bankfull discharge of 1,050 cfs. Surveyed values indicated an average riffle cross sectional area of 232.7 ft² and an average discharge of 1,130 cfs.

Table 2. Summary of riffle cross section variables

XS	W _{bkf}	D _{bkf}	A _{bkf}	W/D Ratio
1	77.9	3.13	243.7	24.9
2	79.9	3.22	257.1	24.8
3	78.5	2.79	219.4	28.1
8	123.4	1.98	245.0	62.3
10	97.3	2.16	210.5	45.0
Average	83.4	2.8	232.7	30.7

Monitoring for ongoing changes to the site is done in a number of ways. The most detailed work would include having monitoring cross-sections at key areas of the streambank where erosion is evident. Streambank profile data is collected along a line perpendicular to the streambank over multiple years to estimate the amount of streambank recession between datasets. Two cross sections collected in 2002, by ADEQ, compared to conditions in 2018 and are shown in Attachment 2. Approximately 100 ft at XS5 and 80 ft at XS6 of streambank recession occurred between these two surveys equating to a loss of 4.2 ft/yr at XS5 and 4.6ft/yr at XS6. More significantly, mature riparian habitat and tree cover was lost during this period. Further and more detailed monitoring involved these and six other cross-sections, three located on the upstream river left bank and the remaining five on the downstream left bank. A year-long monitoring period, discussed in further detail in Attachment 3, began in late April 2018 through May 2019 and shows a yearly erosion rate between years. This period happened to occur during a significantly low number of hours of flow at bankfull discharge as compared to the average at USGS 07048550 further downstream. The average yearly total at the time of the analysis is 56 hours, but a total of 29.25 hours of bankfull discharge was recorded during the monitoring. An additional monitoring event on July 12, 2019, documented in further detail in Attachment 4, followed a major flood event with a peak discharge of 22,100 cfs at the USGS gage. This period in combination with the yearlong monitoring event from 2018 -2019 recorded at total of 56.25 hours of bankfull discharge at the USGS gage. Though similar to the yearly average, the introduction of this major flood significantly conflates the average loading from the site prior to restoration. This is verified by an additional air photo analysis. Readily available leaf off imagery from the same period of the years 2008 and 2018 clearly show the top of bank for each year on site and thus was selected for analysis. The WCRC created a top of bank polyline in GIS for each year allowing for measurement of the planar area of erosion between years. The erosion area is segmented by the surveyed cross sections from 2018, and the measured bank height from that survey was applied to the area of erosion to obtain a volume of erosion. By then applying soil data to the erosion volume estimate, an annualized sediment and nutrient loading value from the site extent that would undergo restoration was calculated. The ten year analysis of all erosion is selected as most representative of typical yearly erosion and sediment and nutrient loading onsite.

Table 3 displays the loading estimates for late April 2018 to May 2018, late April 2018 to July 2019 following the major flood event, and then the annualized loading from the 2008 – 2018 analysis period.

In order to create the loading estimates, the WCRC undertook a sediment sampling survey to collect data for the various soil types identified on streambanks. This allows for a correlation of the streambank erosion monitored to the water quality impacts onsite and downstream. The team collected sediment data as outlined by methodology defined in Brye, et, al³ for streambanks composed of fine sediment material and larger gravels and cobbles and utilizing a Shelby tube sampler for fine streambank materials. Sediment samples were delivered for processing to the Agricultural Diagnostics Laboratory at the University of Arkansas. Laboratory results include soil sample bulk density, particle size distribution, Total Nitrogen concentration, and Total Phosphorous concentration. An average value was calculated for coarse and fine streambank types to develop loading estimates entering the West Fork White River from the site. Mean, maximum, and minimum soil data relevant to this analysis is shown in Table 4. Further discussion and data for the streambank soil sampling is available in Attachment 5.

Table 3. Sediment and Nutrient loading for the Brentwood Mountain site.

XS I.D	Measured Erosion Rate		
	2018 - 2019	2018 - 2019 Post Flood	Aerial Erosion 2008 - 2018
	ft/yr	ft/yr	ft/yr
1	0.4	1.8	1.9
2	1.0	22.5	5.1
3	0.7	35.3	4.8
4	0.0	0.2	2.7
5	0.1	0.1	7.0
6	0.0	0.2	7.7
7	0.7	0.7	8.5
8	8.9	19.1	6.0
Sediment Load ton/yr	1078	5411	2218
Sum TP Load lb/yr	687.9	3066.2	1135.3
Sum TN Load lb/yr	969.2	4197.8	1511.1

By the time of project implementation, an additional maximum of 32 feet of lateral streambank recession had occurred at the downstream bank compared to the post flood survey. Lateral channel expansion, water quality impairment, and habitat loss would have continued to occur at this location without intervention. (Figure 4).

Table 4. Average, Mean and Max Bulk Density and Nutrient Concentrations at the Brentwood Mountain Site

Parameter	Soil Type	Mean	Max	Min
Bulk Density (lb/ft ³)	Coarse	120.7	128.4	94.1
	Fine	90.3	99.4	85.0
T. Phosphorous (lb/ton)	Coarse	0.35	0.7	0.2
	Fine	0.77	0.84	0.71
T. Nitrogen (lb/ton)	Coarse	0.41	0.9	0.2
	Fine	1.13	2.00	0.59



Figure 4. Site instability, the left image shows the over-widened channel left bank downstream with a tree that recently fell from bank instability and the right image shows the aggrading mid channel point bar

³ Brye, K.R., T.L. Morris, D.M. Miller, S.J. Formica, and M.A. Van Eps. 2004. Estimating bulk density in vertically exposed stoney alluvium using a modified excavation method. J. Environ. Qual. 33:1937–1942

Implementation and Results

The design approach taken for the Brentwood Mountain restoration includes analysis of channel pattern and alignment with surveyed records of the stable channel on site and the departure from those conditions spanning 20 years of survey data and evaluation of aerial photography dating back to 1942. Boundary conditions that affected the project design included U.S. Highway 71 with a bluff and rock outcrop, the railroad on river left, property owner participation, providing and protecting a stream crossing, and reducing the amount of construction and fill material input to the project site.

Restoration Design

Natural Channel Design is the approach taken for the restoration basis. This design relies heavily on reference conditions documented in similar areas that indicate signs of resiliency and stability. The Arkansas Department of Environmental Quality documented reference conditions onsite in 2002 as part of a watershed assessment, which was applied here and included as part of a reference reach variable database. During that study, they also evaluated other areas of the watershed, which they documented and the WCRC utilized for design development and comparison purposes. The WCRC conducted the site geomorphology survey from 2018 as well as a GIS study of rivers in vicinity to the project site to develop typical planform geometry patterns. The WCRC then prescribed structural elements in the final design to maintain a stable, self-maintaining channel and a more resilient, diverse terrestrial habitat adjacent to the channel. Figure 5 shows an overview of the restoration planview developed for the restoration. The channel pattern was oriented based on this design, requiring excavation and fill in some areas. Additional data concerning reference variables on site are available in Attachment 6. A complete set of design plans for this restoration project are available in Attachment 7 along with a complete description of the project elements.

Vegetation Establishment

Restoration of the native riparian community in the active channel and floodplain are critical for the success of a river restoration pursuit. The Brentwood Mountain site has undergone severe riparian habitat loss particularly on channel left, with the condition prior to restoration being that of a shallow over-widened channel that was subject to frequent flooding as compared to when the channel was surrounded by a diverse riparian within an active bankfull terrace. Predominant species in the degraded condition within the gravel bar were young sycamore, willow, cocklebur, and other species that emerged within areas of disturbance and gravelly soil conditions. Johnson grass, particular at the downstream extent of the project, was the dominant grass species on the river left floodplain, with few trees. This left little benefits to the aquatic habitat and biodiversity of the riparian habitat. The WCRC has developed and tested techniques for native vegetation establishment. This serves the ecosystem to create surface roughness for flood control, provide shade to decrease water temperatures, provide food and habitat for native aquatic and terrestrial wildlife, prevent the spread of monocultures in the form of invasive species, enhance and secure the topsoil and gravel it is grown from, and many other ecological services. Native plants were selected based on the Boston Mountains Ecoregion. A list of grass, trees, and shrub species native to this ecoregion and incorporated into the project are found in Table 5. Following final site grading, the WCRC planted native bare roots, plugs, potted plants, and harvest plants from onsite and elsewhere into the streambanks, toewood, point bars, floodplain depressions, and terrace. Winter wheat serves as a nursery crop in combination with native wildflower,

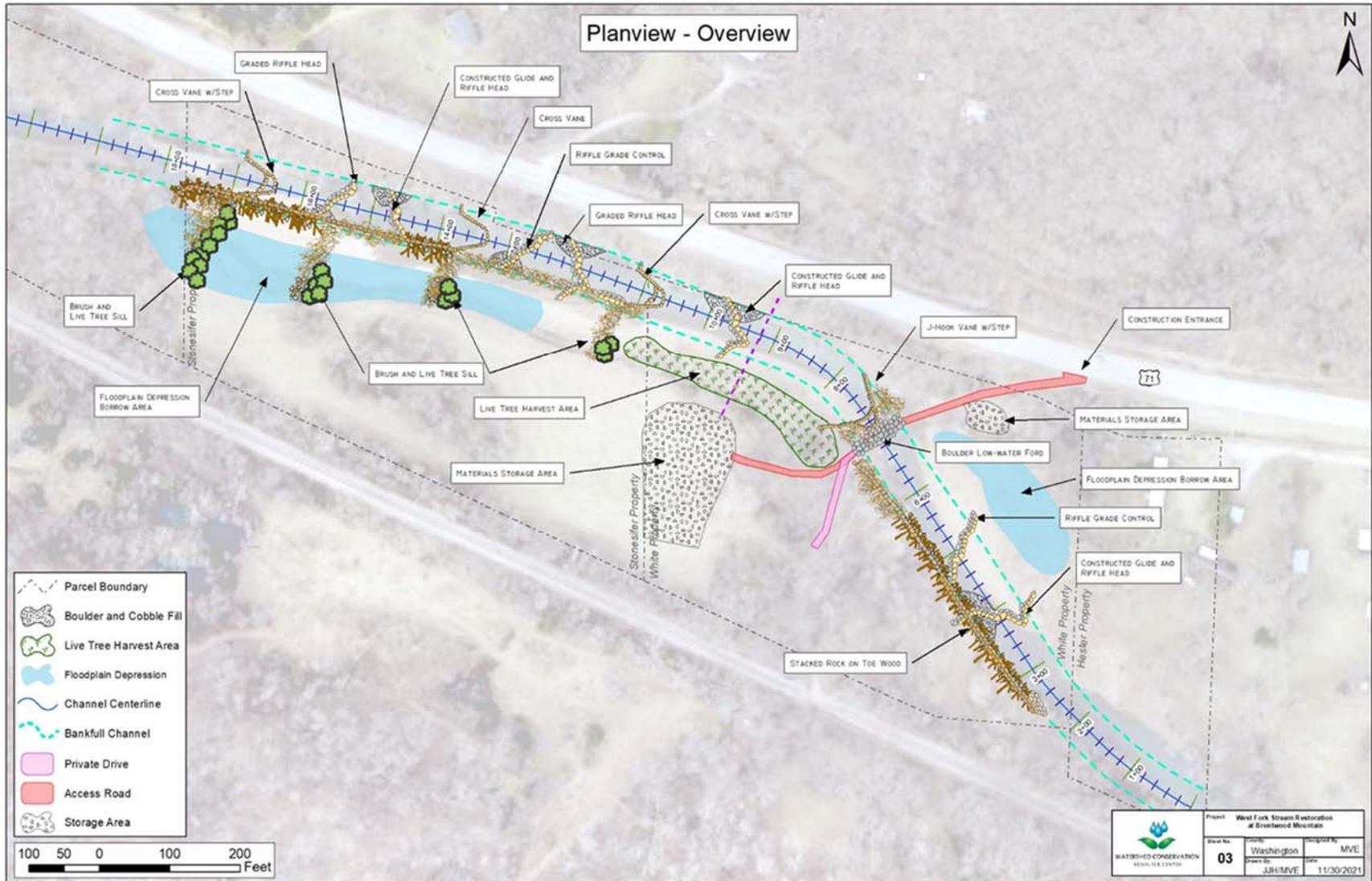


Figure 5. Brentwood Mountain Restoration Overview

forbs and grass mix dispersed throughout the site. Straw covering on all seeded areas kept the seed moist, protected from the wind, and provided nutrients with its decomposition. A list of the native grass, forbs and wildflowers used in the seed dispersal mix is found in Table 6.

Table 5. Native Plant Species Utilized to Establish the Riparian Bench

Native Plant Species used at Brentwood Mountain	
Shrubs	Buttonbush
	False Indigo
	Smooth Sumac
	Ninebark
	Ozark Witchhazel
	Rosemallow
	Roughleaf Dogwood
	Silky Dogwood
Trees	Blackgum
	Bur Oak
	Northern Red Oak
	Ohio Buckeye
	Pawpaw
	Pecan
	Persimmon
	Redbud
	River Birch
	Sycamore
Grasses	Inland Sea Oats
	Juncus
	Tridens Strictus
	Gamagrass

Table 6. Native Seed Mix used to establish the Riparian Bench

Native Seed Mix	
Flower and Forb Seed Species	Grass Seed Species
Aromatic Aster	Indian Grass
Ashy sunflower	Big Bluestem
Bee Balm	Prairie dropseed
Black-Eyed Susan	Purpletop tridens
Blue Vervain	Sideoats grama
Butterfly Milkweed	Switchgrass
Common boneset	Little Bluestem
Giant Goldenrod	Longspike Tridens
Grey-Headed Coneflower	
Illinois Bundleflower	
Lanceleaf Coreopsis	
Mountain Mint	
New England Aster	
Ox-Eye Sunflower	
Pale Purple Coneflower	
Purple Coneflower	
Rattlesnake Master	
Rosinweed	
Smooth Penstemon	
Stiff Goldenrod	
Thickspike Gayfeather	
Wild Bergamot	
Woolly Rose Mallow	

Restoration Construction

Prior to commencement, the WCRC secured all pertinent permits including a US Army Corps of Engineers 404 Permit, ADEQ Short Term Activity Authorization, ADEQ Storm Water Pollution Prevention Plan, and County Floodplain Development Permit.

The WCRC prepared a drawing set and all bidding documents necessary to implement the project. Flowstate LLC was awarded the project on October 26, 2021. Heavy equipment construction began on December 6, 2021. Prior and during the construction, the WCRC acquired all materials necessary to the restoration. Rock was bid out to Yates Excavation and Trucking LLC for over 2,400 tons of rock necessary for all in channel rock structures and revetment boulders. The remaining materials were sourced from the area and stacked in the adjacent field. This includes approximately 900 Toewood Logs, 35 large diameter footer logs, 1,300 yd³ of brush, 670 yd³ of top soil, 125 yd³ of compost, and 4,500 native trees, shrubs, and grasses. The WCRC oversaw all construction activities. A 3d surface model of the design aided the contractor in grading and finish elevations,



Figure 6. Restoration Site during a High Flow Event

two of the machines in use had machine control capabilities calibrated for the site. This provided a more efficient means of moving material around the site for cut and fill purposes. All grade control and toewood structures were constructed without a model, using the construction plans and the WCRC for guidance. Heavy equipment construction completed on March 18, 2022 following review of the project, creation of a project punch list, and finalization. Excess materials were hauled off site to storage for utilization in future projects. All exposed areas of topsoil were seeded and covered in straw. The WCRC Riparian Restoration Team continued to work on site through April, 2022, but continues to monitor and maintain the site by managing invasive vegetation and caring for native plants to establish a healthy stand of native vegetation.

As-Built Survey

The WCRC surveyed the project site on April 8, 2022 to understand the site conditions following construction and prior to any major storm events. A second survey was conducted July 1, 2022 to provide a baseline condition to evaluate the effectiveness of the restoration and to quantify the reduction of sediment and nutrient loads. The project had undergone five bankfull flow events between surveys, the highest flow recorded at USGS 07048550 on May 5, 2022 with a flow of 9,420. Bankfull flow is defined at this downstream USGS location of 3,400 cfs compared to the restoration site estimate of 1,130 cfs, but will provide a good correlation to flow events on site. Despite the significant flood events on the WFWR (almost three times the bankfull flow), there has been effectively no streambank erosion along the project. This correlates to a yearly reduction of 2,200 tons/yr of sediment, 1,100 lb/yr of Total Phosphorous, and 1,500 lbs/yr of Total Nitrogen for an average flow-year. As expected, there has been channel adjustment between monitoring events, but the restoration remains effective, capable of transporting sediment, maintaining its alignment, providing terrestrial and aquatic habitat, depositing material into the floodplain depressions and retaining design dimensions of a stable channel. All grade control features remained intact. The cross-section dimensions for the post-restoration monitoring efforts are presented in Attachment 8.



Figure 7. Top – Photo of low water crossing and J-Hook Vane taken May 2022 following construction and the 3-times bankfull event. Bottom - Photo of the Restoration Site at the Downstream End Looking Upstream during low flow conditions and taken during the as-built survey 7-1-22

Outreach

The WCRC gave at least four tours of the project site before and after restoration. Prior to restoration, the WCRC met with several landowners including the two landowners who owned the property to show the erosion, present the restoration design, and to discuss the design plan and materials storage areas. Seven people participated in this tour which was conducted on April 2, 2021. The WCRC gave tours to two local landowners several times during construction of the project and following restoration, to the Beaver Watershed Alliance that including five staff persons and one board of directors on May 17, 2022 and to ANRD staff on June 30, 2022.

The WCRC assisted with the coordination of the annual West Fork White River Clean-up for 2022, though the event was postponed to September because of a morning thunderstorm.

A fact sheet summarizing the project and the success of the restoration work was developed and will be presented to participants of future tours, workshops, and presentations. The fact sheet handout is attached as Attachment 9.



Figure 8. The WCRC conducted outreach activities with landowners and local watershed protection organizations to provide education about the benefits of stream restoration.

West Fork Stream Restoration at Brentwood Mountain
Attachment 1. Historical Analysis of Channel at Stonesifer Site



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West Fork Stream Restoration at Brentwood Mountain
Attachment 1. Historical Analysis of Channel at Stonesifer Site

Observing historical aerial imagery at the Brentwood Mountain Site provides a means of visualizing change over time to the West Fork White River. Imagery was analyzed for various years between 1942 through current day imagery to measure changes to the most prominent path of the river and surrounding landscape at the site. The time between the years 2001 and 2010 appear to be the largest shift in changes to the Brentwood Mountain site, which was then analyzed further. The upstream area near XS1 – XS3 has cut through the left bank, reversing direction, and the downstream left bank near XS4 – XS6 has eroded a large mass of land on the left bank. This rapid acceleration of erosion has all occurred with minor changes to the perviousness of the watershed, as indicated in Table 1. Further analysis of imagery in google earth shows the onset of the downstream left bank erosion and channel widening occurring in 2005, which coincides with the installment of a bridge downstream of the site. The bridge was eventually destroyed in a flood event, but not before destabilizing the channel in this area. At no other point in time observed in this analysis did this amount of aggravation and lateral channel migration occur so dramatically. The following map images and photographs detail these changes.

Table 1. Impervious Land Percentage Comparison utilizing USGS NLCD data

National Land Cover Database Impervious Area for the WFWR Watershed at the Brentwood Mtn Site	
Year	% Impervious Land
2016	0.490%
2011	0.489%
2006	0.489%
2001	0.487%

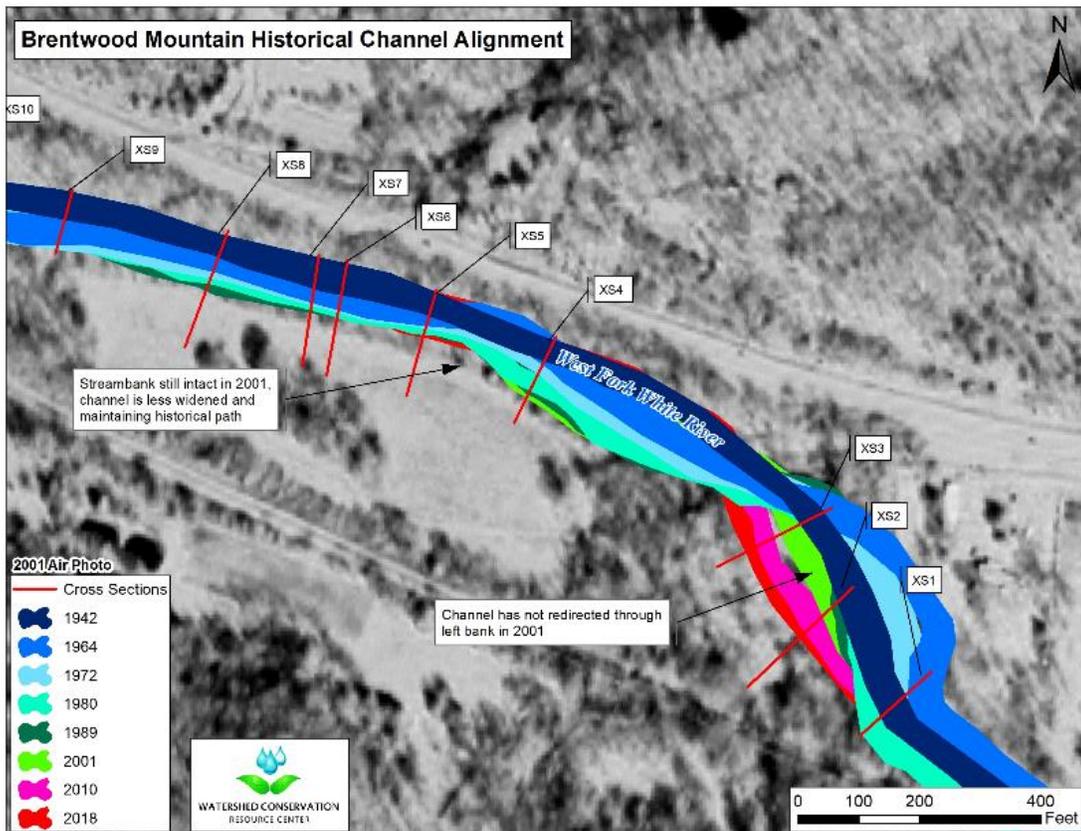


Figure 1. 2001 Air Photo Analysis, channel migration over time

West Fork Stream Restoration at Brentwood Mountain
 Attachment 1. Historical Analysis of Channel at Stonesifer Site

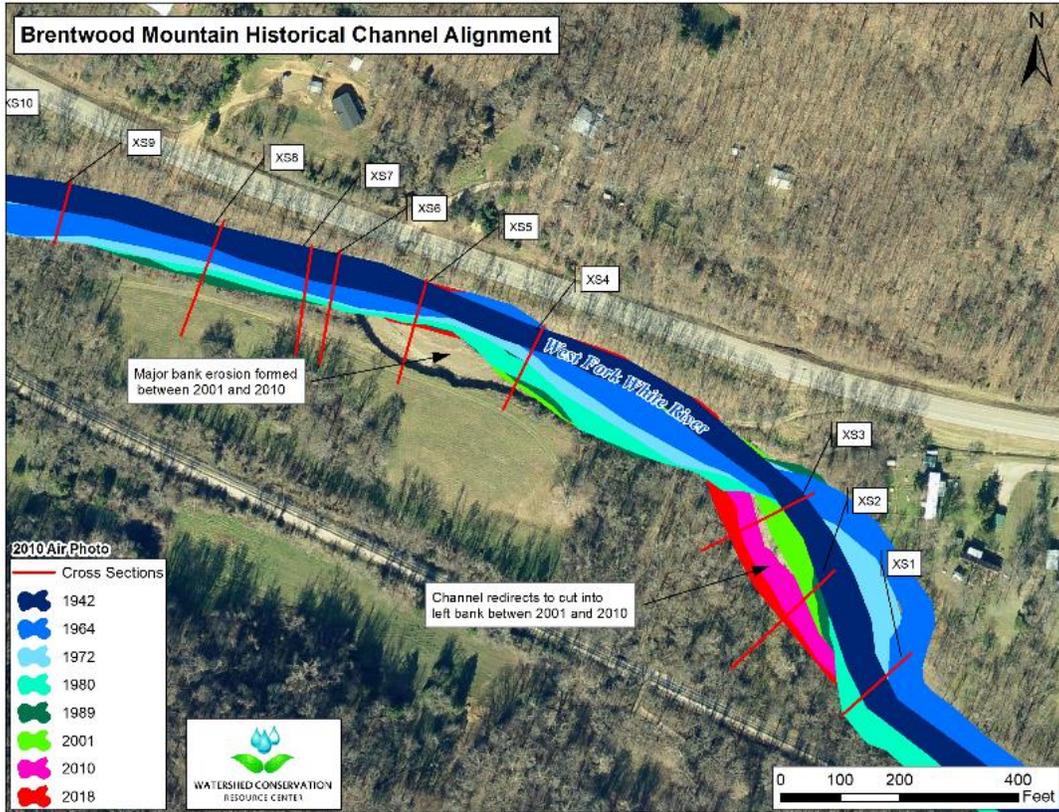


Figure 2. 2010 Air Photo Analysis, channel migration over time

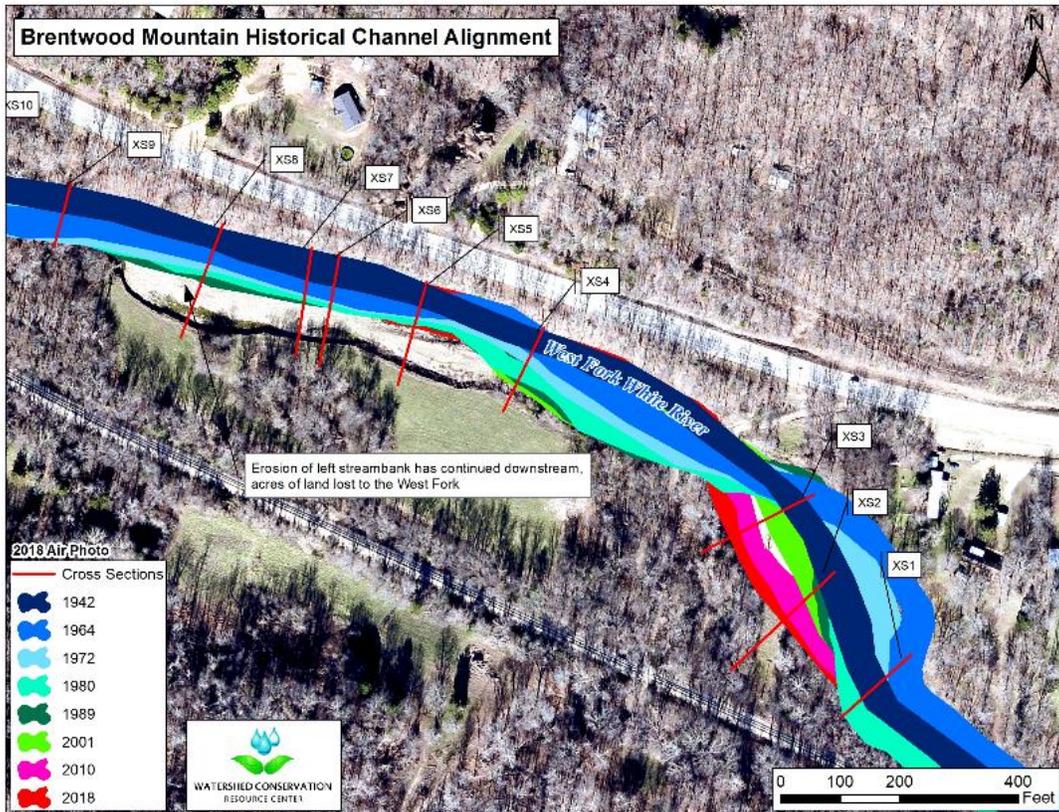


Figure 3. 2018 Air Photo Analysis, channel migration over time

West Fork Stream Restoration at Brentwood Mountain
Attachment 1. Historical Analysis of Channel at Stonesifer Site



Figure 4. Aerial Imagery from 1964, the channel has retained its shape and appears stable.



Figure 5. Aerial Imagery from 2001, left bank erosion between XS4 and XS5 is relatively stable and appears similar in shape to 1964 and 2004

West Fork Stream Restoration at Brentwood Mountain
Attachment 1. Historical Analysis of Channel at Stonesifer Site



Figure 6. Aerial Imagery from 2004, the bridge downstream has yet to be installed, while the bank on XS4 is eroding, but at a more stable rate and the historical shape of the channel is as it was in years previous.



Figure 7. Aerial Imagery from 2006, the bridge downstream is installed, and left bank erosion has initiated downstream, as the erosion area between XS4 - XS5 begins to move downstream

West Fork Stream Restoration at Brentwood Mountain
Attachment 1. Historical Analysis of Channel at Stonesifer Site



Figure 8. Aerial Imagery from 2008, the bridge downstream is still in place as the channel is eroding, widening, and rapidly changing form to adapt to bridge.



Figure 9. Aerial Imagery from 2010, the bridge downstream is removed, but the channel is over widened, destabilized and continue to washout the left streambank upstream and downstream

West Fork Stream Restoration at Brentwood Mountain
Attachment 1. Historical Analysis of Channel at Stonesifer Site



Figure 10. Aerial Imagery from 2020, the bridge is removed and erosion and channel widening has continued and increased dramatically



Figure 11. Photo from a 2006 inventory of bridge downstream, channel is scouring bridge abutments, indicating constriction of channel

West Fork Stream Restoration at Brentwood Mountain
Attachment 1. Historical Analysis of Channel at Stonesifer Site



Figure 12. Bank Erosion between XS4 and XS5 is beginning to accelerate with fallen trees and shear, exposed banks



Figure 13. Approximately same area as Figure 12 in current day, major erosion of the left bank has created an over widened channel

West Fork Stream Restoration at Brentwood Mountain
Attachment 1. Historical Analysis of Channel at Stonesifer Site



Figure 14. The right bank, that is hardened with a rock cliff and boulders along its sheer slope in most places at the site has eroded, destabilized, and created a landslide damaging parts of Highway 71 in 2020.

West Fork Stream Restoration at Brentwood Mountain
Attachment 2. Existing Conditions and Geomorphology Summary Data



7/13/2018

Prepared by:



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West Fork Stream Restoration at Brentwood Mountain
Attachment 2. Existing Conditions and Geomorphology Summary Data

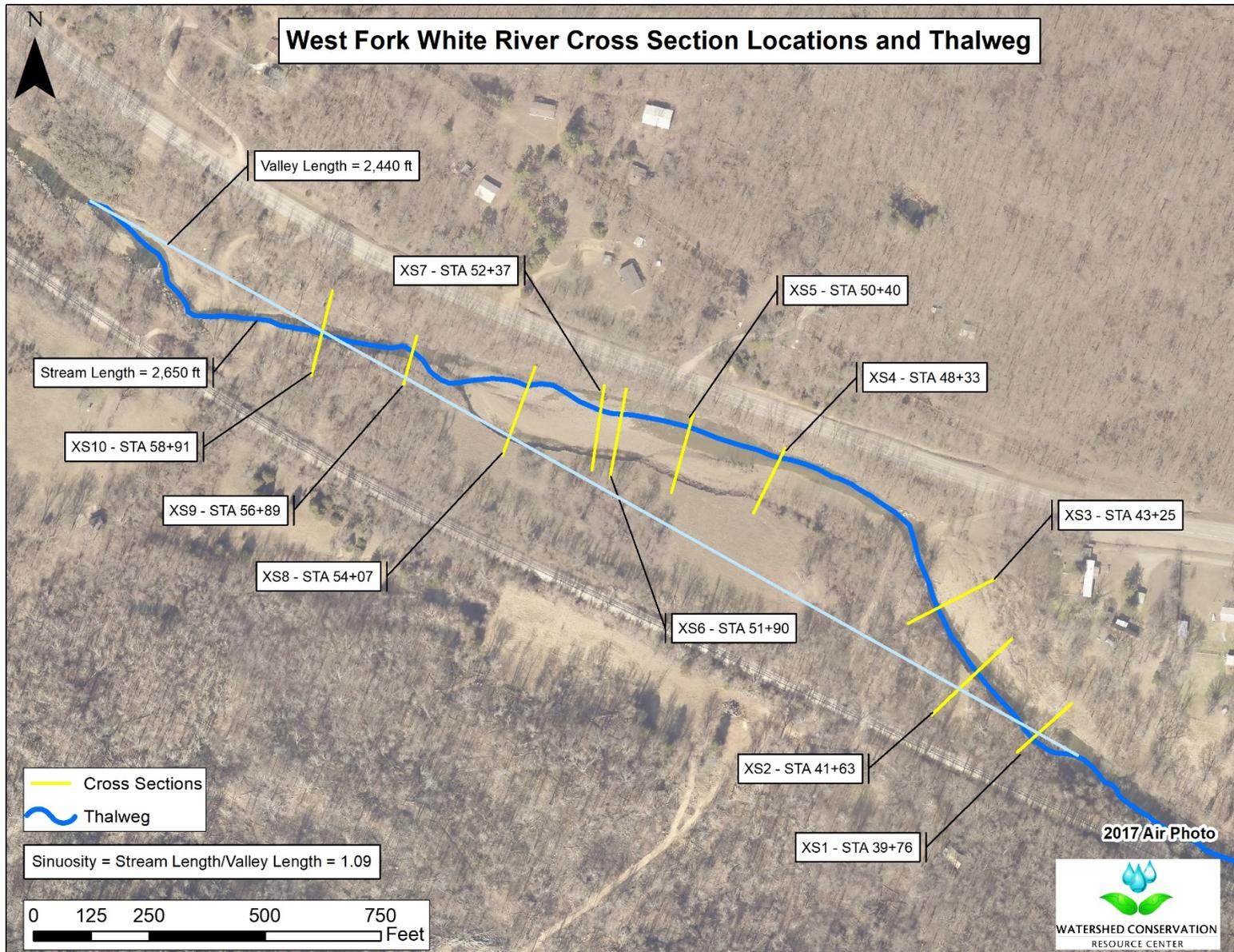


Figure 1. WFWR Site Overview

West Fork Stream Restoration at Brentwood Mountain
 Attachment 2. Existing Conditions and Geomorphology Summary Data

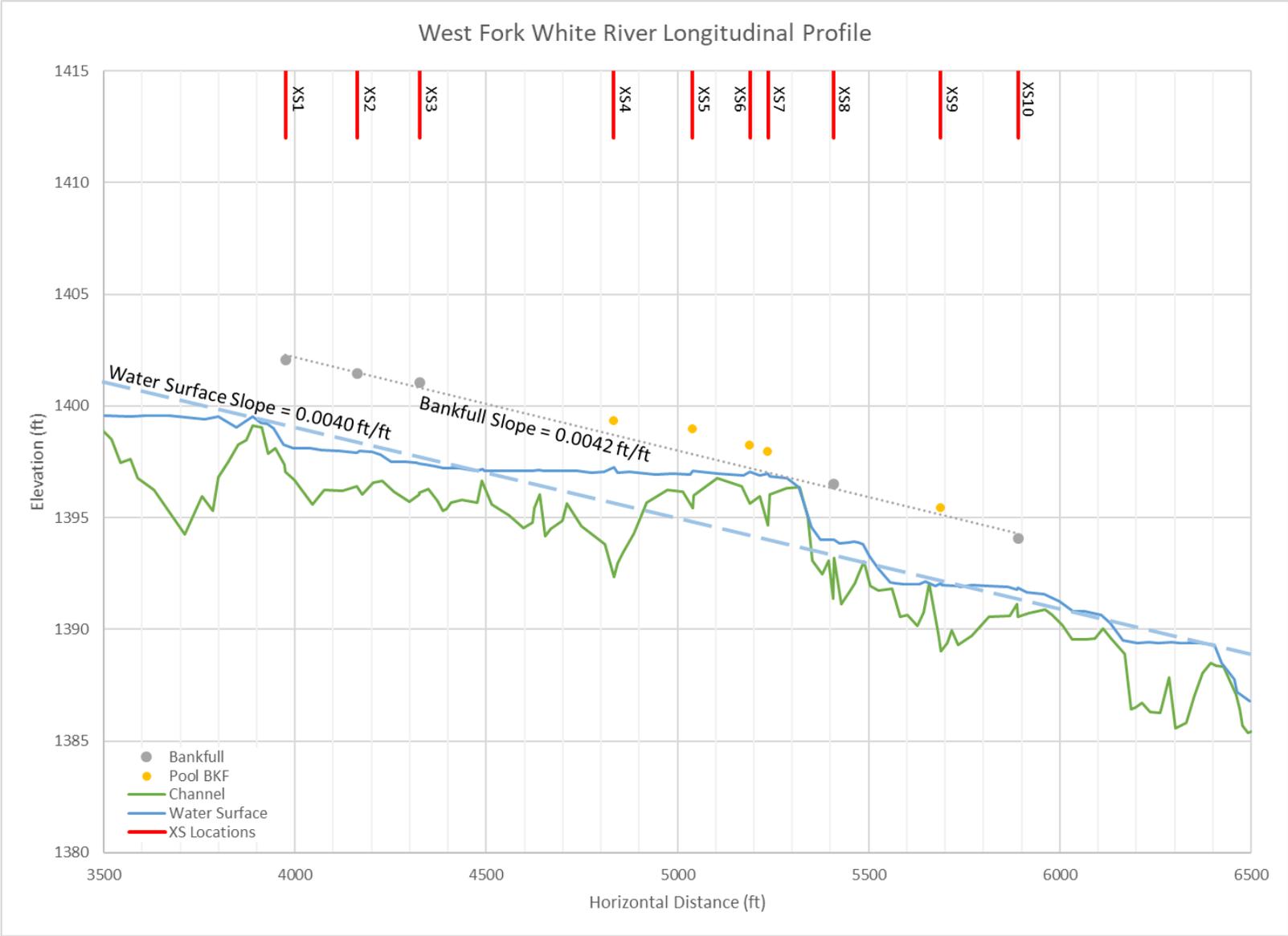


Figure 2. West Fork White River Longitudinal Profile

West Fork Stream Restoration at Brentwood Mountain
Attachment 2. Existing Conditions and Geomorphology Summary Data

Stream: WFWR Brentwood Mountain - XS1	
Basin: White River	Drainage Area: 19904 acres 31.1 mi ²
Location: West Fork White River near Brentwood, AR	
Cross Section Dimensions Based on XS1	
Cross-Section Monuments (Lat./Long.): 35.871 Lat / -94.147 Long Date: 7/13/18	
Observers: TJA, JJH, MVE Valley Type: II	

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	77.9 ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	3.13 ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	243.7 ft ²
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	24.9 ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	5.01 ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	136.8 ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	1.76 ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	49.8 mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	0.0045 ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	1.1

<div style="border: 1px solid black; padding: 5px; display: inline-block;">Stream Type</div>	<div style="border: 1px solid black; padding: 5px; display: inline-block; background-color: #e0f0ff;">B 4c</div>	<div style="border: 1px solid black; padding: 5px; display: inline-block;">(See Figure 2-14)</div>
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West Fork Stream Restoration at Brentwood Mountain
Attachment 2. Existing Conditions and Geomorphology Summary Data

Stream: WFWR Brentwood Mountain - XS8	
Basin: White River	Drainage Area: 19904 acres 31.1 mi²
Location: West Fork White River near Brentwood, AR	
Cross Section Dimensions Based on XS8	
Cross-Section Monuments (Lat./Long.): 35.872 Lat / -94.150 Long	Date: 7/13/18
Observers: TJA, JJH, MVE	Valley Type: II

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	123.4 ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	1.98 ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	245 ft ²
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	62.3 ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	5.11 ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	206.5 ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	1.67 ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	51.3 mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	0.0045 ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	1.1

Stream Type	B 4c	(See Figure 2-14)
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West Fork Stream Restoration at Brentwood Mountain
Attachment 2. Existing Conditions and Geomorphology Summary Data

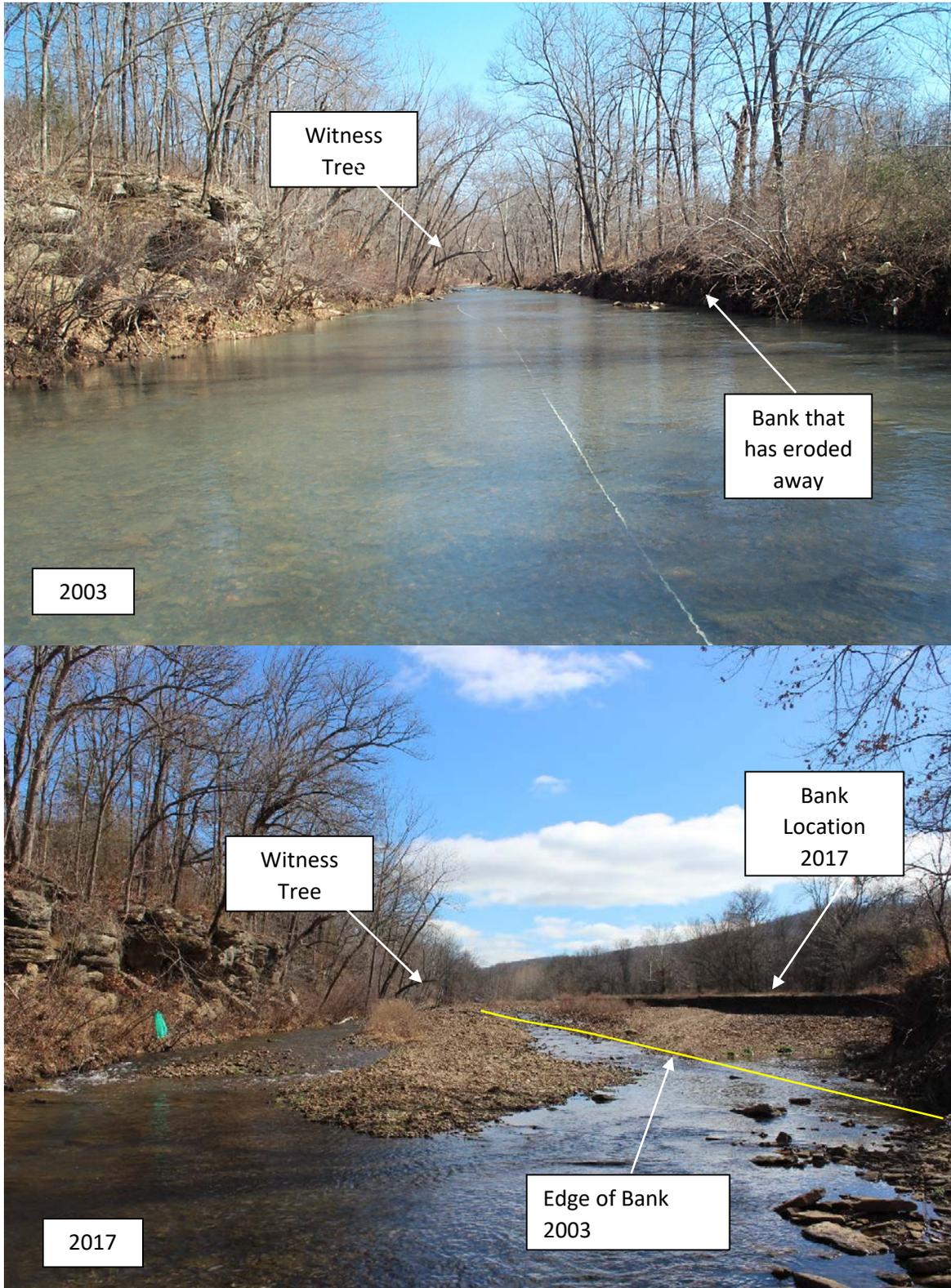
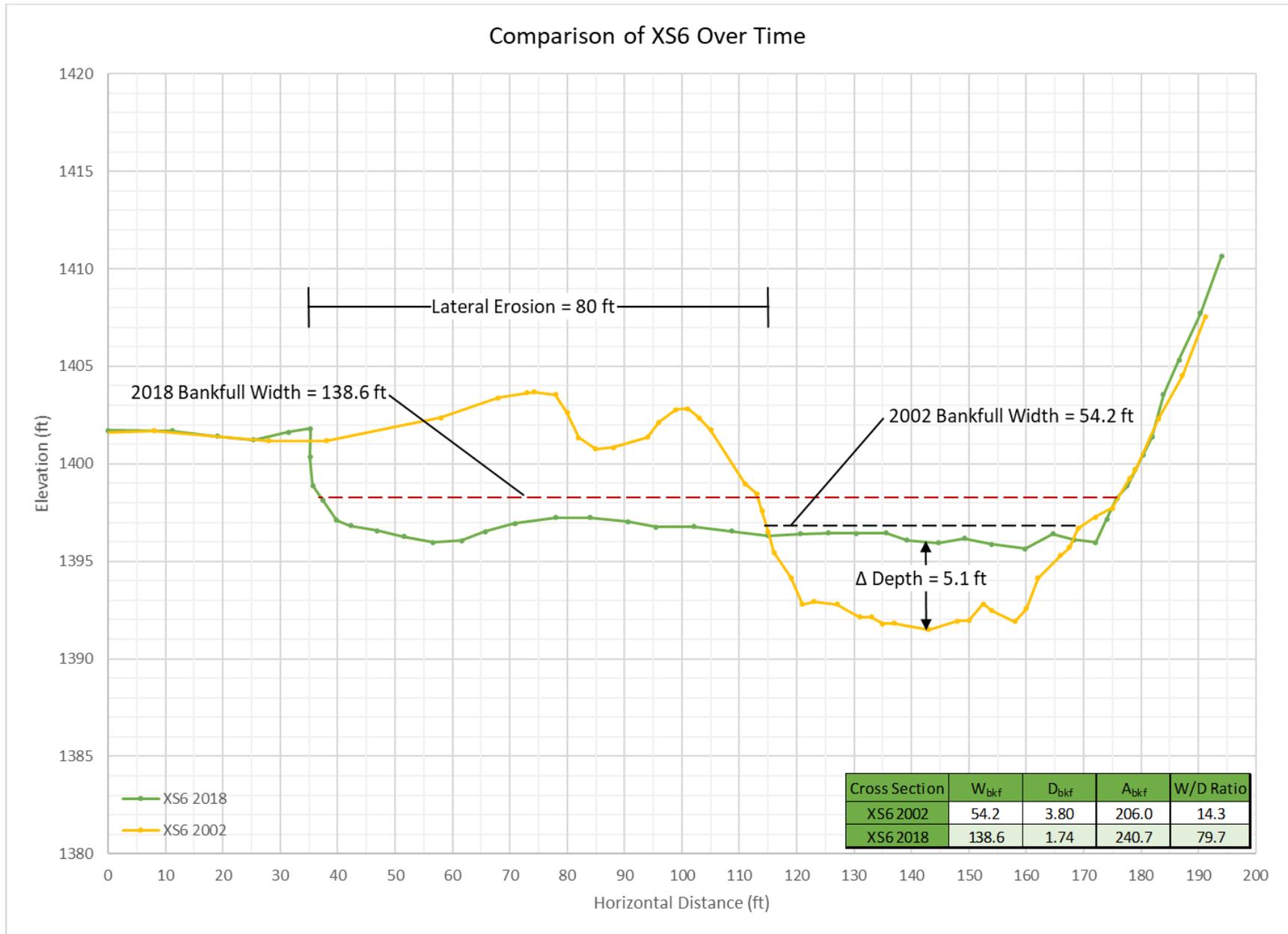


Figure 3. Stream channel instability at the streambank has resulted in severe lateral erosion and the loss of high quality riparian (right side of above images) along the WFWR.

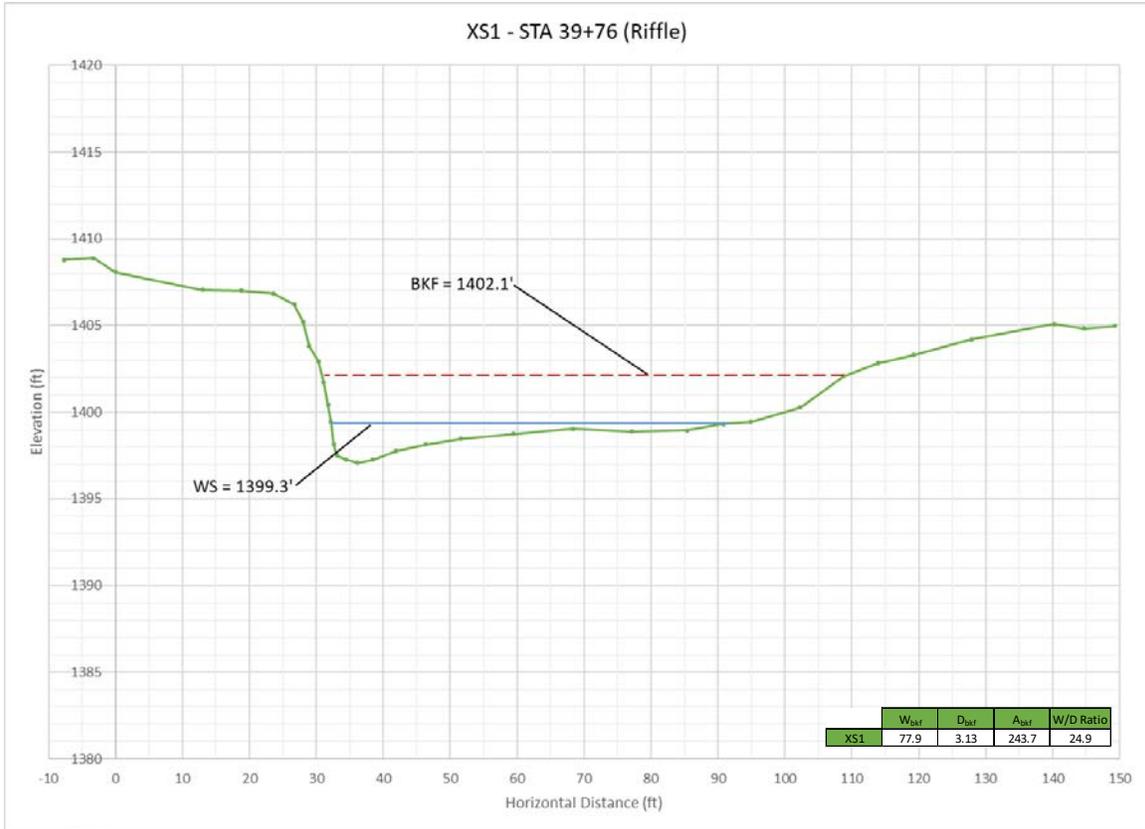
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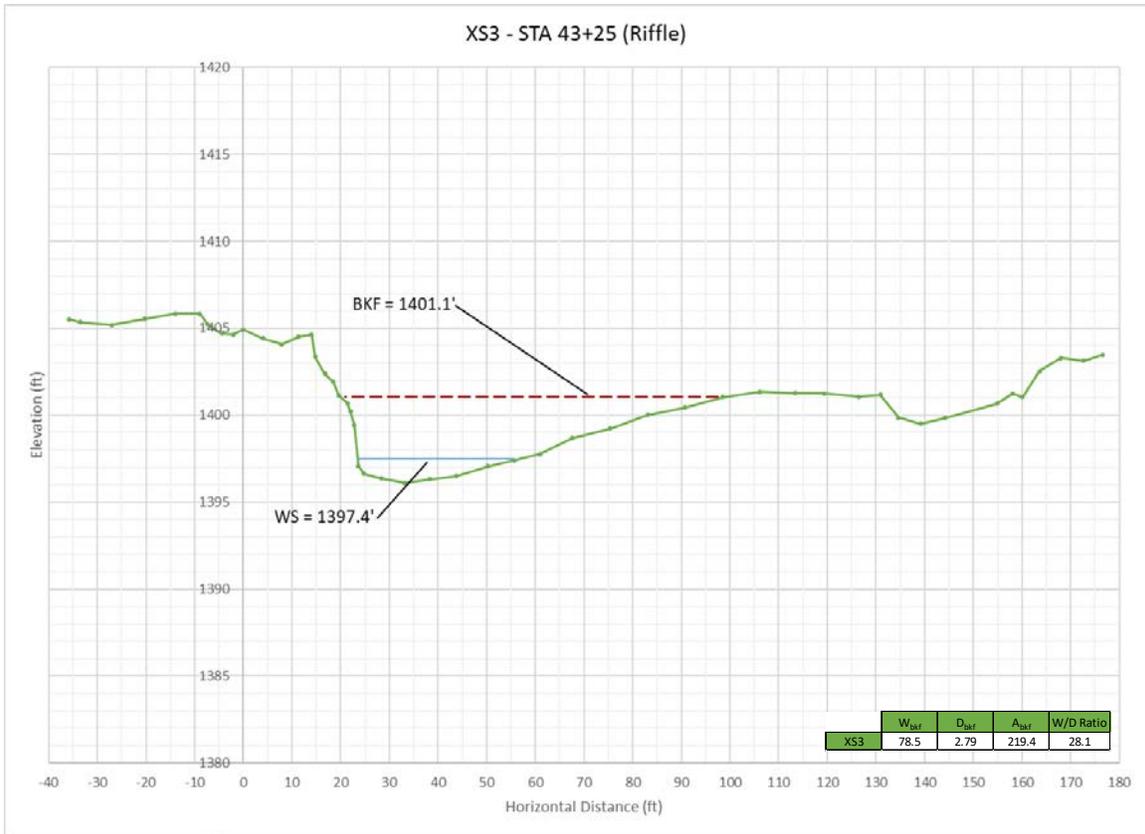
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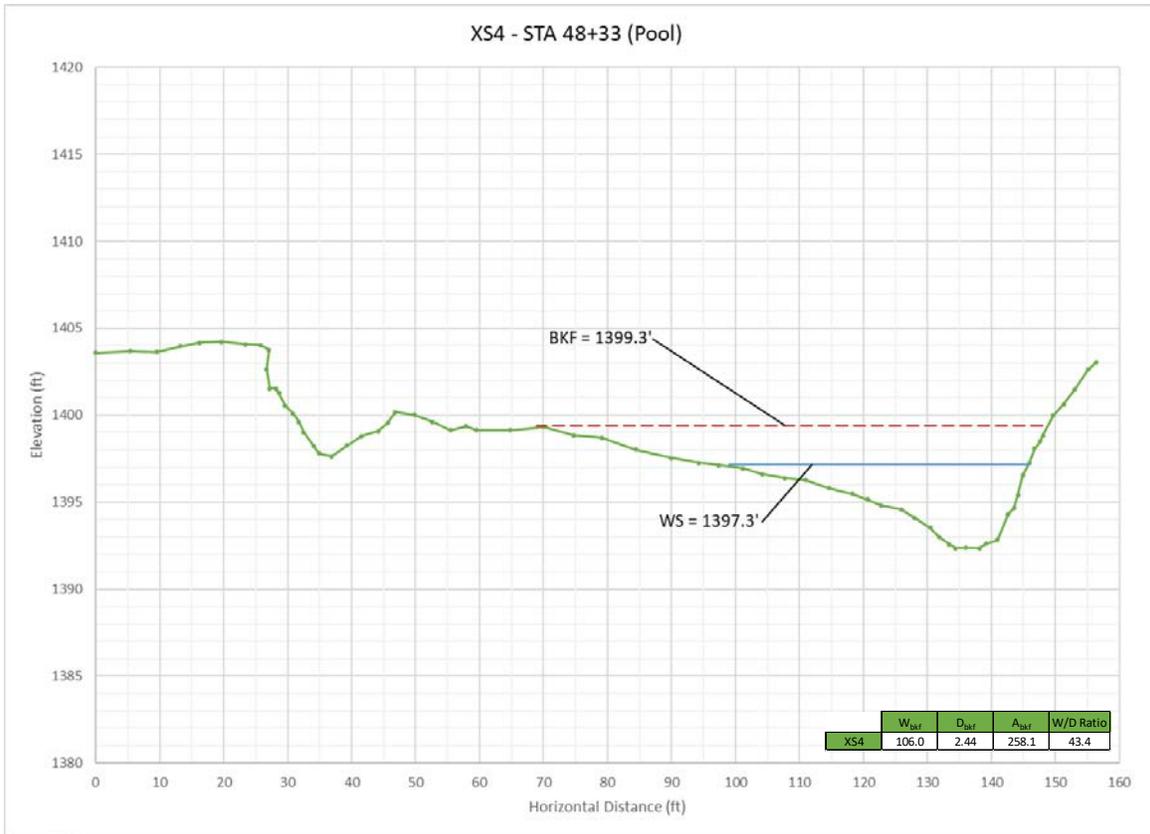
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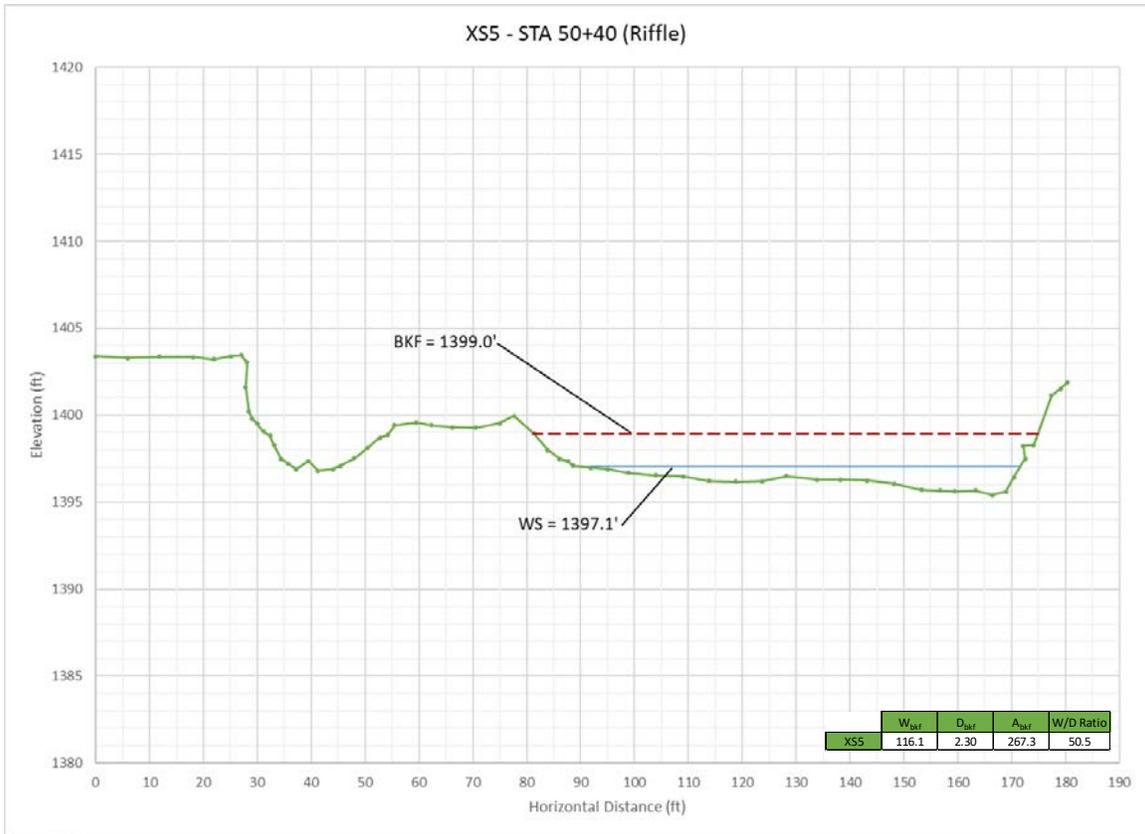
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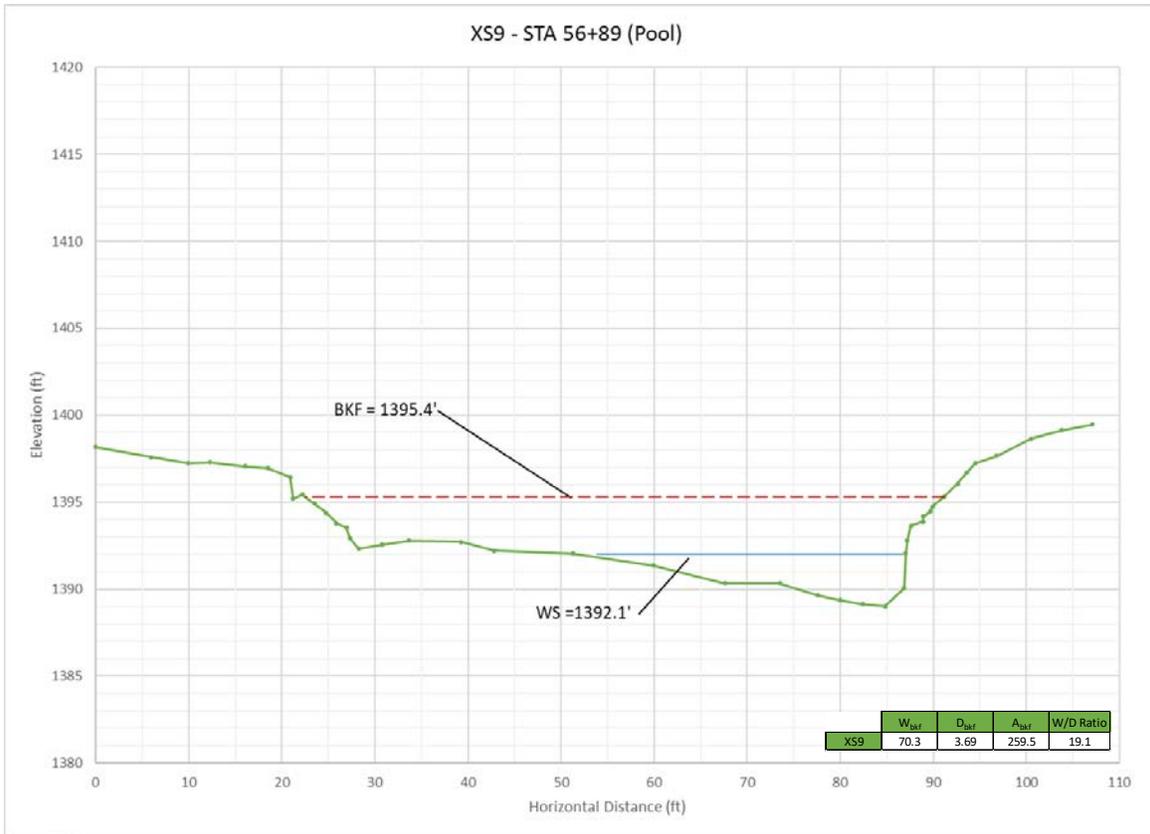
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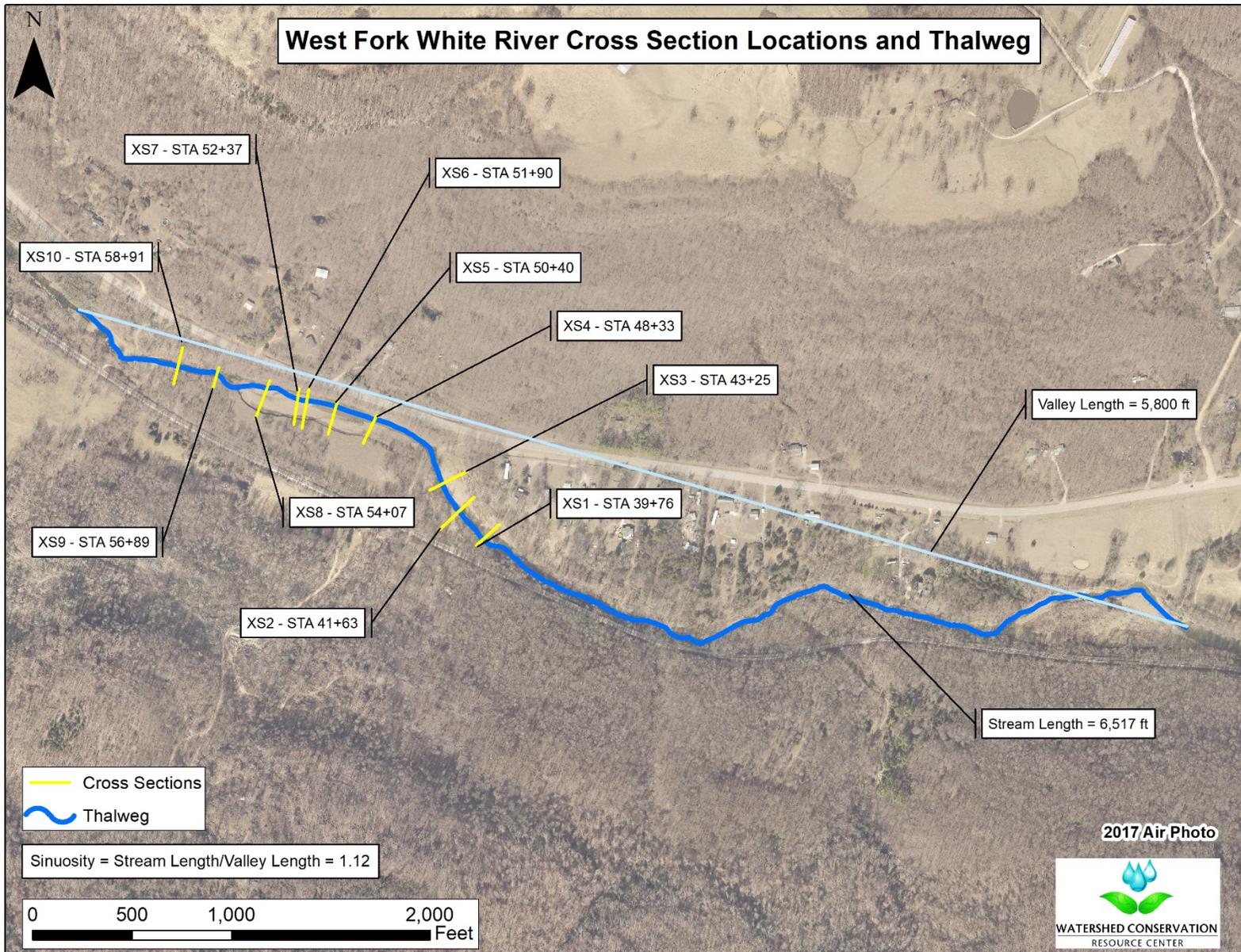
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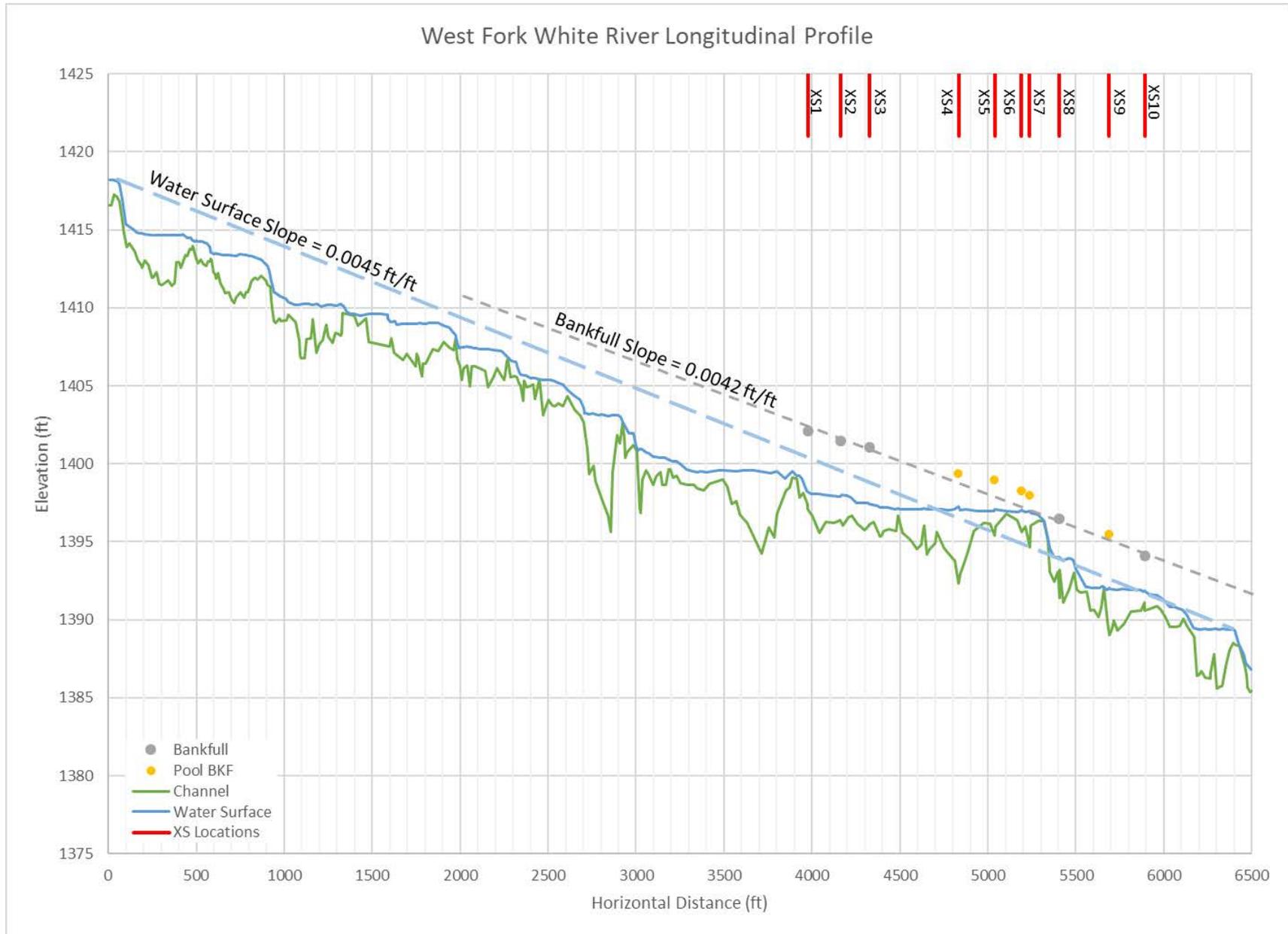
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West Fork Stream Restoration at Brentwood Mountain
Attachment 2. Existing Conditions and Geomorphology Summary Data

XS	W_{bkf}	D_{bkf}	A_{bkf}	W/D Ratio	Feature Type
1	77.9	3.13	243.7	24.9	Riffle
2	79.9	3.22	257.1	24.8	Riffle
3	78.5	2.79	219.4	28.1	Riffle
4	106.0	2.44	258.1	43.4	Pool
5	116.1	2.30	267.3	50.5	Pool
6	138.6	1.74	240.7	79.7	Glide
7	148.3	1.63	242.1	91.0	Glide
8	123.4	1.98	245.0	62.3	Riffle
9	70.3	3.69	259.5	19.1	Pool
10	97.3	2.16	210.5	45.0	Riffle

West Fork Stream Restoration at Brentwood Mountain
Attachment 2. Existing Conditions and Geomorphology Summary Data

XS1

Discharge Method	Velocity (ft/s)	Q (ft ³ /s)
Manning's Equations		
Limerinos	5.23	1273
Darcy Weisbach		
Leopold 1964	5.12	1247
Hey 1979	5.40	1315
U/U*	4.90	1193
Average	5.16	1257

XS2

Discharge Method	Velocity (ft/s)	Q (ft ³ /s)
Manning's Equations		
Limerinos	5.85	1504
Darcy Weisbach		
Leopold 1964	5.68	1461
Hey 1979	5.96	1532
U/U*	5.20	1420
Average	5.67	1479

XS3

Discharge Method	Velocity (ft/s)	Q (ft ³ /s)
Manning's Equations		
Limerinos	5.13	1125
Darcy Weisbach		
Leopold 1964	4.98	1093
Hey 1979	5.30	1162
U/U*	4.82	1057
Average	5.06	1109

XS8

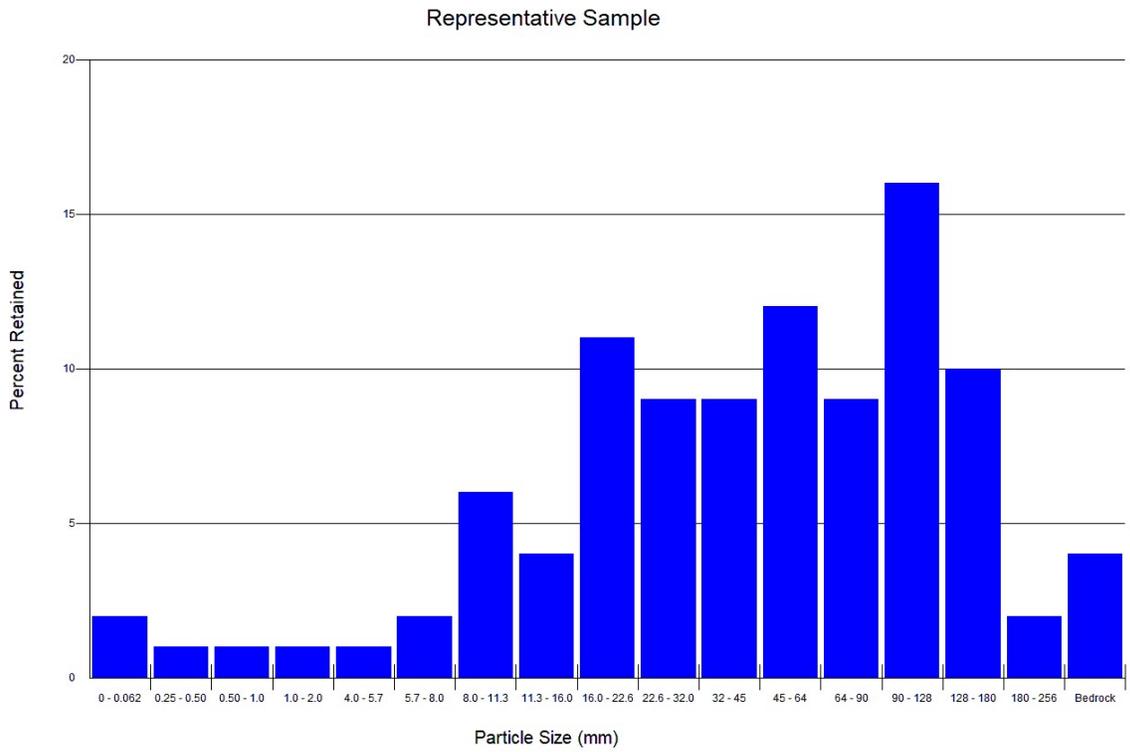
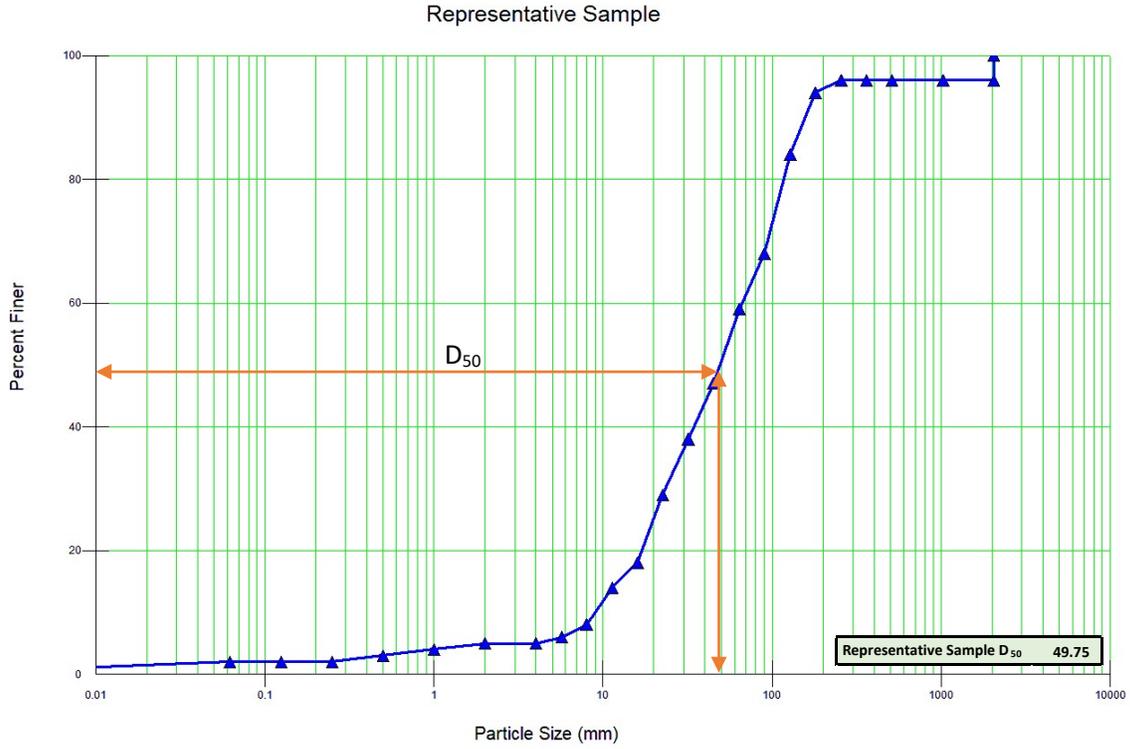
Discharge Method	Velocity (ft/s)	Q (ft ³ /s)
Manning's Equations		
Limerinos	4.09	1003
Darcy Weisbach		
Leopold 1964	3.98	976
Hey 1979	4.41	1079
U/U*	3.83	939
Average	4.08	999

XS10

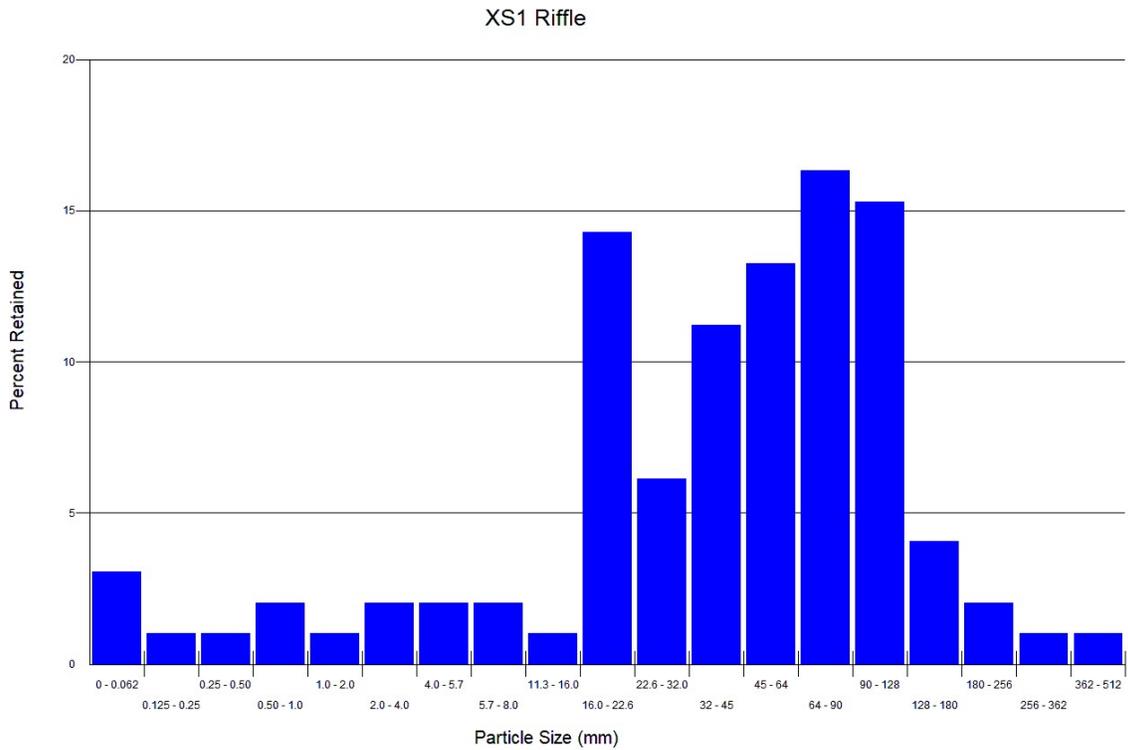
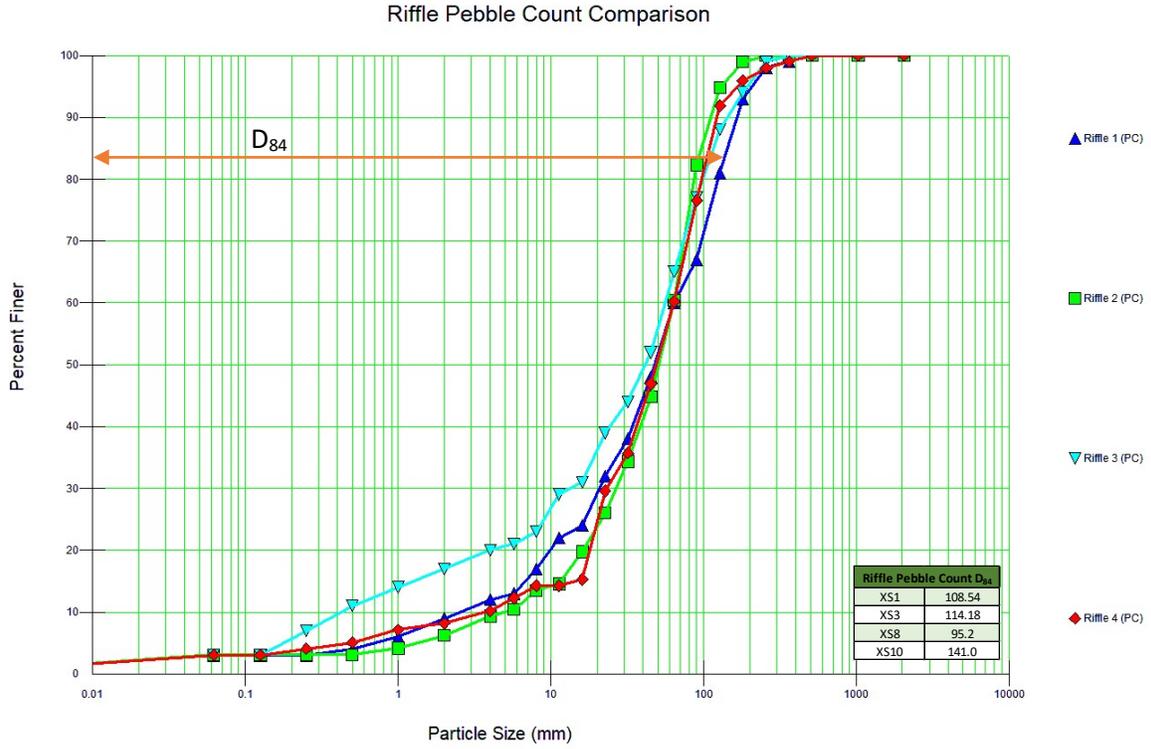
Discharge Method	Velocity (ft/s)	Q (ft ³ /s)
Manning's Equations		
Limerinos	3.93	827
Darcy Weisbach		
Leopold 1964	3.73	786
Hey 1979	3.97	836
U/U*	3.67	772
Average	3.83	805

	Velocity (ft/s)	Q (ft ³ /s)
US Average	5.30	1282
DS Average	3.95	902
Total Average	4.76	1130

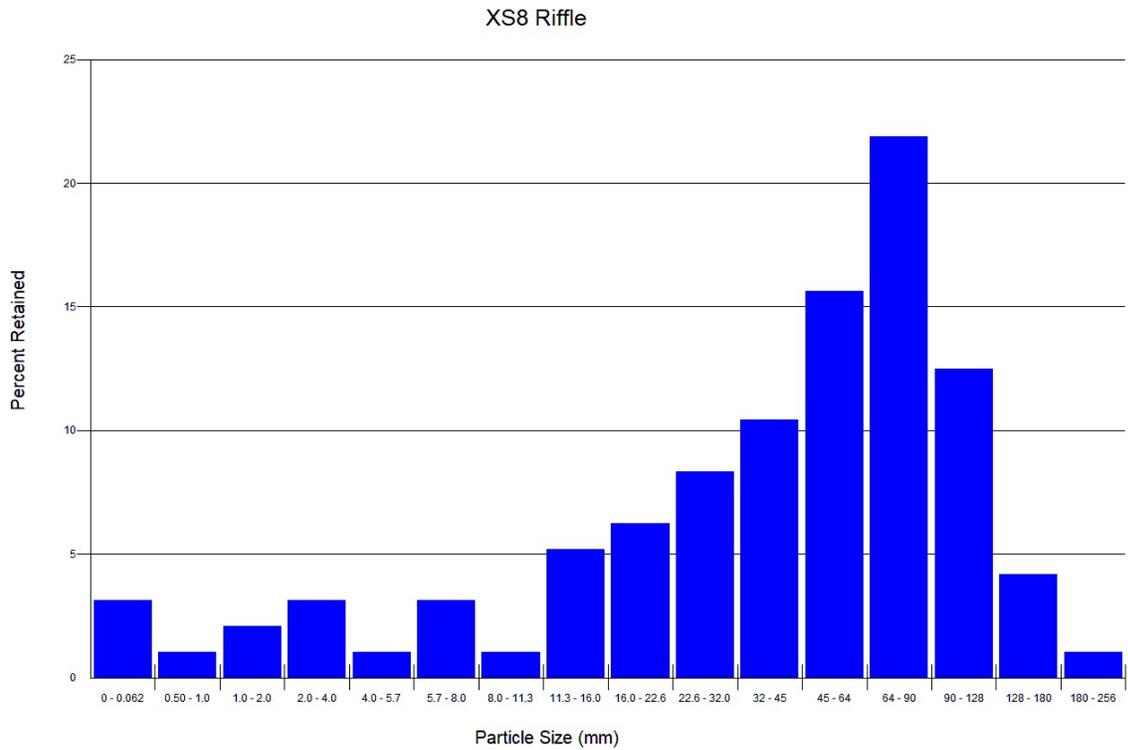
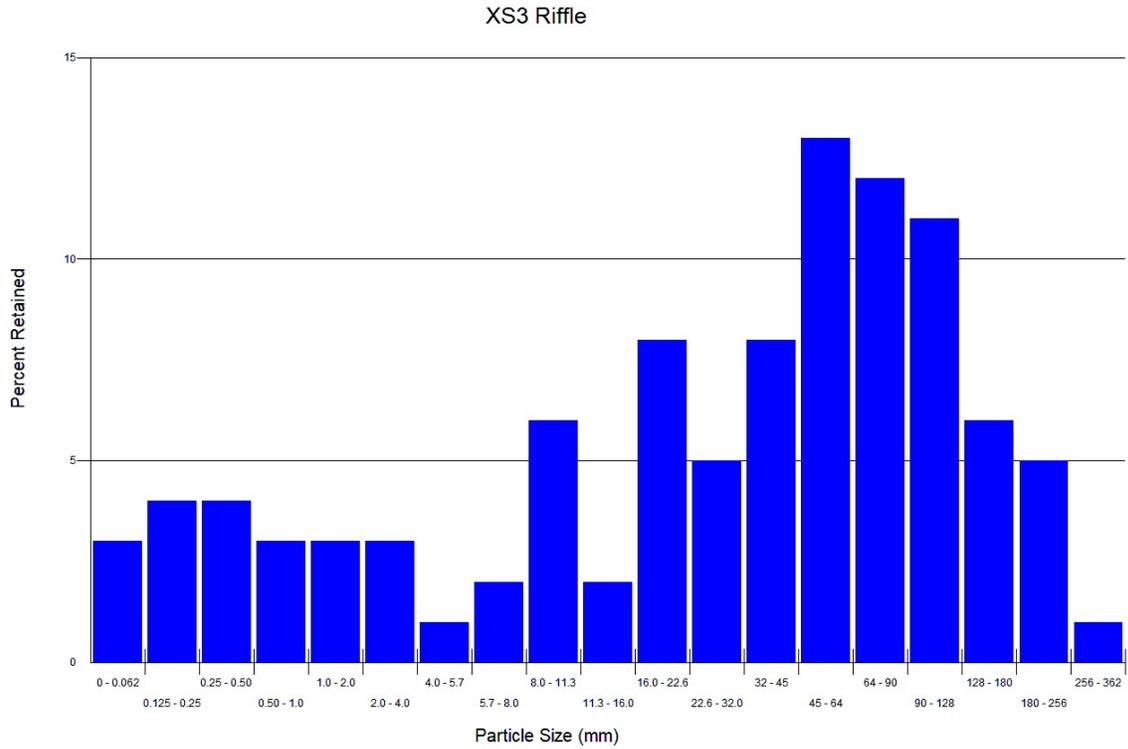
West Fork Stream Restoration at Brentwood Mountain
 Attachment 2. Existing Conditions and Geomorphology Summary Data



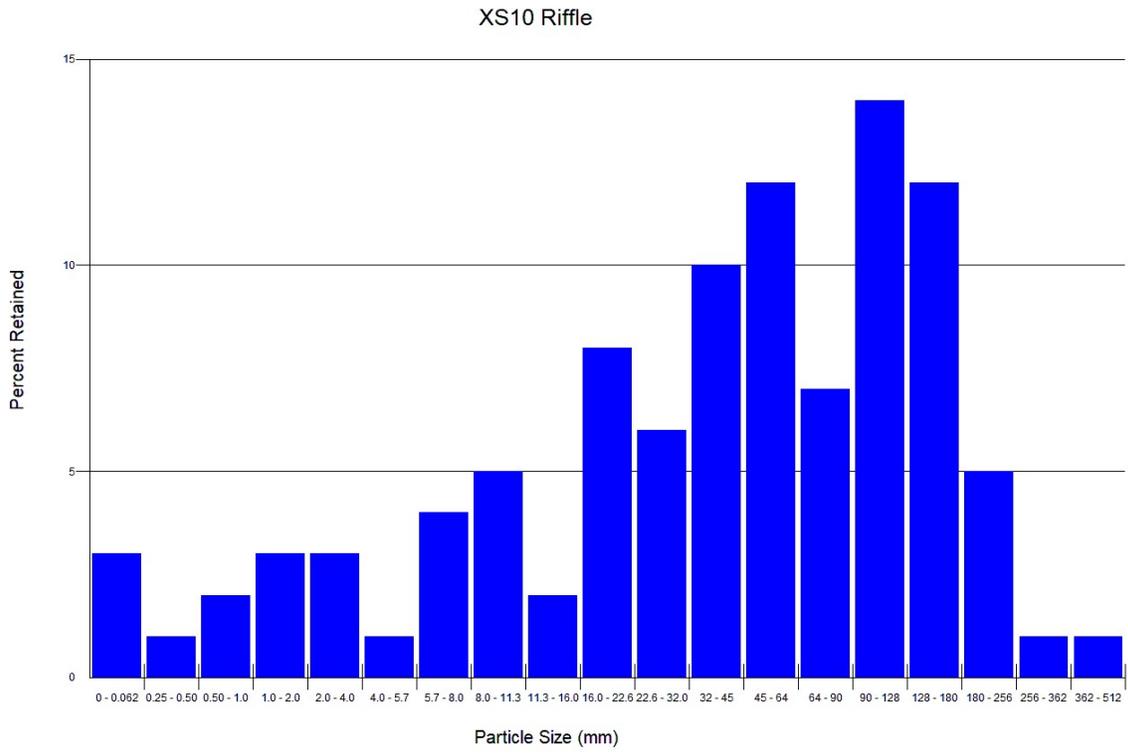
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Attachment 2. Existing Conditions and Geomorphology Summary Data



West Fork Stream Restoration at Brentwood Mountain
Attachment 3. Bank Erosion Monitoring 2018–2019



7/16/2019



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West Fork Stream Restoration at Brentwood Mountain
 Attachment 3. Bank Erosion Monitoring 2018 – 2019

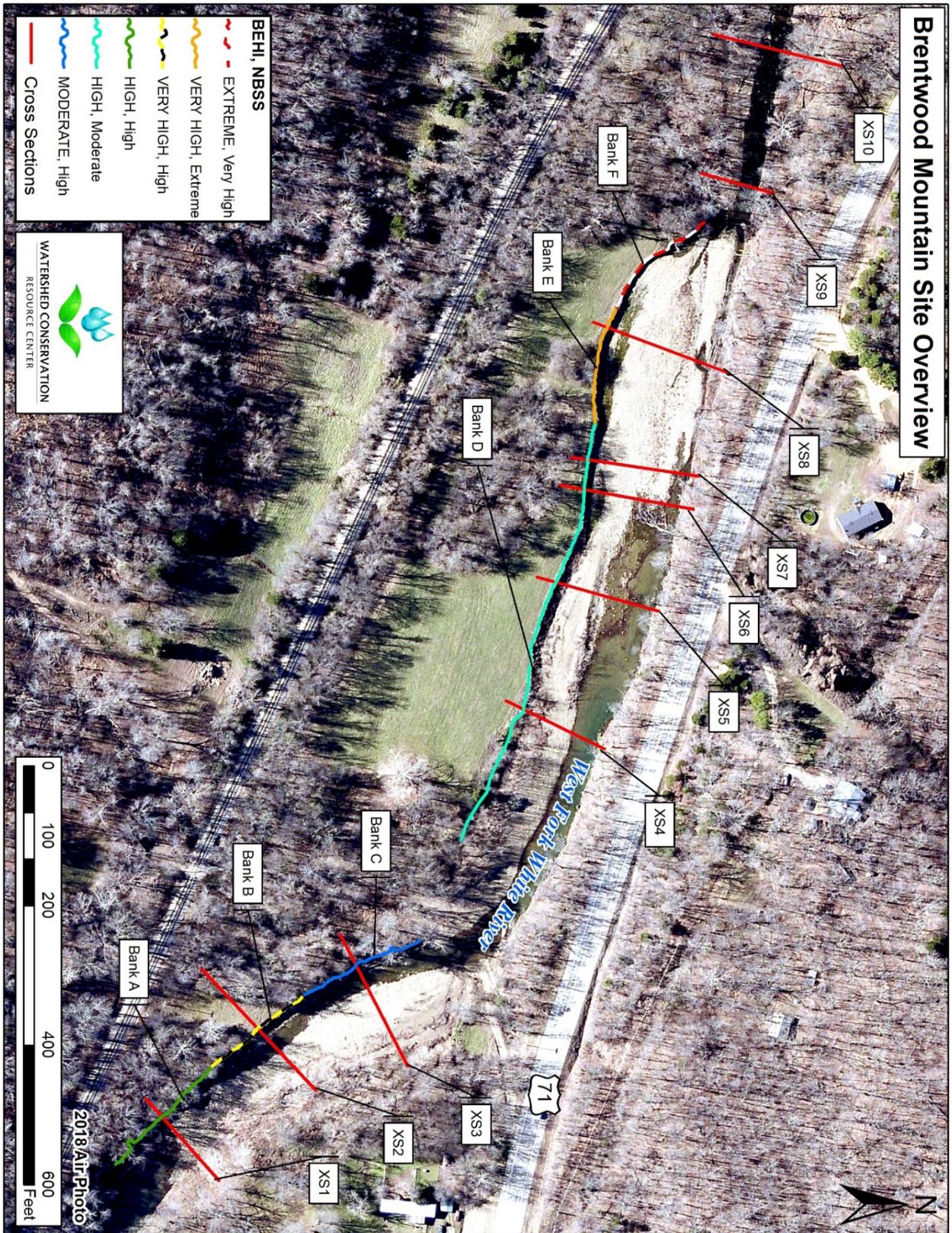


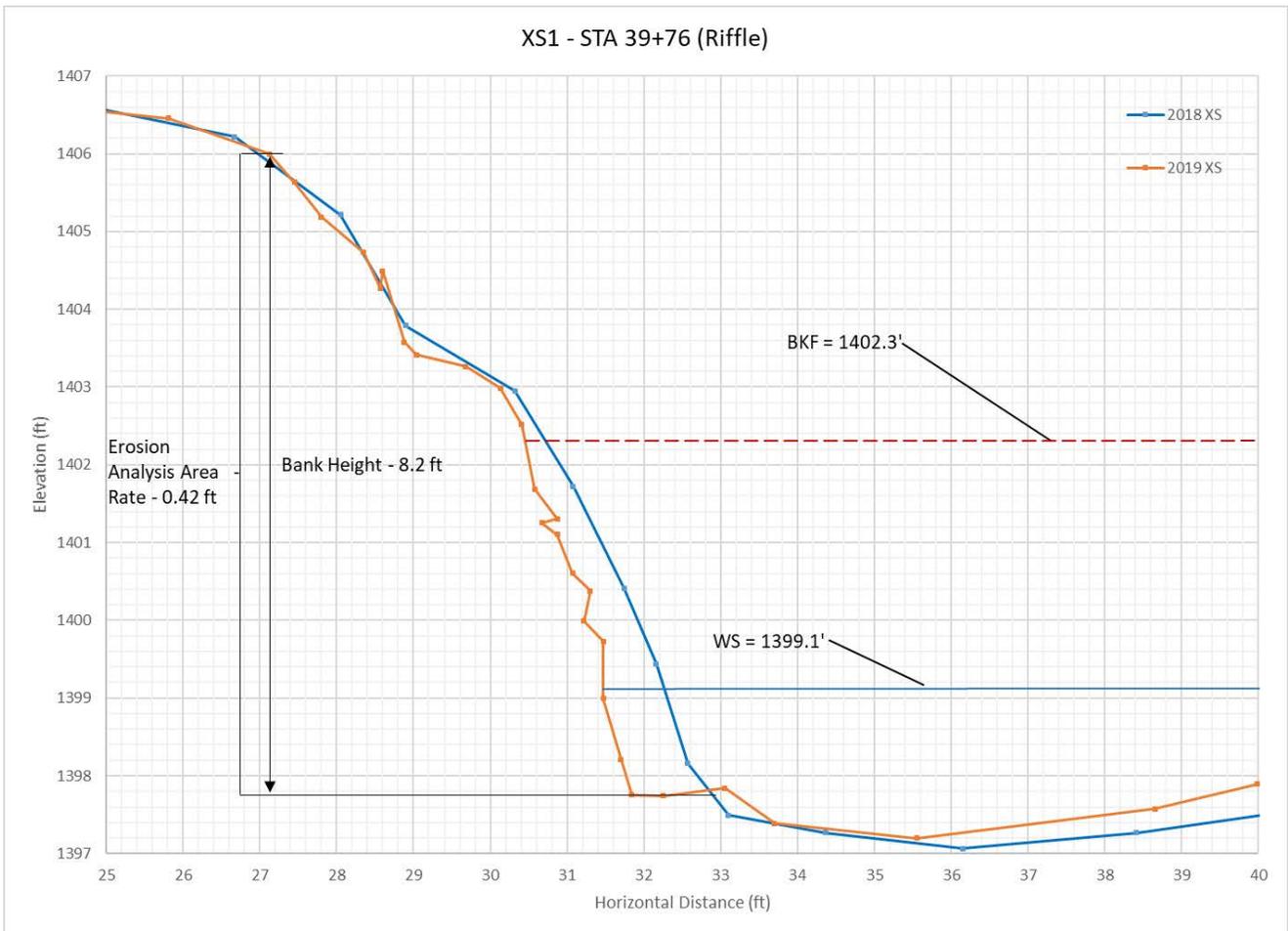
Figure 1. Cross Sections, BEHI and NBSS adjectives and Bank Names for the Stonesifer property

West Fork Stream Restoration at Brentwood Mountain
Attachment 3. Bank Erosion Monitoring 2018 – 2019

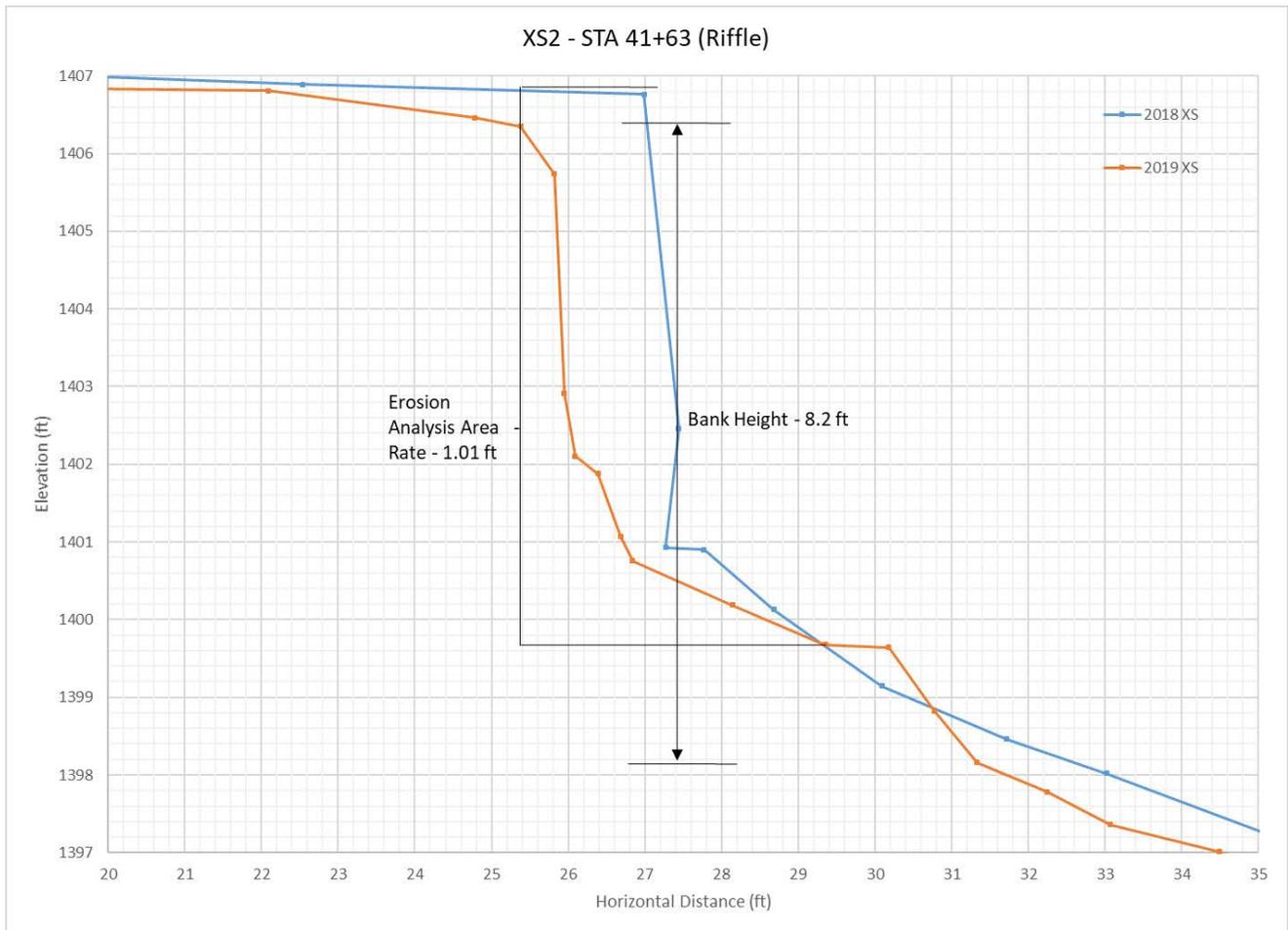


Figure 2. 2018 to 2019 Top of Bank Erosion for the Stonesifer Property

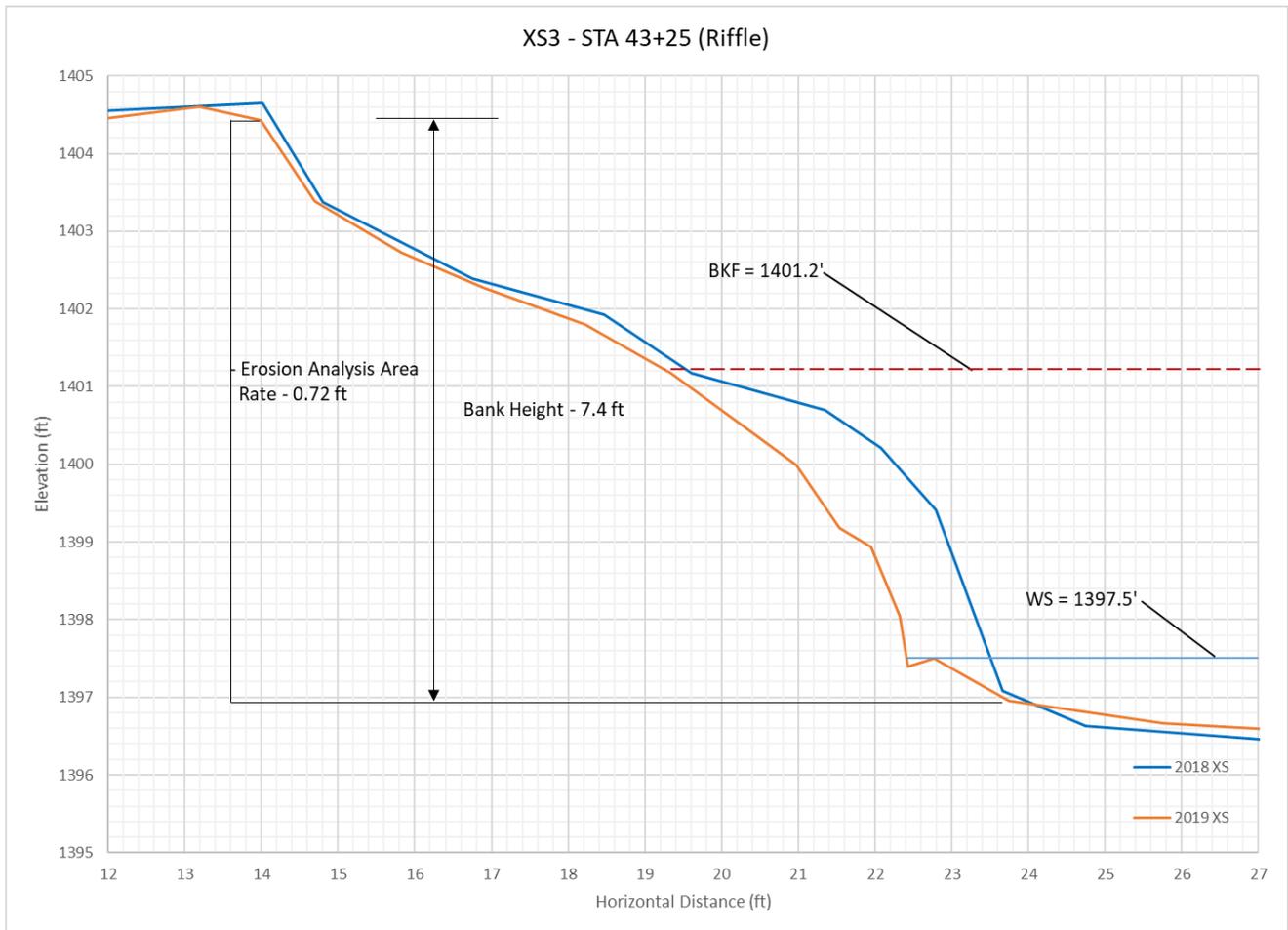
West Fork Stream Restoration at Brentwood Mountain
Attachment 3. Bank Erosion Monitoring 2018 – 2019



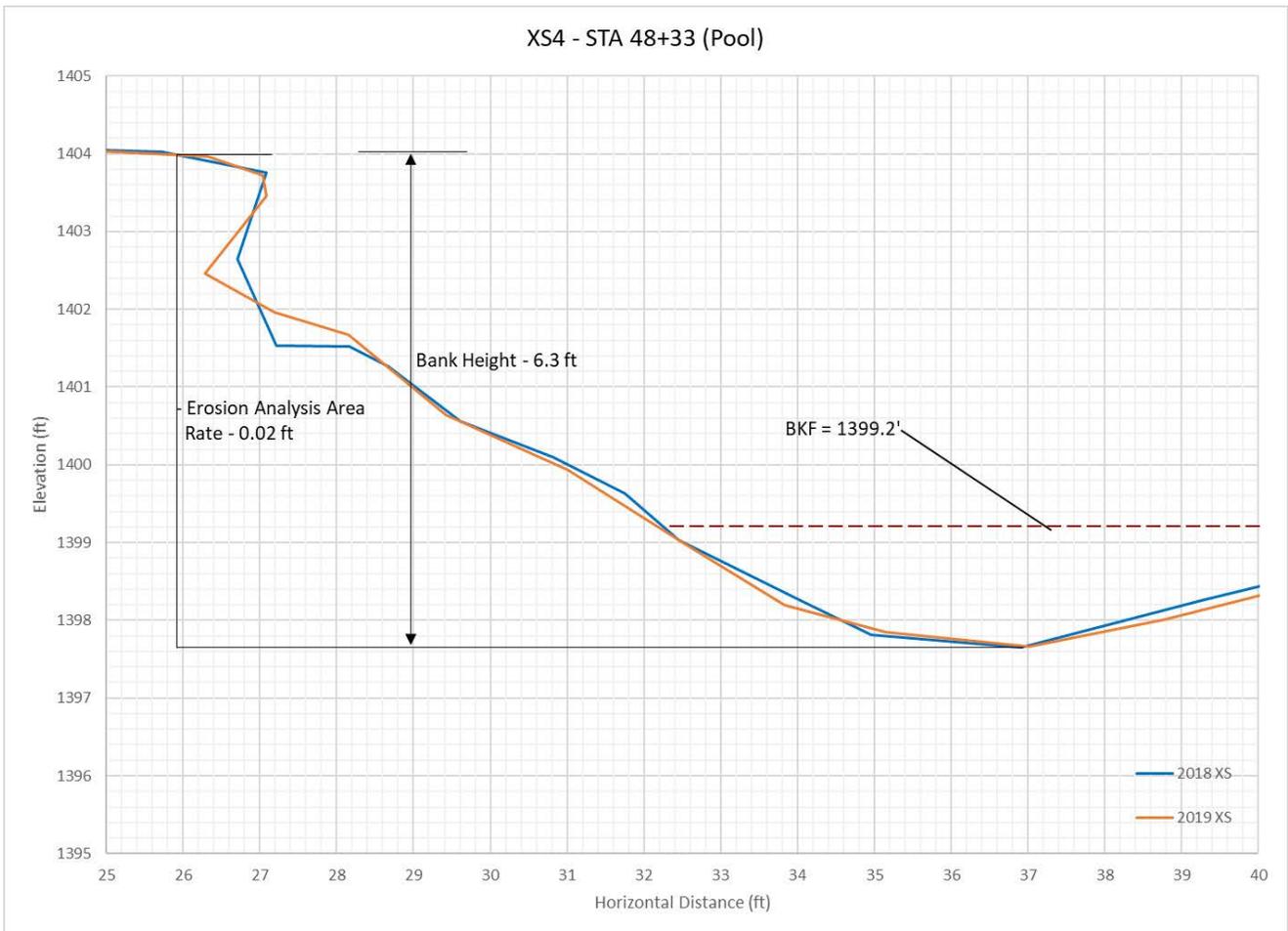
West Fork Stream Restoration at Brentwood Mountain
Attachment 3. Bank Erosion Monitoring 2018 – 2019



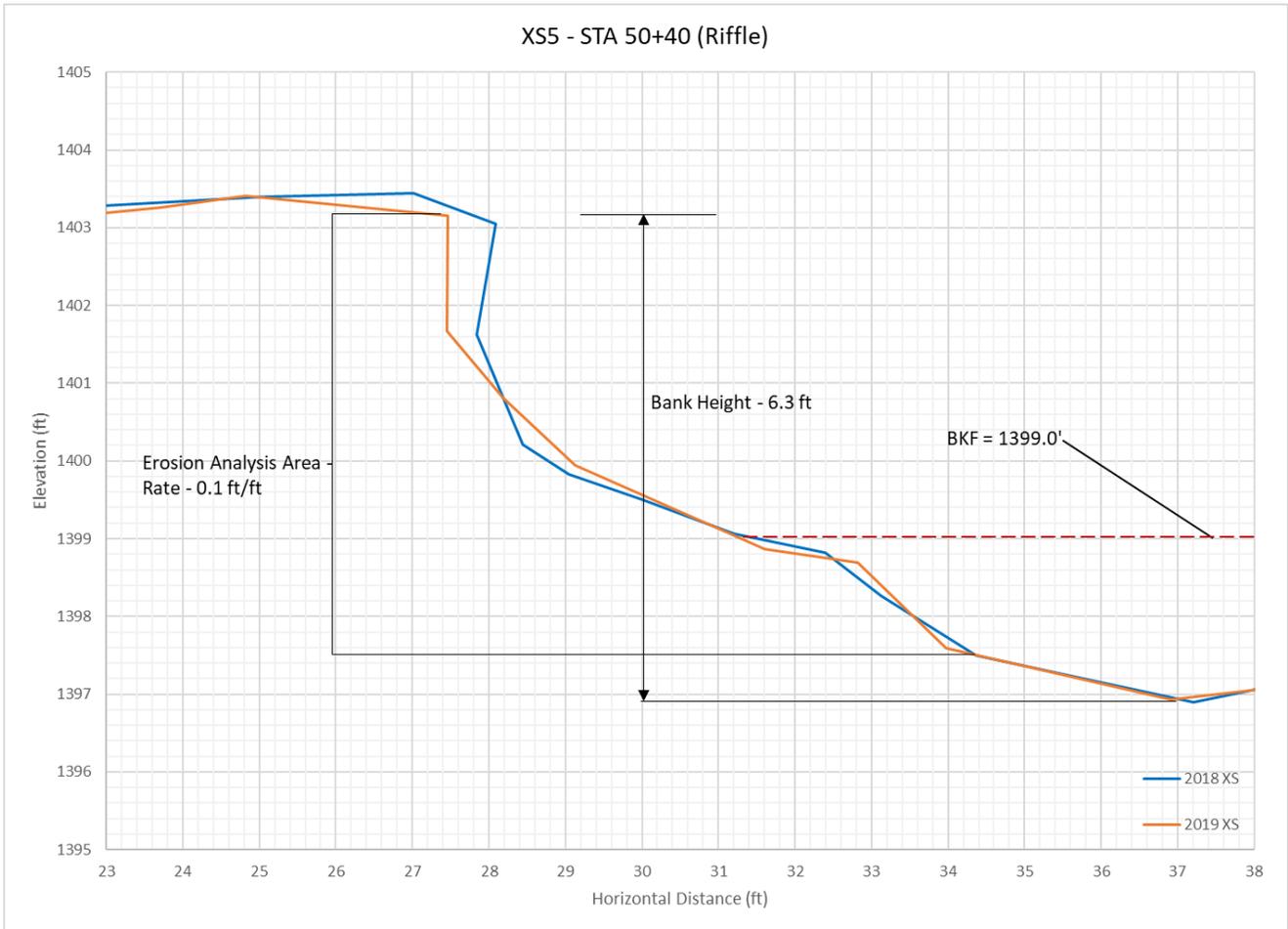
West Fork Stream Restoration at Brentwood Mountain
Attachment 3. Bank Erosion Monitoring 2018 – 2019



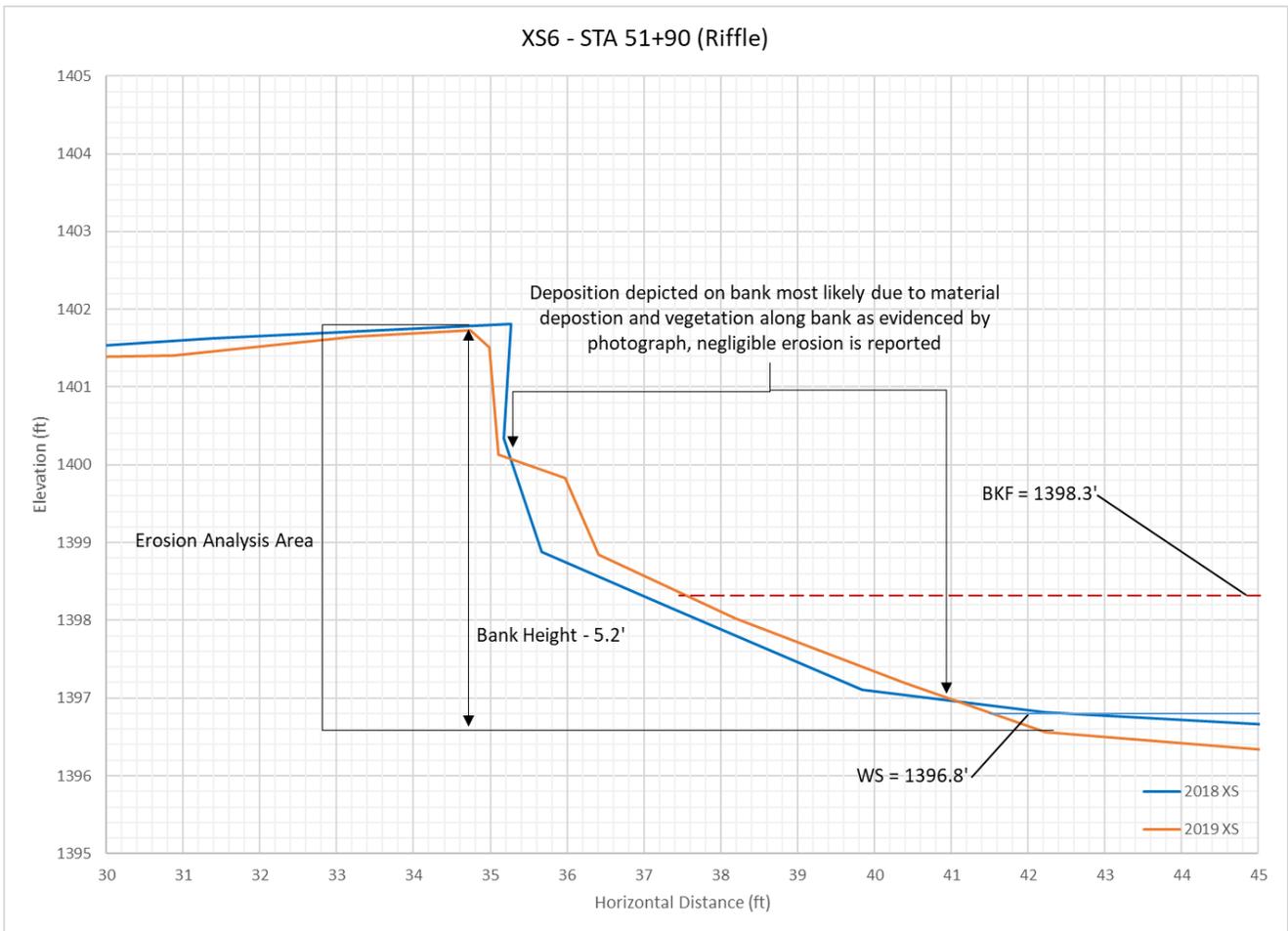
West Fork Stream Restoration at Brentwood Mountain
Attachment 3. Bank Erosion Monitoring 2018 – 2019



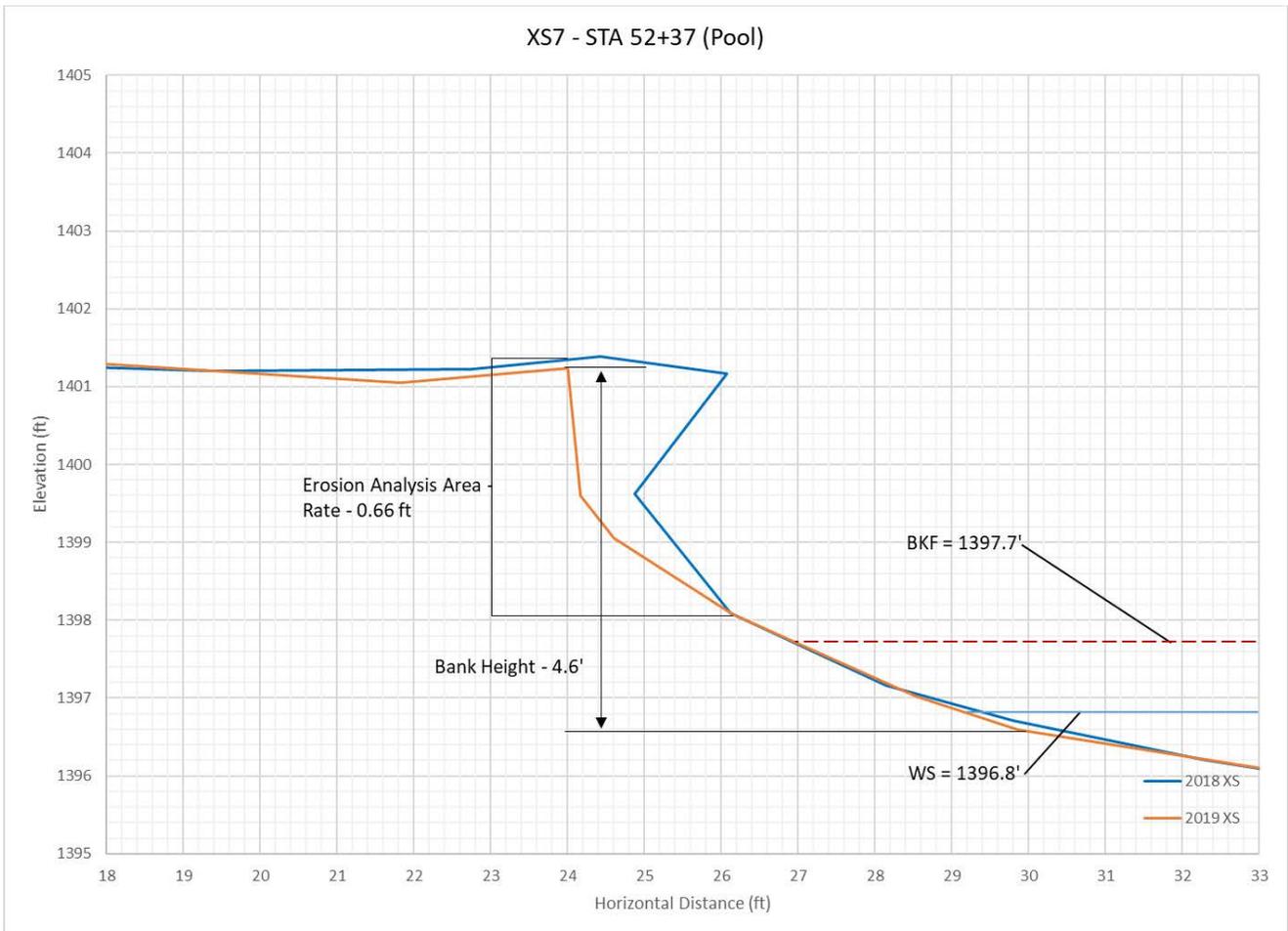
West Fork Stream Restoration at Brentwood Mountain
 Attachment 3. Bank Erosion Monitoring 2018 – 2019



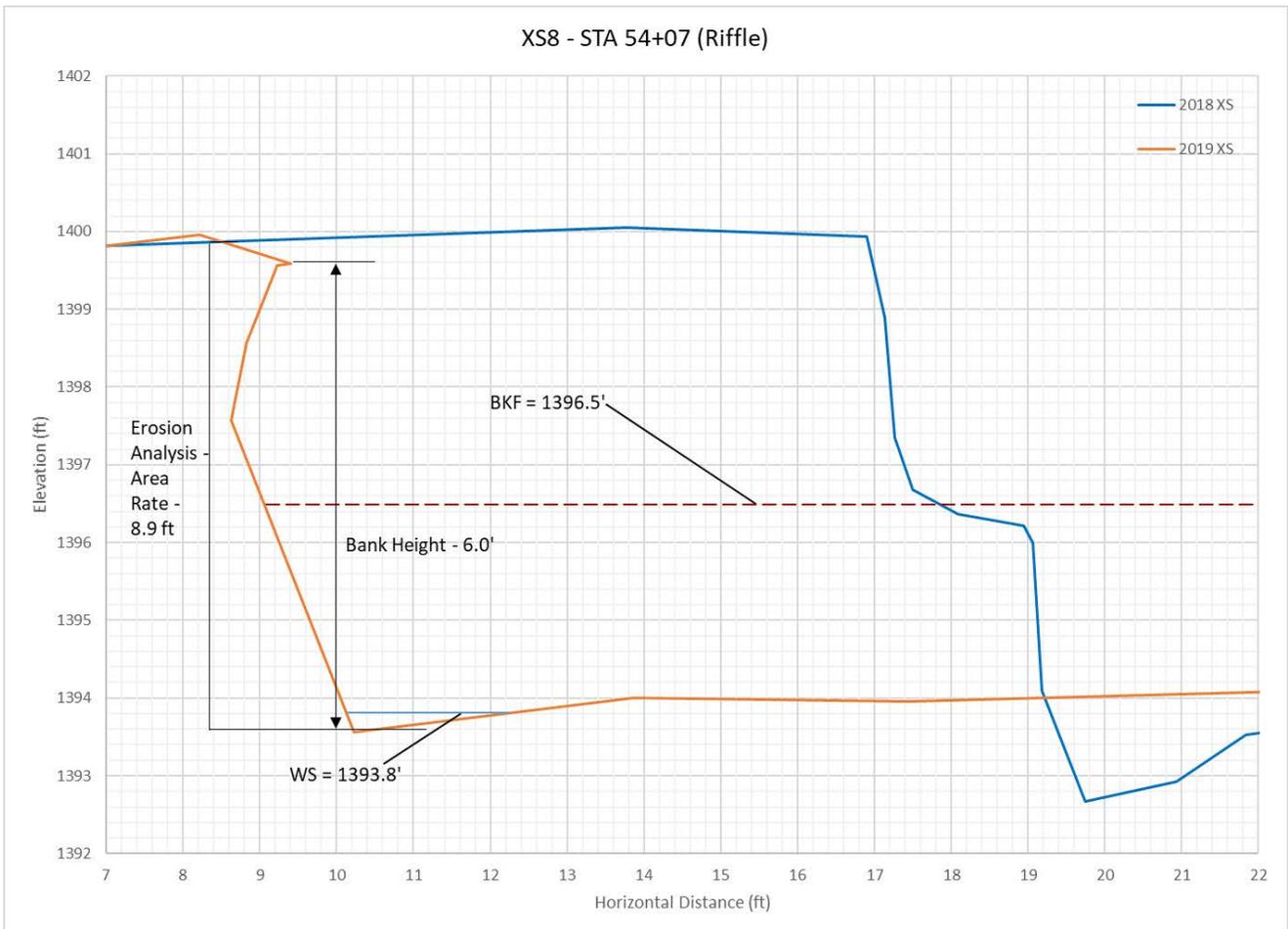
West Fork Stream Restoration at Brentwood Mountain
Attachment 3. Bank Erosion Monitoring 2018 – 2019



West Fork Stream Restoration at Brentwood Mountain
Attachment 3. Bank Erosion Monitoring 2018 – 2019



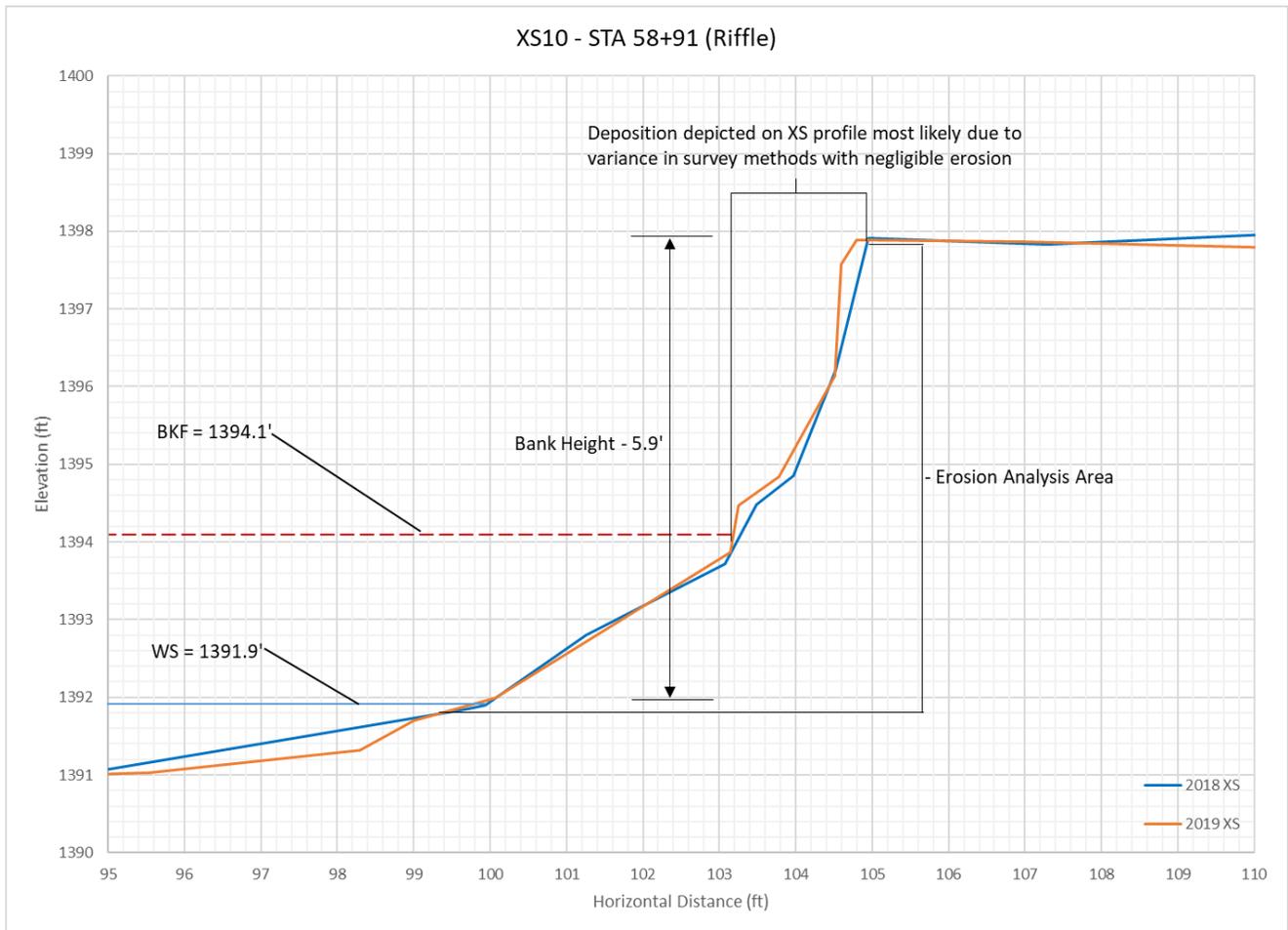
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 Attachment 3. Bank Erosion Monitoring 2018 – 2019



West Fork Stream Restoration at Brentwood Mountain
Attachment 3. Bank Erosion Monitoring 2018 – 2019



West Fork Stream Restoration at Brentwood Mountain
Attachment 3. Bank Erosion Monitoring 2018 – 2019



West Fork Stream Restoration at Brentwood Mountain
Attachment 4. Post Flood Monitoring



07/16/19

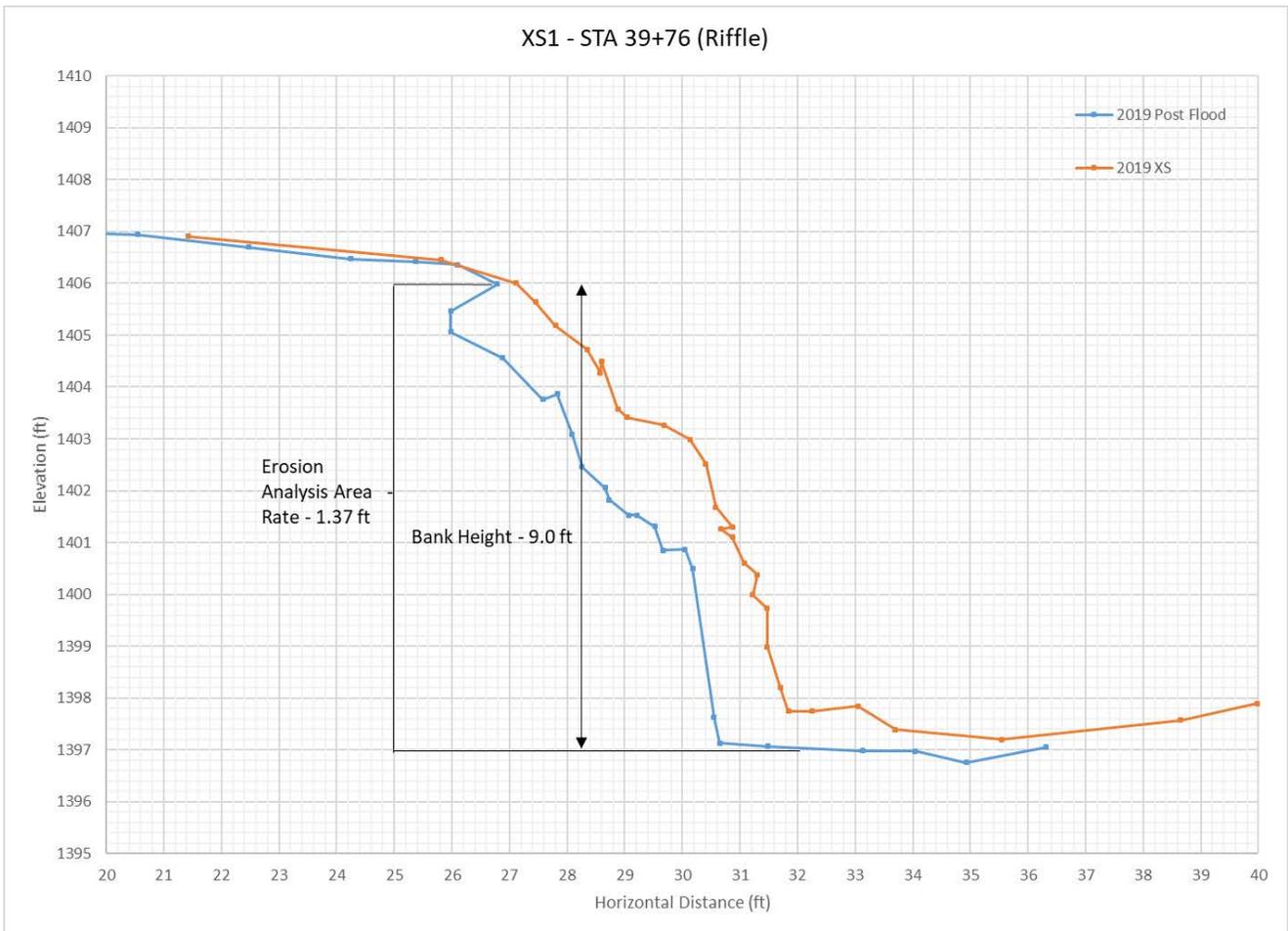


West Fork Stream Restoration at Brentwood Mountain
Attachment 4. Post Flood Monitoring

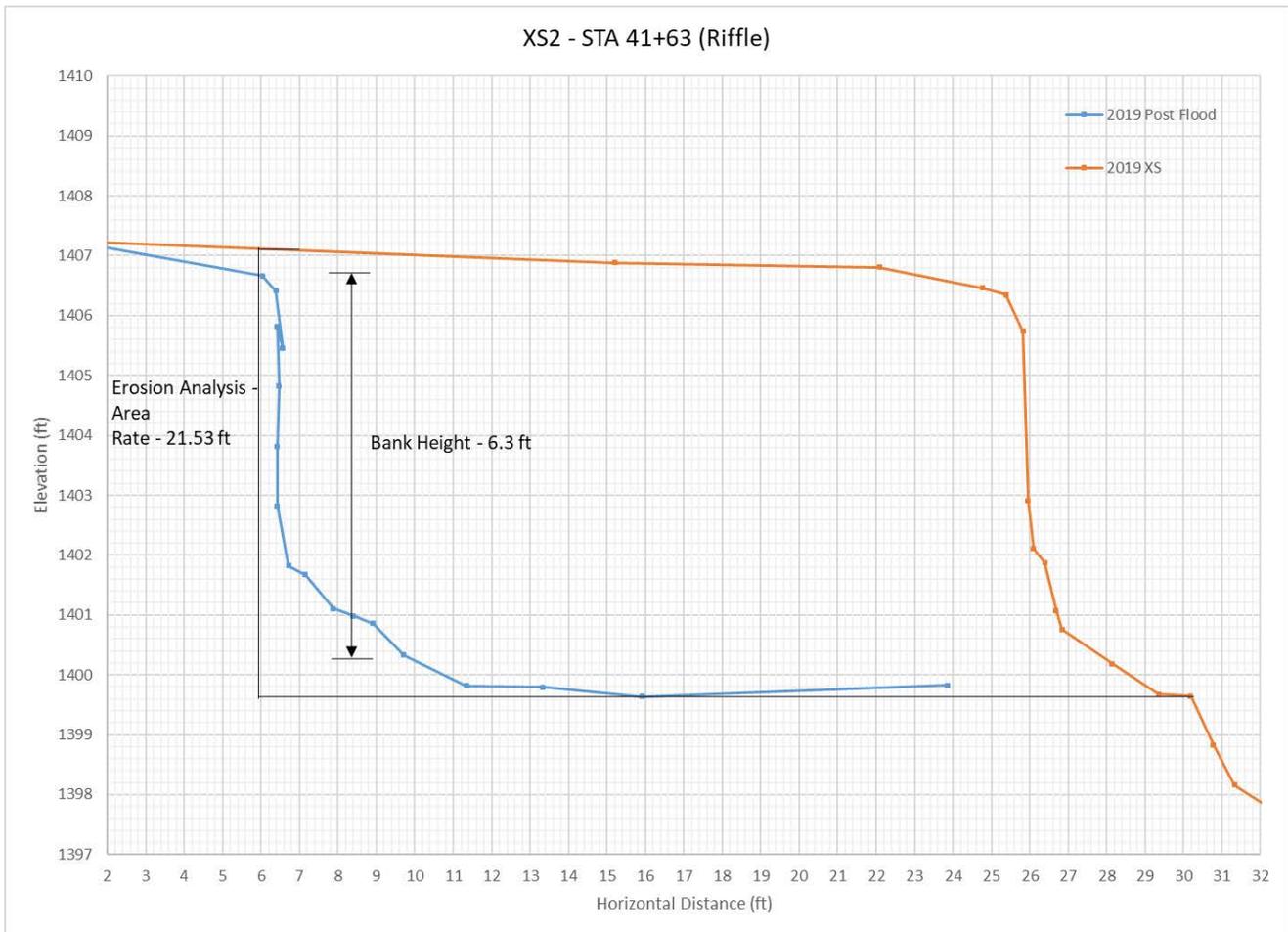


Figure 1. Top of Bank Erosion that occurred between May 17th and July 12th of 2019

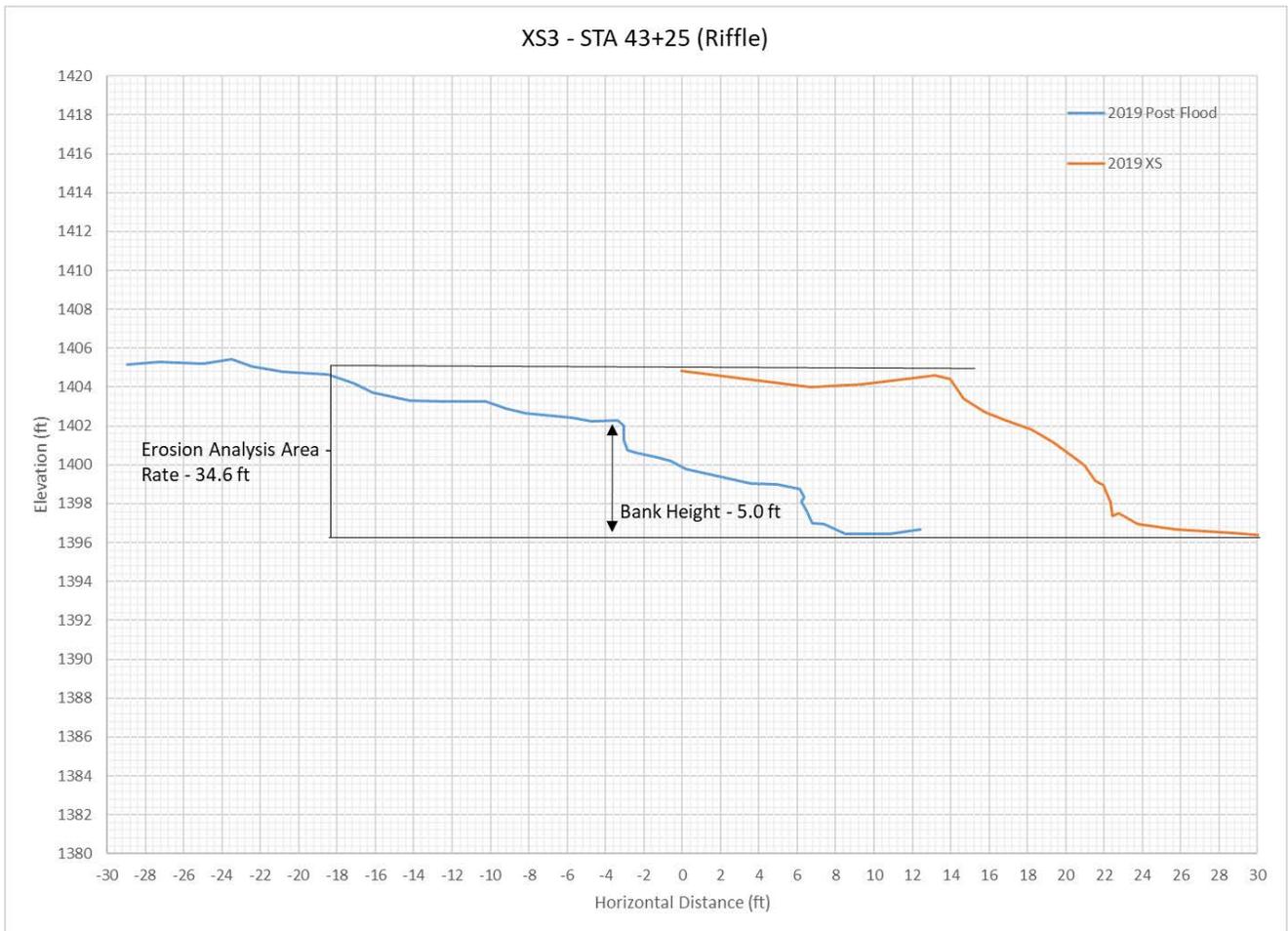
West Fork Stream Restoration at Brentwood Mountain
Attachment 4. Post Flood Monitoring



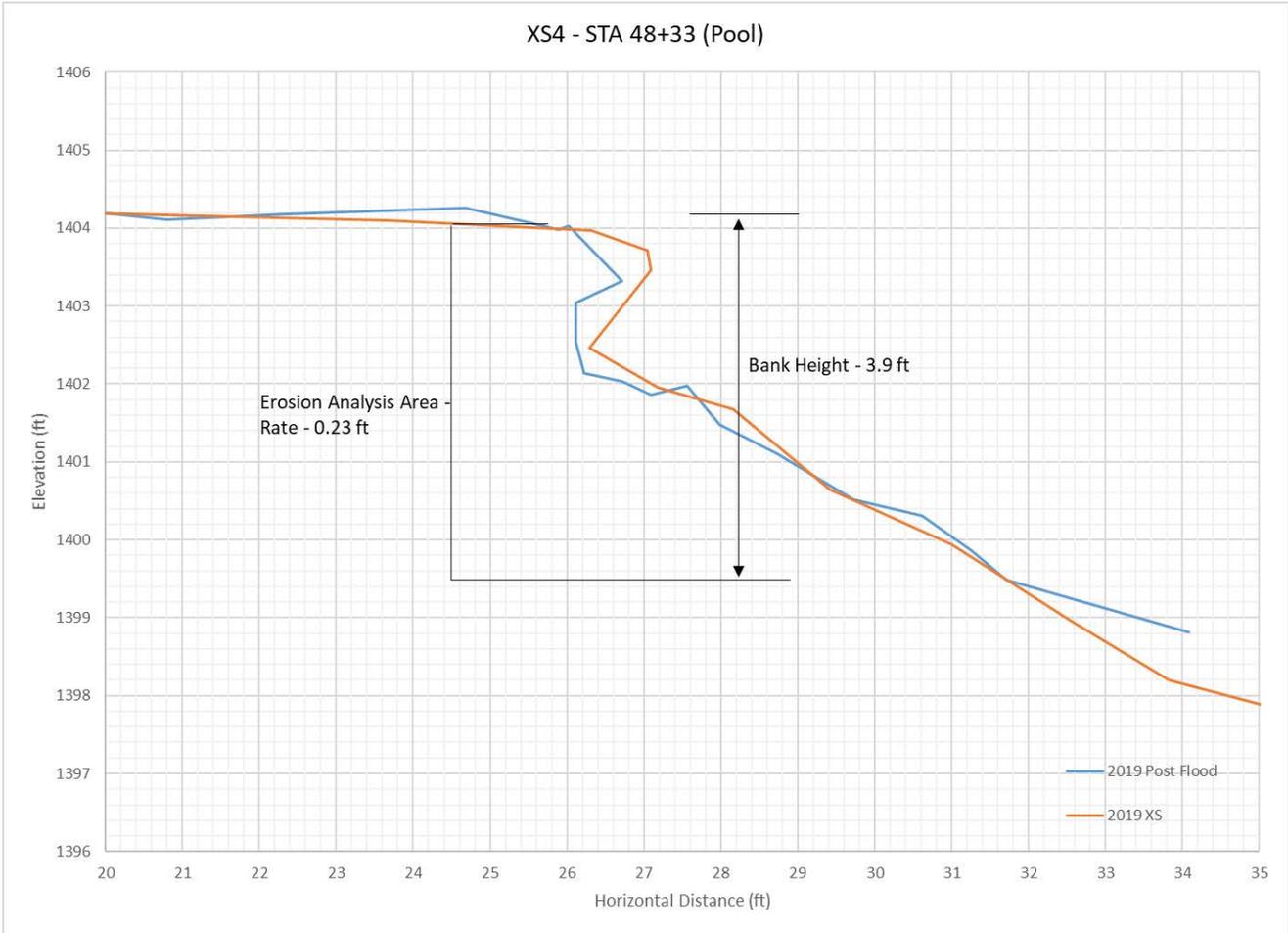
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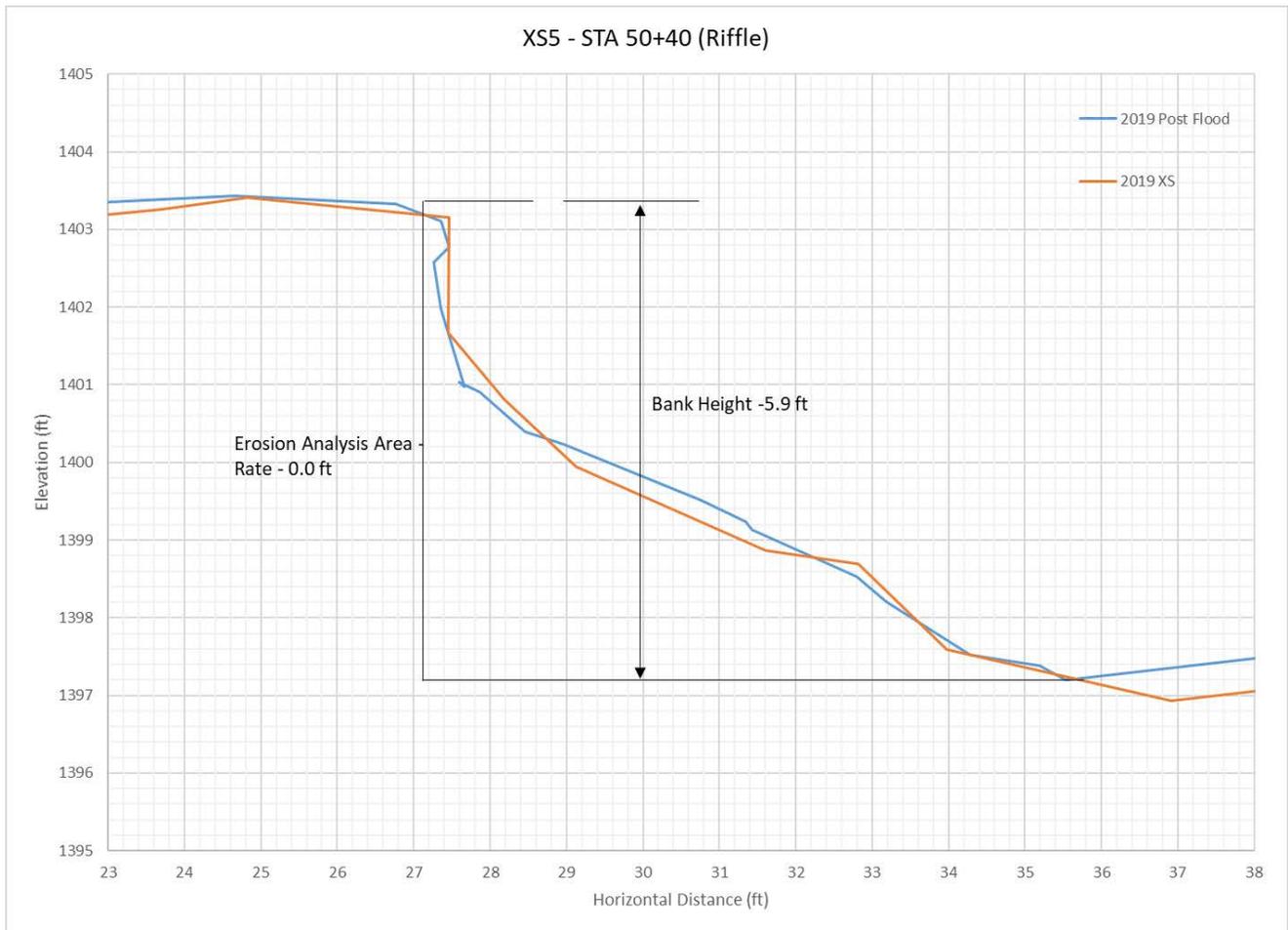
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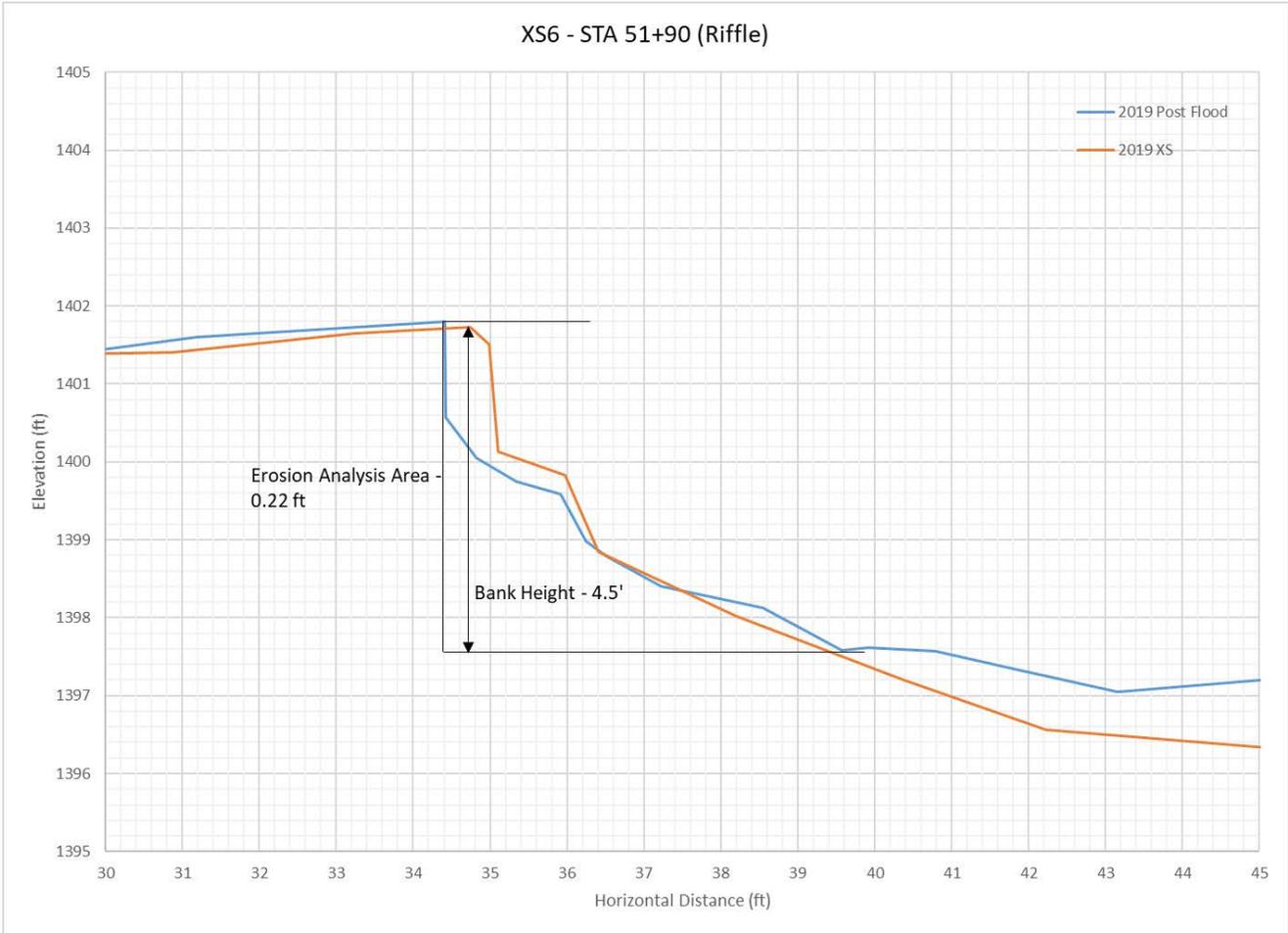
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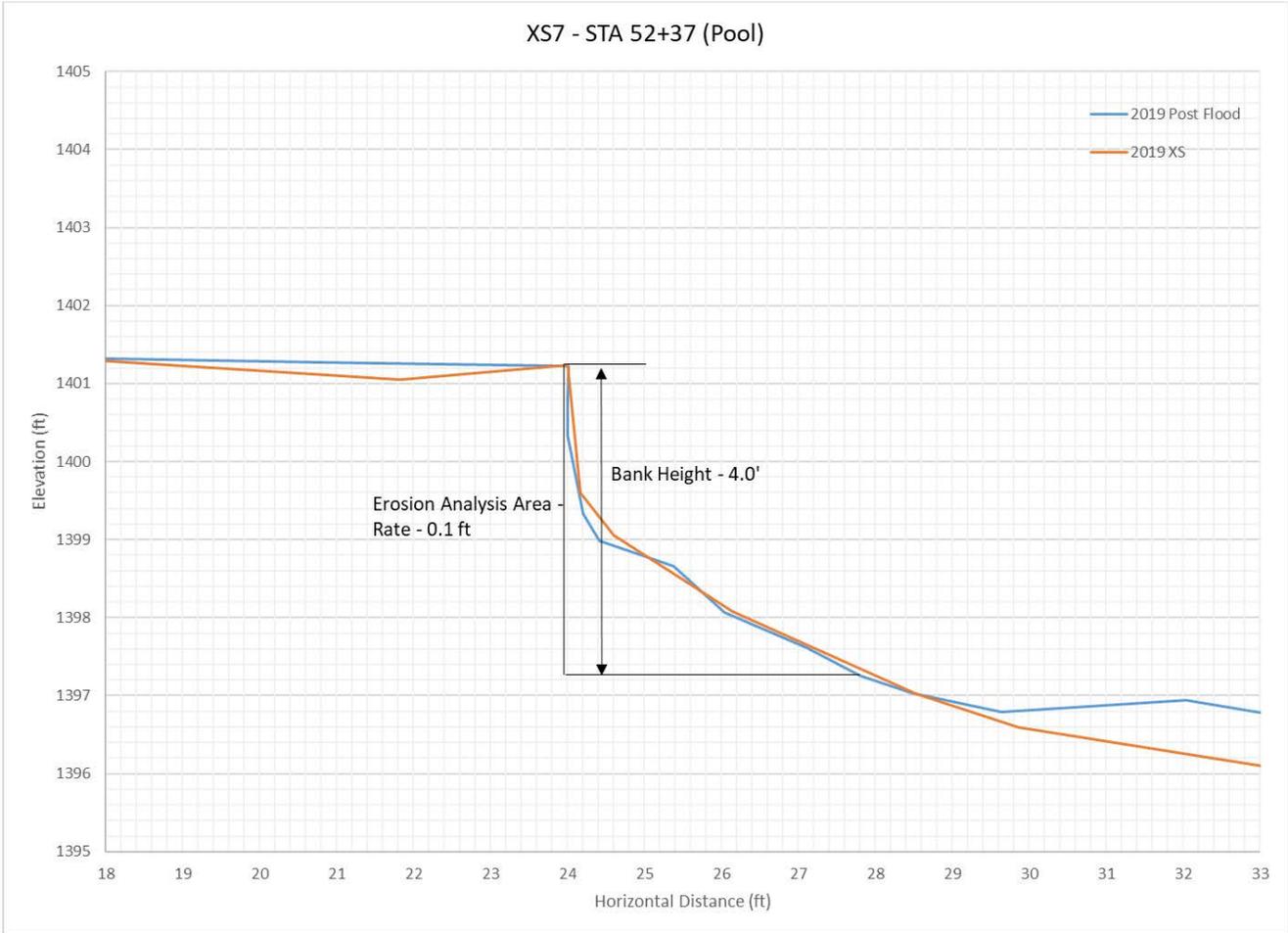
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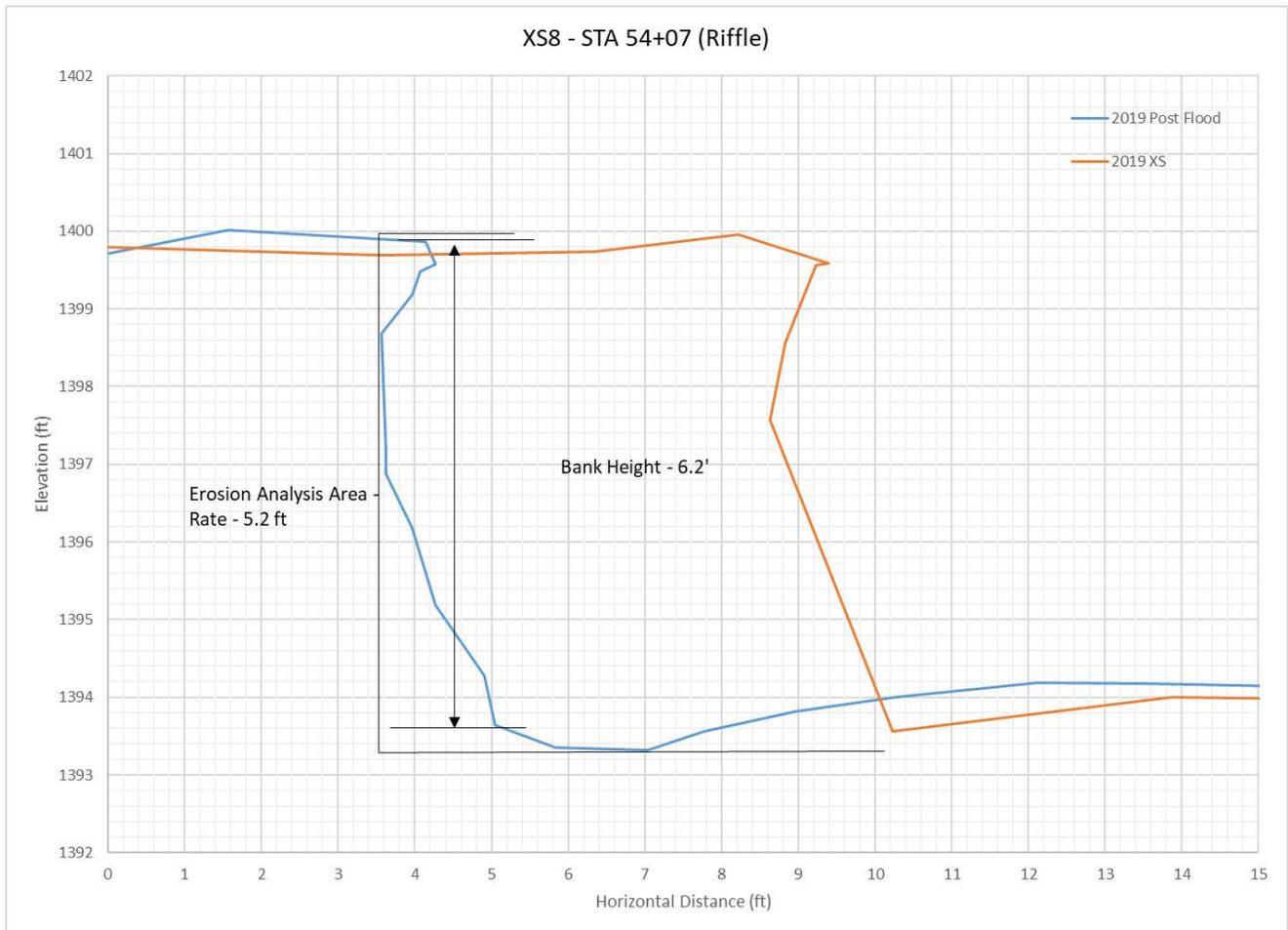
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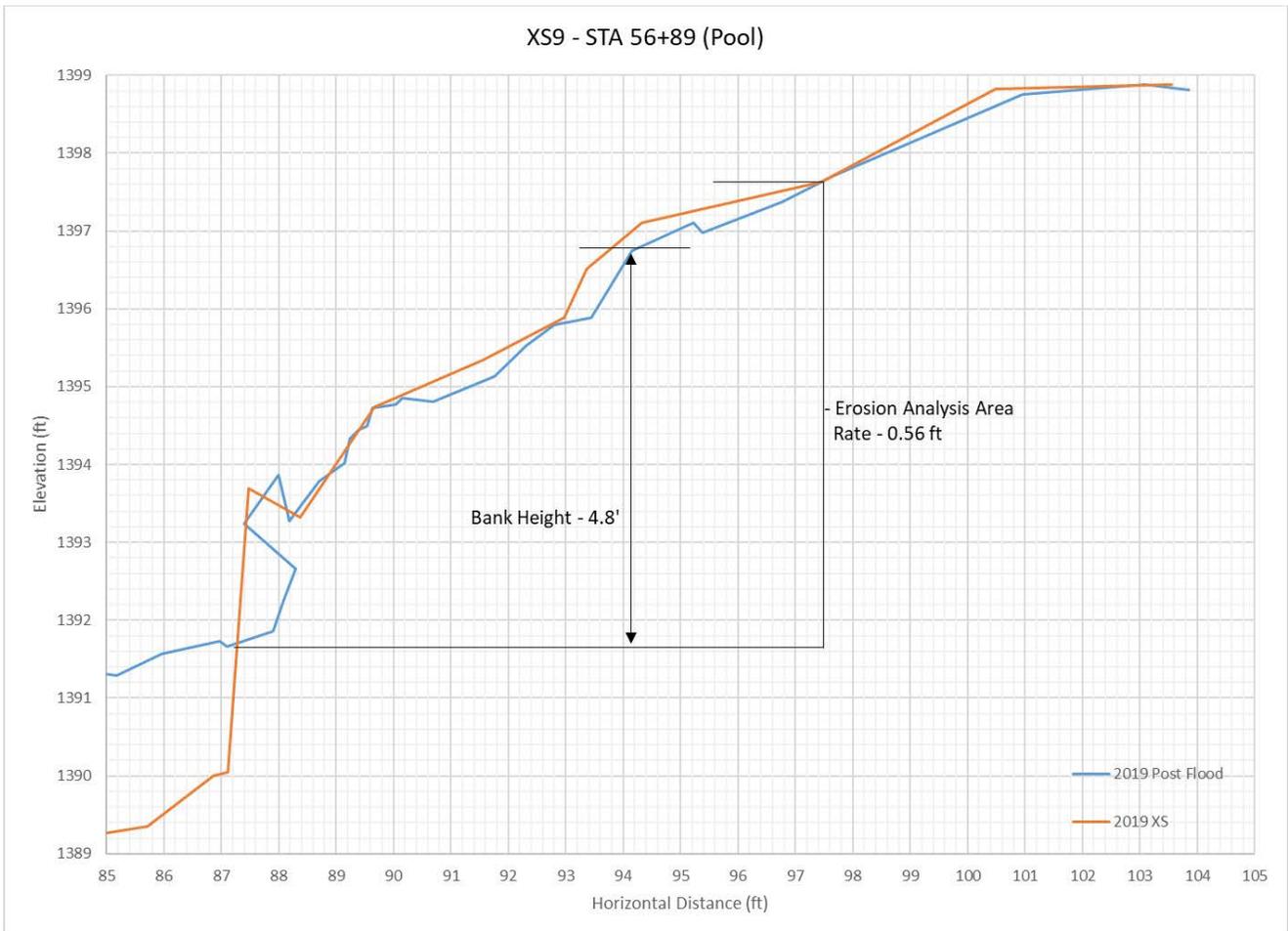
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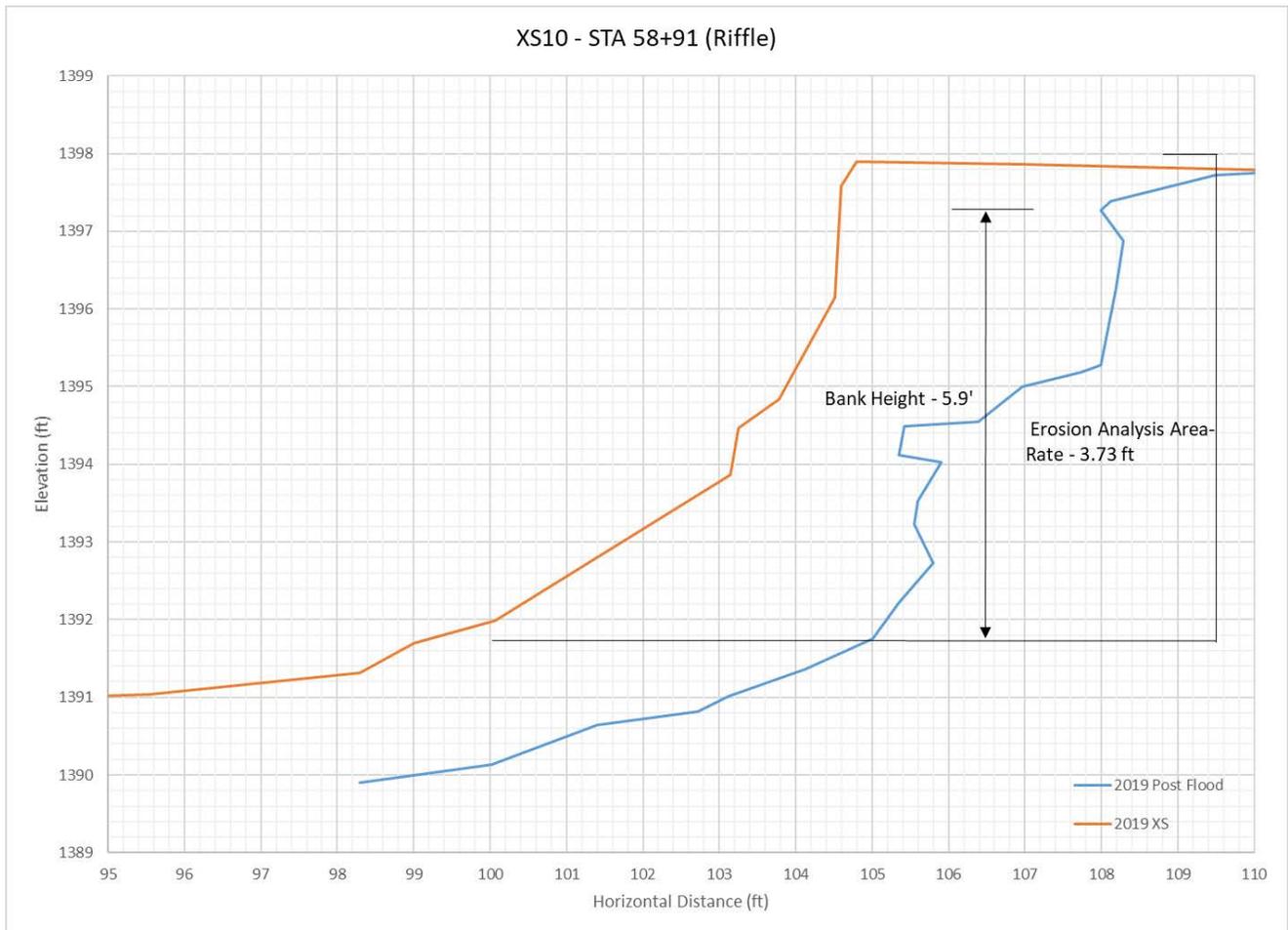
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Attachment 4. Post Flood Monitoring



West Fork Stream Restoration at Brentwood Mountain
Attachment 4. Post Flood Monitoring



West Fork Stream Restoration at Brentwood Mountain
Attachment 4. Post Flood Monitoring



West Fork Stream Restoration at Brentwood Mountain
Attachment 5: Streambank Material Sampling and Sediment and Nutrient Loading



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West Fork Stream Restoration at Brentwood Mountain
Attachment 5. Streambank Material Sampling and Nutrient Loading

Streambank materials were collected at various streambanks throughout the Brentwood Mountain restoration site to provide a generalized means of classifying eroding streambank material entering the West Fork White River (WFWR) from this site. Materials were collected utilizing one of two methodologies dependent on the texture of soil to be analyzed. Streambanks were measured with a GNSS RTK unit for subsequent years to allow for a comparison of the initial streambank profile and then the same profile following erosive action on the streambank to estimate the volume of material released into the WFWR. The area of lateral erosion is divided by the streambank height and then by the length of time between measurements to develop an erosion rate. This will help provide a baseline for sediment and nutrient reduction comparison in the years following the restoration.

Material sampling was conducted in one of two ways depending on the streambank soil composition. The first method (Figure 1) involved a 2 in x 6 in soil core sampler with a slide hammer for soil types that were “fine”, where the streambank consisted of non-gravel materials. For soil types that were “coarse”, the streambank material was composed of a matrix of fine material with gravel and/or cobble intermixed. This was conducted using methods developed by Brye, et al. (2004) that included excavating and collecting soil material with a small shovel or spoon to form a void in the face of the streambank (Figure 2), filling the void with an expanding polyurethane foam to capture the in situ volume of excavated material, excavating the foam the following day once it had completely set, and finally removing all excess foam material.

The soil samples were then processed and sent to the Agricultural Diagnostics Laboratory at the University of Arkansas. Laboratory results determined the bulk density, particle size distribution, Total Nitrogen concentration, and Total Phosphorous concentration for each soil sample. The bulk density and chemical analyses provided generalized data to estimate sediment mass and nutrient loading along the restoration reach. Several sediment and nutrient loading results are provided on the following page. Table 1 outlines the loading estimate for the yearlong monitoring for each cross section within the project area and a total. Table 2 outlines the sediment and nutrient loading for the post flood monitoring. Table 3 displays the loading estimate for the upstream site where additional soil data was collected in comparison to the downstream restoration area.



Figure 1. Utilizing a Shelby tube sampler to excavate fine streambank material



Figure 2. Excavating streambank material to from a void and storing material to be sent to laboratory for analysis

Brye, K.R., T.L. Morris, D.M. Miller, S.J. Formica, and M.A. Van Eps. 2004. Estimating bulk density in vertically exposed stoney alluvium using a modified excavation method. *J. Environ. Qual.* 33:1937–1942

West Fork Stream Restoration at Brentwood Mountain
Attachment 5. Streambank Material Sampling and Nutrient Loading

Table 1. 2018 - 2019 Sediment and Nutrient Loading Analysis at Project Site

2018 to 2019 Sediment and Nutrient Loading (Project Site)				
XS I.D	Measured Erosion Rate ft/yr	Sediment Load ton/yr	T. Phosphorous lb/yr	T. Nitrogen lb/yr
1	0.4	35	21.5	30.1
2	1.0	77	41.2	55.4
3	0.7	59	27.0	34.6
4	0.0	1	0.2	0.3
5	0.1	3	1.4	1.9
6	0.0	0	0.0	0.0
7	0.7	21	9.5	12.2
8	8.9	881	587.1	834.8
	Totals	1078	687.9	969.2

Table 2. Post-flood Sediment and Nutrient Loading Analysis at Project Site

2019 to Post Flood Downstream Area Sediment and Nutrient Loading (Project Site)				
XS I.D	Measured Erosion Rate ft/yr	Sediment Load ton/yr	T. Phosphorous lb/yr	T. Nitrogen lb/yr
1	1.4	148	91.5	128.0
2	21.5	1914	1017.3	1368.9
3	34.6	1137	516.6	661.9
4	0.2	5	2.1	2.7
5	0.0	0	0.0	0.0
6	0.2	5	2.3	3.0
7	0.1	2	0.9	1.2
8	10.2	1122	747.5	1063.0
	Totals	4333	2378.3	3228.5

Table 3. Sediment and Nutrient Loading Data Compiled

	Sediment Load ton/yr	T. Phosphorous lb/yr	T. Nitrogen lb/yr
Upstream Site Year-long XS Analysis	165	119	108
Project Site Year-long XS Analysis	1078	688	969
Project Site Post Flood XS Evaluation	4333	2378	3229
Total - Upstream & Project Site Year-long XS Erosion	1243	807	1077

West Fork Stream Restoration at Brentwood Mountain
Attachment 5. Streambank Material Sampling and Nutrient Loading

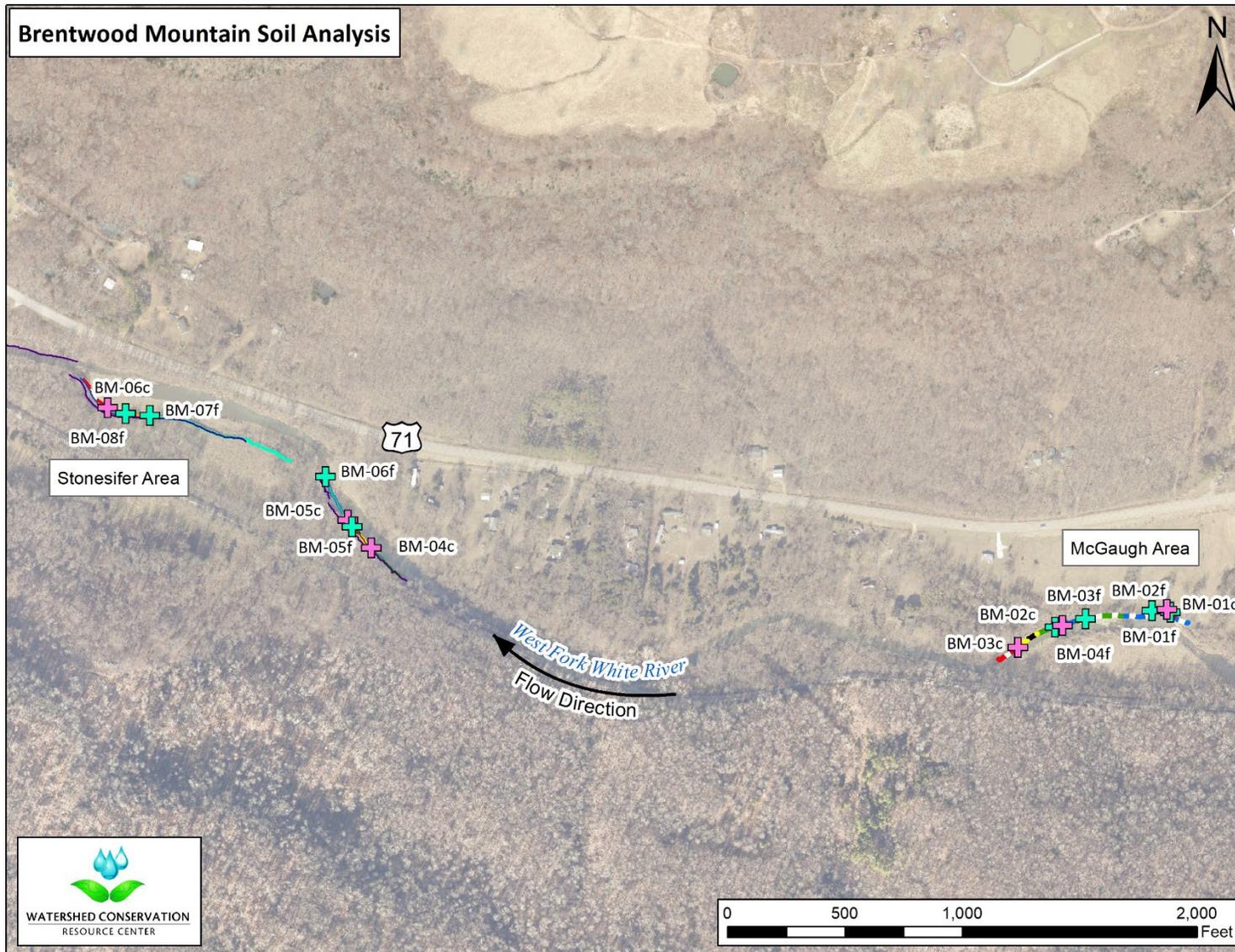


Figure 3. Brentwood Mountain soil sample locations at the upstream site and at the restoration site

West Fork Stream Restoration at Brentwood Mountain
Attachment 5. Streambank Material Sampling and Nutrient Loading



BM-01f
Sandy Loam
Bulk Density –
99.4 lb/ft³
TP – 0.74 lb/ton
TN – 0.80 lb/ton



BM-01c
Sandy Loam
with Cobble
Bulk Density –
119.3 lb/ft³
TP – 0.45 lb/ton
TN – 0.42 lb/ton

West Fork Stream Restoration at Brentwood Mountain
Attachment 5. Streambank Material Sampling and Nutrient Loading



BM-02f
Sandy Loam
Bulk Density –
95.2 lb/ft³
TP – 0.73 lb/ton
TN – 0.95 lb/ton



BM-03f
Sandy Loam
94.3 lb/ft³
TP – 0.84 lb/ton
TN – 1.16 lb/ton

West Fork Stream Restoration at Brentwood Mountain
Attachment 5. Streambank Material Sampling and Nutrient Loading



BM-02c

Sandy Loam
with Cobble

127.9 lb/ft³

TP – 0.27 lb/ton

TN - -0.32 lb/ton



BM-04f

Loamy Fine
Sand

88.2 lb/ft³

TP – 0.78 lb/ton

TN – 0.59 lb/ton

West Fork Stream Restoration at Brentwood Mountain
Attachment 5. Streambank Material Sampling and Nutrient Loading



BM-03c
Sandy Loam
with Cobble
Bulk Density –
127.3 lb/ft³
TP – 0.27 lb/ton
TN – 0.19 lb/ton



BM-04c
Sandy Loam
with Cobble
Bulk Density –
127.0 lb/ft³
TP – 0.21 lb/ton
TN – 0.34 lb/ton

West Fork Stream Restoration at Brentwood Mountain
Attachment 5. Streambank Material Sampling and Nutrient Loading



BM-05f
Sandy Loam
Bulk Density –
85.3 lb/ft³
TP – 0.83 lb/ton
TN – 1.37 lb/ton



BM-05c
Sandy Loam
with Gravel
Bulk Density –
94.1 lb/ft³
TP – 0.68 lb/ton
TN – 0.93 lb/ton

West Fork Stream Restoration at Brentwood Mountain
Attachment 5. Streambank Material Sampling and Nutrient Loading



BM-06f
Sandy Loam
Bulk Density –
85.8 lb/ft³
TP – 0.76 lb/ton
TN – 1.23 lb/ton



BM-07f
Sandy Loam
Bulk Density –
85.0 lb/ft³
TP – 0.71 lb/ton
TN – 0.92 lb/ton

West Fork Stream Restoration at Brentwood Mountain
Attachment 5. Streambank Material Sampling and Nutrient Loading



BM-08f
Sandy Loam
89.2 lb/ft³
TP – 0.79 lb/ton
TN – 2.00 lb/ton



BM-06c
Sandy Loam
with Cobble
Bulk Density –
128.4 lb/ft³
TP -0.24 lb/ton
TN – 0.25 lb/ton

West Fork Restoration at Brentwood Mountain
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West Fork Stream Restoration at Brentwood Mountain
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Reference reach data is the basis for any stream restoration design that utilizes the Natural Channel Design approach (NCD). A database of reference reach variables allows the designer to develop a design that is consistent with the geo-physiography of the region where the project is located. The WCRC has developed a compendium of reference reach data for the West Fork White River restoration project located near Brentwood, Arkansas. The data comes from a variety of sources including previously collected data as well as analysis utilizing remote sensing. A number of analyses were conducted to collect additional reference data for streams interacting with and in a close relative proximity to the West Fork White River (WFWR) so that similar physiographic regions were used for the analysis.

Background

The WFWR at the Brentwood Mountain Restoration site is located in the Boston Mountains Physiographic province with a drainage area of 31.3 square miles. Its watershed has 0.6% imperviousness and 22.1% pasture land according to the 2011 National Land Cover Database. The geology is that of the Bloyd Shale, and Prairie Grove Member of the Hale Formation. Soils present include the Enders-Allegheny complex and Cleora fine sandy loam. The WFWR is a B4c stream type at this location and is exhibiting extreme erosion and loss of land. The channel has widened significantly over peak storm events during monitoring, impacts of which include: repairs made to Hwy 71 on river right due to flood damage, measured rates of yearly erosion of 9 ft/yr downstream on river left, and up to 35 ft of streambank lost in a peak storm releasing an estimated 3854 tons of sediment from the site, all of which indicate the severity of channel migration and sediment pollution at this location.

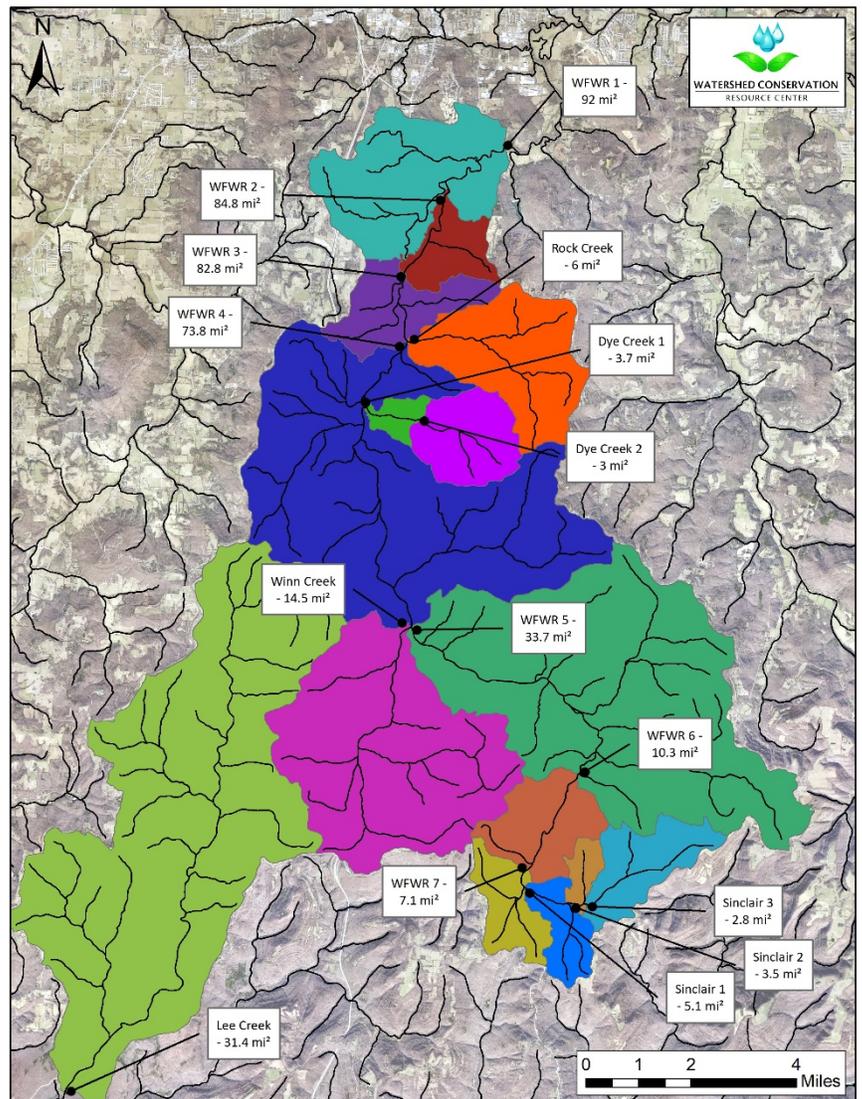


Figure 1. Subwatersheds delineated for analysis in vicinity to the Brentwood Mountain Restoration.

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Included in the tables are all measured parameters and then dimensionless parameters dependent on division by the bankfull width of the channel the measured dimensions were in vicinity to. Expected variables from regional curve predictions are presented here for comparison and the impervious percentage of each subwatershed is included for comparison as well. Lee Creek presents the most similar, most stable point of reference to the Brentwood Mountain Restoration site conducted for this analysis. The drainage area is 31.4 mi² with 0.16% imperviousness and 8.5% pasture land.

Various data collected on site and from previous surveys will inform the restoration of the WFWR at Brentwood Mountain. Presented in Table 3 is morphological data that can be applied to the restoration of this channel, which includes: data collected at the Brentwood Mountain site, previously collected data from "Site 6" downstream of the project and upstream of "Tilly willy" Bridge, previously collected data prior to restoration and proposed restoration variables for the "airport" site or site 13, previously collected data for the proposed design and existing design variables for restoration site 24, Rosgen reference design variables, and data previously collected from historical imagery.

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Table 1. Pattern Analysis Values Measured as Reference to the Brentwood Mountain Site along with Predicted Values Obtained from Regional Curves

Dye Creek 1								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
27.4	163.0	6.0	149.0	5.5	258.0	9.5	3.7	26.4	28.7	1.1	131.8	
29.8	160.0	5.9	220.0	8.1	387.0	14.3	Impervious Area (2011 NLCD)					
24.9	201.0	7.4			371.0							
26.5	232.0	8.5			417.0		1.13					
	160.0	5.9			288.0							
	122.0	4.5										
	123.0	4.5										
	161.0	5.9										
	151.0	5.6										
	147.0	5.4										
Average	27.2	162.0	6.0	184.5	6.8	344.2						
Max	29.8	232.0	8.5	220.0	8.1	417.0						
Min	24.9	122.0	4.5	149.0	5.5	258.0						
Dye Creek 2								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
22.3	175.0	7.3			380.0	15.8	3.0	21.5	26.2	1.0	107.5	
25.8							Impervious Area (2011 NLCD)					
Average	24.1	175.0	7.3		380.0	15.8						0.35%
Max	25.8	175.0	7.3		380.0	15.8						
Min	22.3	175.0	7.3		380.0	15.8						
Winn Creek								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
54.4	295.0	5.3	135.0	2.4	943.0	16.8	14.5	97.7	51.1	2.1	497.6	
57.7	295.0	5.3	210.0	3.7			Impervious Area (2011 NLCD)					
	295.0	5.3	264.0	4.7								1.20%
Average	56.1	338.5	6.0	205.5	3.7	943.0						
Max	57.7	469.0	8.4	264.0	4.7	943.0						
Min	54.4	295.0	5.3	135.0	2.4	943.0						
Sinclair 1								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
35.5	220.0	6.6	137.0	4.1	603.0	18.1	5.1	35.9	32.8	1.3	180.1	
31.0	187.0	5.6	142.0	4.3	515.0	15.5	Impervious Area (2011 NLCD)					
	250.0	7.5	119.0	3.6	504.0	15.2						0.24%
Average	33.3	228.8	6.9	132.7	4.0	479.8						
Max	35.5	258.0	7.8	142.0	4.3	603.0						
Min	31.0	187.0	5.6	119.0	3.6	327.0						
Sinclair 2								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
30.1	202.0	6.9	77.0	2.6	492.0	16.7	3.5	25.0	28.0	1.1	124.9	
28.8	202.0	6.9			472.0	16.0	Impervious Area (2011 NLCD)					
	218.0	7.4			316.0	10.7						0.21%
Average	29.5	222.0	7.5	77.0	2.6	426.7						
Max	30.1	244.0	8.3	77.0	2.6	492.0						
Min	28.8	202.0	6.9	77.0	2.6	316.0						
Sinclair 3								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
23.1	174.0	7.9			267.0	12.1	2.8	20.2	25.5	1.0	100.5	
21.1					304.0	13.2	Impervious Area (2011 NLCD)					
Average	22.1	174.0	7.9		302.0	13.7						0.21%
Max	23.1	174.0	7.9		335.0	15.9						
Min	21.1	174.0	7.9		267.0	12.1						

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Table 1. Continued...

Rock Creek								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
	38.3	272.0	7.1	155.0	4.0	456.0	6.0	41.9	35.2	1.4	210.9	
		255.0	6.7	169.0	4.4	509.0	Impervious Area (2011 NLCD)					
		204.0	5.3	98.0	2.6	562.0						
		215.0	5.6			512.0		n/a				
		168.0	4.4									
Average	38.3	222.8	5.8	140.7	3.7	509.8						
Max	38.3	272.0	7.1	169.0	4.4	562.0						
Min	38.3	168.0	4.4	98.0	2.6	456.0						
Lee Creek								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
	67.9	613.0	9.3	317.0	4.8	1142.0	31.4	205.0	70.9	3.0	1054.8	
	67.6	409.0	6.2	259.0	3.9	1640.0	Impervious Area (2011 NLCD)					
	63.3	697.0	10.5	378.0	5.7	2203.0						
		692.0	10.4	178.0	2.7	1213.0		0.16%				
		664.0	10.0	222.0	3.4	1452.0						
		699.0	10.5	341.0	5.1	1784.0						
		660.0	10.0	607.0	9.2	1405.0						
		511.0	7.7	519.0	7.8							
		649.0	9.8	270.0	4.1							
		440.0	6.6	503.0	7.6							
		699.0	10.5	410.0	6.2							
		622.0	9.4	364.0	5.5							
		425.0	6.4									
		490.0	7.4									
		425.0	6.4									
		425.0	6.4									
		439.0	6.6									
Average	66.3	562.3	8.5	364.0	5.5	1548.4						
Max	67.9	699.0	10.5	607.0	9.2	2203.0						
Min	63.3	409.0	6.2	178.0	2.7	1142.0						
WFWR 7								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
	36.2	293.0	8.1		477.0	13.2	7.08	49.109	37.732	1.492	247.790	
					767.0	21.2	Impervious Area (2011 NLCD)					
Average	36.2	293.0	8.1		622.0	17.2		0.93%				
Max	36.2	293.0	8.1		767.0	21.2						
Min	36.2	293.0	8.1		477.0	13.2						
WFWR 6								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
	46.5	170.0	3.8	246.0	5.5	717.0	10.3	70.4	44.2	1.8	356.8	
	42.5	223.0	5.0	178.0	4.0	526.0	Impervious Area (2011 NLCD)					
				266.0	6.0			0.85%				
				181.0	4.1							
				114.0	2.6							
Average	44.5	196.5	4.4	197.0	4.4	621.5						
Max	46.5	223.0	5.0	266.0	6.0	717.0						
Min	42.5	170.0	3.8	114.0	2.6	526.0						
WFWR 5								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
	46.5	247.0	5.3	310.0	6.7	726.0	33.7	219.4	73.1	3.1	1129.9	
		230.0	4.9	304.0	6.5	926.0	Impervious Area (2011 NLCD)					
				257.0	5.5	902.0		0.59%				
				224.0	4.8							
Average	46.5	238.5	5.1	273.8	5.9	851.3						
Max	46.5	247.0	5.3	310.0	6.7	926.0						
Min	46.5	230.0	4.9	224.0	4.8	726.0						

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Table 1. Continued...

Brentwood Mountain								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
	110.6	431.0	5.3	357.0	4.4	1380.3	31.3	204.4	70.8	3.0	1051.6	
		408.0	5.0	304.0	3.7	1456.0	Impervious Area (2011 NLCD)	0.60%				
		408.0	5.0	310.0	3.8	1632.0						
		408.0	5.0									
		383.0	4.7									
		383.0	4.7									
Average	81.9	383.0	4.9	323.7	4.0	1489.4						
Max	91.5	383.0	5.3	357.0	4.4	1632.0						
Min	81.9	404.0	4.7	304.0	3.7	1380.3						
WFWR 4								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
	110.6	611.0	5.5	1105.0	10.0	2167.0	73.8	465.3	101.8	4.4	2421.6	
		708.0	6.4				Impervious Area (2011 NLCD)	1.15%				
		636.0	5.8									
Average	110.6	651.7	5.9	1105.0	10.0	2167.0						
Max	110.6	708.0	6.4	1105.0	10.0	2167.0						
Min	110.6	611.0	5.5	1105.0	10.0	2167.0						
WFWR 2/3								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
	97.3	646.0	6.1	622.0	5.9	1990.0	84.8	531.7	108.0	4.7	2772.0	
		604.0	5.7				Impervious Area (2011 NLCD)	1.30%				
		610.0	5.8									
		385.0	3.7									
		670.0	6.4									
		482.0	4.6									
Average	105.1	566.2	5.4	622.0	5.9	1990.0						
Max	112.2	670.0	6.4	622.0	5.9	1990.0						
Min	97.3	385.0	3.7	622.0	5.9	1990.0						
WFWR 1								Regional Curve Data				
Bankfull Width (Wbkf)	Radius of Curvature (Rc)	Rc / Average Wbkf	Beltwidth	Beltwidth / Bankfull Width	Wavelength	Wavelength / Bankfull Width	Drainage Area	Abkf	Wbkf	Dbkf	Discharge	
ft	ft	ft/ft	ft	ft/ft	ft	ft/ft	mi ²	ft ²	ft	ft	ft ³ /s	
	107.5	514.0	4.9	598.0	5.7	1303.0	92.0	574.9	111.8	4.9	3000.6	
		405.0	3.8	470.0	4.5	1181.0	Impervious Area (2011 NLCD)	1.54%				
		573.0	5.4	426.0	4.0	1072.0						
		717.0	6.8	377.0	3.6	967.0						
				347.0	3.3	1208.0						
				725.0	6.9	1244.0						
Average	105.5	552.3	5.2	490.5	4.6	1162.5						
Max	107.5	717.0	6.8	725.0	6.9	1303.0						
Min	103.5	405.0	3.8	347.0	3.3	967.0						

Table 2. Overall Average Values for the Brentwood Mountain Reference Pattern Analysis Data

	Overall Rc / Average Wbkf	Beltwidth / Average Wbkf	Wavelength / Average Wbkf
	ft/ft	ft/ft	ft/ft
Average	6.5	4.9	16.1
Max	10.5	10.0	33.2
Min	3.7	2.4	9.2

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Table 3. Morphological Variables for Brentwood Mountain and Others

Variable	Existing Conditions Brentwood Mountain (2019)	Existing Conditions Brentwood Mountain (2003)	Existing Conditions (Site 24)	Proposed Design (Site 24)	Existing Site 13	Proposed Reach Site 13	Rosgen Reference (Average)	Historical Map
1. Stream Type	B4c		C3-4	C4	C 4/1	C 4/1	C 4	
2. Drainage Area	31.1	31.1	18.2	18.2	84.5	84.5		
3. Mean Riffle Depth, ft. (d_{bkt})	Mean: 2.8 Range: 1.8 - 5.2	2.8	2.3	2.1	Mean: 4.9 Range: 3.4 - 5.8	4.8		
4. Riffle Width (W_{bkt})	Mean: 90.1 Range: 81.9 - 109.2	54.2	61	65	Mean: 120 Range: 92 - 180	110		
5. Width/Depth Ratio (W_{bkt}/d_{bkt})	Mean: 42.2 Range: 17.9 - 98.9	14.3	26.4	31	Mean: 27 Range: 16 - 53	22.9	18 - 35 (26)	
6. Riffle Cross-Sectional Area, ft ² (A_{bkt})	Mean: 246.5 Range: 214.1 - 246.5	206	141	135	Mean: 558 Range: 540 - 608	530		
7. Max Riffle Depth (D_{mbkt})	Mean: 4.1 Range: 1.8 - 5.2	5.2	3.7	3.5	Mean: 7.0 Range: 6.1 - 7.5	6.5		
8. Max Riffle Depth/Mean Riffle Depth (D_{mbkt}/d_{bkt})	Mean: 1.4 Range: 0.8 - 1.8	1.4	1.6	1.7	Mean: 1.5 Range: 1.3 - 1.8	1.35	1.3 - 1.6 (1.45)	
9. Mean Pool Depth, ft. (d_{bktp})	Mean: 3.2 Range: 2.7 - 3.9	4.3	3.2 XS9	3.3	Mean: 6.0 Range: 5.3 - 6.8	5.6		
10. Mean Pool Depth/Mean Riffle Depth (d_{bktp}/d_{bkt})	Mean: 1.1 Range: 0.8 - 1.8	1.5	1.4	1.6	Mean: 1.2 Range: 1.1 - 1.4	1.2		
11. Pool Width, ft. (W_{bktp})	Mean: 81.2 Range: 69.7 - 95.4	55.3	72	65	Mean: 113 Range: 97 - 124	115		
12. Pool Width/Riffle Width (W_{bktp}/W_{bkt})	Mean: 0.9 Range: 0.6 - 1.2	1.0	1.3	1	Mean: 1.1 Range: 0.9 - 1.2	1.0	0.8 - 1.5 (1.3)	
13. Pool Cross-Sectional Area, ft ² (A_{bktp})	Mean: 254.1 Range: 231.1 - 272.1	238.3	256	212	Mean: 668 Range: 622 - 724	640		
14. Pool Area/Riffle Area (A_{bktp}/A_{bkt})	Mean: 1.0 Range: 0.8 - 1.3	1.2	1.8	1.6	Mean: 1.2 Range: 1.1 - 1.3	1.2		
15. Max Pool Depth, ft. (d_{mbktp})	Mean: 11.5 Range: 10.6 - 13.0	6.4	7.34	6.9	Mean: 11.5 Range: 10.6 - 13.0	Mean: 10.0 Range: 9.3 - 10.7		
16. Max Pool Depth/Mean Riffle Depth (d_{mbktp}/d_{bkt})	Mean: 2.3 Range: 2.2 - 2.6	2.3	3.2	3.3	Mean: 2.3 Range: 2.2 - 2.6	Mean: 2.1 Range: 1.9 - 2.2	2.5 - 3.5 (3.0)	
17. Low Bank Height (LBH)	...	...	...	...	...	...
18. Low Bank Height/Max Riffle Depth (LBH/ d_{mbkt})	...	...	...	...	...	...
19. Width of Floodprone Area, ft. (W_{fpa})	206.5 XS8 2018	80	359	300	2600	2000		
20. Entrenchment Ratio (W_{fpa}/W_{bkt})	1.67 XS8 2018	1.5	5.9	4.5	22	21		
21. Point Bar Slope	...	...	0.18	0.22	14%	14%		
22. Bankfull Mean Velocity, ft/s (U_{bkt})	Mean: 4.76 Range: 3.83- 5.67	6.2	4.6-4.9 4.9-5.3	5.4	5.3	5.5		

West Fork Stream Restoration at Brentwood Mountain
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Table 3. Continued...

Variable	Existing Conditions Brentwood Mountain (2019)	Existing Conditions (Site 24)	Proposed Design (Site 24)	Existing Site 13	Proposed Reach Site 13	Rosgen Reference (Average)	Historical Map
23. Bankfull Discharge, ft ³ /s (Q_{bkt})	Mean: 1129.8 Range: 805- 1129.8	644-687 697-741	725	2951	2937		
24. Meander Length, ft. (L_m)	Mean: 1489.4 Range: 1380.3- 1632.0	Mean:1092 Range: 870 - 1230	Mean: 773 Range: 641 - 936	Mean: 927 Range: 658 - 1233	Mean: 1326 Range: 1164 - 1568		Mean: 1,983 Range: 1,326 - 2,677
25. Meander Length Ratio (L_m/W_{bkt})	Mean: 18.2 Range: 16.9- 19.9	Mean: 18 Range: 14 - 20	Mean: 12.1 Range: 9.9 - 14.6	Mean: 10.0 Range: 7.1 - 13.4	Mean: 12.1 Range: 10.6 - 14.3	11.0 - 12.0	Mean: 19.3 Range: 12.9 - 26.0
26. Radius of Curvature, ft. (R_c)	Mean: 403.6 Range: 404.0- 431.0	Mean: 106 Range: 91 - 121	Mean: 277 Range: 258 - 300	Mean: 287 Range: 151 - 650	Mean: 451 Range: 317 - 625		Mean: 796 Range: 585 - 1,041
27. Ratio of Radius of Curvature to Bankfull Width (R_c/W_{bkt})	Mean: 4.9 Range: 4.7- 5.3	Mean: 1.7 Range: 1.5 - 2.0	Mean: 4.3 Range: 4.0 - 4.7	Mean: 3.1 Range: 1.6 to 7.0	Mean: 4.1 Range: 2.9 - 5.7	3.0 - 4.0	Mean: 7.7 Range: 5.7 - 10.1
28. Belt Width, ft. (W_{bit})	Mean: 4.0 Range: 3.7- 4.4	Mean: 495 Range: 298 - 644	Mean: 488 Range: 418 - 558	Mean: 504 Range: 386 - 604	Mean: 422 Range: 312 - 574		Mean: 653 Range: 339 - 979
29. Meander Width Ratio (W_{bit}/W_{bkt})	Mean: 4.0 Range: 3.7- 4.4	Mean: 8.1 Range: 4.9 - 10.6	Mean: 7.6 Range: 6.5 - 8.7	Mean: 5.5 Range: 4.2 - 6.5	Mean: 3.8 Range: 2.8 - 5.2		Mean: 6.5 Range: 3.4 - 9.8
30. Individual Pool Length, ft. (L_p)	Mean: 224 Range: 120 - 330	Mean: 258 Range: 98 - 464	Mean: 355 Range: 334 - 377	Mean: 554 Range: 197 - 1191	Mean: 512 Range: 402 - 646		
31. Pool Length/Riffle Width (L_p/W_{bkt})	Mean: 2.49 Range: 1.33 - 3.66	Mean: 4.2 Range: 1.6 - 7.6	Mean: 5.5 Range: 5.1 - 5.8	Mean: 6.0 Range: 2.1 - 12.9	Mean: 4.6 Range: 3.6 - 5.9		
32. Pool to Pool Spacing, ft. (P-P)	Mean: 650 Range: 209 - 966	Mean: 441 Range: 287 - 803	Mean: 640 Range: 597-689	Mean: 660 Range: 336 -1247	Mean: 748 Range: 544 - 973		
33. Ratio P-P Spacing to W_{bkt}	Mean: 7.21 Range: 2.32 - 10.72	Mean: 7.2 Range: 4.7 - 13.2	Mean: 9.8 Range: 9.1 - 10.6	Mean: 7.1 Range: 3.6 - 13.5	Mean: 6.8 Range: 4.9 - 8.8	4.0 - 7.0	
34. Stream Length (SL)	2900	1610	1772	5221	4246		
35. Valley Length (VL)	2684	1073	1366	3919	3740		
36. Valley Slope (VS)	0.00495			0.0029	0.0029		
37. Average Water Surface Slope	0.0045	0.005	0.0063	0.0023	0.0026		
38. Sinuosity (K)	1.1	1.5	1.3	1.33	1.14		
39. Riffle Slope (water surface facet slope) (S_{rif})	Mean: 0.015 Range: 0.004 - 0.03	Mean: 0.022 Range: 0.0076 - 0.044	0.0137	Mean: 0.019 Range: 0.007 - 0.048	Mean: 0.0060 Range: 0.0050 - 0.0065		
40. Ratio Riffle Slope to Average Water Surface Slope (S_{rif}/S)	Mean: 3.33 Range: 0.89 - 6.67	Mean: 4.3 Range: 1.4 - 8.4	2.1	Mean: 8.1 Range: 3.2 - 20.6	Mean: 1.9 Range: 1.6 - 2.1	1.5 - 3.5 (2.5)	
41. Run Slope (water surface facet slope) (S_{run})	Mean: 0.0039 Range: 0.0003 - 0.00568	Mean: 0.008 Range: .003-.013	0.0096	Mean: 0.0021 Range: 0.0003 - 0.004	0.0038		

West Fork Stream Restoration at Brentwood Mountain
Attachment 6. Reference Data

Table 3. Continued...

Variable	Existing Conditions Brentwood Mountain (2019)	Existing Conditions (Site 24)	Proposed Design (Site 24)	Existing Site 13	Proposed Reach Site 13	Rosgen Reference (Average)	Historical Map
42. Ratio Run Slope/Average Water Surface Slope (S_{run}/S)	Mean: 0.86 Range: 0.067- 1.26	Mean: 1.6 Range: .6-2.6	1.5	Mean: 0.9 Range: 0.14 - 1.7	1.5	1.0 - 2.0 (1.5)	
43. Pool Slope (water surface facet slope) (S_p)	Mean: 0.000185 Range: 0.00013- 0.00029	Mean: 0.0001 Range: 0.000 - 0.0004	0.0006	Mean: 0.0003 Range: 0.0001 - 0.001	0.00025		
44. Ratio of Pool Slope/Average Water Surface Slope (S_p/S)	Mean: 0.041 Range: 0.0289- 0.064	Mean: 0.03 Range: 0.0-0.07	0.1	Mean: 0.14 Range: 0.04 - 0.4	0.1	0.10 - 0.30 (0.2)	
45. Glide Slope (water surface facet slope) (S_g)	Mean: 0.00107 Range: 0.00087 - 0.00122	Mean: 0.0038 Range: 0.001 - 0.0064	0.0013	Mean: 0.001 Range: 0.001 - 0.002	0.00065		
46. Ratio Glide Slope/Average Water Surface Slope S_g/S)	Mean: 0.238 Range: 0.193 - 0.27	Mean: 0.7 Range: 0.2-1.2	0.2	Mean: 0.4 Range: 0.2 - 0.7	0.25	0.1 - 0.5 (0.3)	
47. Max Run Depth, ft. (d_{run})	7.91	Mean: 3.9 Range: 2.8-5.0	4.5	Mean: 6.8 Range: 5.7 - 8.1	6.9		
48. Ratio Max Run Depth/Bankfull Mean Depth (d_{run}/d_{bkf})	2.82	Mean: 1.7 Range: 1.2-2.2	2.1	Mean: 1.2 Range: 1.0 - 1.4	1.4	1.8 - 2.2 (2.0)	
49. Max Glide Depth (d_g)	4.44	Mean: 3.0 Range: 2.8-3.3	2.9	Mean: 5.6 Range: 3.6 - 7.4	5.9		
50. Ratio Max Glide Depth / Bankfull Mean Depth (d_g/d_{bkf})	1.58	Mean: 1.3 Range: 1.2-1.4	1.4	Mean: 0.9 Range: 0.6 - 1.3	1.2	0.9 - 1.4 (1.25)	
51. Particle Size Distribution of Channel Material (active channel)							
D16 (mm)	13.65	11	11	15	15		
D35 (mm)	28.87	25.2	25.2	35	35		
D50 (mm)	49.8	35.8	35.8	48	48		
D84 (mm)	128	75.1	75.1	107	107		
D95 (mm)	218	106	106	157	157		
52. Particle Size Distribution of Bar Material							
D16 (mm)		6.6 7.1	6.6 7.1	0	0		
D35 (mm)		24.3 24.7	24.3 24.7	4	4		
D50 (mm)		44.9 47.2	44.9 47.2	14	14		
D84 (mm)		123 119	123 119	58	58		
D95 (mm)		130 147	130 147	85	85		
Target Particle on Lower 1/3 or bar (mm)		130 160	130 160	110	110		

Attachment 7. West Fork White River: Brentwood Mountain Construction Report



Prepared by:

Watershed Conservation Resource Center

For:

Natural Resources Division, Arkansas Department of Agriculture

U.S. Environmental Protection Agency, Region 6

4/15/2022

Introduction

The Watershed Conservation Resource Center (WCRC) in partnership with the Beaver Watershed Alliance and Beaver Water District was selected by the Natural Resources Division of the Arkansas Department of Agriculture (NRD) and U.S. EPA Region 6 for grant funding to implement a stream restoration project on the West Fork White River (WFWR) in southern Washington County, AR. The site, referred to as the Brentwood Mountain Restoration site (Figure 1) has been a site with on-going severe streambank erosion. The WFWR is listed on the state of Arkansas' 303(d) list for impaired waterways for turbidity. The WFWR meets the White River and then forms Beaver Lake, the drinking water source for Northwest Arkansas. Protection of this water resource is critical to the function of both the ecosystem and people that rely on it. Improvements to water quality by creating channel stability, and enhancing terrestrial and aquatic habitat formed the justification for this ecosystem restoration project. This site prior to the restoration was undergoing severe channel instability. Some of the observed instability is likely due to floodplain modifications downstream with the construction of a bridge crossing in 2004 that did not adequately convey flows through the floodplain of the WFWR. The loss of stream power created by the floodplain restriction resulted in mid-channel bar formation and the initiation of a downstream meander migration along the left descending river bank. At the upstream extent of the project site, lateral meander migration was causing significant streambank erosion along the left descending bank as well. This instability in this portion of the project is likely the result of a channel construction between the bluff and riparian vegetation that has grown in the channel.

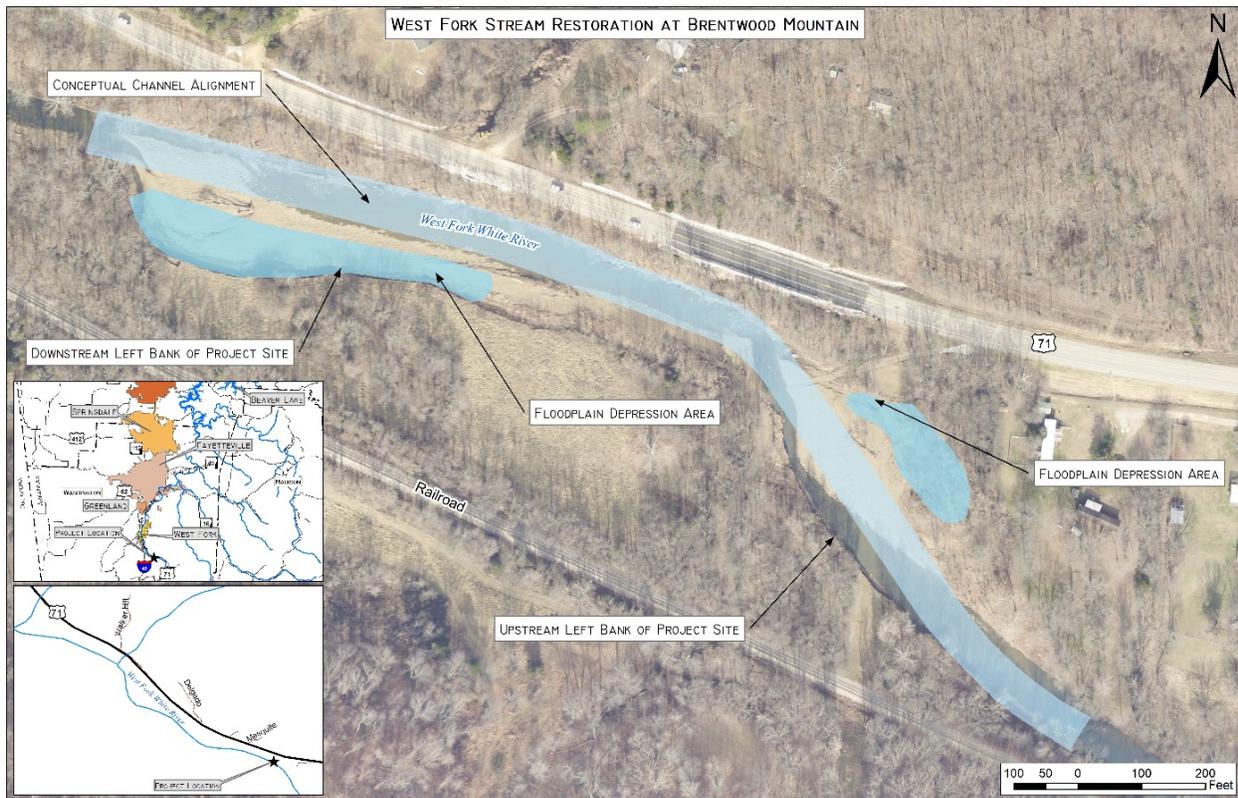


Figure 1. Brentwood Mountain site undergoing erosion and channel instability prior to restoration

Implementation and Results

The design approach taken to the Brentwood Mountain restoration included analysis of channel pattern and alignment with surveyed records of the stable channel on site and the departure from those conditions (Figure 2) spanning 20 years of survey data and evaluation of aerial photography back to 1942. Boundary conditions that affected the project design included U.S. Highway 71 with a bluff and rock outcrop, the railroad on river left, property owner participation, providing and protecting a stream crossing, and reducing the amount of construction and fill material input to the project site.



Figure 2. Site instability, the left image shows the over-widened channel downstream with a tree that was recently washed into the area and the right image shows the aggrading mid channel point bar

Natural Channel Design was utilized as the approach for the initial basis of design. Reference conditions were documented in 2002 by the Arkansas Department of Environmental Quality as part of a watershed assessment. This data was used a part of the reference reach variable database. Other areas of the watershed were evaluated for reference reach variables that were used to inform the design parameters needed for a stable channel. Structural elements were prescribed in the final design to maintain a stable, self-maintaining channel and a more resilient, diverse terrestrial habitat adjacent to the channel. An overview of the restoration planview and profile is shown in Figures 4 and 5. A new channel pattern was established, requiring excavation and fill in some areas to create the design form shown. A complete set of design plans for this restoration project are available in Attachment 1.

The upstream portion of the restoration reach begins at the downstream end of a pool and stream meander. The pool was excavated to provide additional deep-water habitat and to improve the glide transition from the pool to the first riffle head. A stacked rock revetment at STA 2+40 through 2+80 ties into the existing bank and continues along the design meander radius for forty feet. The rock revetment then transitions to a combination of toe wood and stacked rock revetment. Toewood logs (Figure 3) are placed perpendicular to stream action to provide a stable medium for the riparian bench and resist high shear stress. Toewood logs are placed on footer logs that are parallel to stream flow and are excavated to rest on bedrock. The meander radius continues for approximately 100 feet to a constructed channel glide structure put in place at STA 3+80 to redirect flow and lateral channel meander migration away from channel left to channel right. A riffle forms below this

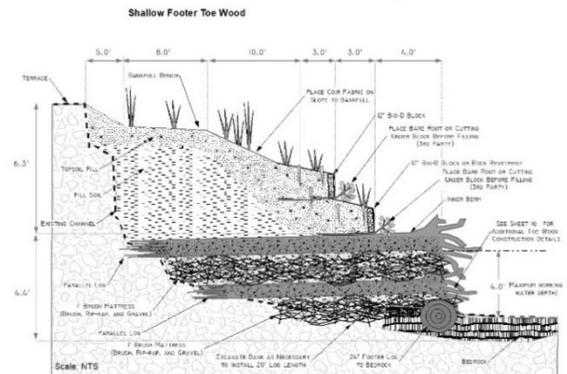


Figure 3. Toewood Design profile used to stabilize the impaired riparian bench

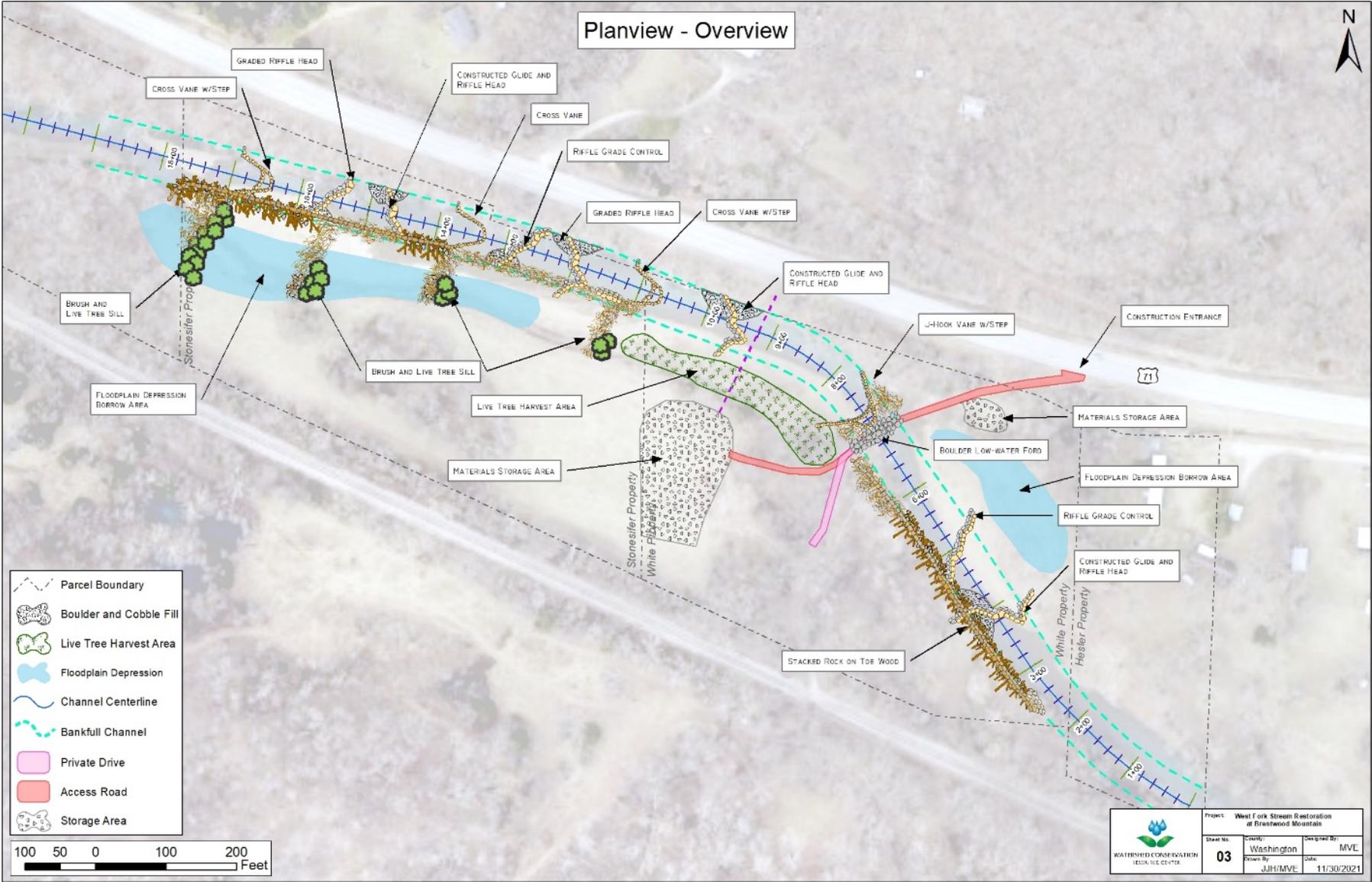


Figure 4. Planview of the restoration design at Brentwood Mountain

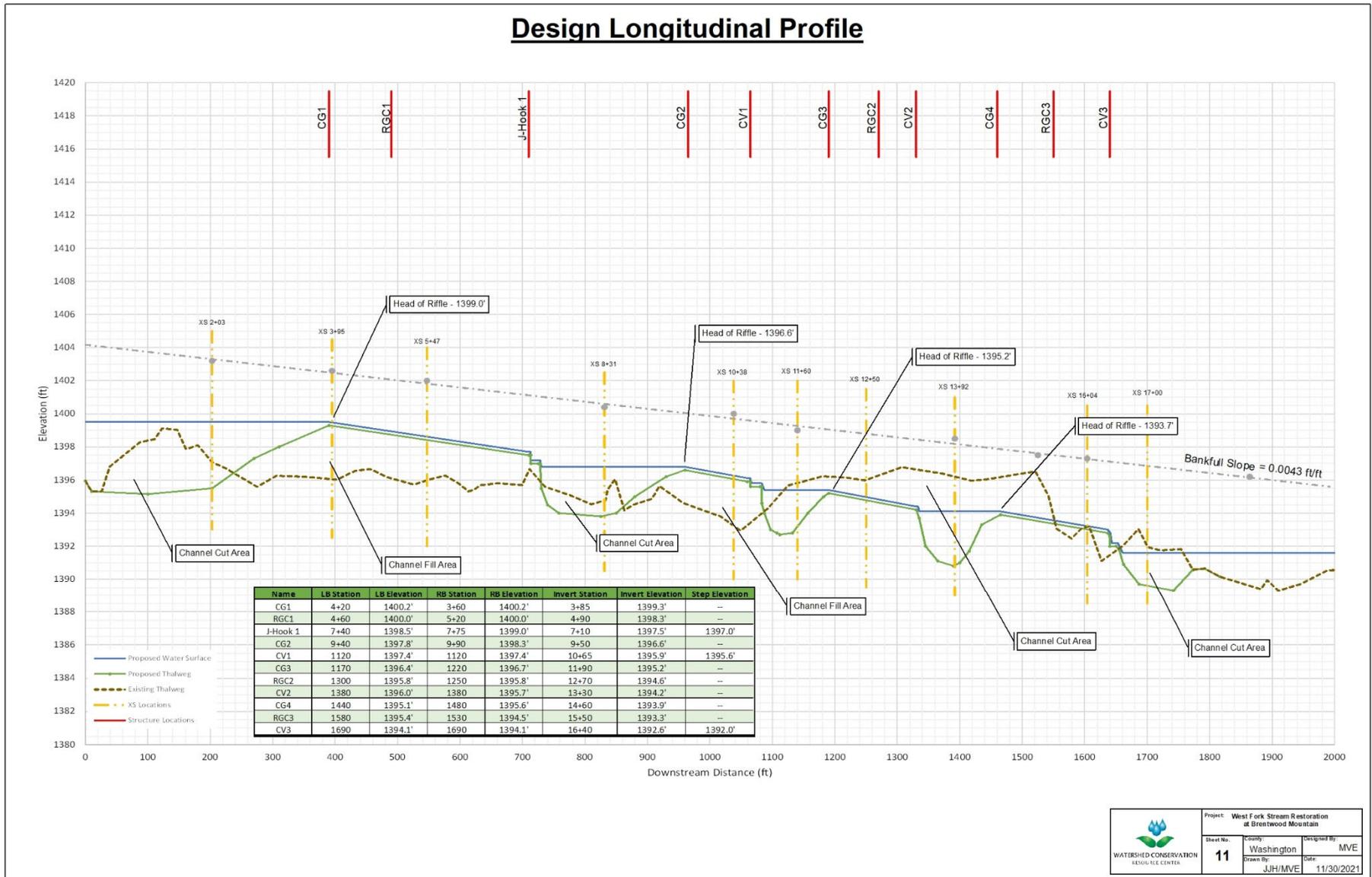


Figure 5. Design longitudinal profile of the Brentwood Mountain restoration

structure and the toewood bench continues to fill in the channel left bank and provide protection and habitat. On top of the toewood, two layers of stacked rock boulders are utilized to protect the high bank as it approaches the existing terrace and promotes flood relief on channel right (Figure 6). Above the stacked rock revetment, biodegradable blocks (BioD-Blocks®) are placed behind the rock and then filled with topsoil to create an encapsulated planting medium for native plants to ensure the long term success of the project (Figure 7 and 8). The success of any stream restoration project required two conditions to be met. First, the channel must be created to be able to convey the flow of sediment and water through the project without aggrading or degrading. Second, the site must be revegetated so that the boundary roughness on the bank slopes and floodplain prevents lateral erosion and enhances sediment transport within the active channel. Construction of the soil mattresses, planting native vegetation during the construction process, and long-term care of the vegetation help to meet the requirements of condition 2 described above. A mix of native grasses, trees and shrubs are placed in a manner to promote growth and spacing for a successful plant habitat. Additionally, surface roughness is created with coir waddles and gamma grasses placed perpendicular to high flow along the bench. At STA 4+90 a riffle grade control was installed to maintain the desired riffle grade through the upstream portion of the project reach. On river right along this riffle a floodplain depression feature was implemented to provide needed fill for the project site while also recreating wetland habitat conditions. A cross section of the design at STA 5+47 in Figure 9 shows the details for a toewood bank, one stack rock, and BioD-Block to establish the riparian bench, along with excavation for a floodplain depression on river right. At the downstream end of this feature sycamore cuttings were placed at an angle downstream to inhibit the channel from cutting into this feature and inducing deposition. At the downstream extent of the toewood on river left an additional 100 feet of brush mattress material finishes out the left bank and recedes into the left floodplain as the channel reaches a low water ford crossing and J-Hook flow direction structure.

The low water ford crossing is constructed upstream of the J-Hook feature to provide access to residents needing to cross the river to the south from U.S. Highway 71. This was placed to tie into the



Figure 6. Stack rock being placed on top of toewood to protect and establish the left riparian streambank



Figure 7. BioD-Blocks staked to the ground behind stack rock with plant prior to filling with topsoil



Figure 8. Topsoil and compost being distributed into the river left riparian streambank restoration

RIFFLE BRUSH MATTRESS AND GRADE CONTROL CROSS SECTION (STA 5+47)

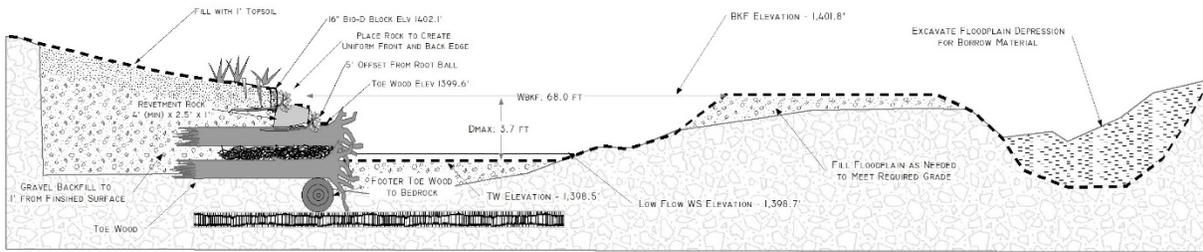


Figure 9. Design Cross-section view for the channel at STA 5+47 to establish a riffle

downstream end of the first riffle at an elevation just below the invert provided by the J-Hook immediately downstream. This J-hook at STA 7+25 redirects high flow velocities away from the river right bank and towards the channel centerline (Figure 10). The structure helps to maintain a deep pool downstream of the structure for aquatic habitat and protects the riparian habitat on river right. Fill from the floodplain depression and channel material was placed on river left to the appropriate grade for the point bar elevation. The channel then forms a glide that ties into a constructed glide structure at STA 9+60 at the design riffle invert elevation and directs flow to the left, forming a riffle that ends with a cross vane structure at STA 10+65. The cross-vane keeps flow in the channel center and promotes scour depth in the downstream pool. This ties directly into a brush mattress designed to protect the toe of the left bank. The brush mattress was constructed in a way to provide and protect an inner berm bench, and then protects one foot above this elevation as the bank slopes toward bankfull at a gravel floodplain. A view of the design cross section for a brush mattress riparian bench at a riffle section further downstream at STA 12+50 is shown in Figure 11. Limestone rock of a similar color as the existing rock outcrops was placed on river right in two areas along this downstream extent to provide additional bank protection.

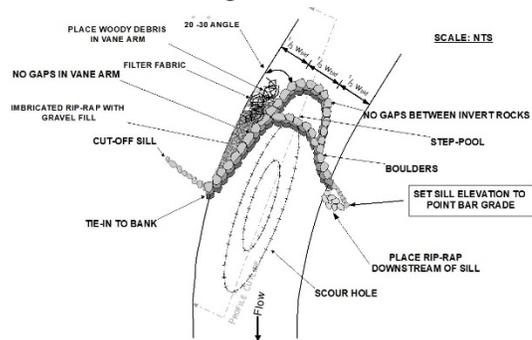


Figure 10. J-Hook flow redirection plan view

RIFFLE - BRUSH MATTRESS CROSS SECTION (STA 12+50)

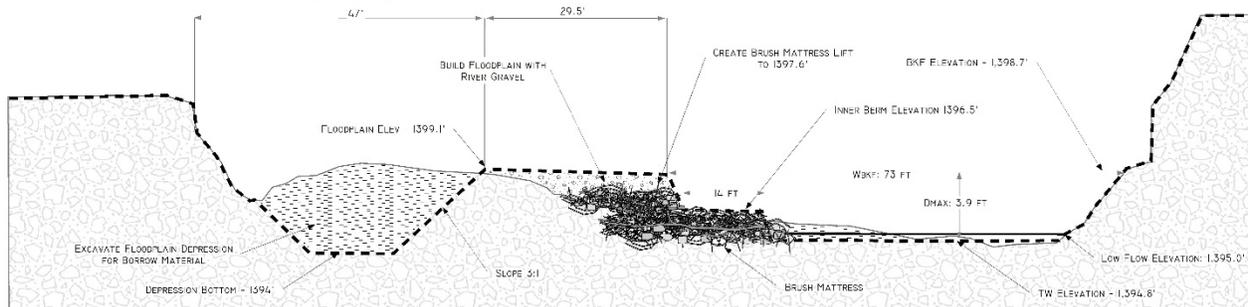


Figure 11. Cross-section of XS 12+50, a riffle formed by excavation of gravels, construction of a brush mattress bank to establish an inner berm and protect the inflection towards bankfull, with a gravel floodplain and floodplain depression.

A glide structure was constructed below this pool that creates a riffle head at STA 12+00. An additional riffle grade control constructed of large boulders was placed at STA 12+90. Another cross-vane forms a

pool at STA 13+30. This cross-vane ties into the start of a toewood left bank at STA 13+80. This toewood, establishing the left bank, proceeds along the contraction scour pool generated by the cross vane and provides boundary roughness to the channel width. Rock is placed on top of the wood to provide additional protection and to reflect the natural occurrence of limestone outcrops along the right bank. This bank protection, dependent on the project location and potential for high lateral shear stress, would involve brush mattresses at low shear, toe wood at high shear, and then one or two stacked rock features for the greatest need of bank protection. Below, between, and behind the rock bank protection native plants appropriate for conditions in proximity to the stream were planted. Above the rock, a biodegradable, coconut coir roll is placed and staked into the soil to provide a medium for soil, compost and native riparian vegetation critical for surface roughness to further protect the bank and establish habitat (Figure 12). This constructed riparian corridor will help to reduce the risk for the channel to leave its designed alignment. The area between the left bank that existed prior to restoration and constructed left bank includes a series of floodplain depressions. Material was pulled from this area to create the floodplain depressions as needed for fill in the riparian bench and channel. Sycamore sills, as described for the upstream portion of the project, were placed to limit the channel from cutting through this area by creating resistance through foliar and tree stem roughness. The roughness of the vegetative sills will also induce deposition on the re-constructed floodplain over time. This will help to create a forested riparian area over the long-term evolution of the restored site (Figure 13).



Figure 12. Riparian bench showing native trees, grasses, and shrubs planted along with winter wheat and seed mix establishing on top of the toewood bench. Also shown are grass and waddle breaks for added



Figure 13. Constructed floodplain depression on river left downstream with live sycamore sills

Continuing along the channel, at STA 14+60 a head of riffle grade control structure ties directly into the toewood bench. This forms the final riffle for the project extent, with one more mid riffle grade control structure at STA 15+50 and a final cross vane at STA 16+40. A final contraction scour pool is created and the left bank ties into the existing left floodplain as the channel to continues downstream.

Vegetation Establishment

Restoration of the native riparian community in the active channel and floodplain are critical for the longevity of a river restoration pursuit. Brentwood Mountain has undergone severe bank erosion, particularly on river left, and the condition prior to restoration was that of a shallow over-widened channel that was subject to frequent flooding as compared to when the channel was more confined

within an active bankfull floodplain. Predominant species within the gravel bar was young sycamore, willow, cocklebur, and other species that emerged within areas of disturbance and gravelly soil conditions. These plants provide little benefit to the aquatic habitat and biodiversity of the riparian corridor. The WCRC has developed and tested techniques for vegetation establishment to create surface roughness, shade to decrease water temperatures, create and provide food and habitat for native aquatic and terrestrial wildlife, prevent the spread of monocultures in the form of invasive species, to enhance and secure the soil and gravel it is grown from, and many other ecological services. Native plants were selected based on the Boston Mountains Ecoregion. A list of grass, trees, and shrub species native to this ecoregion and incorporated into the project are found in Table 1. Following final site grading, native bare roots, plugs, potted plants, and harvest plants from onsite and elsewhere were planted into the streambanks, toewood, point bars, floodplain depressions, and terrace. Winter wheat was used as a nursery crop in combination with native wildflower, forbs and grass mix and was dispersed throughout the site. Straw covering on all seeded areas kept the seed moist, protected from the wind, and provided nutrients with its decomposition. A list of the native grass, forbs and wildflowers used in the seed dispersal mix is found in Table 2.

Table 2. Native Plant Species Utilized to Establish the Riparian Bench

Native Plant Species used at Brentwood Mountain	
Shrubs	Buttonbush
	False Indigo
	Smooth Sumac
	Ninebark
	Ozark Witchhazel
	Rosemallow
	Roughleaf Dogwood
	Silky Dogwood
Trees	Blackgum
	Bur Oak
	Northern Red Oak
	Ohio Buckeye
	Pawpaw
	Pecan
	Persimmon
	Redbud
	River Birch
	Sycamore
	Grasses	Inland Sea Oats
Juncus	
Tridens Strictus	
Gamagrass	

Table 1. Native Seed Mix used to establish the Riparian Bench

Native Seed Mix	
Flower and Forb Seed Species	Grass Seed Species
Aromatic Aster	Indian Grass
Ashy sunflower	Big Bluestem
Bee Balm	Prairie dropseed
Black-Eyed Susan	Purpletop tridens
Blue Vervain	Sideoats grama
Butterfly Milkweed	Switchgrass
Common boneset	Little Bluestem
Giant Goldenrod	Longspike Tridens
Grey-Headed Coneflower	
Illinois Bundleflower	
Lanceleaf Coreopsis	
Mountain Mint	
New England Aster	
Ox-Eye Sunflower	
Pale Purple Coneflower	
Purple Coneflower	
Rattlesnake Master	
Rosinweed	
Smooth Penstemon	
Stiff Goldenrod	
Thickspike Gayfeather	
Wild Bergamot	
Woolly Rose Mallow	

Administration

Prior to commencement of restoration activities, the WCRC secured all required permits including a US Army Corps of Engineers 404 Permit, ADEQ Short Term Activity Authorization, ADEQ Storm Water Pollution Prevention Plan, and County Floodplain Development Permit.

The WCRC prepared a drawing set, quantities of work, and prepared all bidding documents necessary to implement the project. Flowstate, LLC was awarded the project on October 26, 2021. Heavy equipment construction began on December 6, 2021. Prior and during the construction, the WCRC acquired all

materials necessary to the restoration. Rock was bid out to Yates Excavation and Trucking LLC for over 2,400 tons of rock necessary for all in channel rock structures and revetment boulders. The remaining materials were sourced from the area and stacked in the adjacent field. This includes approximately 900 Toewood Logs, 35 large diameter footer logs, 1300 yd³ of brush, 670 yd³ of top soil, 125 yd³ of compost, and 4,500 native trees, shrubs, and grasses. The WCRC oversaw all construction activities described above, commencing heavy equipment use on December 6, 2021. A 3-d surface model of the design aided the contractor in grading and achieving desired finish elevations. Two of the machines in use had GPS enabled machine control capabilities calibrated for the site. This provided a more efficient means of moving material around the site for cut and fill purposes. All grade control and toewood structures were be constructed without a model, using the construction plans and the WCRC for guidance. Heavy equipment construction was completed on March 18, 2022 after review of the project, creation of a project punch list, and finalization. Excess materials were hauled off site to storage for utilization in future projects. All exposed areas of topsoil were seeded and covered in straw. The WCRC Riparian Restoration Team continues to work on the site intermittently, and completed nearly all of the revegetation work prior to April 2022.

Photo Points along Stream Restoration before and after Construction

Figure 14-20 show a series of before and after photos of the Brentwood Mountain site

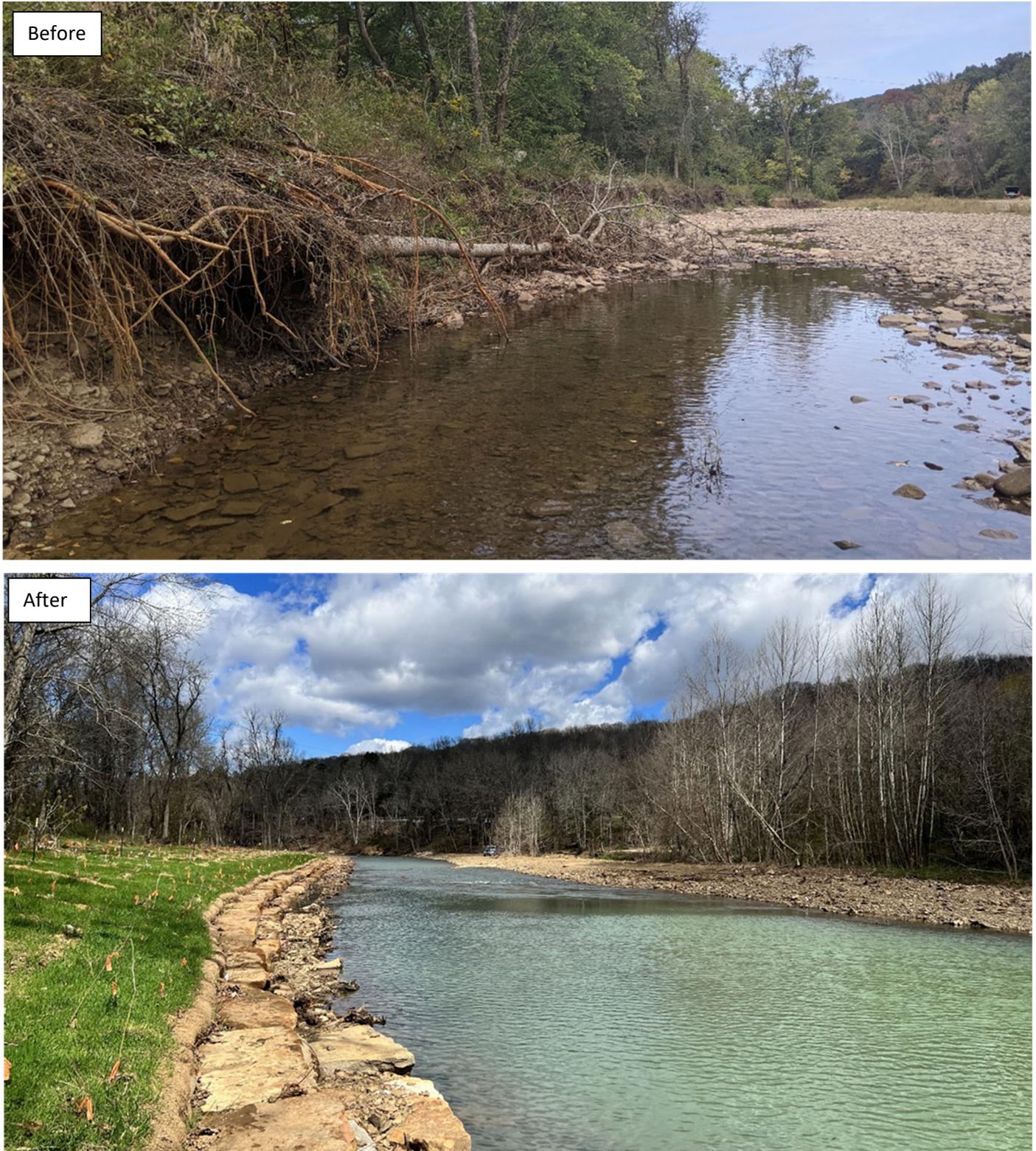


Figure 14. The upstream cut bank before and after restoration. The upper photo shows the eroding streambank prior to restoration. The lower photo shows the constructed riparian bank with a toewood bench, stack rock, and a soil mattress filled with native species of trees, shrubs, grass, and forbs. The bright green aspect of the bank at this point is due to winter wheat sprouting as a cover crop.



Figure 15. The upstream floodplain depression before and after restoration. The upper photo shows the low lying area full of gravels, cobbles and sandy soils. The bottom photo shows the area that was excavated for fill that would help recreate the left riparian streambank, filled with water and revegetated along its banks recreating wetland conditions



Figure 12. A before and after view of the riparian upstream bank looking upstream. The upper photo shows the eroding cut bank and shallow overwidened channel conditions. The bottom photo shows the constructed riparian bank with native plant species now conducive for sediment transport. Two riffle grade control structures are visible in the channel, maintaining flow in the channel centerline, maintaining the riffle shape, dissipating energy, and oxygenating water.



Figure 13. This photo shows the downstream gravel bar shaped to decrease the high width to depth ratio of the evolving channel prior to restoration. The upper photo shows this area prior to restoration, the bottom photo shows the low width to depth ratio stream with limestone rock protection added to tie in to river right, gravel fill placed to create the floodplain, and native vegetation.



Figure 18. This photo shows the downstream area of the restoration extent looking upstream. The upper photo shows the stream with shallow pool features and poor riparian vegetation. The bottom photo shows the start of the riparian streambank, well established riffle and cross vane structure to help establish and maintain depth in the channel.



Figure 19. This photo shows the downstream cut bank. The upper photo shows the secondary, high flow channel path that was eroding the left streambank. Fallen trees are visible with a large, unvegetated gravel floodplain feature between the primary and secondary channel. The bottom photo shows the restored area, with a series of floodplain depression to create wetland conditions, sycamore sills to induce deposition and reduce the potential for the channel to cut through this area.



Figure 20. The Brentwood Mountain site looking upstream at the downstream project extent. The upper photo shows the site prior to restoration. A large midpoint channel bar is formed with cobbles and gravels due to the overwidened channel not able to transport materials. This feature is redirecting high flows around this aggradation leading to erosion of the left bank while having poor soil conditions for native, long lasting riparian vegetation. The bottom photo shows the restored channel ending with a cross vane structure and with a riparian streambank.

WCRC for ANRC NPS Program -- Hwy 71, West Fork, AR 72774

West Fork Stream Restoration at Brentwood Mountain

West Fork White River

SCHEDULE OF DRAWINGS

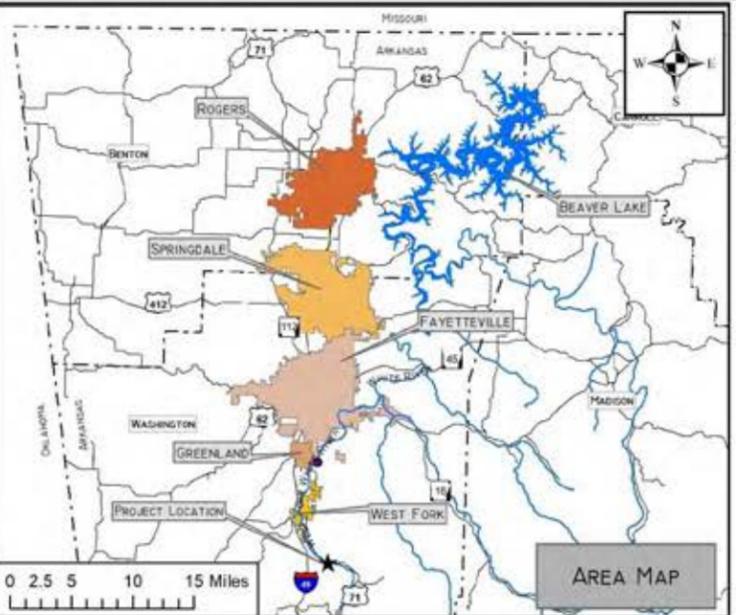
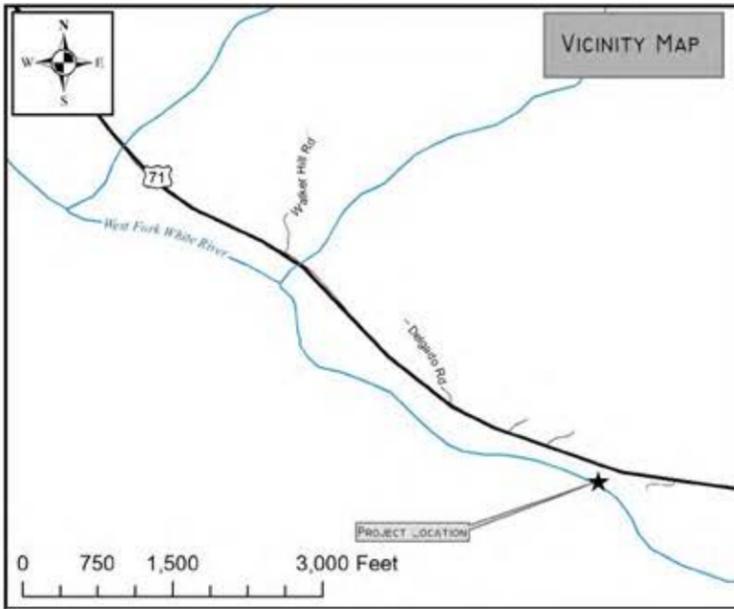
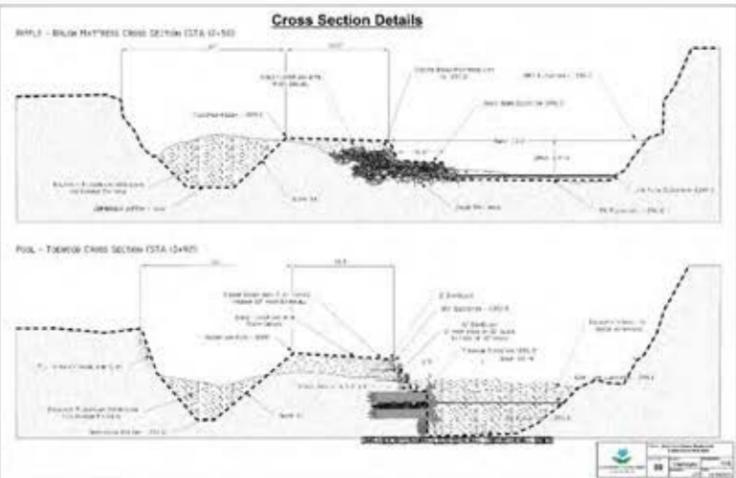
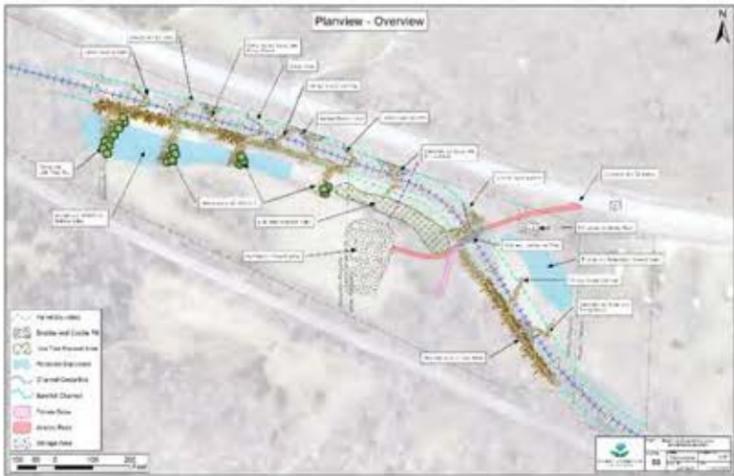
COVER SHEET.....	1
BID ITEMS.....	2
PLAN VIEW DETAILS.....	3 - 5
CROSS SECTION DETAILS.....	6 - 10
LONGITUDINAL PROFILE.....	11
CONSTRUCTION DETAILS.....	12 - 21

Storm Water Pollution Prevention Plan

THIS PROJECT REQUIRES A STORM WATER POLLUTION PREVENTION PLAN (SWPPP). THE OWNER WILL PREPARE THE SWPPP AND OBTAIN THE REQUIRED PERMITS/DOCUMENTATION FROM THE ARKANSAS DEPARTMENT OF ENVIRONMENTAL QUALITY. IT SHALL BE THE CONTRACTOR'S RESPONSIBILITY TO MAINTAIN A COPY OF THE SWPPP ON THE PROJECT SITE. THE CONTRACTOR SHALL FOLLOW ALL PROVISIONS OF THE SWPPP AND NPDES GENERAL STORM WATER PERMIT NO. ARKJ 50000, INCLUDING BUT NOT LIMITED TO:

- INSTALLING AND MAINTAINING ALL BMPs AND EROSION CONTROL MEASURES
- INSPECTING AND DOCUMENTING INSPECTIONS OF ALL BMPs AND EROSION CONTROL MEASURES

ADDITIONALLY, THE CONTRACTOR SHALL BE RESPONSIBLE OF ANY ENFORCEMENT ACTION(S) TAKEN OR IMPOSED BY FEDERAL OR STATE AGENCIES, INCLUDING THE COSTS OF FINES, CONSTRUCTION DELAYS AND REMEDIAL ACTION(S) RESULTING FROM THE CONTRACTOR'S FAILURE TO COMPLY WITH THE PERMIT PROVISIONS.



PROJECT CONTACT INFORMATION:

PROJECT DESIGN: WATERSHED CONSERVATION RESOURCE CENTER
 MATTHEW VAN EPS, P.E.
 (501) 352-7294
 380 W. ROCK ST.
 FAYETTEVILLE, AR 72701

	Project: West Fork Stream Restoration at Brentwood Mountain		
	Sheet No. 01	County: Washington	Designed By: MVE
		Drawn By: JH/MVE	Date: 11/30/2021

Pay Quantities and Project Notes

Pay Quantities

General Construction and Grading Notes

1. AREAS DISTURBED BY CONSTRUCTION, INCLUDING AREAS OUTSIDE THE LIMITS OF CONSTRUCTION SHALL BE RETURNED TO A STABILIZED CONDITION AT CONTRACTOR'S EXPENSE. LIMITS OF CONSTRUCTION ARE DEFINED ON THE DRAWINGS.
2. CONTRACTOR IS RESPONSIBLE FOR VERIFYING ALL UNDERGROUND UTILITIES PRIOR TO ANY EXCAVATION OR DIGGING. ENGINEER OR OWNER WILL CALL THE ARKANSAS ONE-CALL SYSTEM (1-800-482-8998).
3. CONTRACTOR SHALL BE RESPONSIBLE FOR MEETING ALL ARKANSAS DEPARTMENT OF ENVIRONMENTAL QUALITY (ADEQ) AND ENVIRONMENTAL PROTECTION AGENCY (EPA) REQUIREMENTS FOR STORM WATER MANAGEMENT FOR THIS PROJECT. ENGINEER WILL PROVIDE ALL MATERIALS. ANY COST INCURRED BY THE CONTRACTOR SHALL BE INCLUDED IN THE PRICE OF OTHER ITEMS.
4. CONTRACTOR SHALL BE RESPONSIBLE FOR DISPLAYING ALL NECESSARY PERMITS ON SITE AS REQUIRED BY THE CITY OF WEST FORK. FEES FOR CITY PERMITS WILL BE WAIVED.
5. CONTRACTOR SHALL NOTIFY ENGINEER OF ANY SUBGRADE CONDITIONS ENCOUNTERED WHICH MAY VARY FROM THOSE FOUND DURING PREVIOUS SUBGRADE INVESTIGATIONS AND/OR THAT MAY NOT HAVE BEEN KNOWN DURING DESIGN.
6. STRIP, STOCKPILE AND REPLACE TOPSOIL IN AREAS THAT ARE DISTURBED. ANY STORED TOPSOIL MUST BE SURROUNDED BY SILT FENCE, STRAW WATTLES, OR HAY BALES.
7. AREAS DISTURBED BY THE CONSTRUCTION, IF NOT RECEIVING NEW IMPROVEMENTS SHALL BE RESTORED AS SHOWN ON THE PLANS AND IN THE SPECIFICATIONS.

Minimum Erosion Control Requirements

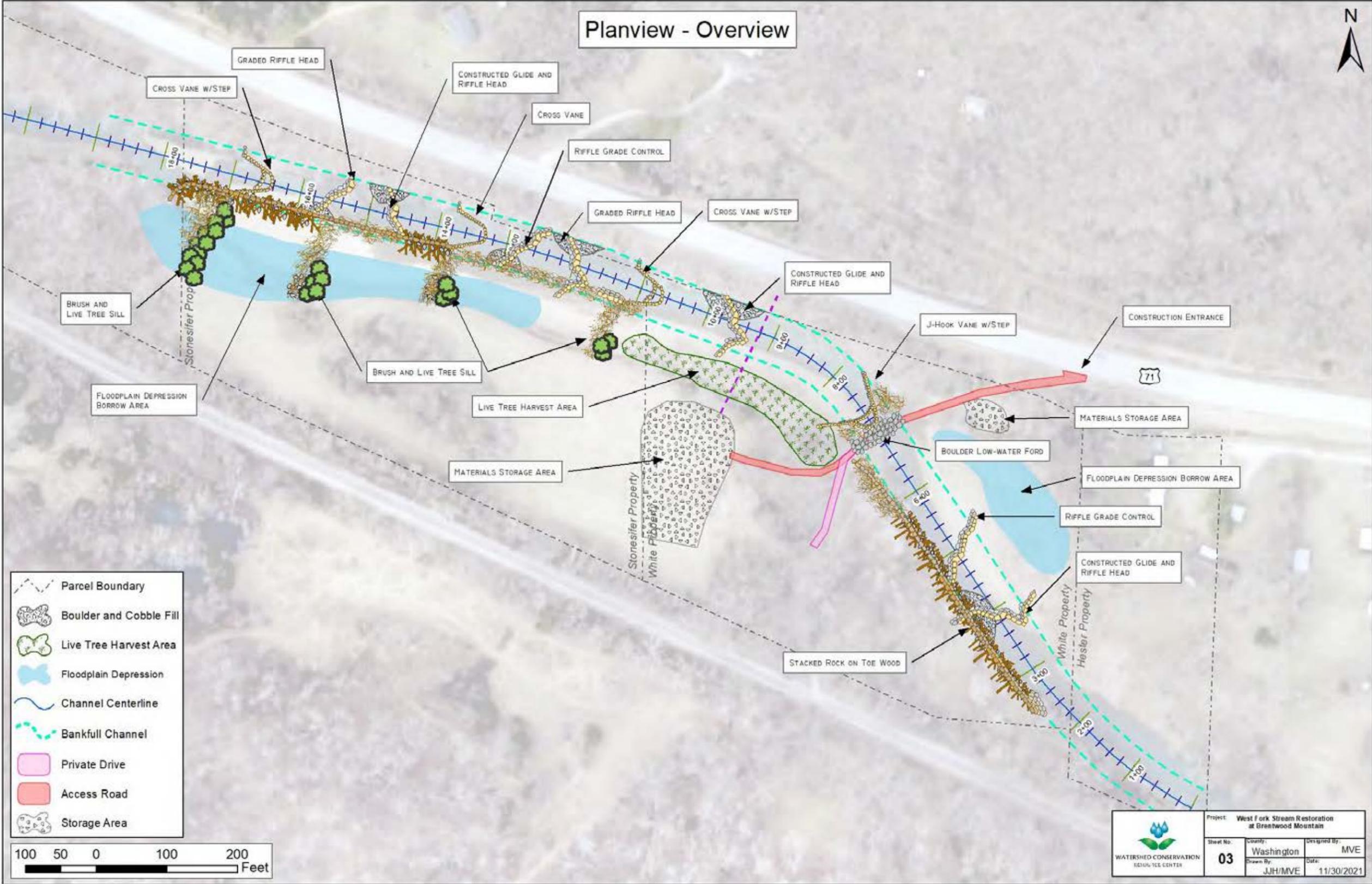
1. THE POTENTIAL FOR SOIL LOSS SHALL BE MINIMIZED BY RETAINING NATURAL VEGETATION WHEREVER POSSIBLE.
2. A RECORD OF THE DATES WHEN GRADING ACTIVITIES OCCUR, WHEN CONSTRUCTION ACTIVITIES TEMPORARILY OR PERMANENTLY CEASE ON A PORTION OF THE SITE, AND WHEN STABILIZATION MEASURES ARE INITIATED AS SOON AS PRACTICABLE ON PORTIONS OF THE SITE WHERE CONSTRUCTION ACTIVITIES HAVE TEMPORARILY OR PERMANENTLY CEASED, BUT IN NO CASE MORE THAN 14 DAYS AFTER THE CONSTRUCTION ACTIVITY IN THAT PORTION OF THE SITE HAS TEMPORARILY OR PERMANENTLY CEASED.
 - A. WHERE THE INITIATION OF STABILIZATION MEASURES BY THE 14TH DAY AFTER CONSTRUCTION ACTIVITY TEMPORARILY OR PERMANENTLY CEASES IS PRECLUDED BY SNOW COVER, STABILIZATION MEASURES SHALL BE INITIATED AS SOON AS PRACTICABLE.
 - B. WHERE CONSTRUCTION ACTIVITY WILL RESUME ON A PORTION OF THE SITE WITHIN 21 DAYS FROM WHEN ACTIVITIES CEASED, (E.G. THE TOTAL TIME PERIOD THAT CONSTRUCTION ACTIVITY IS TEMPORARILY CEASED IS LESS THAN 21 DAYS) THEN STABILIZATION MEASURES DO NOT HAVE TO BE INITIATED ON THAT PORTION OF THE SITE BY THE 14TH DAY AFTER CONSTRUCTION ACTIVITY TEMPORARILY CEASED.
3. STABILIZATION PRACTICES MAY INCLUDE: TEMPORARY SEEDING, PERMANENT SEEDING, MULCHING, GEOTEXTILES, SOD STABILIZATION, VEGETATIVE BUFFER STRIPS, PROTECTION OF TREES, AND PRESERVATION OF MATURE VEGETATION AND OTHER APPROPRIATE MEASURES FROM WHEN ACTIVITIES CEASED.
4. EXCAVATION MATERIAL SHALL NOT BE STORED IN OR SO NEAR STREAMS AND OTHER STORM WATER DRAINAGE SYSTEMS WHERE IT MAY BE WASHED DOWNSTREAM BY HIGH WATER OR RUNOFF. MATERIALS, OTHER THAN RIVER GRAVEL, TEMPORARILY PLACED IN THE STREAM DURING CONSTRUCTION SHALL BE REMOVED FROM THE CHANNEL IF A RISE IN WATER IS IMMINENT OR FORECASTED TO OCCUR WITHIN 12 HOURS.
5. FORDING OF THE STREAM IS ALLOWED. ALL ENTRANCES AND EXITS FROM THE CHANNEL MUST BE HARDENED WITH RIPRAP OR CREEK GRAVEL.
6. DEBRIS, MUD, AND SOIL SHALL NOT BE ALLOWED ON PUBLIC STREETS. IF ANY DEBRIS, MUD, OR SOIL FROM THE PROJECT SITE REACHES THE PUBLIC STREET, IT SHALL BE IMMEDIATELY REMOVED VIA SWEEPING OR OTHER METHODS OF PHYSICAL REMOVAL AT THE EXPENSE OF THE CONTRACTOR. DEBRIS, MUD, OR SOIL IN THE STREET MAY NOT BE WASHED OFF THE STREET OR WASHED INTO THE STORM DRAINAGE SYSTEM.
7. DIVERSION CHANNELS SHALL BE CONSTRUCTED AROUND WORK AREAS WHEN PRACTICAL AND WHEN DIRECTED BY THE PROJECT MANAGER OR ENGINEER.
8. CONTRACTOR IS REQUIRED PERFORM CONSTRUCTION ACTIVITIES WITH AWARENESS AND INTENT TO MINIMIZE GENERATING IN-STREAM TURBIDITY BEYOND THE LEVEL THAT CANNOT OTHERWISE BE AVOIDED, DUE TO THE NATURE OF RIVER

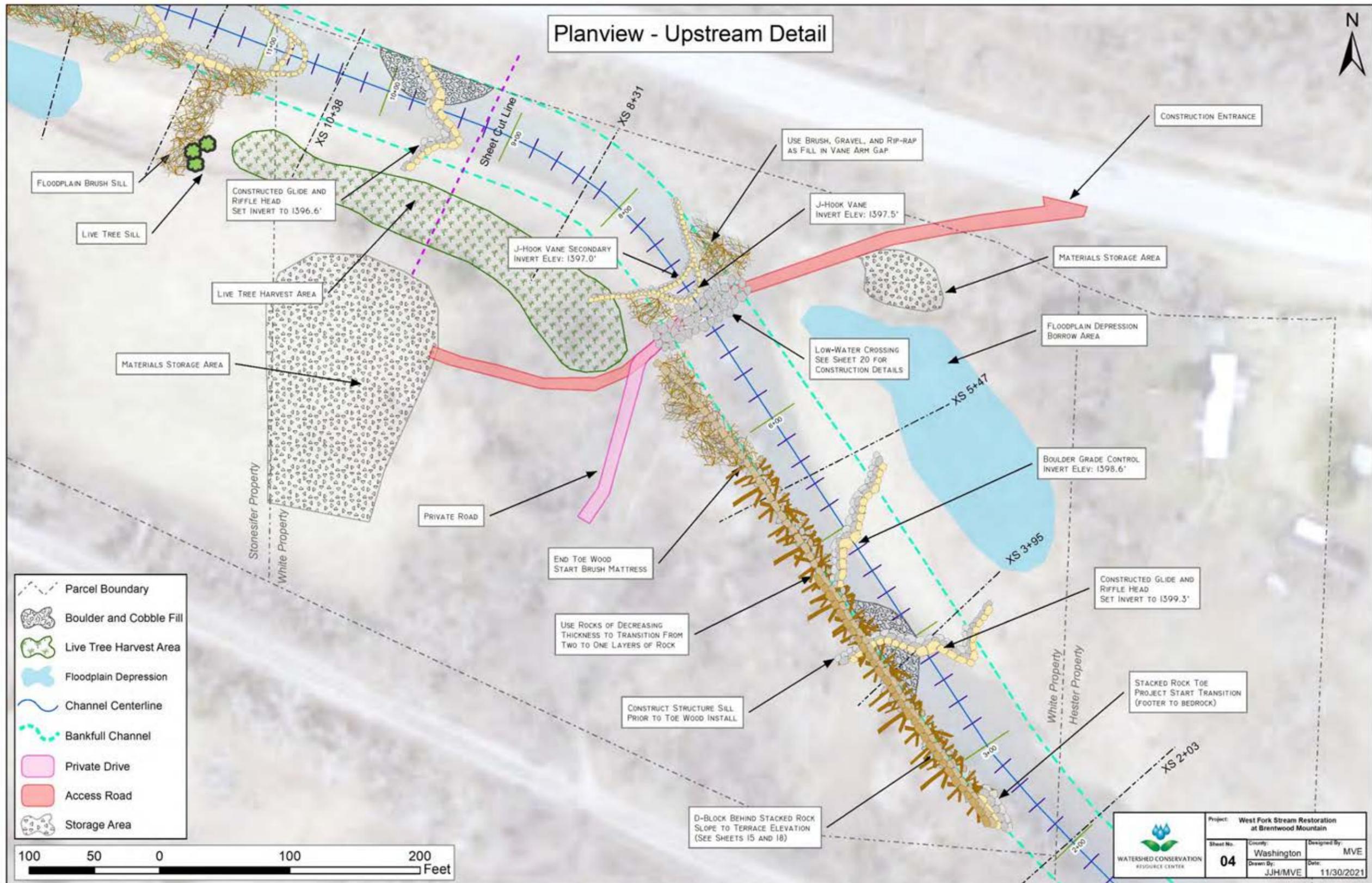
Item #	Description	Unit	Est. Qty.
Work Items			
1	Mobilization (not to exceed 5% of total bid amount)	L.S.	1
2	Bonds and insurance	L.S.	1
3	Toe Wood Bench (Deep Footer) - complete in place per specifications and drawings	L.F.	650
4	Brush Mattress Construction	L.F.	450
5	Wetland Sill Construction	L.F.	350
6	Live Tree Harvest and Live Sill Installation	L.F.	250
7	River Channel and Floodplain Excavation / Channel Shaping / Streambank Filling, Wetland Fill and Excavation, Shaping and Grading	Plan QTY (yd3)	6,500
8	Double Rock Revetment	L.F.	730
9	Stacked Rock to Bedrock (5 tier)	L.F.	130
10	Stacked Rock to Bedrock (3 tier)	L.F.	45
11	Low-water Ford and Revetment	E.A.	1
12	Installation of soil mattresses - complete in place per specifications and drawings	L.F.	810
13	Boulder Grade Control	E.A.	7
14	Cross-Vane	E.A.	3
15	J-Hook Vane	E.A.	1
16	Site Clean-up	L.S.	1

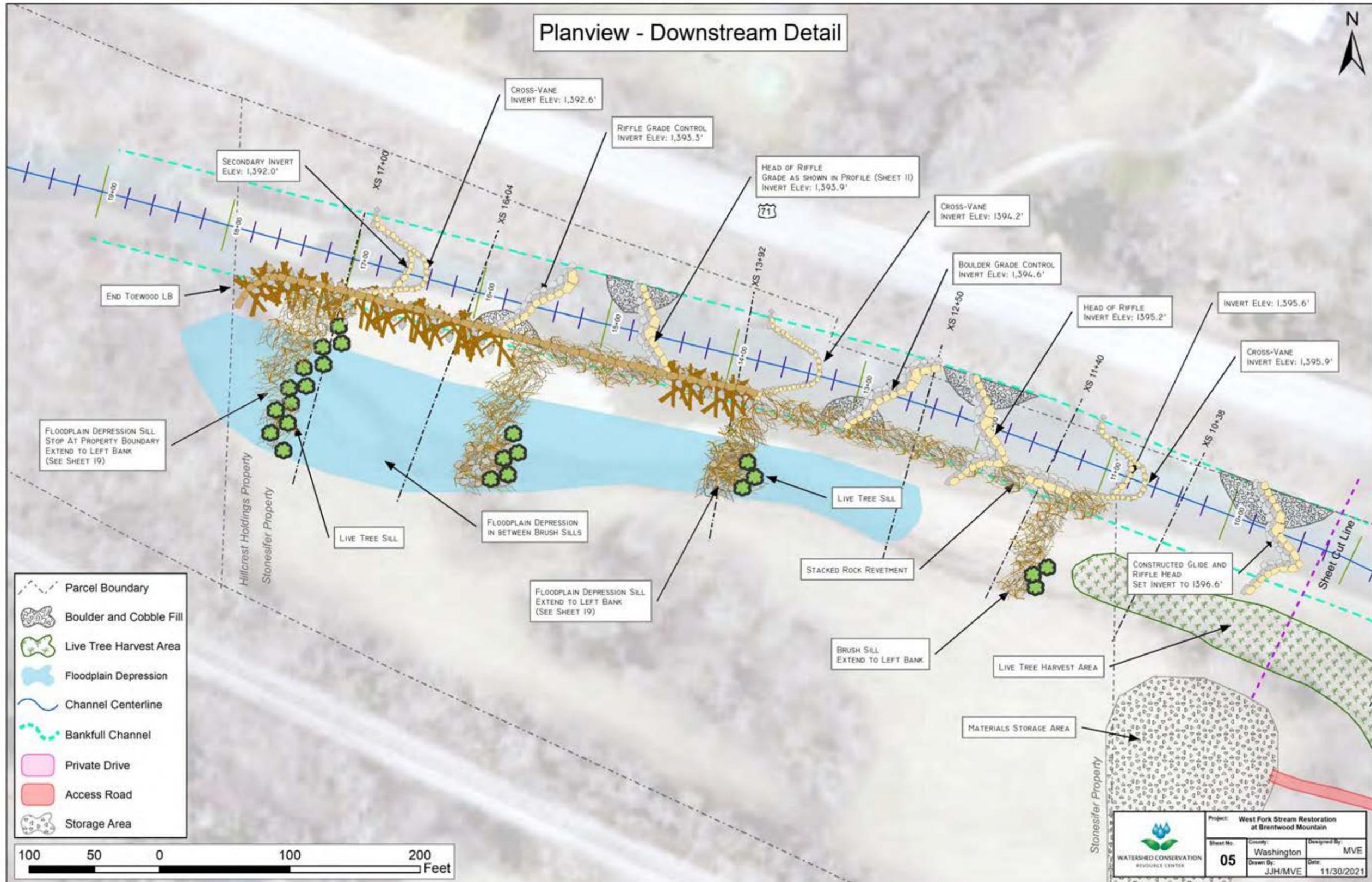
BID ITEM AND PAY QUANTITY NOTES

1. MOBILIZATION COSTS SHALL NOT EXCEED 5% OF THE TOTAL PROJECT COST.
2. BID ITEMS INCLUDE ALL LABOR, EQUIPMENT AND INCIDENTAL REQUIRED TO COMPLETE THE WORK AS SHOWN IN THE PLANS AND WRITTEN SPECIFICATIONS FOR A COMPLETE, IN-PLACE ITEM.
3. OWNER/ENGINEER WILL PROVIDE ALL MATERIALS NEEDED TO COMPLETE THE WORK AS DESCRIBED IN THE PLANS AND SPECIFICATIONS.
4. ITEMS LISTED ON DRAWINGS AND NOT INCLUDED AS A SEPARATE PAY QUANTITY SHALL BE CONSIDERED INCIDENTAL AND THE COST SHALL BE INCLUDED IN THE PRICE BID FOR OTHER ITEMS.

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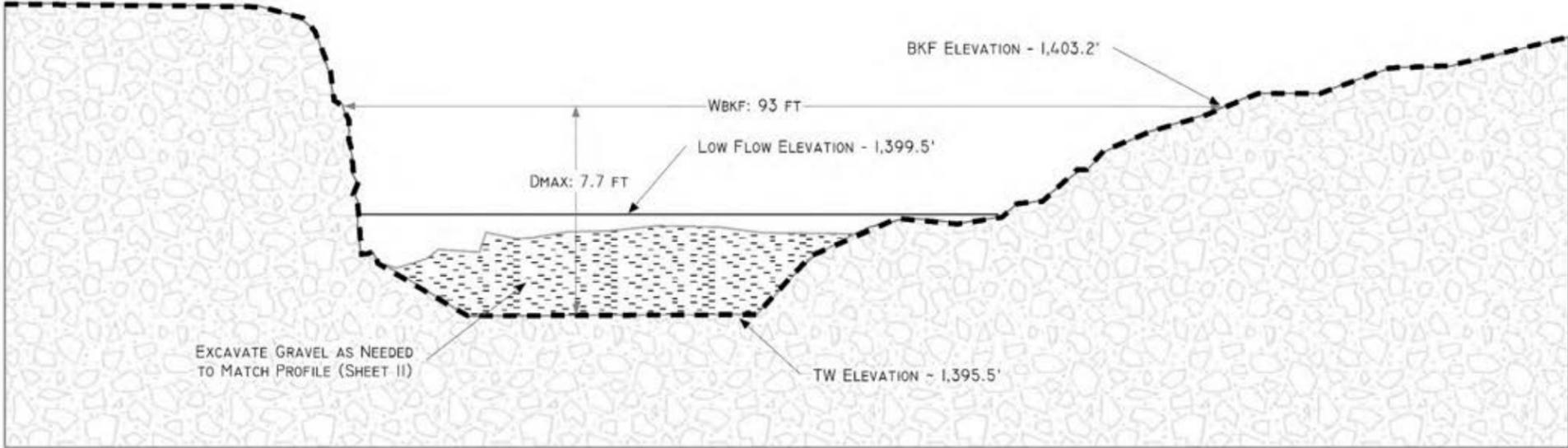




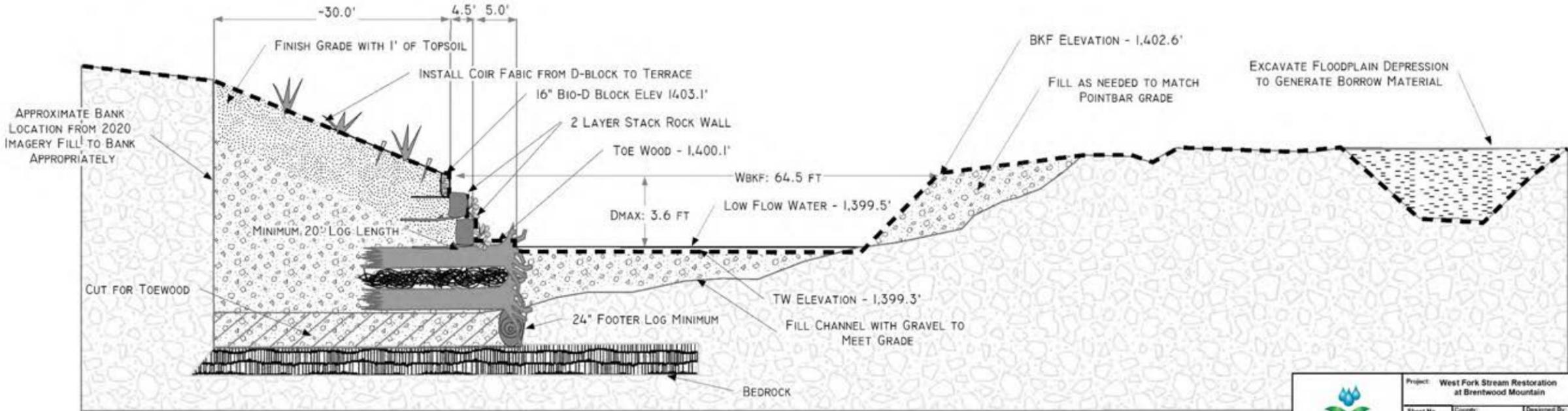


Cross Section Details

POOL CROSS SECTION (STA 2+03)



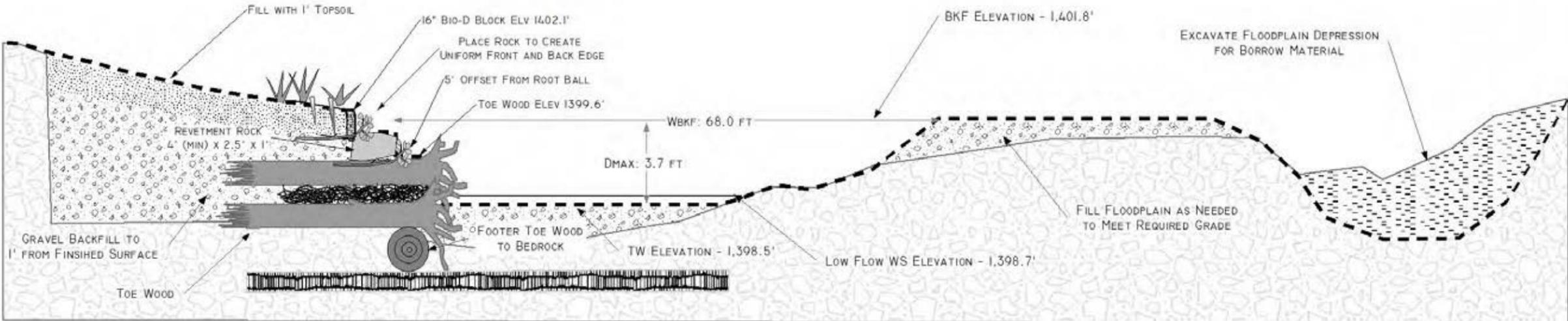
RIFFLE TOEWOOD CROSS SECTION (STA 3+95)



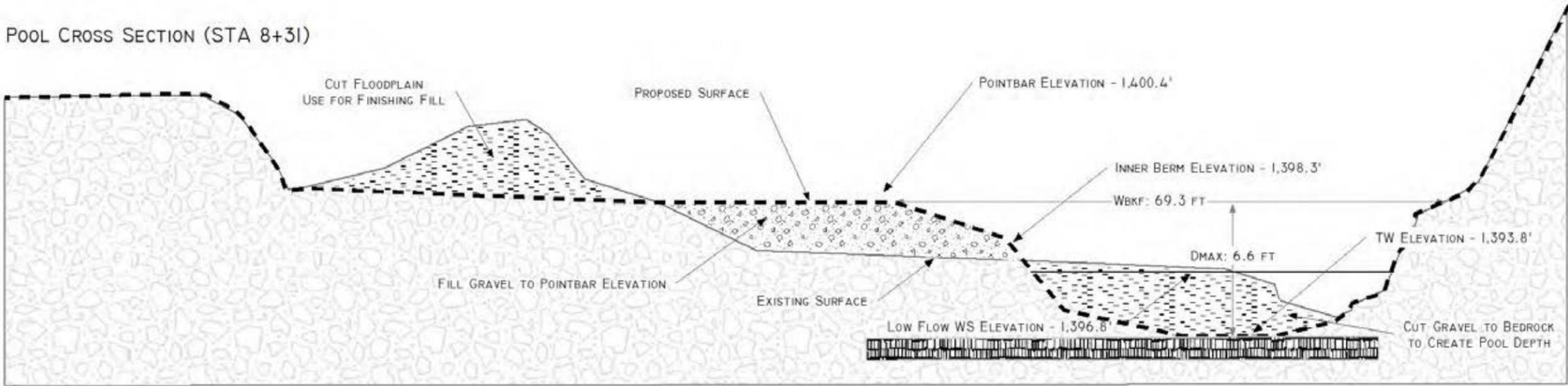
	Project: West Fork Stream Restoration at Brentwood Mountain		
	Sheet No. 06	County: Washington	Designed By: MVE
	Drawn By: JJH	Date: 11/30/2021	

Cross Section Details

RIFFLE BRUSH MATTRESS AND GRADE CONTROL CROSS SECTION (STA 5+47)



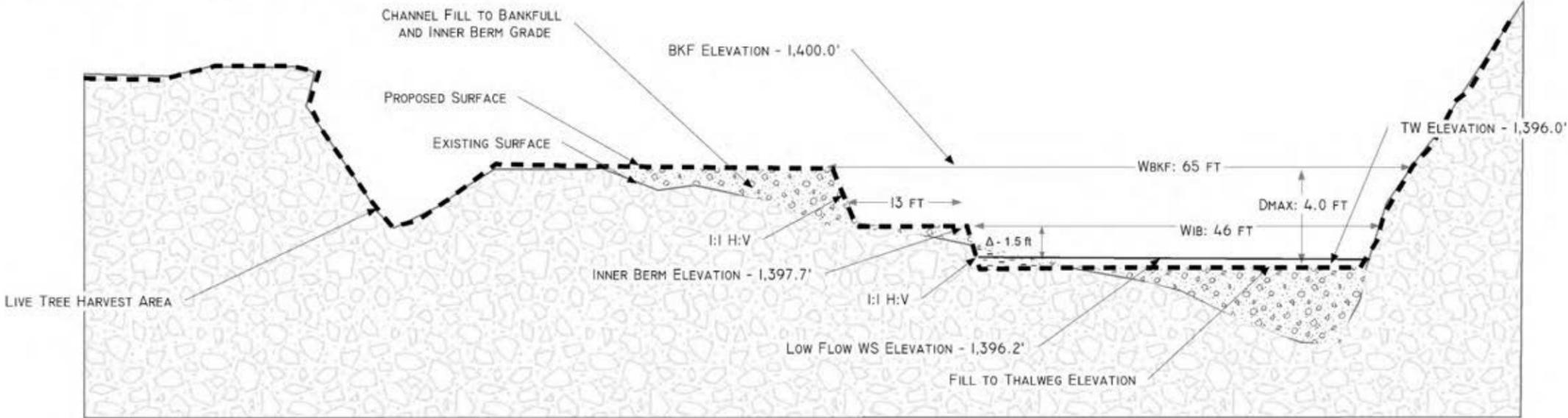
POOL CROSS SECTION (STA 8+31)



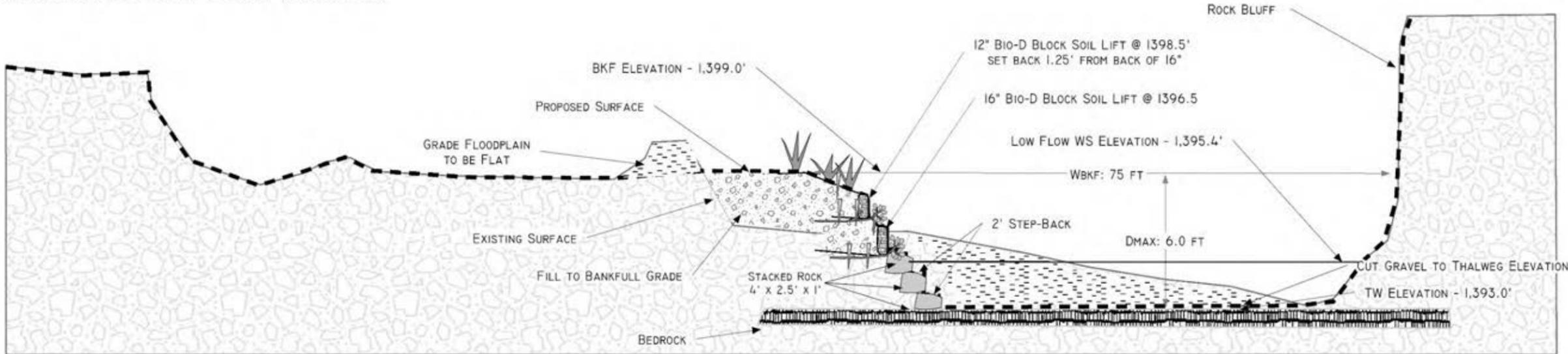
	Project: West Fork Stream Restoration at Brentwood Mountain		
	Sheet No. 07	City: Washington	Designed By: MVE
		Drawn By: JJJ	Date: 11/30/2021

Cross Section Details

DOWNSTREAM RIFFLE CROSS SECTION (STA 10+38)



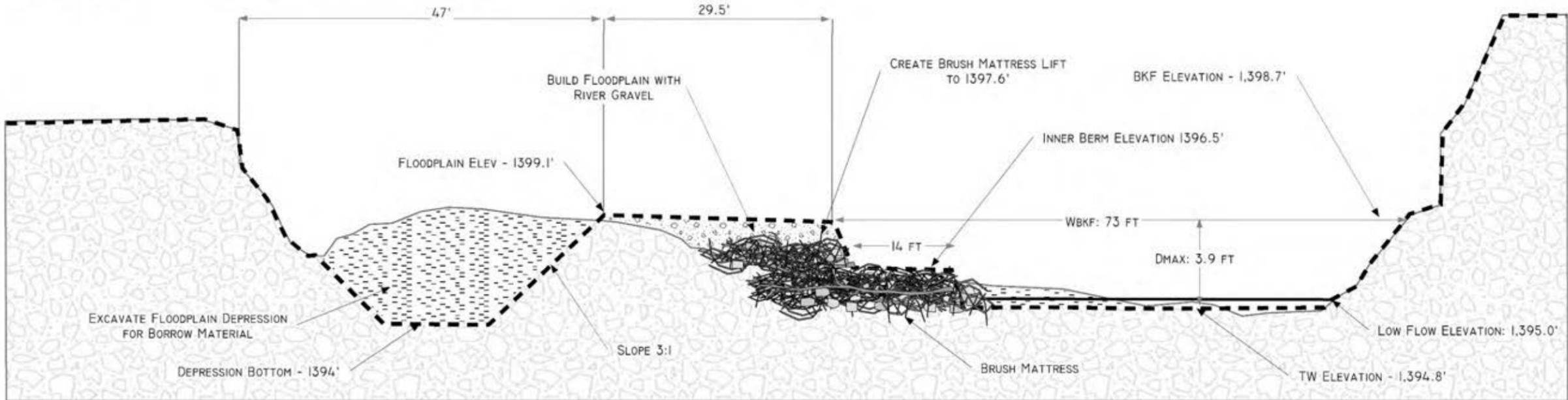
DOWNSTREAM POOL CROSS SECTION (STA 11+40)



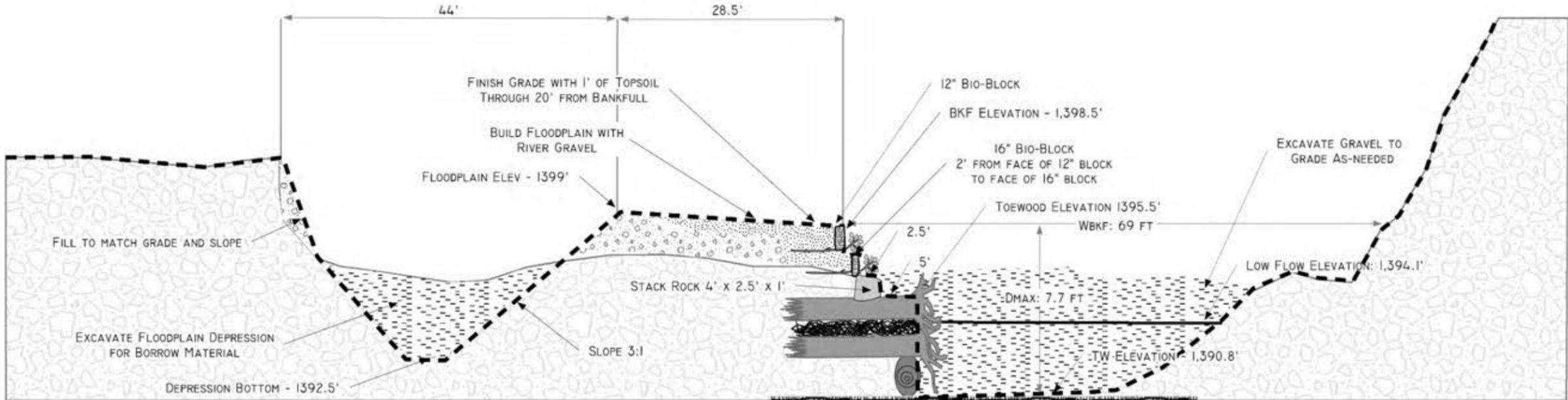
	Project: West Fork Stream Restoration at Brentwood Mountain		
	Sheet No. 08	County: Washington	Designed By: MVE
	Drawn By: JJH	Date: 11/30/2021	

Cross Section Details

RIFFLE - BRUSH MATTRESS CROSS SECTION (STA 12+50)



POOL - TOEWOOD CROSS SECTION (STA 13+92)



	Project: West Fork Stream Restoration at Brentwood Mountain		
	Sheet No. 09	County: Washington	Designed By: MVE
	Drawn By: JJH	Date: 11/30/2021	

Design Longitudinal Profile



Name	LB Station	LB Elevation	RB Station	RB Elevation	Invert Station	Invert Elevation	Step Elevation
CG1	4+20	1400.2'	3+60	1400.2'	3+85	1399.3'	--
RGC1	4+60	1400.0'	5+20	1400.0'	4+90	1398.3'	--
J-Hook 1	7+40	1398.5'	7+75	1399.0'	7+10	1397.5'	1397.0'
CG2	9+40	1397.8'	9+90	1398.3'	9+50	1396.6'	--
CV1	1120	1397.4'	1120	1397.4'	10+65	1395.9'	1395.6'
CG3	1170	1396.4'	1220	1396.7'	11+90	1395.2'	--
RGC2	1300	1395.8'	1250	1395.8'	12+70	1394.6'	--
CV2	1380	1396.0'	1380	1395.7'	13+30	1394.2'	--
CG4	1440	1395.1'	1480	1395.6'	14+60	1393.9'	--
RGC3	1580	1395.4'	1530	1394.5'	15+50	1393.3'	--
CV3	1690	1394.1'	1690	1394.1'	16+40	1392.6'	1392.0'

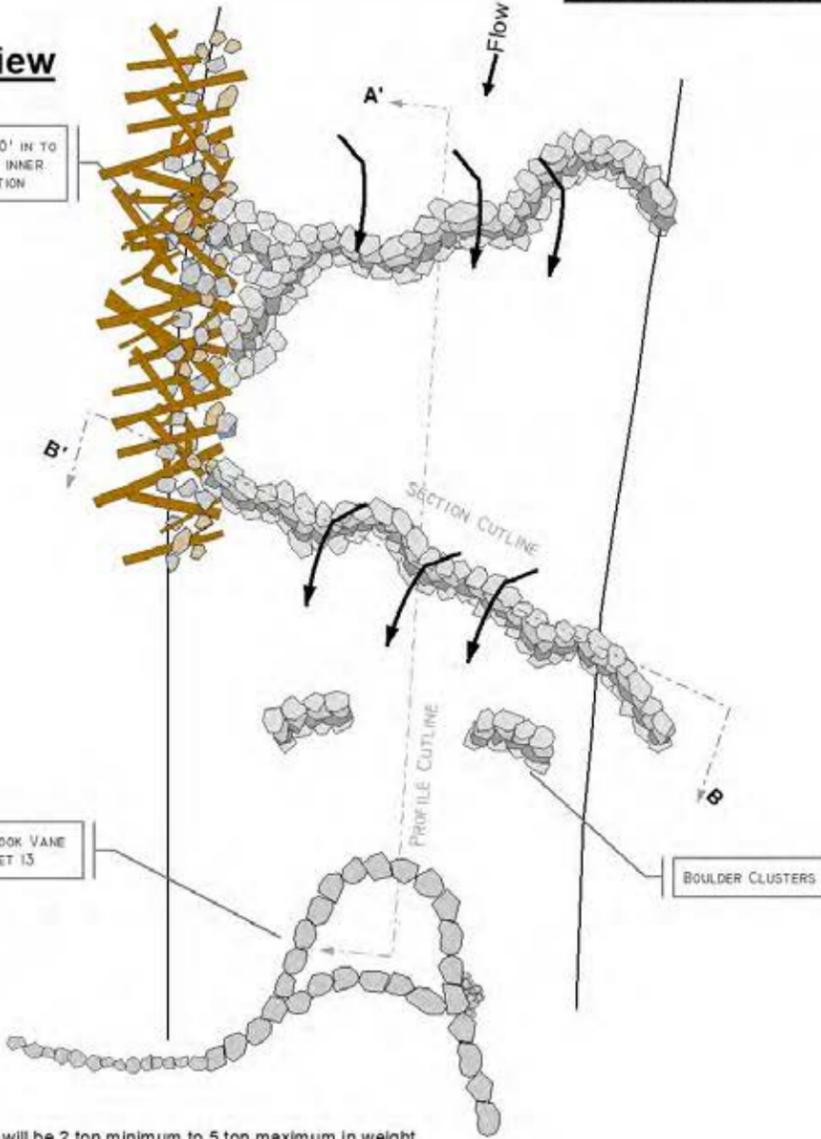
	Project: West Fork Stream Restoration at Brentwood Mountain		
	Sheet No. 11	City: Washington	Designed By: MVE
		Drawn By: JJH/MVE	Date: 11/30/2021

Typical Grade Control Construction Details

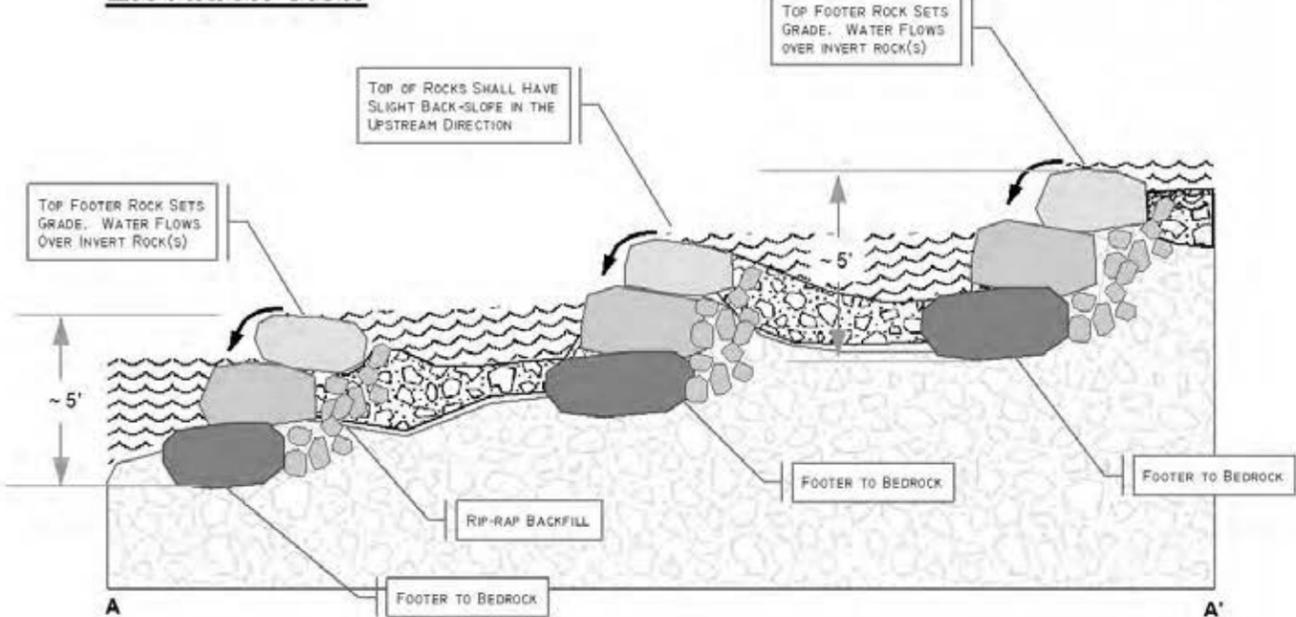
SCALE: NTS

Plan View

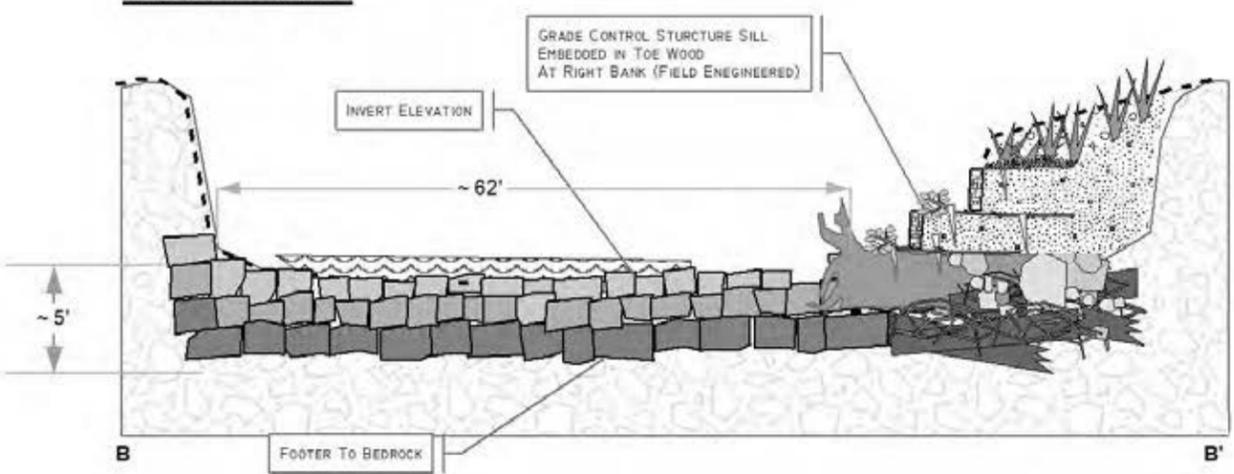
SILL -- EXTEND 10' IN TO FLOODPLAIN AT INNER BERM ELEVATION



Elevation View



Section View



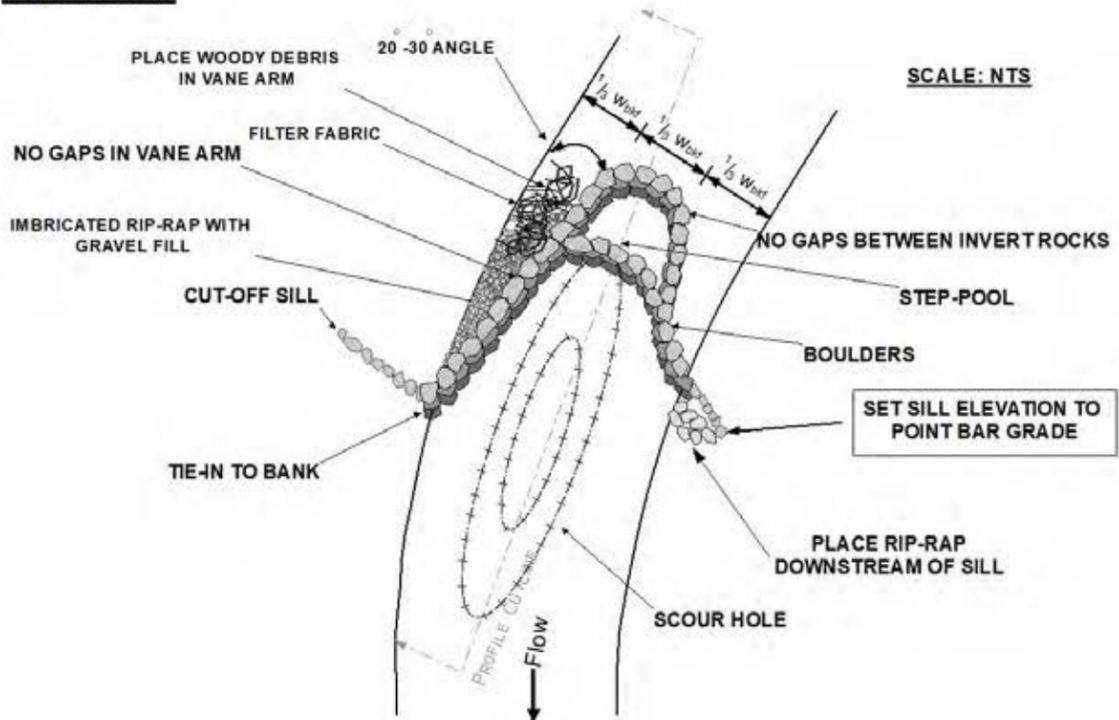
- NOTES: Boulders will be 2 ton minimum to 5 ton maximum in weight
- The Rock Riffle Grade Control Structure will be field engineered to meet the general design specifications presented in the plan set
- Water surface grade will be controlled by the invert elevation. The final invert elevation will be dependent on field conditions and will be specified by the Engineer during construction
- All structures shall be footered to bedrock unless specified by the Engineer in the field
- All boulders will be installed with a slight backslope in the upstream direction
- All boulders shall have direct contact to the adjacent boulder so that no gap between adjacent boulders is present.
- Filter fabric will be installed on the upstream side of the upstream grade control structure
- Rip-rap shall be placed in front of structure boulders to prevent scour and undermining of boulders

<p>WATERSHED CONSERVATION DESIGN/CON CENTER</p>	Project: West Fork Stream Restoration at Brentwood Mountain		
	Sheet No. 12	City: Washington	Designed By: MVE
	Drawn By: JH/MVE	Date: 11/30/2021	

J-Hook Vane Construction Details

SCALE: NTS

Plan View



NOTES: Minimum rock size is 3' mean diameter or 2 tons.

Fabric shall be draped into the depression excavated between J-Hook vane arm and streambank then backfilled with gravel up to an elevation 1 foot lower than the top level of the structure boulders. Above this elevation, imbricated rip-rap with a gravel veneer will be placed up to the elevation of the top of the boulders. Place filter fabric between streambank and upstream face of vane arms. Fabric should run up to 3/4 of the top rock height and to an equivalent elevation on the bank side.

Boulders in drawing are for illustration purposes only and should not be used as the basis for vane construction

Boulders shall be stacked in a manner that achieves the desired vane arm slope with boulders forming a smooth plane along the top of the boulders.

All boulders shall have direct contact to the adjacent boulder so that no gap between adjacent boulder is present.

Entire structure shall be footered to bedrock.

Rip-rap shall be placed on the upstream side of upper level boulders before backfilling with gravel to prevent scour and under-mining of boulders.

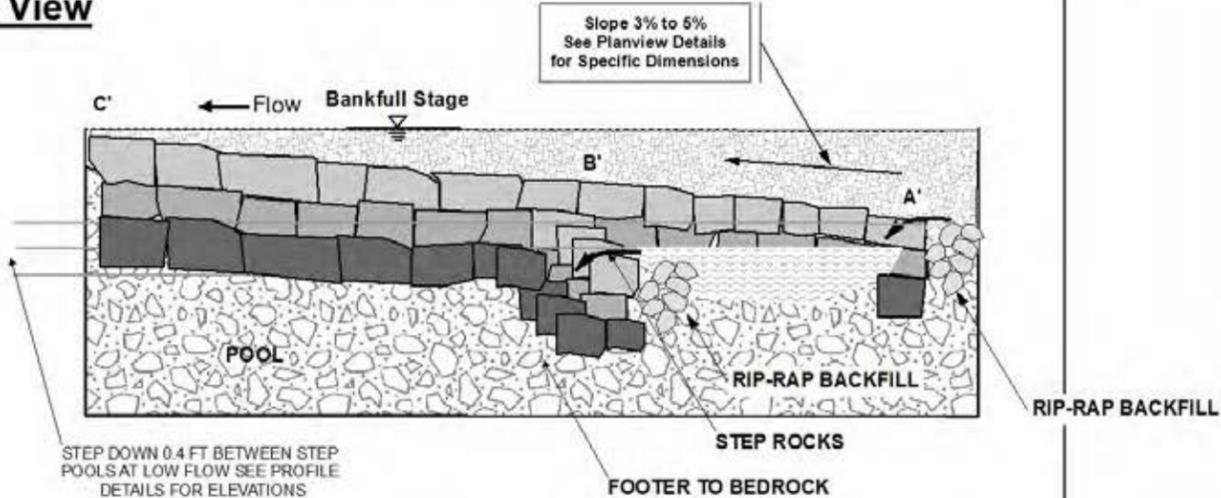
The exposed surface of the area between vane arm and streambank shall be filled with imbricated rock consisting of flat boulders and rip-rap.

Expect no less than three layers of stacked rock for each structure.

A splash apron constructed of rip-rap will be placed immediately downstream of the sill located opposite of the vane arm tie-in to prevent scour and under-mining of the sill.

Final invert elevations will be determined in the field.

Profile View



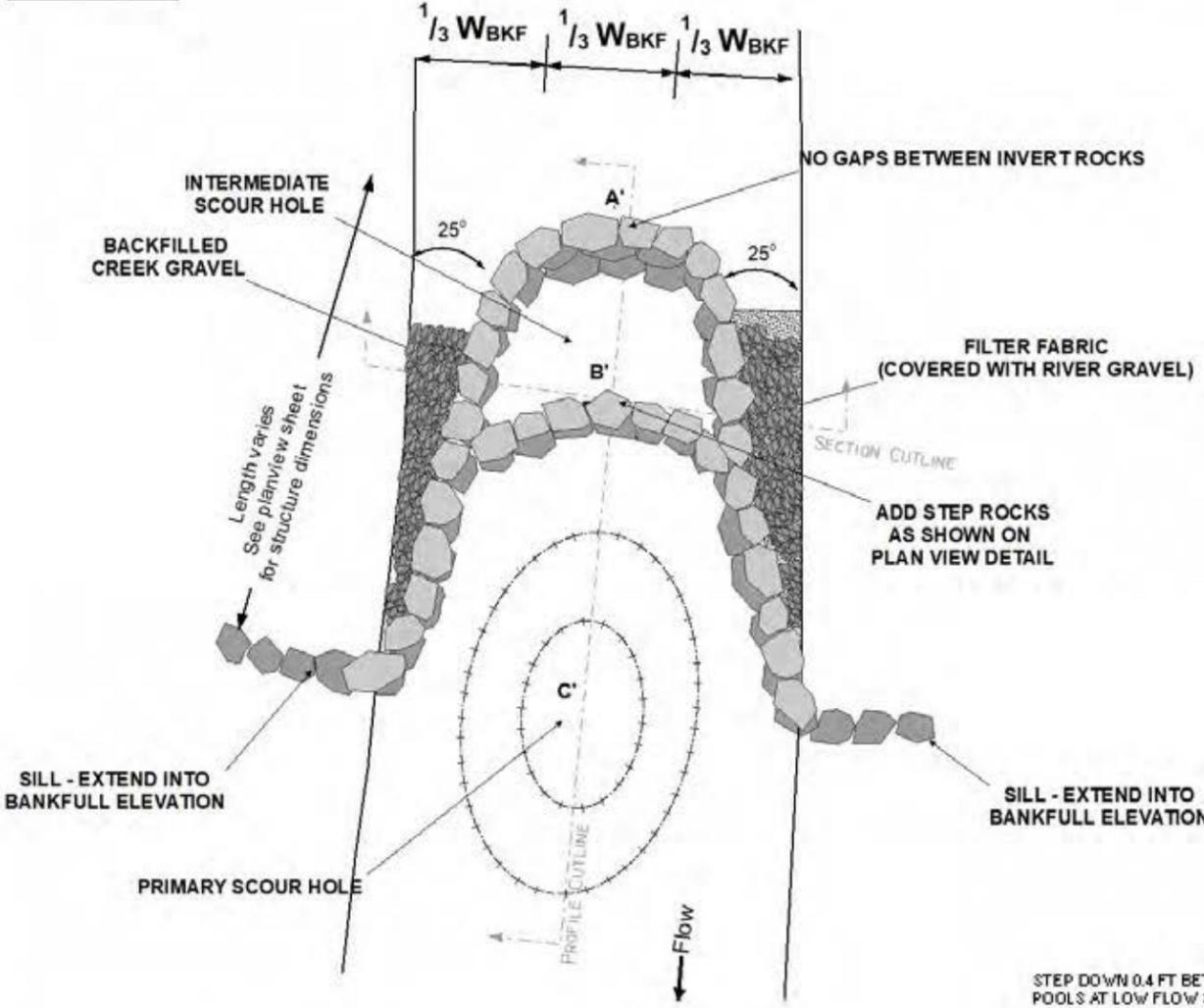
SEE TABLE OF STRUCTURE VARIABLES FOR INVERT AND TIE-IN ELEVATIONS

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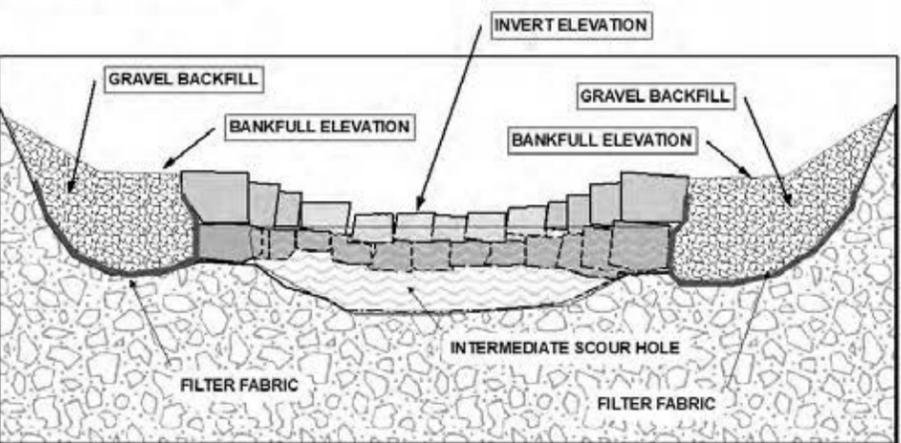
Cross Vane Construction Details

SCALE: NTS

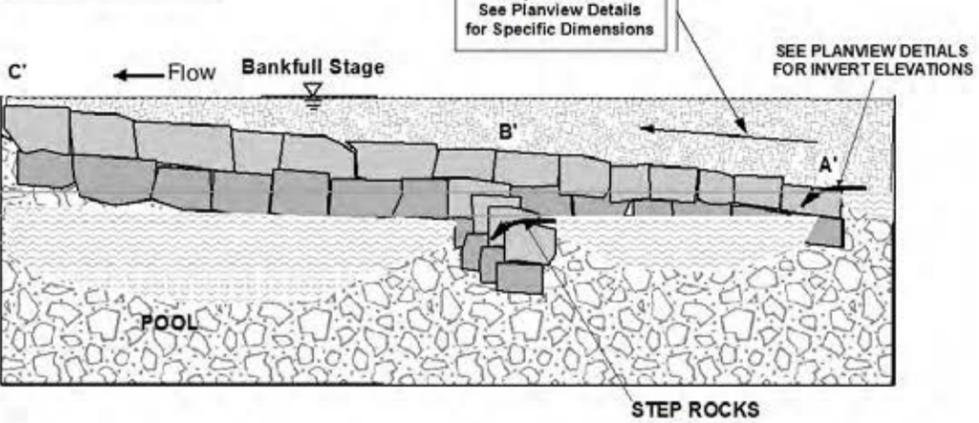
Plan View



Section View



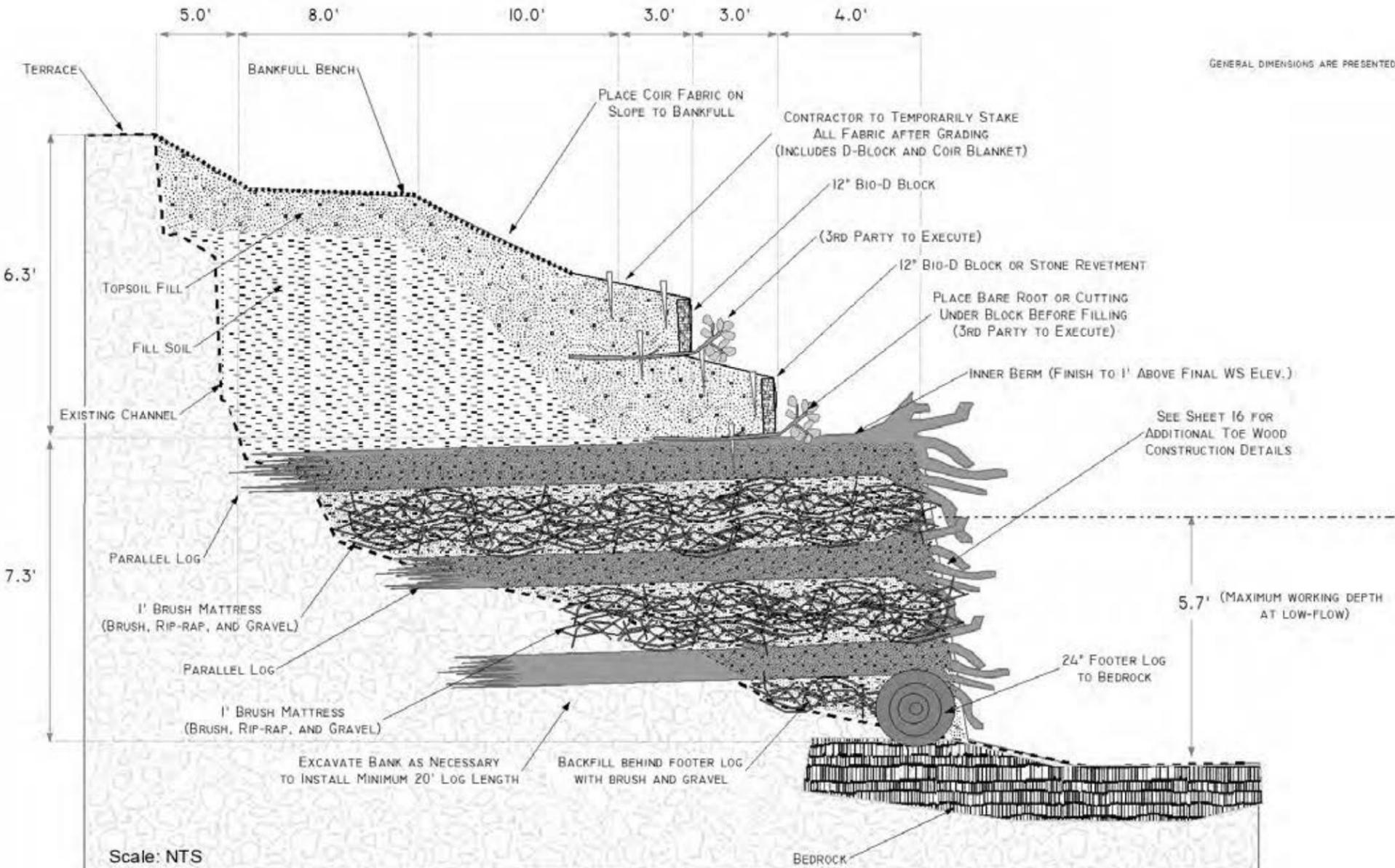
Profile View



- NOTES: Minimum rock size is 3' mean diameter or 2 tons.
- Fabric shall be draped into a depression excavated between vane arm and streambank then backfilled with gravel. Place filter fabric between streambank and outside edge of vane arms. Fabric should run up to 3/4 of the top rock height and to an equivalent elevation on the bank side.
- Fabric shall be draped into intermediate scour holes then back filled with river gravel mixture. Fabric shall be placed into depression and cut so that the fabric rises 3/4 of the height of all walls within the scour hole.
- Boulders in drawing are for illustration purposes only and should not be used as the basis for vane construction
- Boulders shall be stacked in a manner that achieves the desired vane arm slope with boulders forming a smooth plane along the top of the boulders.
- All boulders shall have direct contact to the adjacent boulder so that no gap between adjacent boulder is present.
- All boulders require footers to bedrock. Multiple footers will be required to reach bedrock.

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Deep Footer Toe Wood Construction Details

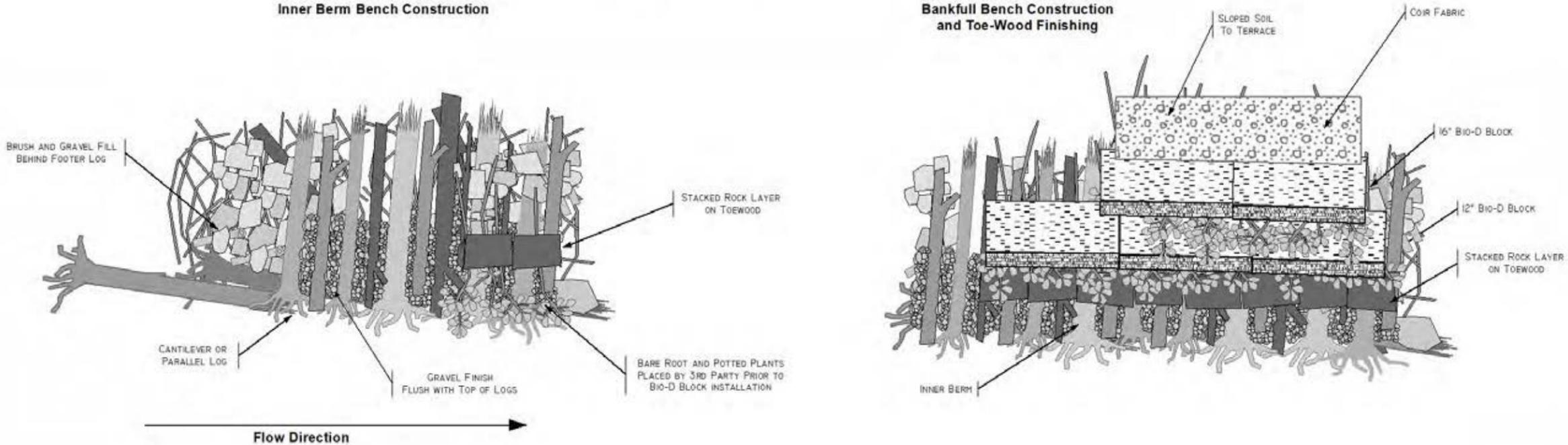


- Scale: NTS
- NOTES:
1. ENGINEER WILL ALIGN BIO-D BLOCKS ALONG LENGTH OF FINISHED BENCH
 2. A 3RD PARTY WILL INSTALL EMPTY BLOCKS FOR FILLING BY THE CONTRACTOR
 3. CONTRACTOR WILL WAIT TO FILL BLOCKS UNTIL 3RD PARTY HAS COMPLETED PRE-INSTALLATION
 4. CONTRACTOR WILL FILL BLOCKS TO 0.2' ABOVE FINISHED GRADE TO ALLOW FOR COMPACTION
 5. CONTRACTOR WILL INCORPORATE COMPOST INTO TOPSOIL VIA ALTERNATING PLACEMENT OF SOIL AND COMPOST
 6. CONTRACTOR WILL TEMPORARILY STAKE FABRIC OF BLOCKS AFTER BLOCKS HAVE BEEN FILLED
 7. CONTRACTOR WILL INSURE THAT BLOCKS ARE NOT OVERFILLED AND THAT THE BLOCKS REMAIN VERTICAL DURING THE BLOCK FILLING PROCESS. BLOCKS THAT ARE LEANING FORWARD WILL BE EMPTIED, RESET, AND REFILLED AT CONTRACTORS EXPENSE

 <p>WATERSHED CONSERVATION DESIGN/TEC CENTER</p>	Project: West Fork Stream Restoration at Brentwood Mountain		
	Sheet No. 15	City: Washington	Designed By: MVE
	Drawn By: JJH	Date: 11/30/2021	

SCALE: NTS

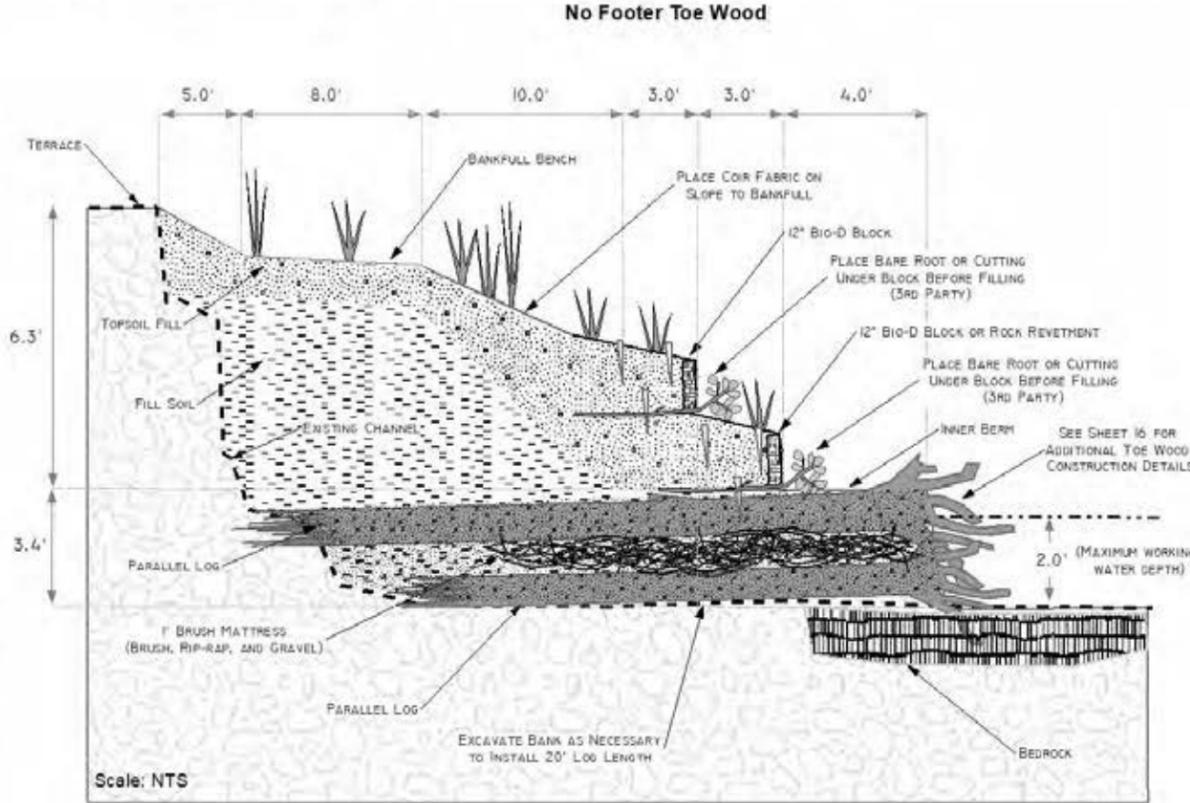
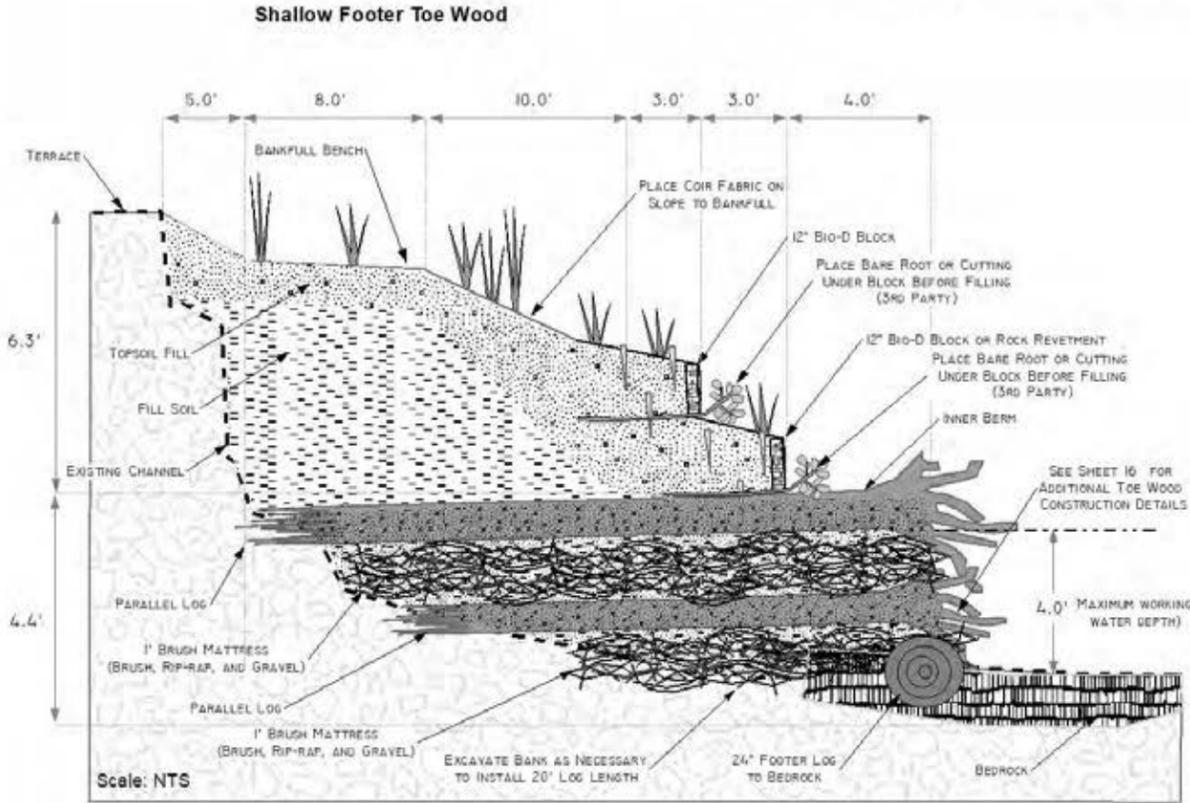
Toe Wood Bench - Plan View Detail



- Construction Notes:**
1. TOE WOOD IS CONSTRUCTED BY PLACING A FOOTER LOG ALONG THE EDGE OF THE PROPOSED BANK. THE BED MATERIAL SHALL BE EXCAVATED TO BEDROCK WHERE THE FOOTER LOG IS PLACED IN A MANNER THAT IS 10 DEGREES AWAY FROM PARALLEL OF THE PROPOSED BANK. THE ROOT WAD SHALL BE SCRAPED SO THAT THE ROOT WAD IS FLAT WHERE IT MAKES CONTACT WITH THE BEDROCK. BRUSH AND GRAVEL SHALL BE PLACED BEHIND THE FLARE OF LOG TO PREVENT GRAVEL FROM BEING SIPHONED OUT FROM BETWEEN THE LOG AND THE BEDROCK. THE AREA BEHIND THE FOOTER LOGS WILL THEN BE FILLED WITH GRAVEL AND BRUSH UP TO THE ELEVATION OF THE TOP OF THE FOOTER LOG.
 2. PARALLEL LOGS ARE THEN PLACED GENERALLY PERPENDICULAR TO THE FOOTER LOG, WITH THE NEAR CHANNEL END OF THE LOG ORIENTED SLIGHTLY IN THE UPSTREAM DIRECTION. PARALLEL LOGS BELOW THE WATER SURFACE SHALL BE SPACED NO CLOSER THAN 2 FEET APART. BRUSH AND LIMBS SHALL BE PLACED DENSELY IN-BETWEEN THE PARALLEL LOGS THEN BACKFILLED WITH GRAVEL AND COARSE ROCK UP TO THE ELEVATION OF THE CANTILEVER LOGS. LOGS SHALL NEVER BE PLACED IN A MANNER THAT THEY ARE PARALLEL TO THE STREAM FLOW.
 3. LIVE TREES SHALL BE INCORPORATED INTO THE TOE WOOD BENCH BY TRANSPLANTING TREES FROM ADJACENT GRAVEL BARS INTO THE BOULDER, WOOD, AND GRAVEL MATRIX. WHEN INCORPORATING THE LIVE TREES, SOME PORTION OF THE TREE SHALL REMAIN EXPOSED ABOVE WATER SO PHOTOSYNTHESIS CAN TAKE PLACE ALLOWING TREES TO GROW AND PROTECT THE BENCH. THE LIVE TREES SHOULD BE HARVESTED USING THE EXCAVATOR AND PLACED BY HAND TO ENSURE ADEQUATE INCORPORATION INTO THE BENCH STRUCTURE.
 4. WHERE DEEP BEDROCK IS ENCOUNTERED, A LAYER OF BRUSH AND LIMBS SHALL BE PLACED ON TOP OF THE FIRST LAYER OF CANTILEVERED LOGS TO CREATE A LIFT OF APPROXIMATELY ONE FOOT. THE LIMBS AND BRUSH SHALL BE PLACED SO THAT THEY FORM OBLIQUE ANGLES WITH THE FIRST LAYER OF LOGS. VOIDS SHALL BE FILLED WITH GRAVEL AS THE LAYER IS CONSTRUCTED IN LIFTS. SEE BEDROCK AND REQUIRED TOE WOOD BENCH HEIGHT DETAILS ON THE SECTION DRAWINGS.
 5. THE TOE WOOD BENCH SHALL BE BUILT TO THE ELEVATION SHOWN ON THE CROSS-SECTION DETAIL. THE WOOD AND ROCK SHALL EXTEND TOWARDS THE EXISTING BANK AT LEAST 20 FEET OR UNTIL THE BANK IS REACHED. ALL VOIDS MUST BE BACKFILLED WITH GRAVEL AND COARSE FILL AS THE BENCH IS CONSTRUCTED. GRAVEL FILL PLACED INTO THE TOE WOOD STRUCTURE SHALL BE HEAVILY WASHED INTO THE TOE WOOD AS EACH LIFT IS BUILT.
 6. THE FINAL LAYER OF PARALLEL LOGS SHALL BE PLACED SO THAT THE GAPS BETWEEN LOGS ARE NO MORE THAN ONE FOOT (1') AND NOT LESS THAN ONE-HALF FOOT (0.5')
 7. THE TOP LOGS SHALL BE PLACED SO THAT THE PORTION OF THE ROOT BALL FLARE THAT IS THE LARGEST AND PROJECTS FURTHEST FROM THE STEM OF THE TREE SHALL BE ORIENTED TOWARDS THE BOTTOM OF THE STREAM CHANNEL
 8. THE FINISHED SURFACE OF THE TOE WOOD BENCH SHALL BE FINISHED SO THAT THE LOGS THAT COMPOSE THE FINAL LAYER OF THE BENCH ARE BARELY OBTSCURED BY FINISH GRAVEL. NO GRAVEL SHALL BE PLACED OVER THE FINAL LAYER OF WOOD.
 9. PRIOR TO BEGINNING INSTALLATION OF THE BIO-D BLOCK LIFTS A 3RD PARTY WILL PLACE BARE ROOTS AND POTTED PLANTS BEFORE LAYING OUT AND SECURING THE BIO-D BLOCKS. SEE BIO-D BLOCK INSTALLATION DETAILS ON SHEET 18 FOR MORE DETAILS.
 10. TOPSOIL WILL BE PLACED TO CREATE A TRANSITION SLOPE FROM THE END OF THE BANKFULL BENCH UP TO THE EXISTING BANK TERRACE AS SHOWN IN THE DRAWINGS.
 11. CONTRACTOR IS RESPONSIBLE FOR INCORPORATING COMPOST AND SMOOTHLY GRADING SOIL PLACED TO CREATE SLOPED STREAMBANKS.
 12. EROSION CONTROL FABRIC WILL BE INSTALLED BY A 3RD PARTY ON ALL AREAS OF THE CONSTRUCTED BENCH WHERE SOIL MATTRESSES ARE NOT PRESENT.

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		Drawn By: JH/MVE	Date: 11/30/2021

Toe Wood Construction Details



NOTES:

1. DIMENSIONS ABOVE ARE TYPICALS. SEE XS DETAIL SHEETS FOR SPECIFIC DIMENSION DETAILS.
2. ENGINEER WILL ALIGN BIO-D BLOCKS ALONG LENGTH OF FINISHED BENCH
3. A 3RD PARTY WILL INSTALL EMPTY BLOCKS FOR FILLING BY THE CONTRACTOR
4. CONTRACTOR WILL WAIT TO FILL BLOCKS UNTIL 3RD PARTY HAS COMPLETED PRE-INSTALLATION
5. CONTRACTOR WILL FILL BLOCKS TO 0.2' ABOVE FINISHED GRADE TO ALLOW FOR COMPACTION
6. CONTRACTOR WILL INCORPORATE COMPOST INTO TOPSOIL VIA ALTERNATING PLACEMENT OF SOIL AND COMPOST
7. CONTRACTOR WILL TEMPORARILY STAKE FABRIC OF BLOCKS AFTER BLOCKS HAVE BEEN FILLED
8. CONTRACTOR WILL INSURE THAT BLOCKS ARE NOT OVERFILLED AND THAT THE BLOCKS REMAIN VERTICAL DURING THE BLOCK FILLING PROCESS. BLOCKS THAT ARE LEANING FORWARD WILL BE EMPTIED, RESET, AND REFILLED AT CONTRACTORS EXPENSE

 WATERSHED CONSERVATION DESIGN/CON CENTER	Project: West Fork Stream Restoration at Brentwood Mountain		
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	Drawn By: JJH/MVE	Date: 11/30/2021	

Construction Details

BioD-Block Assembly and Installation

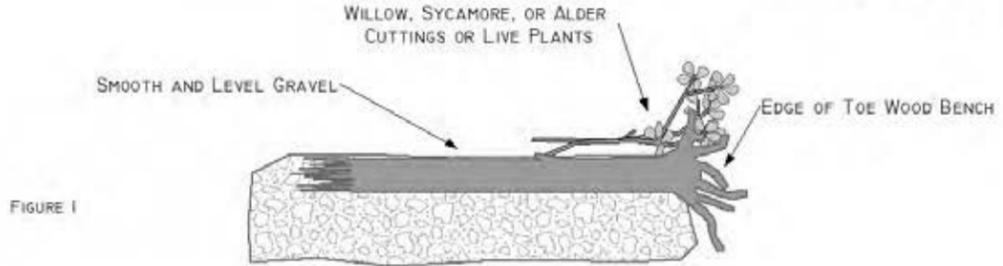


FIGURE 1

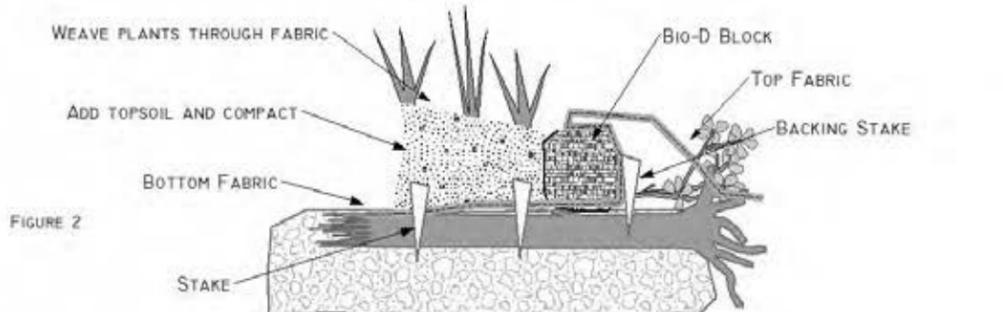


FIGURE 2

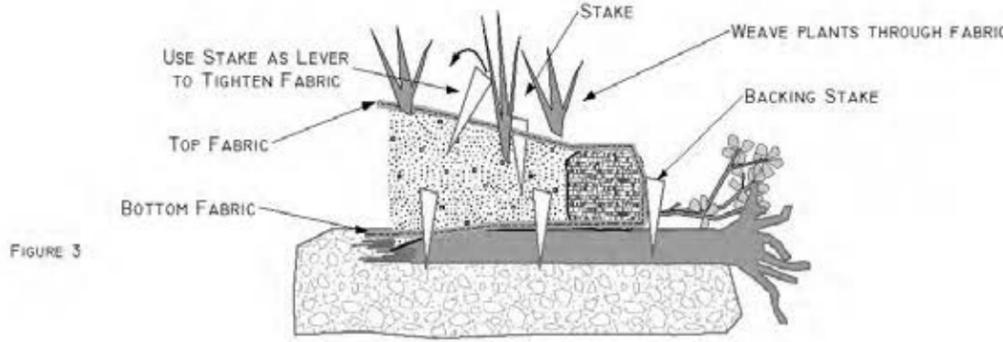


FIGURE 3

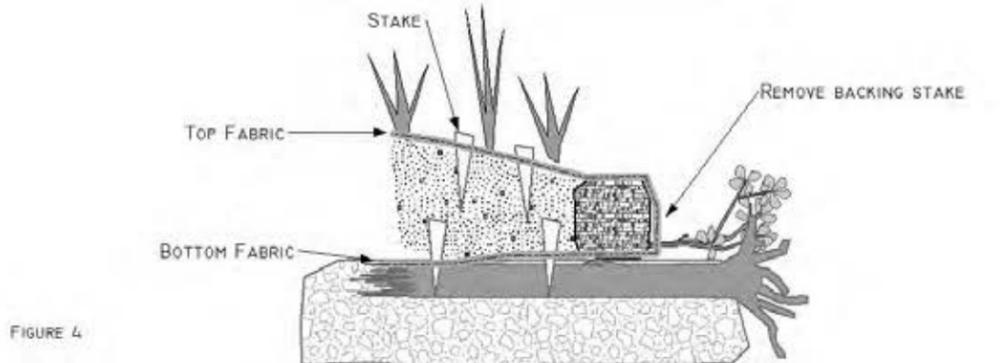


FIGURE 4

Contractor's Responsibility

The contractor will be responsible for completing a portion of the BioD-Block installation process, while coordinating with a 3rd party who will place and secure blocks for filling. The illustrations shown present the general installation details for installing BioD-Blocks. The work to be performed by the contractor for the "Installation of Soil Mattress" bid item is as follows:

1. The engineer will stake out and align the blocks
2. A third party will be onsite at the time of BioD-Block installation and will place and secure the BioD-Blocks and pre-plant them in preparation for filling.
3. The contractor will fill each block with a mixture of top soil and compost to a height of 0.2' above the finish grade, to allow for compaction and subsidence. Top soil and compost shall be well mixed within the filled layer.
4. During the fill process, BioD-Blocks shall remain vertically oriented and will need to be reset if they are disturbed.
5. Soil near the streamward edge of the block will need to be compacted manually using a hand tamper or similar tool. Slopes will be manually raked and smoothed to their finish elevations. Large clumps of soil shall be discarded on the terrace.
6. Contractor will pull back top fabric and temporarily stake it down. Temporary staking requires at least 2 stakes per side seam and 4 stakes along the back edge of the fabric. Stakes shall be driven a minimum of 1' deep into the ground. 18" hardwood stakes will be used to secure the fabric to the ground.
7. While the third party is installing blocks in preparation for filling, the contractor will need to wait before being able to fill and grade the soil lift.

Additional details of the entire BioD-Block installation process are presented below.

BioD-Block Assembly Details

1. Soil mattress will be constructed using BioD-Blocks, a coir fiber block system that consists of a densely packed mattress coir fiber block attached to a bristle coir woven fabric. This layer provides a 2 to 5 year structure that will allow plants to root and mature.
2. Before installation, the toe wood bench should be cleaned and leveled with river gravel. Lay willow, sycamore, or other live plants/cutting on finished sub-grade (Figure 1).
3. The engineer on site will align the backing stakes. BioD-Blocks should be laid out along the backing stakes beginning at the upstream end. Untie the block fabric, save the coir ties, and spread the bottom fabric. Place additional blocks on the bench and untie them. Join the BioD-Block by inserting the male end of the second block to female end of the first block.
4. Tie the BioD-Block fabric together by weaving the saved coir ties through the coir netting. At minimum, one tie shall be placed on the front face and top edge of the block. Additional ties can be used to join the back of the block.
5. Anchor the bottom fabric to the ground using wooden 1" x 3" x 18" stakes. The row of stakes placed closest to the block shall be no more than 3" from the BioD-Block and shall be placed at the fabric seams and every 2' along the length of the blocks. A second row of stakes shall be placed at the back edge of the fabric. These stakes shall be placed at the fabric seams and every 3-4' along the length of the block (Figure 2). Care should be taken to avoid damaging plants placed in step 2 when staking in the fabric.
6. Fill soil up to the height of the coir block and mechanically compact the soil. Add compost after compacting so that the finish level is slightly higher than the height of the coir block (Figure 2).
7. Plant bareroot seedlings and grass plugs into the soil/compost mixture. Apply native and nursery grass seed.
8. Pull back the top fabric and anchor it with wooden 1" x 3" x 18" stakes. Use the stakes to create leverage to pull fabric tight to the ground (Figure 3). This first row of stakes should be placed 1.5' from the streamward edge of the blocks. While staking the top fabric, carefully weave bareroot stems through openings in the fabric (Figure 4).
9. Place additional stakes in a staggered pattern between the front and back of the BioD-block to hold the fabric in place.
10. Anchor the back of the block along the seams and every 3-4' while using the same technique as described in step 8. If additional fabric is being installed up-slope of the BioD-Block, do not anchor the back edge of the fabric until the other fabric has been overlapped and installed. Approximate placement of stakes can be seen in Figure 5.

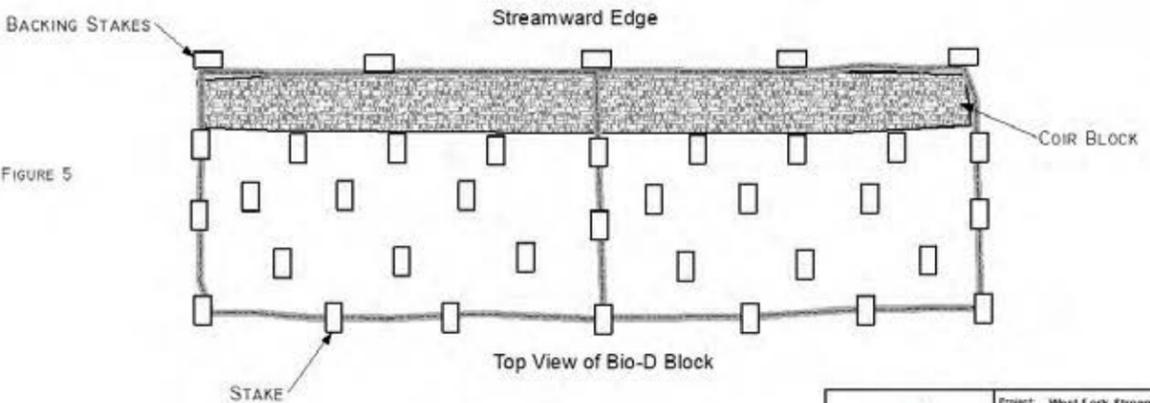
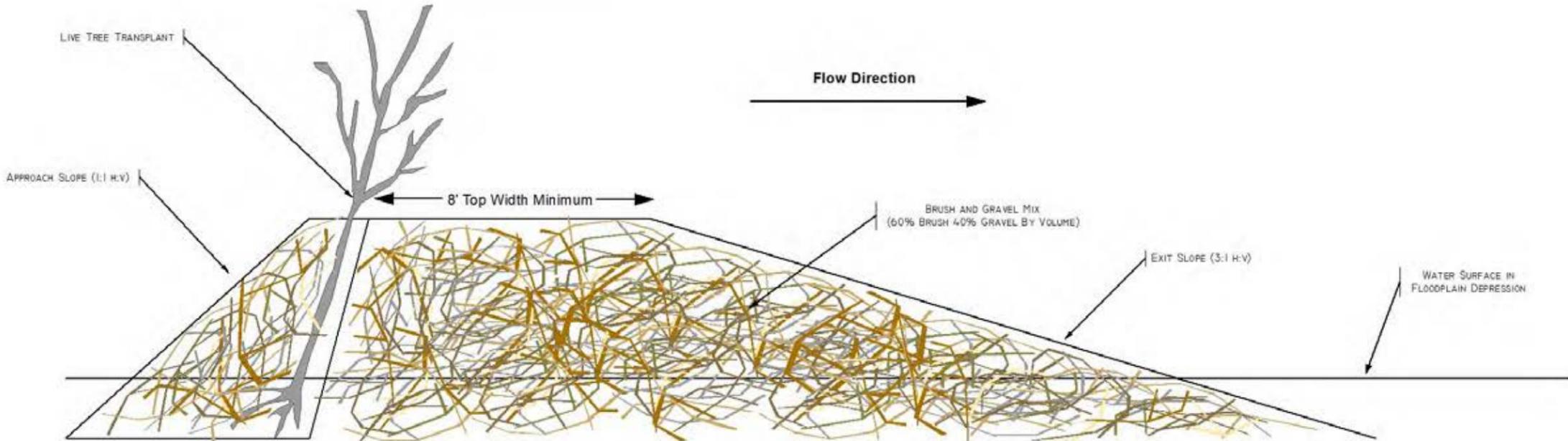


FIGURE 5

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		Drawn By: JJH/MVE	Date: 11/30/2021

SCALE: NTS

Floodplain Depression and Live Tree Sill - Construction Details

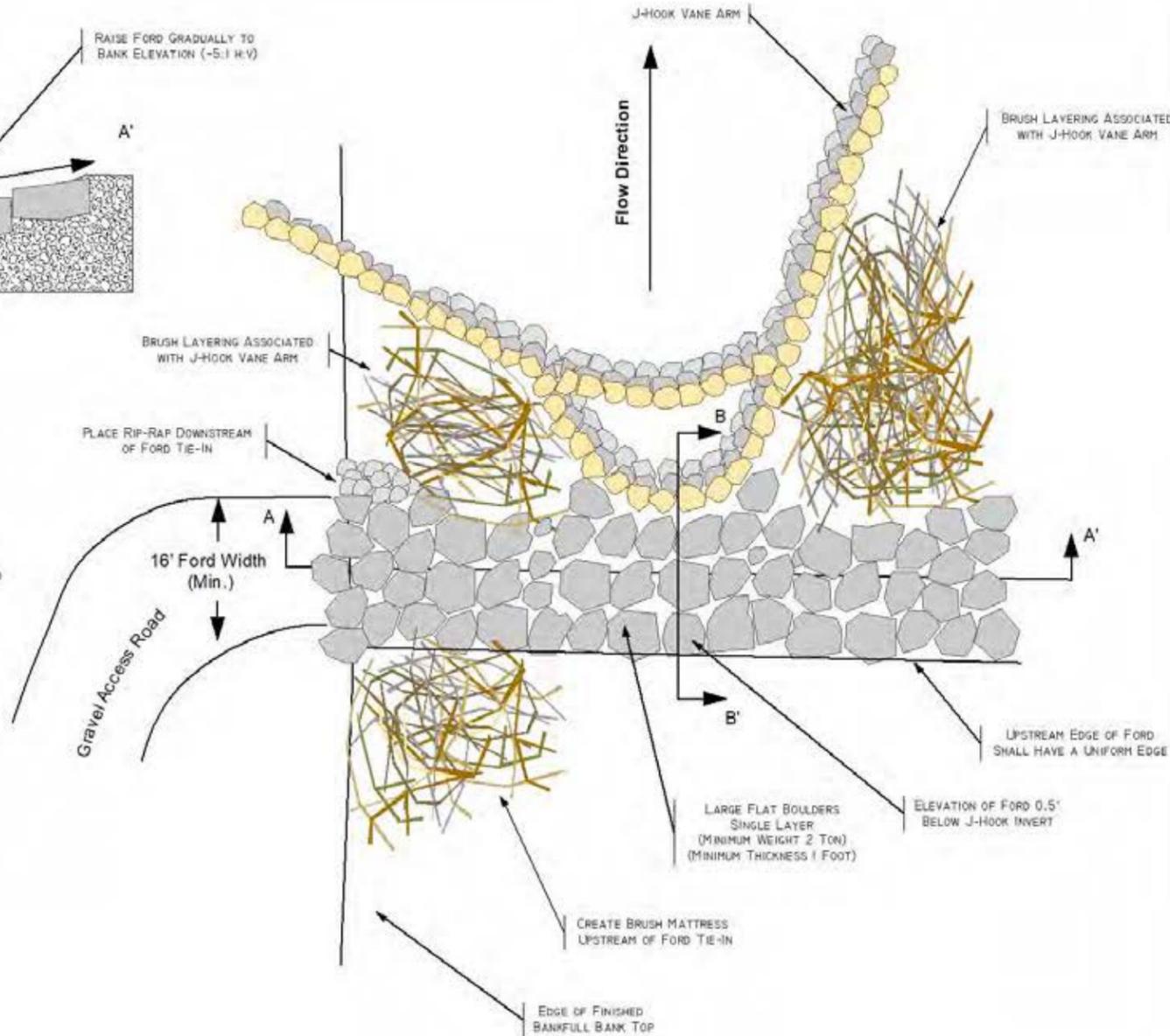
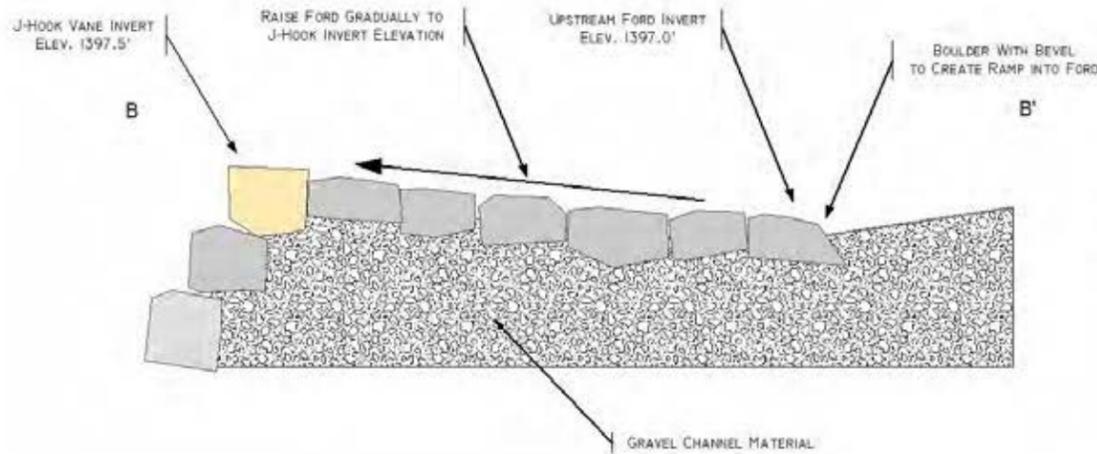
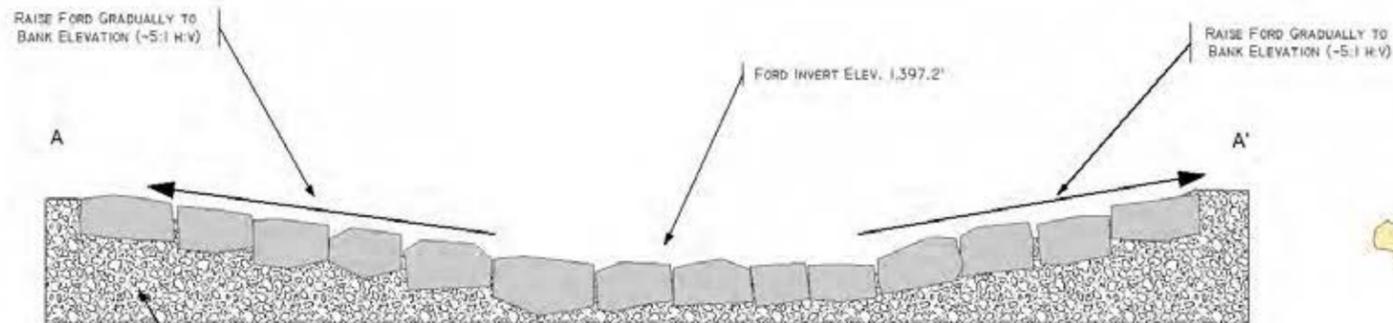


- Construction Notes:**
1. THE LIVE TREE AND BRUSH FLOODPLAIN DEPRESSION SILL IS DESIGNED TO PREVENT THE ACTIVE CHANNEL FROM TAKING A PREFERENTIAL PATH THROUGH THE FORMER CHANNEL. THE LIVE TREE SILLS ARE DESIGNED TO PROTECT THE CORE OF THE BRUSH SILL AND TO INDUCE DEPOSITION OF FINE PARTICLES FROM THE WATER COLUMN BY REDUCING WATER VELOCITIES.
 2. THE PLUG SHALL BE CONSTRUCTED WITH A MIXTURE OF GRAVEL AND BRUSH. 60% BY VOLUME SHOULD CONSIST OF BRUSH. LOGS AND OTHER WOODY DEBRIS CAN BE USED FOR SILL CONSTRUCTION.
 3. THE CORE OF THE PLUG SHALL BE NO LESS THAN 8' WIDE AT THE TOP, MATCH THE BANKFULL ELEVATION AND SHALL EXTEND TO BEDROCK.
 4. THE APPROACH (UPSTREAM SLOPE OF PLUG) SHALL BE CONSTRUCTED AFTER LIVE TREE SILLS HAVE BEEN PLACED.
 5. LIVE TREES SHALL BE PLACED ALONG THE UPSTREAM SIDE OF THE PLUG CORE AND A SLIGHT ANGLE IN THE DOWNSTREAM DIRECTION.
 6. SPACING OF THE LIVE TREES SHALL BE NO LESS THAN 3 FEET UNLESS APPROVED BY THE ENGINEER.
 7. LIVE TREES SHALL BE EXCAVATED FROM THE DESIGNATED AREA AND PLACED SO THAT THE ROOTS ARE PLACED WITHIN 1' OF THE SUBSURFACE WATER.
 8. A COMBINATION OF GRAVEL AND BRUSH SHALL BE USED TO CREATE A 1:1 SLOPE UPSTREAM OF THE PLACED LIVE TREES.
 9. THE EXIT SLOPE SHALL BE CONSTRUCTED OF BRUSH AND GRAVEL AND HAVE A SLOPE OF 3:1 H:V.

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SCALE: NTS

Low-Water Ford - Construction Details

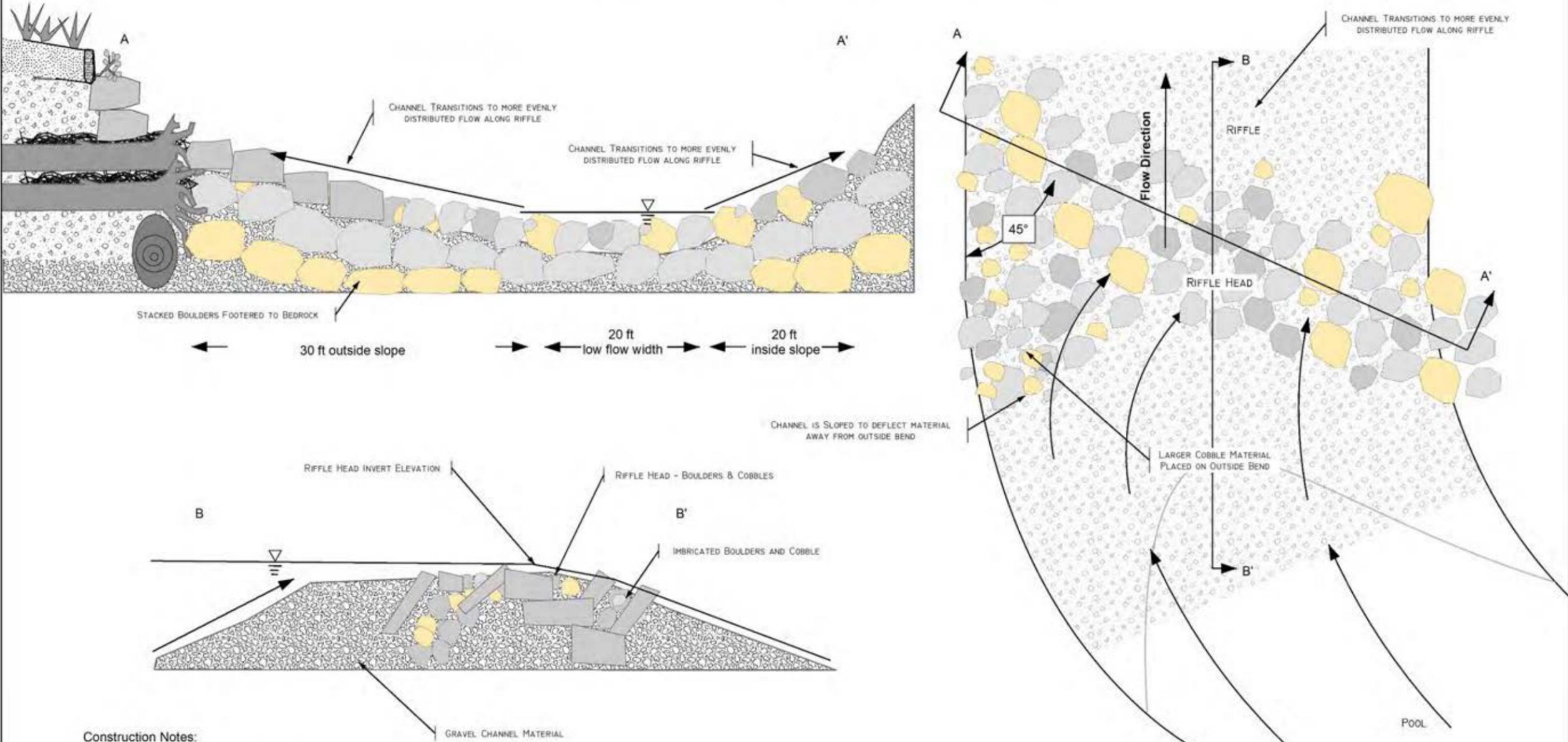


- Construction Notes:**
1. ADJACENT BOULDERS SHALL BE NO MORE THE 0.2' DIFFERENTIAL IN ELEVATION.
 2. SAW CUT BOULDERS AS NEEDED TO ACHIEVE TIGHTEST FIT.
 3. WASH RIVER GRAVEL INBETWEEN VOIDS OF ADJACENT BOULDERS
 4. BOULDERS SHOWN ARE NOT DRAWN TO SCALE.
 5. CONSTRUCTION ELEMENTS ASSOCIATED WITH THE J-HOOK ROCK VANE ARE INDEPENDENT OF THE LOW-WATER FORD CONSTRUCTION AND ARE PAID AS A SEPARATE BID LINE ITEM.

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	Drawn By: JJH/MVE	Date: 11/30/2021	

SCALE: NTS

Sloped Glide - Construction Details



- Construction Notes:**
1. BOULDERS WILL BE 2 TO 4 TON MAXIMUM WEIGHT
 2. WATER FLOW INVERT WILL BE ESTABLISHED 2/3 OF CHANNEL WIDTH AWAY FROM OUTSIDE BEND (A)
 3. THE OUTER BEND (A') WILL BE 0.5 TO 1.0 FEET HIGHER THAN THE INSIDE BEND (A)
 4. ALL RIFFLE HEAD ELEVATION STRUCTURES WILL BE FOOTERED TO BEDROCK UNLESS SPECIES BY THE ENGINEER IN THE FIELD
 5. ALL BOULDERS WILL BE INSTALLED WITH A SLIGHT BACKSLOPE IN THE UPSTREAM DIRECTION
 6. ALL BOULDERS WILL HAVE DIRECT CONTACT TO THE ADJACENT BOULDER SO THAT NO GAP IS PRESENT

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	Drawn By: JJH/MVE	Designed By: MVE
		Date: 11/30/2022

West Fork Restoration at Brentwood Mountain
Attachment 8. As Built Monitoring Comparison



7/1/2022

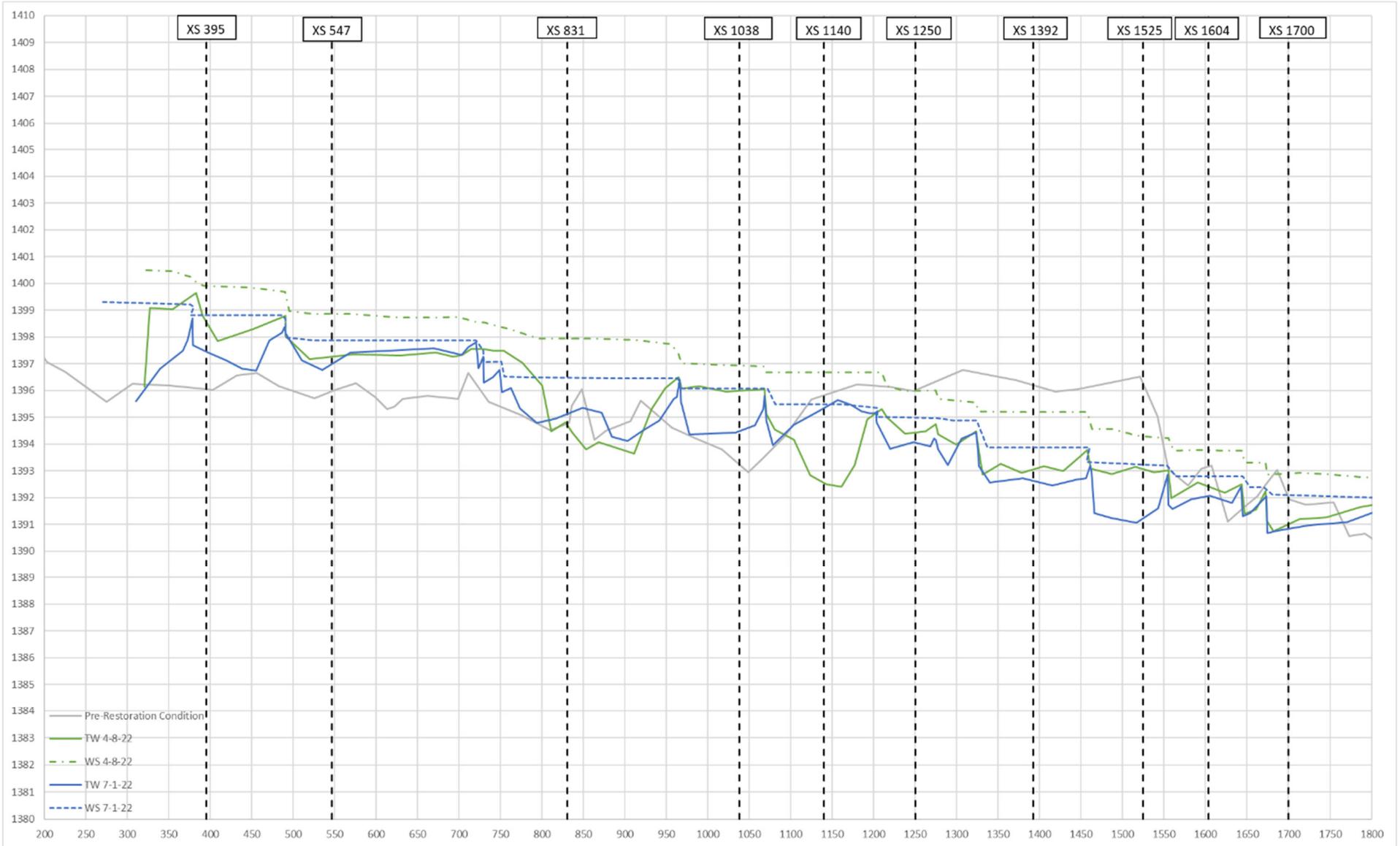


WATERSHED CONSERVATION
RESOURCE CENTER

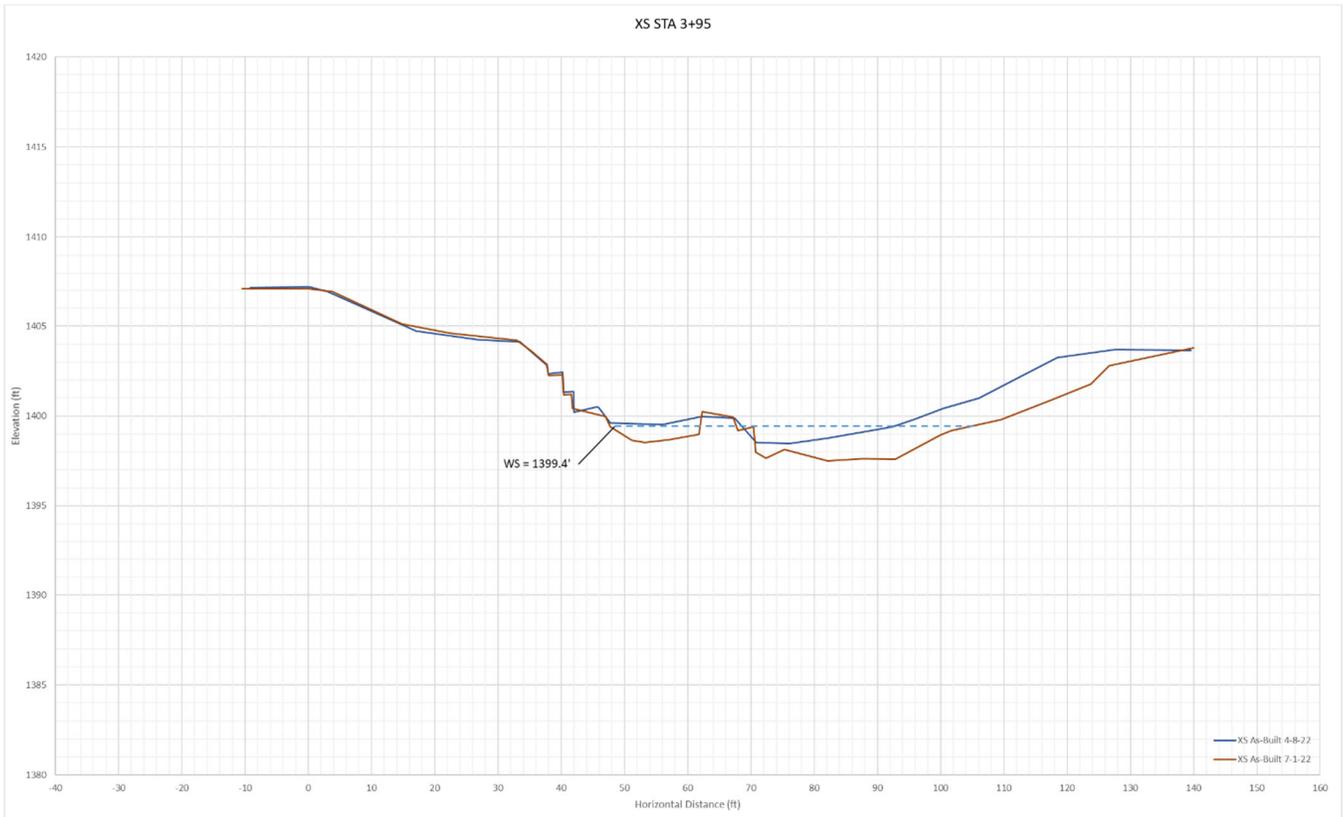
Attachment 8. As Built Monitoring Comparison



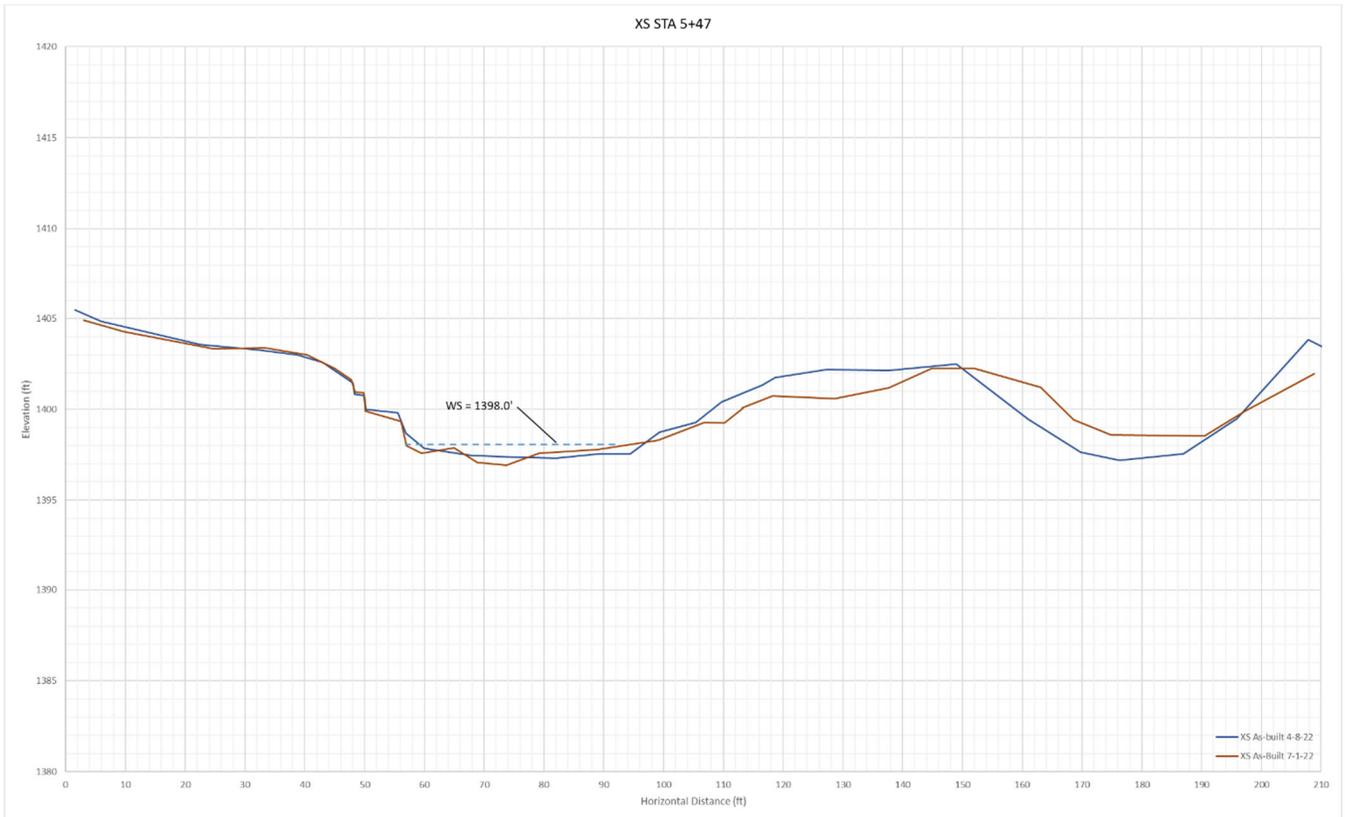
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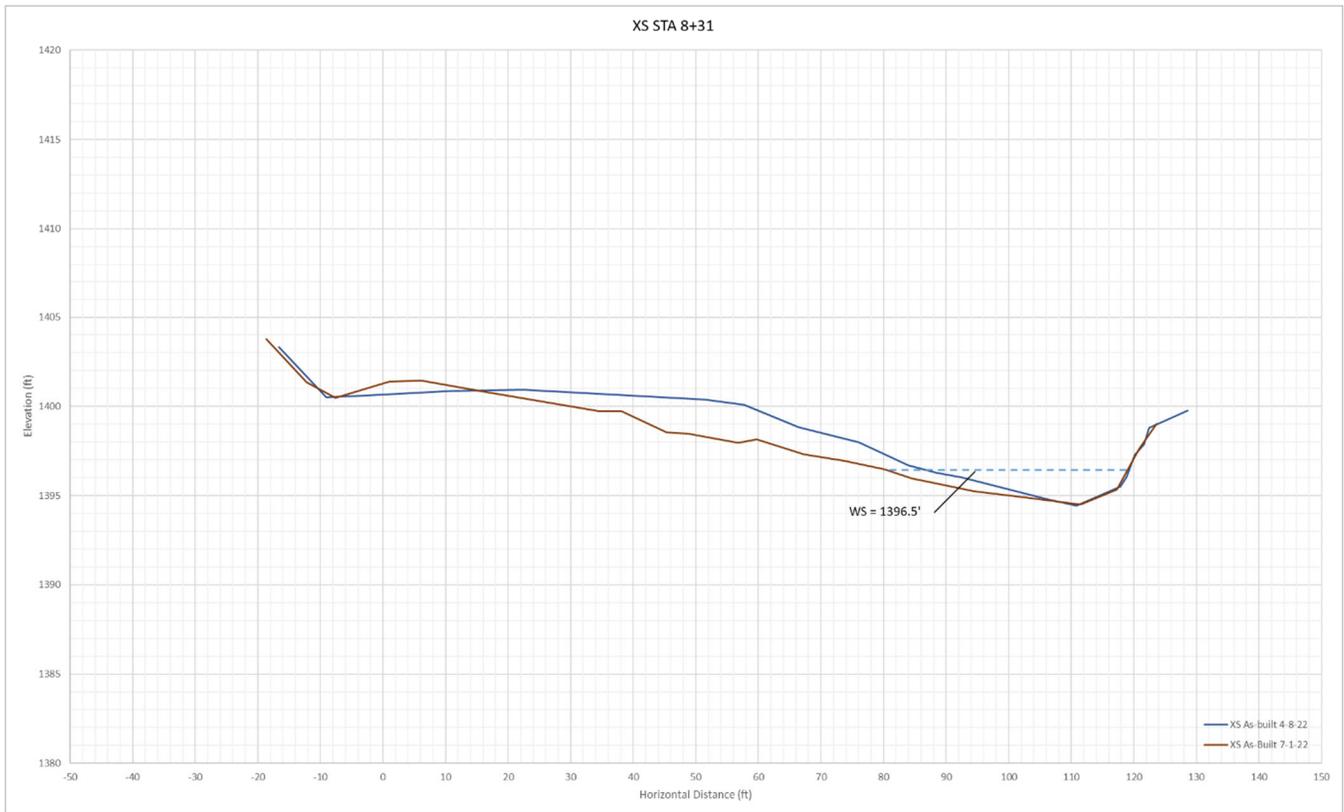
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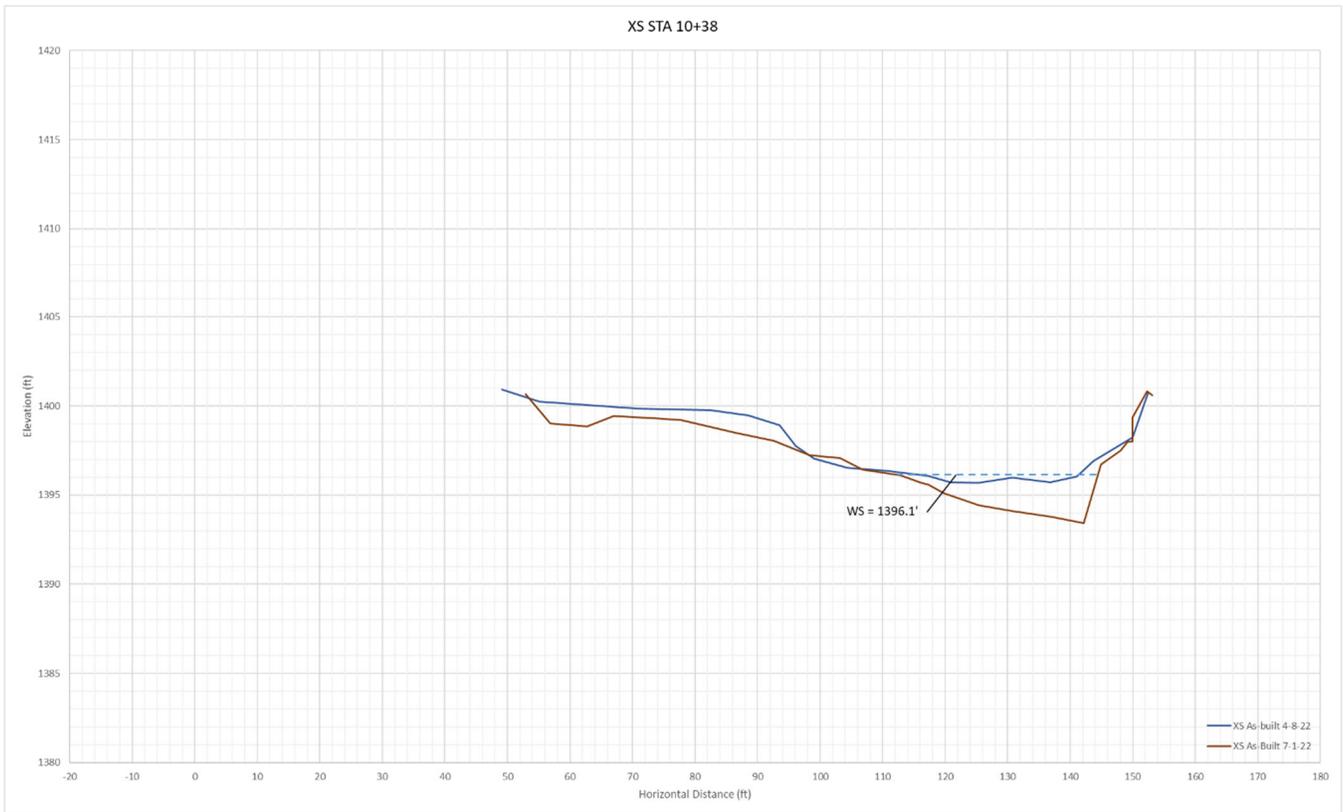
Attachment 8. As Built Monitoring Comparison



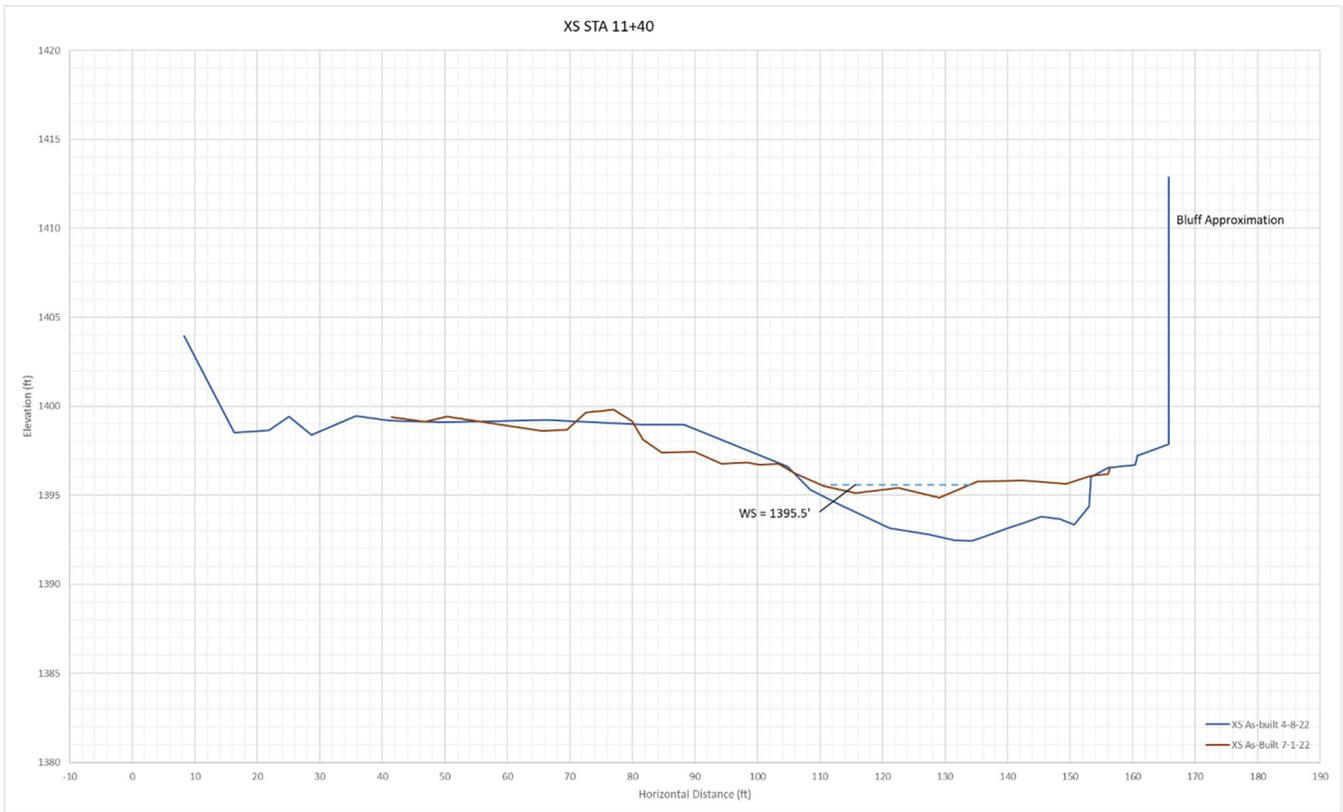
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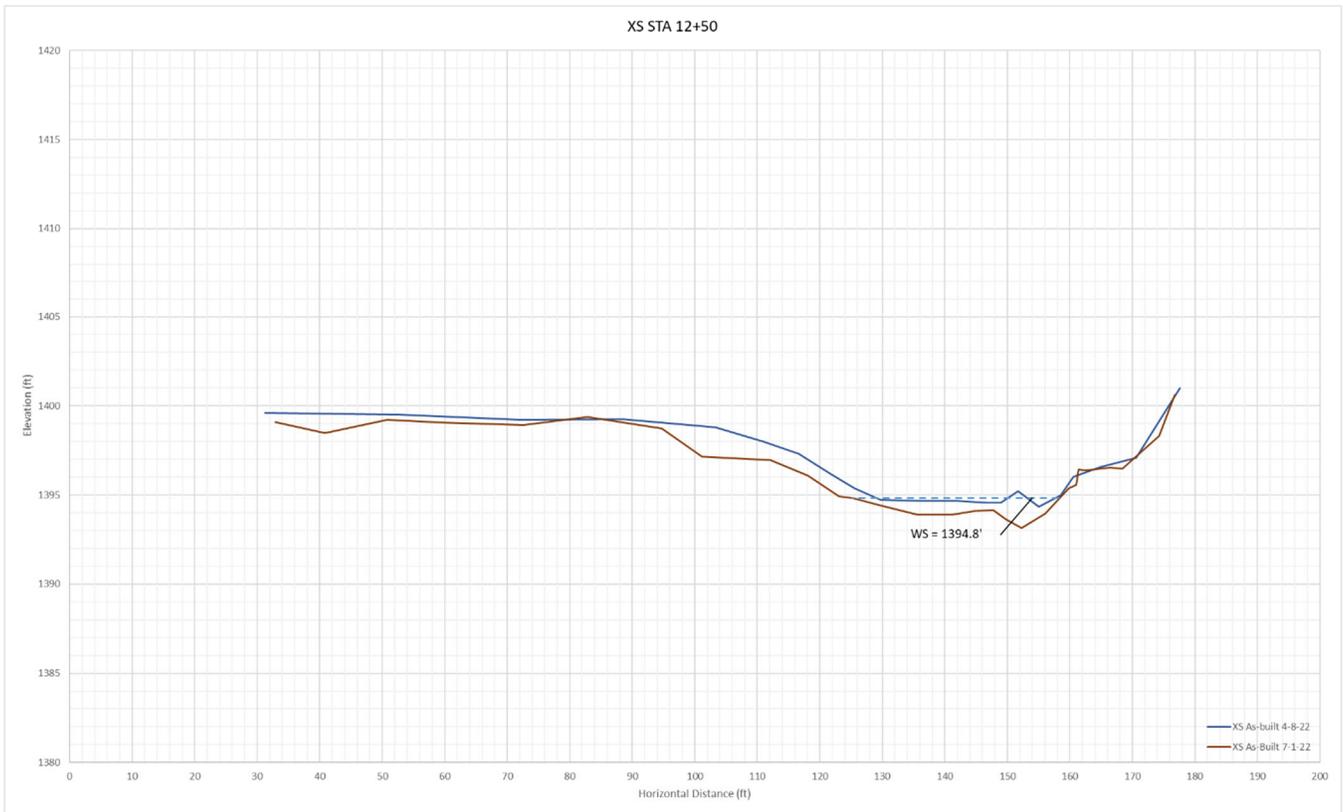
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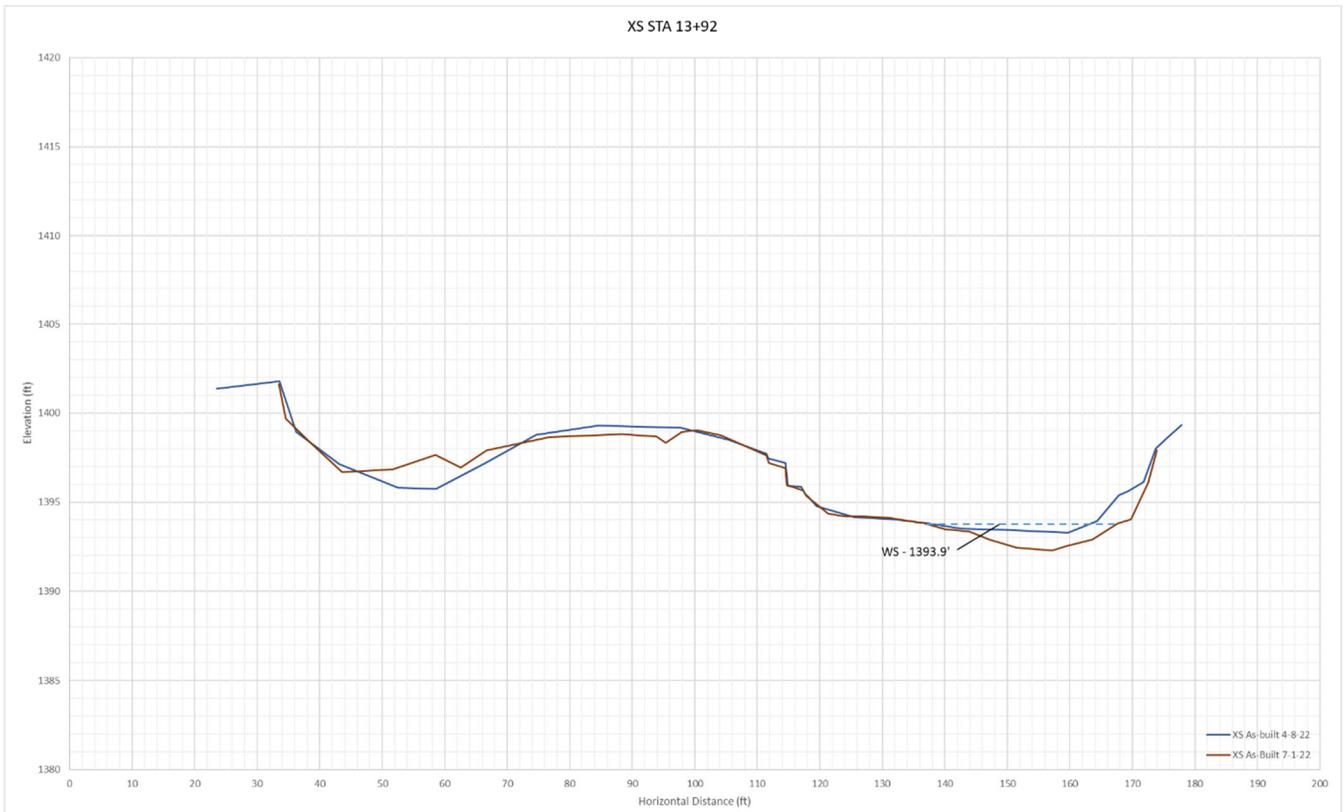
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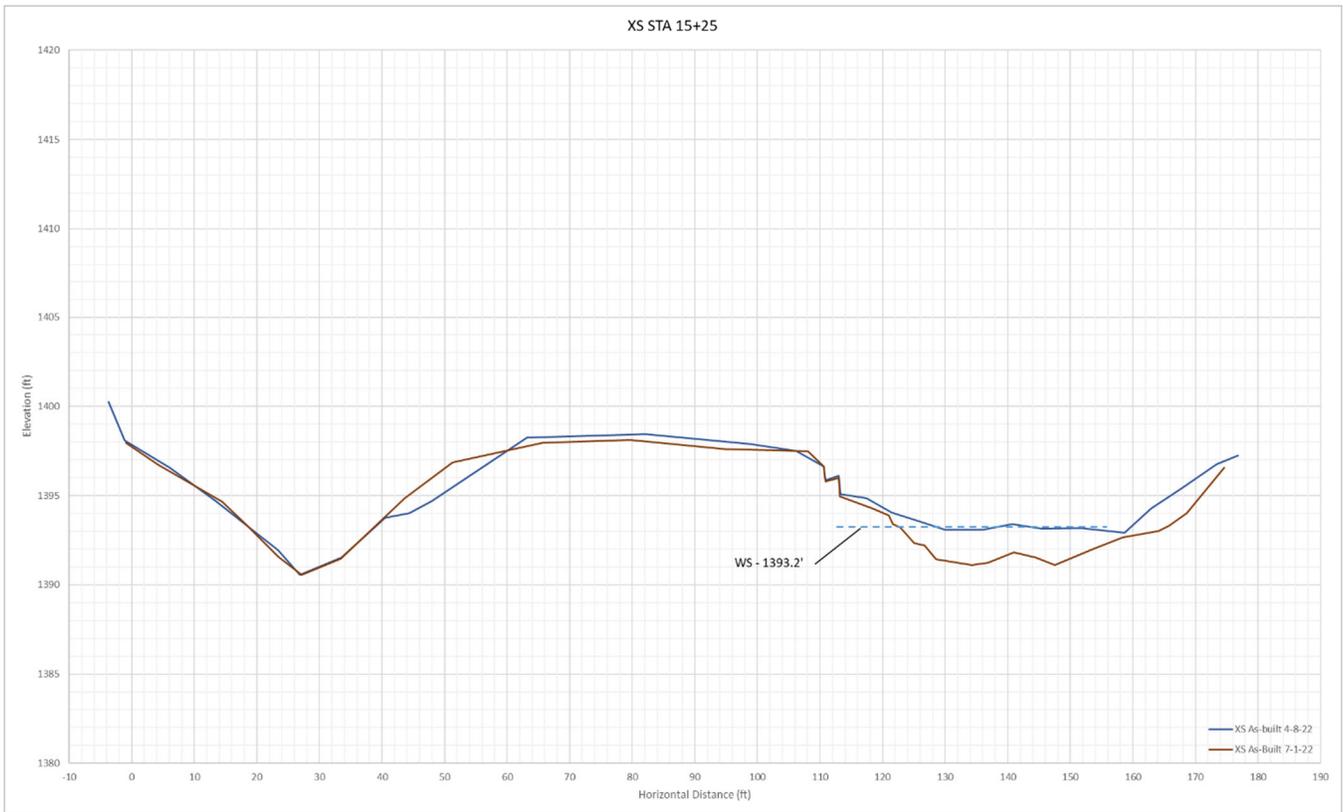
Attachment 8. As Built Monitoring Comparison



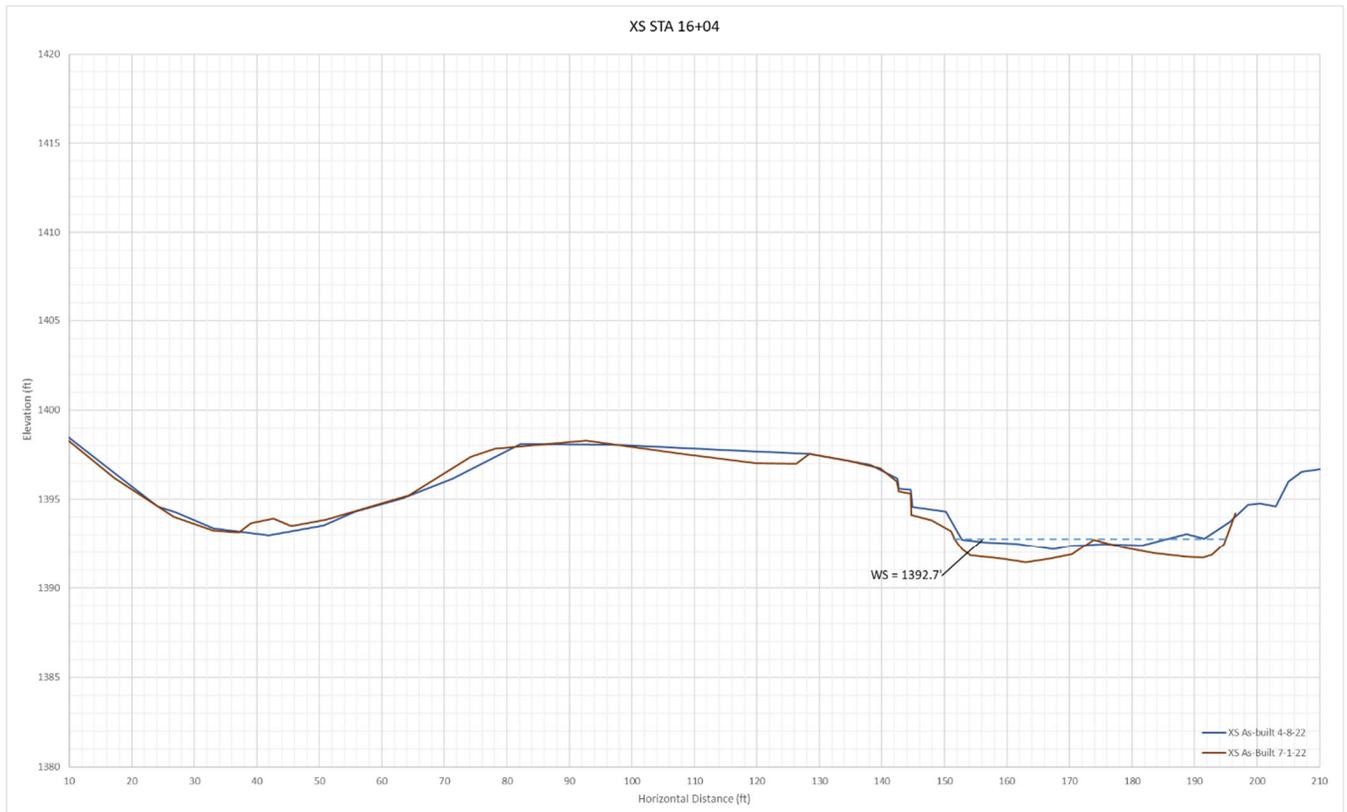
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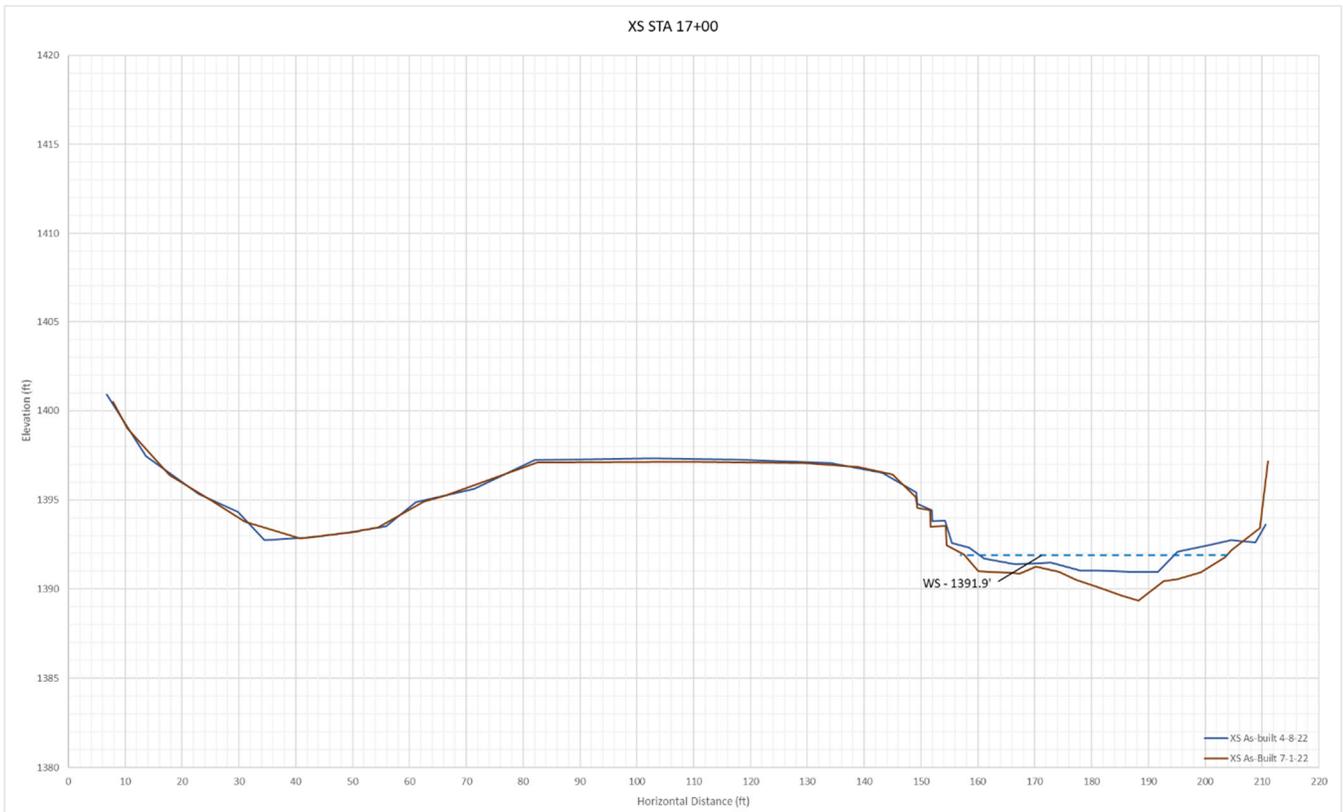
Attachment 8. As Built Monitoring Comparison



Attachment 8. As Built Monitoring Comparison



Attachment 8. As Built Monitoring Comparison



WEST FORK WHITE RIVER RESTORATION AT BRENTWOOD MOUNTAIN

The Watershed Conservation Resource Center (WCRC) worked with project partners to restore river channel stability along a reach of the West Fork White River (WFWR) near Brentwood, AR. A detailed assessment of the site was conducted and a design was developed using the natural channel design approach. The project was completed in April of 2022. Monitoring of the project site before and after restoration indicates that the project will reduce sediment loads by 2,200 tons/yr and phosphorus and nitrogen loads by 1,100 lb/yr and 1,500 lb/yr, respectively. The project was funded by an EPA Section 319(h) grant administered by the Natural Resources Division - Arkansas Dept. of Agriculture. Matching funds were provided by Beaver Watershed Alliance (BWA) and Beaver Water District (BWD).

Project Partners

Natural Resources Division—Arkansas
Department of Agriculture
U.S. Environmental Protection Agency
Watershed Conservation Resource Center
Beaver Watershed Alliance
Beaver Water District

Background: The WFWR is a major tributary of Beaver Lake, which is the primary drinking water source for over 400,000 Northwest Arkansas residents. Since, 1998, the WFWR has been on the 303(d) list of impaired water bodies with the Arkansas Department of Environmental Quality citing the cause of impairment to be excessive amounts of siltation. A 2004 WFWR watershed assessment indicated that sediment loads from streambank erosion contributed 66% of the total sediment load. Based on previous work conducted by the WCRC, the site was identified as a high priority for restoration.



Design & Implementation: The WCRC utilized natural channel design principles to develop the restoration plan. FlowState, LLC of Fayetteville, AR constructed the channel to specific dimensions designed to restore the river to a stable form based on local reference reach data. 'Toe wood' benches were designed and constructed using large trees, boulders, and gravel. The edges of the benches, with exposed root wads and boulders provide excellent fish habitat and also reduces the power of the passing floodwaters.

The use of native vegetation is a critical component of the stabilization design. Soil layers consisting of topsoil wrapped in a coconut fiber blanket, were constructed on top of the toe wood benches to provide a medium for plants to take root and grow. Soil lifts were seeded with a mix of native riparian seed types. Approximately 500 trees, 2,000 shrubs, and 800 grass plugs. Maturing plants help to bind the structure through root growth and will also help to dissipate water velocity as the leaves, branches, and stems of the plants interact with flood waters.

Post Restoration: The restored river channel provides water quality benefits almost immediately following construction. Several floods have taken place since the completion of heavy construction and inspections conducted indicated that no erosion occurred along the previously eroding riverbanks. As a result of this work and similar work by the WCRC in addition to the efforts of BWA, BWD, and other stakeholders in the watershed, a portion of the WFWR has been removed from the 303(d) list. For more information, visit www.watershedconservation.org or contact the WCRC at (479) 444-1916.



WEST FORK WHITE RIVER RESTORATION



A. Before Construction



B. 2 Months After Construction



C. Construction of Soil Lift



D. Boulder Grade Control



E. Low-water Ford



F. Cross-Vane and Brush Mattress

Starting from top left: A. Two streambanks along the project reach had severe erosion prior to restoration. Streambank erosion rates were observed to be 37 feet per year in some areas. B. After restoration (2022), the project reduced sediment loads by 2,200 tons/year. The channel and banks were restored using a combination of boulders, trees, and gravel to construct toe wood benches. C. Soil lifts were constructed on top of the toe wood and vegetated with native trees, shrubs, and grasses to create roughness along the channel edges and improve stream cover. D. Boulder grade controls were used to redirect flows and improve aquatic habitat. E. A low-water crossing constructed of large flat boulders helps to control channel grade and provide access. F. Cross-vanes were built to protect the streambanks and increase pool scour.

The [Watershed Conservation Resource Center \(WCRC\)](#) is a nonprofit organization whose mission is to protect, restore and conserve natural resources using a watershed approach. The [WCRC](#) would like to thank their project partners, [Natural Resources Division—Arkansas Department of Agriculture](#), [U.S. EPA Region 6](#), [Beaver Watershed Alliance](#), and [Beaver Water District](#) for their contributions that helped to make this project successful.