Vermilion River Project #2

Miners Gulch Reach

2018 Post Run-off Monitoring Report

Miners Gulch Improvement Reach

US Department of Agriculture
Kootenai National Forest
Cabinet Ranger District

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1.0 Introduction

The Vermilion River is a major tributary to the Lower Clark Fork River (see Figure 1.1) and lies in the Northwest corner of Montana. This river is a perennial fourth order stream draining a watershed influenced by land uses including historic and ongoing placer mining as well as commercial forestry. The Vermilion River is one of only a few fourth order drainages in the Lower Clark basin that ensure perennial streamflows throughout the entire length of the mainstem.

The runoff regime, in particular snowmelt runoff, is periodically influenced by rain-on-snow and rain on snowmelt events that can occur anytime during the winter months in response to warm air temperatures and rain. Typically, however the peak flow event occurs in May or early June.

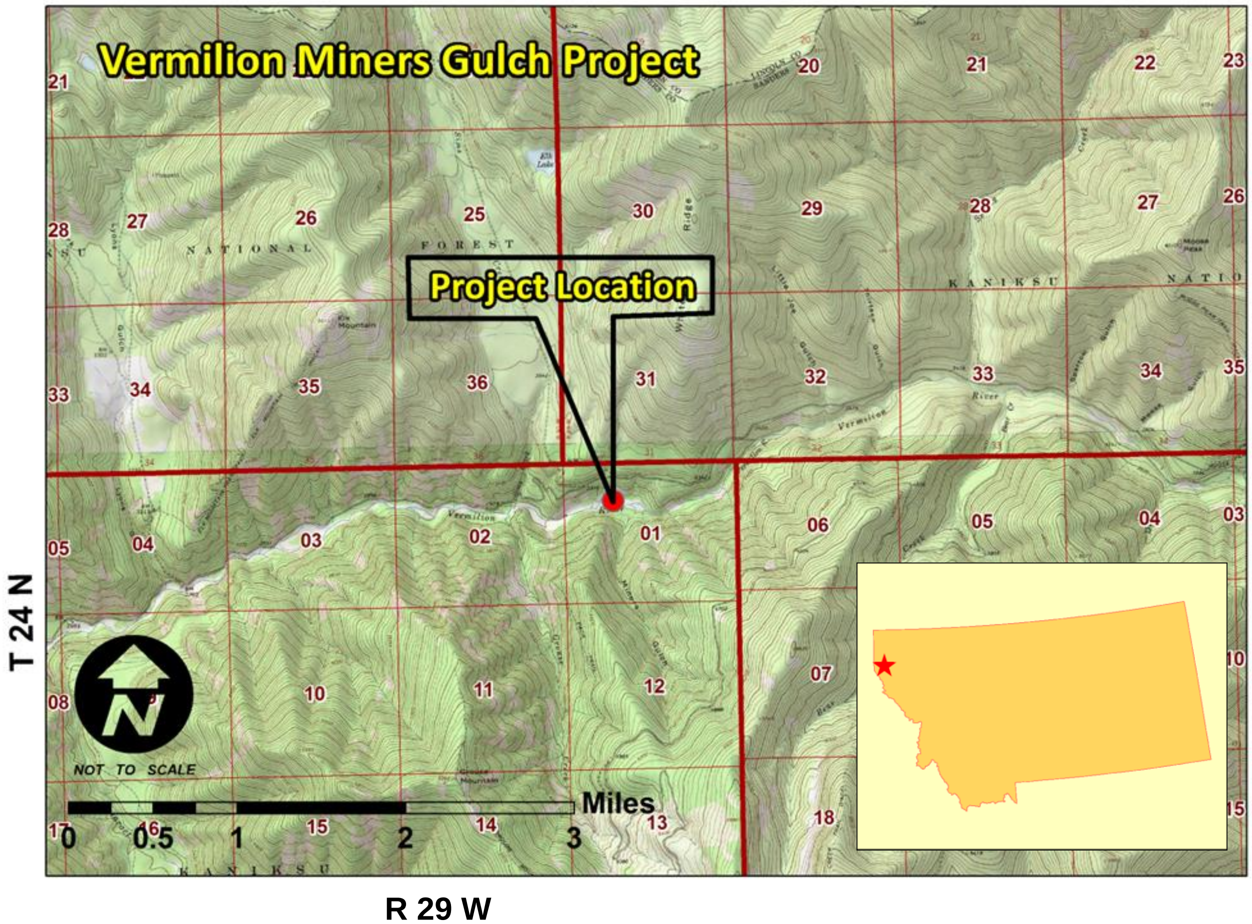


Figure 1.0 Vermilion River Miners Gulch Project Location

Montana's 1996 303(d) list classified 22.5 miles of the Vermilion River as impaired and only partially supporting its beneficial uses of aquatic life and cold water fisheries. At this time sediment was listed as the pollutant of concern and directly linked to past placer mining activity. In 2005, the Lower Clark Fork River Drainage Habitat Problem Assessment ranked the Vermilion River as the highest priority for improving and protecting native fish habitat in the Lower Clark Fork drainage. In 2007, the USFS in cooperation with Avista and Montana Fish, Wildlife and Parks completed a watershed assessment that analyzed the existing geomorphic, vegetative, sediment and fisheries conditions. At this time restoration projects were prioritized in the Vermilion drainage with a focus on sediment reduction and improving populations of native bull trout and westslope cutthroat trout. The assessment determined that reach 6 of the mainstem was the highest priority for restoration.

Figure 1.1 Chapel Slide 2005

Figure 1.2 Chapel Slide 2009

Within the upper end of reach 6 was the Chapel Slide, a large (300' long, 140' high) mass wasting hillside that since 1997 has delivered roughly 700 tons per year of fine sediment into the Vermilion River. This site was the single largest source in the Vermilion drainage, accounting for over 80% of all bank derived sediment produced in Reach 6.

Reach 6 had limited pool depth/frequency, poor substrate quality, and relatively little LWD. Sediment input from the Chapel Slide was thought to be adding to the altered spawning habitat in the next downstream Miners Gulch reach. In 2008, a year of above average runoff, approximately 7100 tons of fine sediment was lost from the slide area and thought to have partially deposited within the Miners Gulch reach below.

During the summer of 2012 employees from the Cabinet and Libby ranger districts initiated channel realignment and stream restoration activities within the Chapel Slide reach of the Vermilion River. The base of the slide was stabilized and approximately 500 feet of new channel was reconstructed over the course of three weeks.

Figure 1.3 Chapel Slide restoration reach in 2018, 6 years post project.

Physical dimensions of the as-built channel were measured post-project as well as an intensive revegetation effort that took place in 2013. Subsequent to the flows of 2013 and 2014, post run-off monitoring was replicated at the original monumented locations. These results were used to evaluate the effectiveness and the associated trends this project influenced throughout this portion of the Vermilion River.

The results of the study displayed reductions in sediment, floodplain reactivation, riparian vegetation establishment, added stream channel stability, the sorting of gravel in pool tails and added habitat complexity (Neesvig, 2015).

Continuing to follow the recommended strategy outlined in the Vermilion River watershed assessment (Neesvig, 2007) the Miners Gulch reach was the next downstream site planned for improvement. This was a larger project, at roughly 1500 feet long, and occurred over a 4 week period during the summer of 2016. The Miners Gulch project site exists in the SE ¼ of the NW ¼ of section 1, Township 24N, Range 29W (Figure 1.0)

Numerous entities were involved from the projects initiation to its completion. Outside funding mechanisms included grants from Avista Utilities, Montana Fish Wildlife and Parks (MFWP) Future Fisheries Improvement Program, National Fish & Wildlife Foundation Bring Back the Natives, National Fish Habitat Action Plan, Sanders County Resource Advisory Committee, and the Kootenai National Forest. The combination of funding sources allowed for this project to occur in a single phased approach.

Although the USFS Cabinet Ranger District took the lead on this project, deliverables would have not been attained without the involvement and similar goals of these outside agencies as well The Lower Clark Fork Watershed Group and the Green Mountain Conservation District of Western Sanders County.

This document outlines trends through the first two years of post-project runoff and has provided as a tool for assessing the progress toward achieving the goals and objectives recommended in the Vermilion River Watershed Assessment.

2.0 Existing Condition – Prior to Restoration

Prior to reconstruction the approximate 1500 foot reach functioned as continuous riffle morphology. Pool features were non-existent in this subset of reach 6 (0 pools per mile) and related to the lack of in-channel large woody debris. Reference values on the Kootenai National Forest (KNF) range from 66 to 2003 pieces per mile with a mean value of 664 (Libby RD, 2005) . Along with this, the vast percentage of the adjacent riparian area was void of mature trees and riparian vegetation for recruitment (Figure 2.). This condition was thought to be related to the unstable streambanks, lack of floodplain roughness (to capture and hold flood deposited fine material) and associated frequent channel migration.

Table 2.0 Pre-Project Existing Stream Corridor Condition

Site Name	Length of Channel (lineal feet)	Pools per Mile	In-Channel LWD per Mile (pieces)	Site Sediment (tons/year)	Riparian Area Trees (>1m) per Acre	Unstable Riparian Area (acres)
Miner's Gulch Complex	1500	0	17	207	3	11

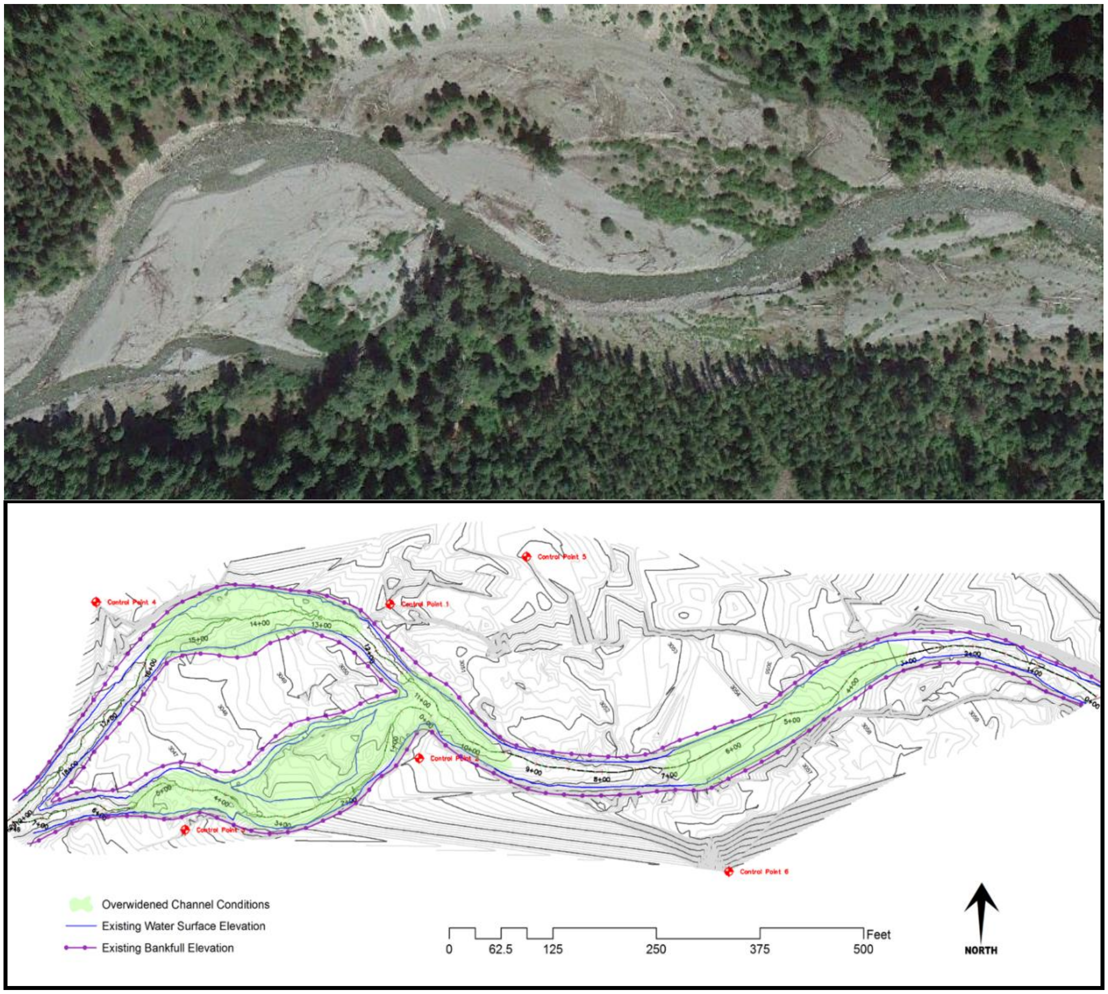


Figure 2.0 2013 aerial photograph and topographic mapping of the pre-project existing condition in the Miners Gulch project area.

The aquatic habitat complexity consisted of an overwidened riffle and minimal, functional in-channel Large Woody Debris (LWD). Historic placer mining, and the ensuing larger magnitude flood events, most recently the 1996 event, along with the over-bankfull type flooding that occurred during the spring of 2008, were directly linked to the degraded condition of this reach.

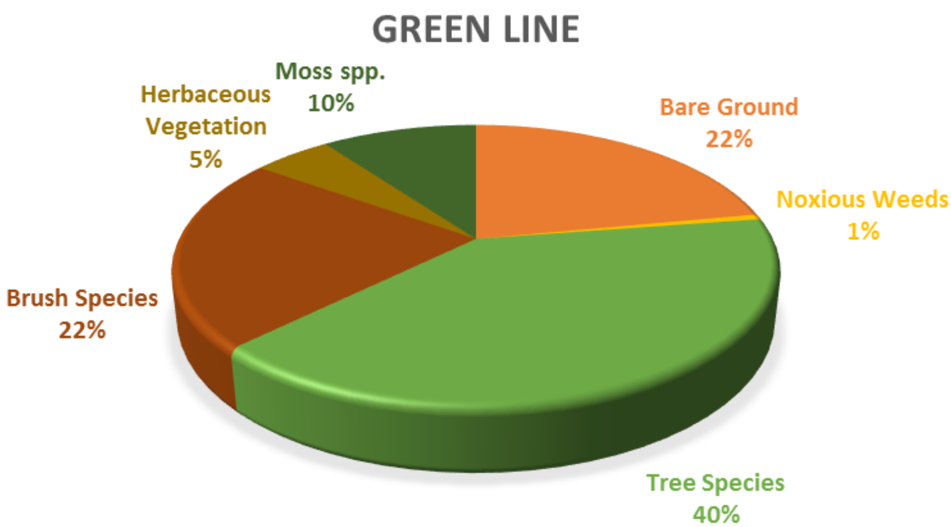
2.1 Riparian Condition

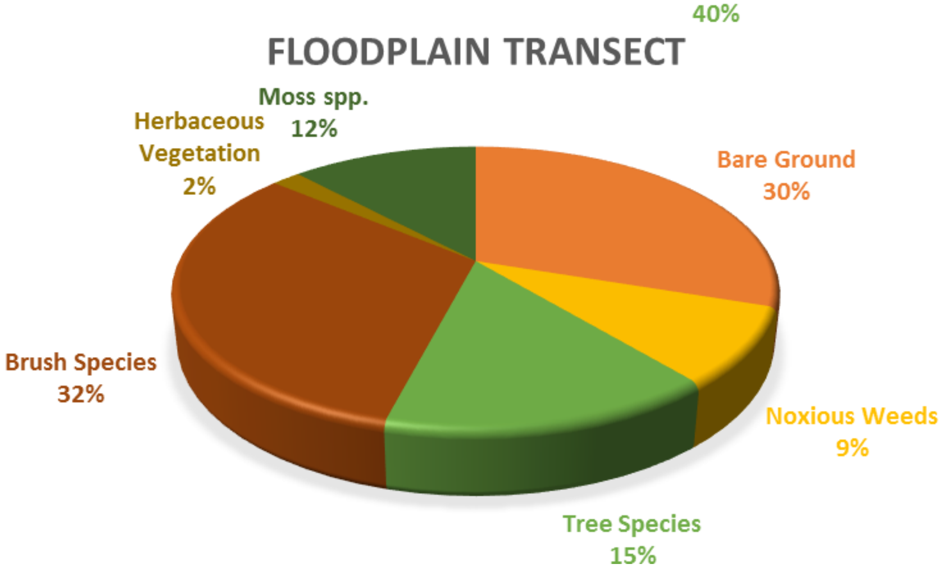
Prior to project activities, PACFISH/INFISH Biological Opinion (PIBO) vegetation surveys were completed along the banks of the entire reach and multiple transects throughout the Miners Gulch area. Both components of the PIBO survey, greenline plots and floodplain transects (Archer et al, 2016), provided for a baseline riparian condition within this section of the Vermilion River.

The transect portion of the survey (coded XS) provided for the best depiction of the existing riparian condition in the floodplain. Six 50X20 cm quadrats were evenly spaced along each transect that incorporated the width of the floodplain on both the left and right sides of the active channel. The greenline plots (coded GL) were more representative of the nearbank region as one 50X20 cm quadrat per plot near the water's edge assessed the immediate bankfull vegetation. Observations within both methods looked at vegetation 1 meter in height or less (lower layer coded L) and vegetation taller than 1 meter (upper layer coded U). A summary of the percent cover is displayed below while the entire pre-project vegetation survey is attached within Appendix C.

Table 2.1 Summary of pre-project riparian vegetation greenline plot and floodplain transect surveys

Greenline plots	% Cover	**Floodplain transects**	% Cover
Bare Ground - Sand, Gravel, Cobble, Rock	22	**Bare Ground** - Sand, Gravel, Cobble, Rock	30
Noxious Weeds - Spotted Knapweed, Orange Hawkweed	1	**Noxious Weeds** - Spotted Knapweed, Northern Hawkweed	9
Tree Species - Black Cottonwood	40	**Tree Species** - Black Cottonwood, Douglas fir	15
Brush Species - Thinleaf Alder, Red-Osier Dogwood, Drummond's Willow, Mockorange	22	**Brush Species** - Thinleaf Alder	32
Herbaceous Vegetation - Misc. Species	5	**Herbaceous Vegetation** - Misc. Species	2
Moss spp.	10	**Moss spp.**	12
TOTAL	100		100





The roughly seven acres of riparian floodplain scheduled for revegetation had a large component (62%) of bare ground and sporadic Alder brush roughly 5 years old. Tree species comprised 15% of the area and were primarily black cottonwood saplings less than 1 meter in height. Noxious weeds such as spotted knapweed and northern hawkweed were present throughout roughly 9% of the entire area.

Directly adjacent to the stream, greenline plots displayed more vegetative diversity and less noxious weeds. Although mostly less than 1 meter in height, black cottonwood trees occupied roughly 40% of the area in the nearbank region. Thirty percent of the banks were void of any vegetation and composed of highly friable substrate. As expected, more riparian indicator species such as Thinleaf Alder (Alnus incana), Red-Osier Dogwood (Cornus stolonifera), Drummond's Willow (Salix drummondiana), and common horsetail (Equisetum arvense) were found in these locations due to the close proximity to perennial water.

2.2 Flood Frequency and Associated Geomorphic Change

Since the fall of 2005 continuous automated stream gaging has occurred near the mouth of the Vermilion River. Figure 6 displays a hydrograph of the Vermilion River at this location for water years 2006 to 2009. The 2008 water year noticed the largest return interval flow. This roughly 6 year flood event is what drove the majority of channel progression during this time. Through time series air photo analysis and ground surveys, the rate of lateral and vertical channel migration was assessed from these events in the Miner's Gulch area within reach 6 of the mainstem of the Vermilion River.

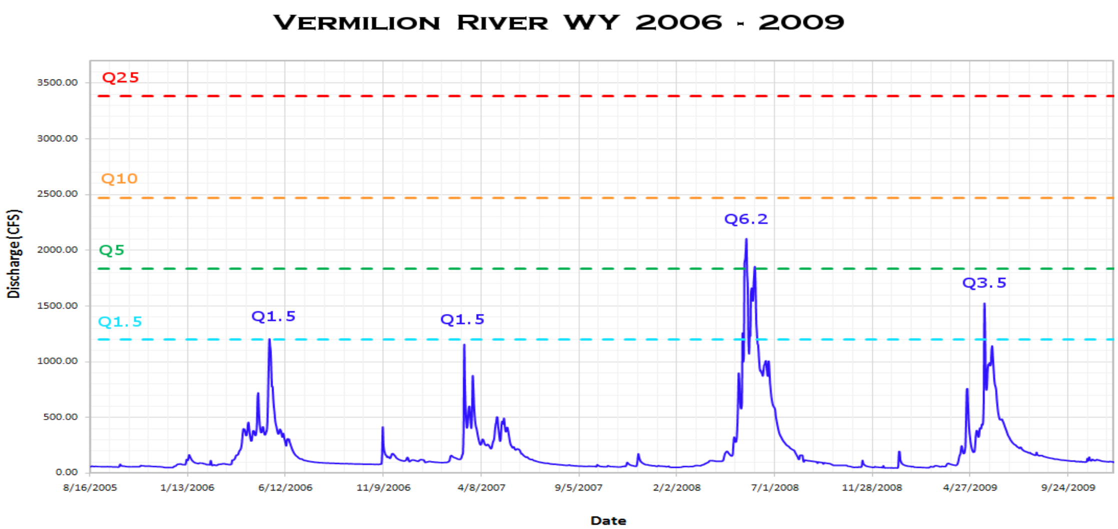


Figure 2.1 Hydrograph of the Vermilion River Water Years 2006 – 2009.

The magnitude of flood flows of the 1996/97 season approached 60 year return interval flows in other gaged basins in the Lower Clark Fork (USGS, 2018). Runoff of this level was thought to have occurred within the project reach. During these events the majority of larger riparian vegetation was undermined and transported downstream. Historically it is believed that this site had a substantial amount of hydraulic placer mining which also removed riparian vegetation, in-stream wood and larger substrate. Figure 2.3 displays the Miner's Gulch reach in the summer of 2005. Figure 2.4 is a picture of the same area in the summer of 2009. Active lateral channel migration was noticed to be close to 400 feet during this period. The largest event within this time compared to a 6 year flood event with most flood peaks averaging 1.5 year bankfull flow or slightly larger (Figure 2.1). These types of flood flows are considered maintenance flows within reference watersheds in and around the Kootenai National Forest. Floodplain vegetation consisted of 12 year old cottonwood and willow saplings. Prior to these events, this vegetation was thought to be reestablishing the floodplain area and naturally providing for bank stability. These more recent lesser events allowed for the majority of this vegetation to be undermined, displaced and transported downstream, repeating the cycle that occurred 20 years prior by way of lower magnitude flows.

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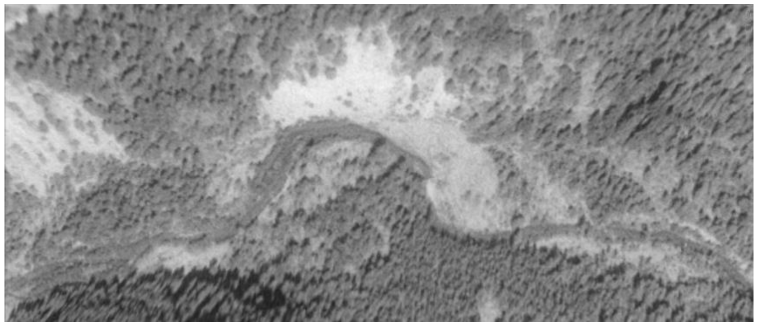


Figure 2.2 Miners Gulch reach 1995

Figure 2.3 Miners Gulch reach 2005

Figure 2.4 Miners Gulch reach 2009

Reference watersheds that are similar to the Vermilion River within the Cabinet and Libby Ranger Districts of the Kootenai National Forest have maintained resilient channel characteristics preceding flood magnitudes up to 16 year flood events. Based on historic flow and stream channel stability information within reference watersheds on the Kootenai National Forest, a 25 year return interval flow or greater is considered a channel changing event on the Kootenai National Forest.

Although the pre-restoration channel dimensions within the Miner's Gulch reach, in terms of morphological variables such radius of curvature (R_c) and meander wavelength (L_m), were within tolerable limits, other channel metrics such as the entrenchment and width to depth ratios, which are often used to evaluate sediment transport and floodplain accessibility, were not. These values displayed a departure from stable reference conditions. Where high w/d exist, such was the case within portions of the Miner's Gulch reach (Figure 2.0), a decrease in stream power added to channel aggradation and accelerated lateral channel migration.

Table 2.2 – Existing Morphological variables at the Miners Gulch project site.

XS#	STA	Bankfull Width	Floodprone Width	Entrenchment Ratio	Mean Depth	Maximum Depth	Width/Depth Ratio	Bankfull Area	Water Surface Slope	Rosgen Channel Type
1	2+00	67.99	110	1.62	2.49	5.08	27.31	169.31	0.020	B
2	5+00	65.74	203	3.09	2.59	3.41	25.38	169.97	0.018	C/B
3	7+05	53.33	200	3.75	3.14	4.68	16.98	167.35	0.018	C
4	14+55	81.23	382	4.68	2.06	3.10	39.43	167.65	0.013	D
Mean	-	67.07	224	3.29	2.57	4.07	27.28	168.57	0.017	C/D

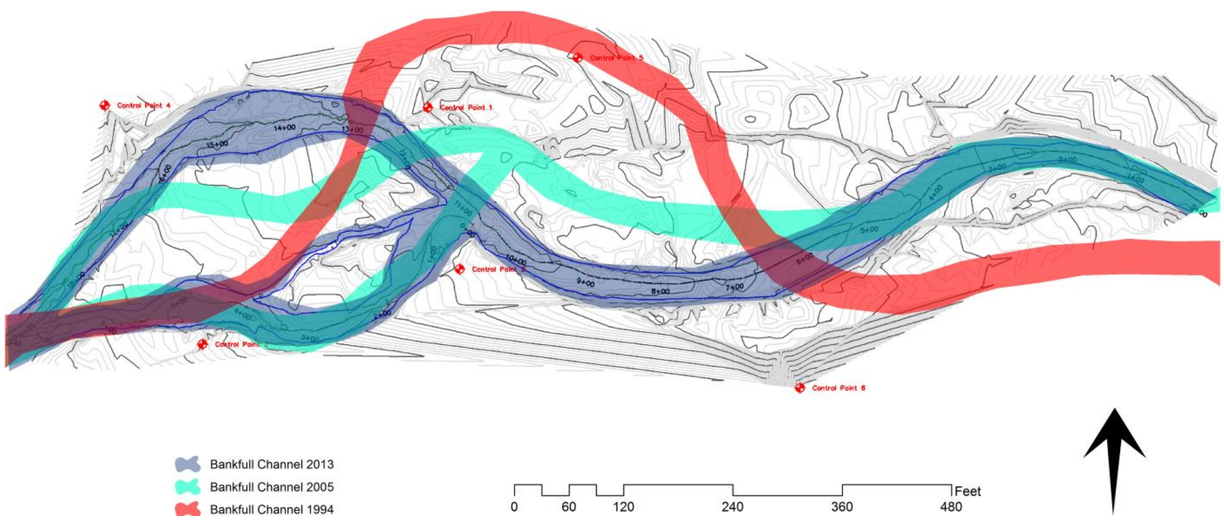


Figure 2.5 Changes in channel geometry over a 19 year period in the Miner's Gulch Reach

3.0 Reference Reach Descriptive Information and Project Design

Information was gathered in similar channels with reference reach characteristics, or channel reaches with dimensions, slopes and profiles that seem to be naturally providing for long-term stability. The main reference reach utilized for the Chapel Slide project design was located directly upstream. Applicable reference reach data was compiled from a few other nearby locations and provided for a range of options. All of these reaches displayed similar channel types and substrate, as well as local slope, flow regime and bankfull characteristics. The riparian corridor within these reference locations is what is believed the project site was like prior to the vegetation alteration and channel changing events. Table 2.3 displays the reference reach variables by site.

Table 3.0 Summary of reference reach variables by site

Reference Variables	Vermilion River B3c Channel type	West Fork Trout Creek C4 Channel Type	East Fork Bull River B3c Channel type	Upper Bull River B4c Channel type
Drainage Area (sq. miles)	49.92	19.5	26.05	37.6
Bankfull Area (Riffle)	135	91.54	45.59	126.2
Bankfull Q	650	280	228	550
Width/Depth (Riffle)	23.6	20.0	15.4	18.2
Entrenchment Ratio	1.82	4.69	5.67	3.13
Bankfull Width (Riffle)	55.9	42.7	26.4	47.9
Bankfull Mean Depth (Riffle)	2.44	2.15	1.72	2.63
Bankfull Max Depth (Riffle)	4.74	3.51	2.41	4.31
Bankfull Max Depth (Run)	2.90	4.20	3.8	4.5
Bankfull Max Depth (Pool)	4.64	5.61	4.6	5.7
Bankfull Max Depth (Glide)	4.60	3.22	4.1	3.5
Average Riffle Slope	.018	.012 - .018	.02	.015
Average Run Slope	.060	.529	.09	.23
Average Pool Slope	.005	.016	.007	.002
Average Glide Slope	.011	.030	.12	.04
Run length (RL)	17-25	15-30	6-25	10-23
Glide length (GL)	13-25	12-30	15-55	13-31
Total Pool Length (RL+GL+PL)	15-40	20-75	18-60	36-78

Figure 3.0 Existing reference channel conditions above the Miners Gulch reach of the Vermilion River

The project design included more pool habitat and was designed to provide for a more stable grade that will help maintain the long term stability within this section of the Vermilion River. Proposed channel design characteristics such as Bankfull area (BFA), Bankfull width (BFW), Bankfull mean depth (BFDMN), Bankfull maximum depth (BFDMX) Bankfull discharge (BFQ), and Bankfull mean velocity (BFU) have been calculated for the design constructed riffle, run, pool, and glides within the project reach (see Table 2.4). Design depths have taken reference reach information into account. Local scour depths have been calculated at all of the constricted channel features (run locations). The calculated scour depths have taken variables such as sediment density, particle size, bankfull discharge, gravitational acceleration, water density, run slope, run width, and fall height into account. Maximum scour depths at these locations were approaching 6 feet in the project area under an above bankfull type (5 yr.) flood event. These calculations have provided additional insight into how, and at what elevation footer rock and logs would be installed to ensure function until the riparian community can become established.

Table 3.1 Summary of Design Dimensions

Dimension Variables	Pre-Project Riffle (C3)	Design Riffle	Design Run	Design Pool	Design Glide
Drainage Area (sq. miles)	53.93	53.93	53.93	53.93	53.93
BFA	141	143	113	250	225
BFQ (cfs)	675	675	675	675	675
BFU (fps)	4.50	4.5	6	2.7	3.0
Width/Depth (Riffle)	26.04	24	19	15.0	22
Entrenchment Ratio	2.63	4.16	5.26	3.45	3.33
BFW	62.49	55	48	58.2	60
BFDMN	2.4	2.6	2.10	3.40	2.67
BFDMX	3.27	4.2	3.35	6.50	3.58
Average Slope	.018 -.02	.02 - .024	.09 - .14	.007 - .016	.030 - .12

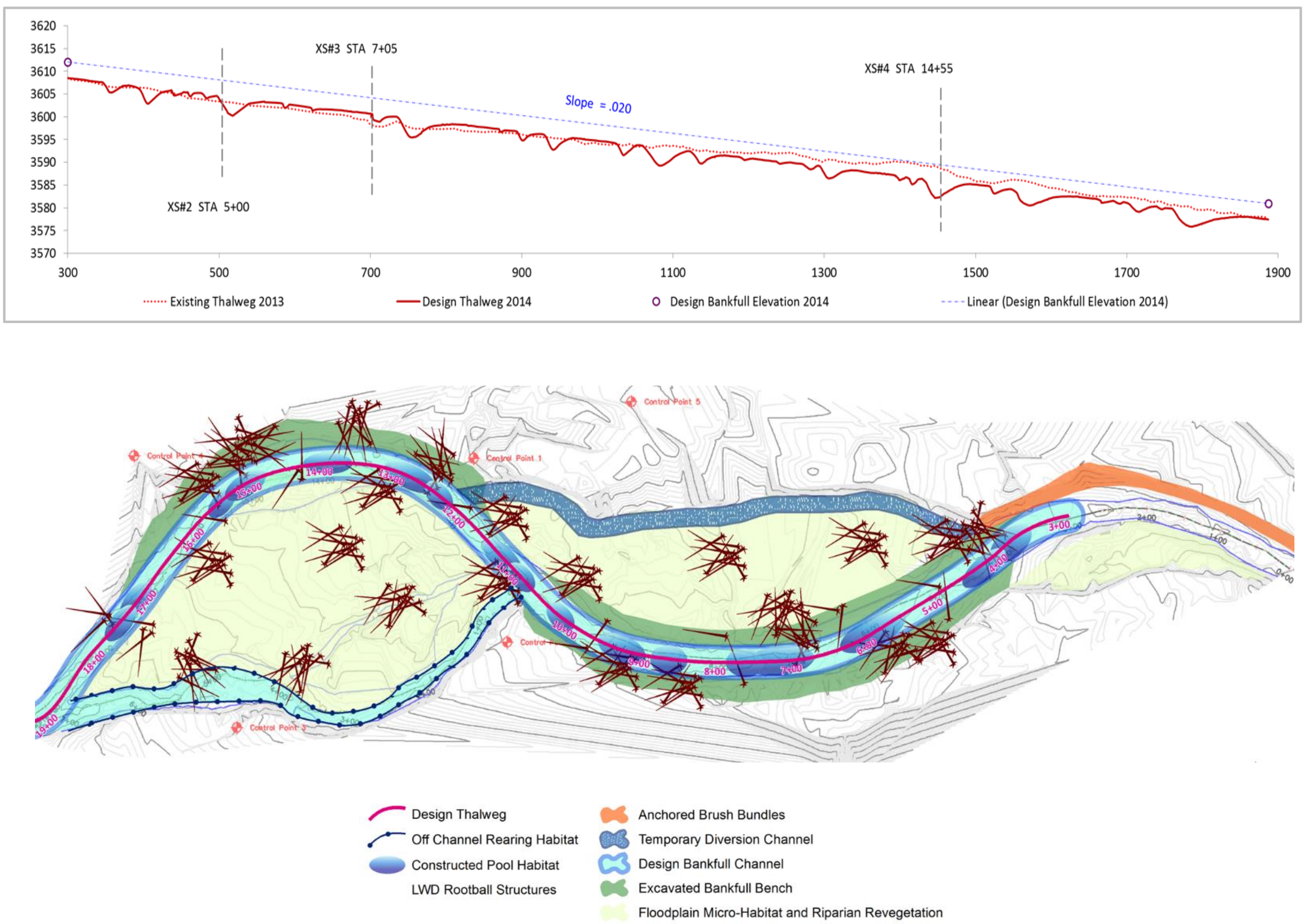


Figure 3.1 Miners gulch design longitudinal profile and associated planform

The channel prior to restoration was thought to be in an established historic location, with stable meander form and pattern. Portions of this channel were fairly incised with some banks adjoining near vertical 7 foot raw terraces. This depth in relation to the well-drained coarse alluvium that comprised these terraces limited access to the late season groundwater reserves preferred by the local riparian vegetation. Vegetation surveys concluded that these areas were largely devoid of vegetation or colonized by non-native spotted knapweed with minimal stunted black cottonwood seedlings. All of the reference reaches utilized in the design displayed well developed floodplains that are accessed regularly by annual runoff.

Overwidened depositional features existed in other portions of the reach and consisted of in-channel perched coarse alluvium which allowed for reduced late season surface flow. By design the constructed channel and floodplain required excavation to increase late season capacity, reduce the near bank shear stress and increase floodplain accessibility. These techniques hoped to provide the planted vegetation future depositional fines, more available water and access to the late season interstitial flow.

Figure 3.2 Example of a constructed floodplain and riparian plantings being accessed during flood flows of water year 2018

Two different entrainment calculations were evaluated using the pebble count data that was taken just above the project site (see Table 1.2). Both calculations determined the critical shear stress at a riffle during a bankfull type flood event (1.5 yr. flood). The first method uses the D50 size particle of a representative pebble count, the largest particle size found on a local channel bar, the bankfull mean depth and the average slope of the riffle. The second method uses the gravitational acceleration, hydraulic radius and average slope of the riffle, and the density of water (Gordon, 1992). The entrainment results for the first equation showed particles up to the D95 size were mobile under bankfull type flows. The results for the second equation were a little more conservative and yielded particle movement up the D84 size particle during a bankfull event. Both results provided valuable input into the design as far as the current movement of bedload through the project site directly downstream. Based on these results the pool tail controls utilized the more conservative method and were constructed using a D95 size cobble/boulder matrix (~ 650 - 800 mm), some of which was native material already in place. The table below displays the particle size distribution used within the entrainment calculations (the riffle particle size distribution just above the project area).

Table 3.2 Existing particle size distribution just above and within the project site

Cumulative % and Finer	Particle Size (mm) (Riffle above project reach)	Particle Size (mm) (Riffle in depositional area of project site)
D16	89	17
D50	211	96
D84	359	243
D95	731	437
Silt / Clay (<.062 mm)	0 %	0 %
Sand (.062 – 2.0 mm)	0 %	0 %
Gravel (2.0 – 64 mm)	5 %	42 %
Cobble (64 – 256 mm)	60 %	45 %
Boulder (256 – 2048 mm)	35 %	14 %
Bedrock (> 2048 mm)	0 %	0 %

4.0 2016-2017 Restoration Activities

From mid-July through August in 2016 approximately 1500 feet of new channel was constructed within the Miners Gulch reach. A roughly 1/2 mile stretch of roadway was built to accommodate equipment access and delivery of materials. This road was constructed on adjacent alluvial terraces that bisected the 100 year floodplain. Minimal vegetation was disturbed as the road location weaved through barren ground composed of predominantly coarse alluvium. Three temporary stream crossings were built and used throughout the length of the project.

The duration of the project was roughly 4 weeks. The initial road building and temporary stream crossings began activities, while materials were being gathered. Onsite materials were also sorted and used within the project. Heavy equipment such as excavators, front end loaders, dump trucks and log skidders were utilized daily for moving materials. The in-stream portion of the project began with the construction of the design channel thalweg elevations and associated bankfull depths and widths.

Figure 4.0 Temporary bridge built and installed for the Miners gulch reach restoration.

A total of 400 trees with attached rootballs were utilized within this project. The processing of this material was gathered on flat upland sites not in proximity to riparian areas and delivered to the staging area within the project reach. Round cobble and boulders were imported to the site and used in conjunction with native rock for grade control and habitat feature creation. As well as the imported materials, on-site resources such as the in-channel alluvium helped in the development of the new floodplain.

Figure 4.1 2016 construction activities during the Miners gulch reach restoration.

Figure 4.2 Large wood stockpile at staging area within the immediate project work site.

The newly constructed channel contains cobble/boulder near bank habitat as well as large wood to add complexity to the stream corridor. This placed material provided for grade control and pool tail stabilization. All structures incorporated the final channel shaping to appropriate channel dimensions which were based on applicable local reference data. These techniques helped to protect adjacent banks by reducing localized shear stress and positioning the thalweg in a more historic location within the reach. The channel pattern was designed to allow the river to utilize as much of the valley as thought feasible. By constructing a wider floodplain area for this portion of the Vermilion it was foreseen that this technique would allow for more riparian vegetation to become established as well as aid in sediment and debris transport.

Figure 4.3 Pre-project (4/2014 –top) and most recent (11/2018 – bottom) photos of channel conditions at station 11+25 of the project reach.

Although a permit for short-term turbidity in the Vermilion River was obtained, a temporary water diversion completed in two phases (Figure 4.4) routed the majority of water around the work site to limit the amount of construction related sediment increases. Culverts were installed at one location to allow for equipment access.

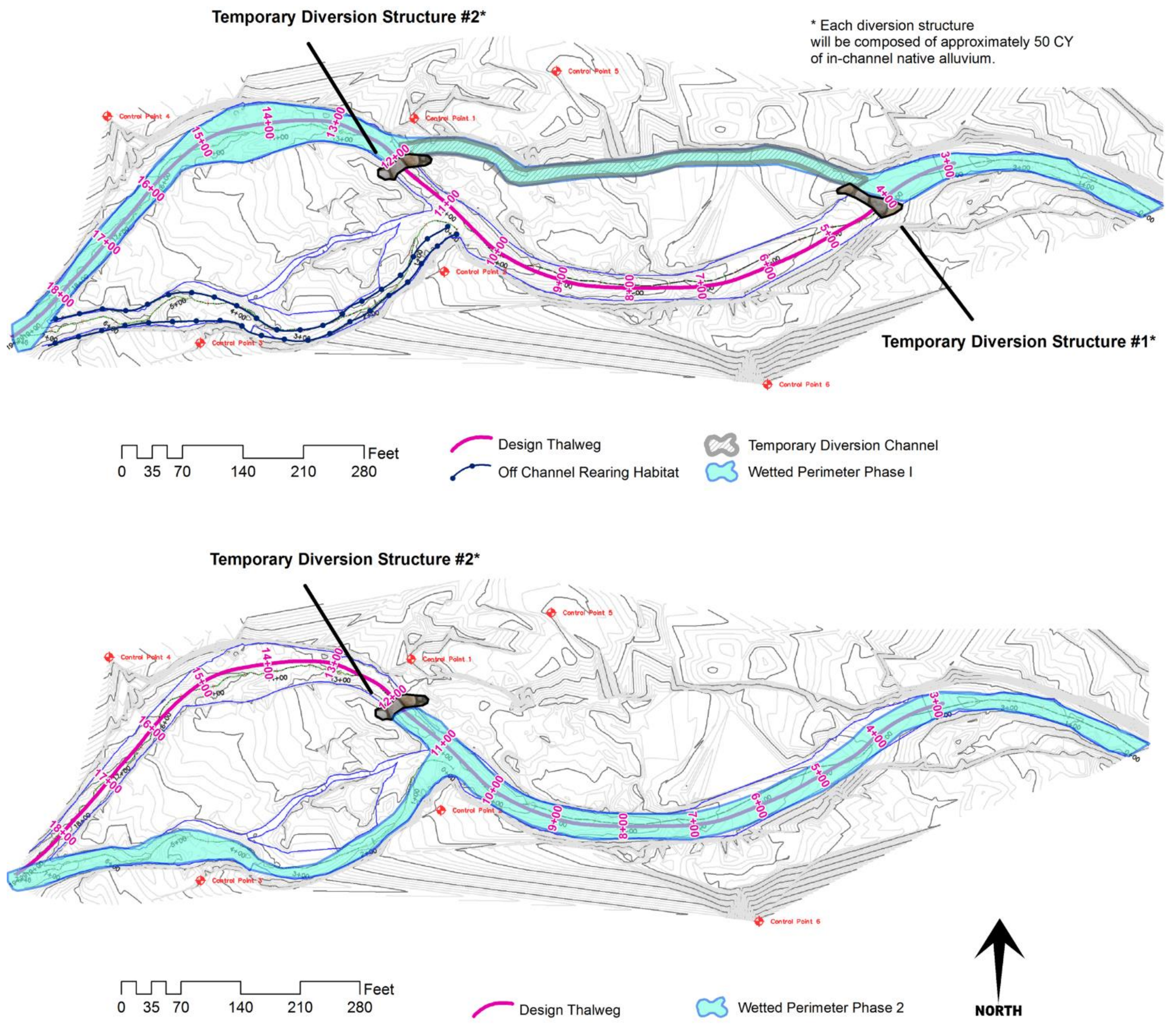
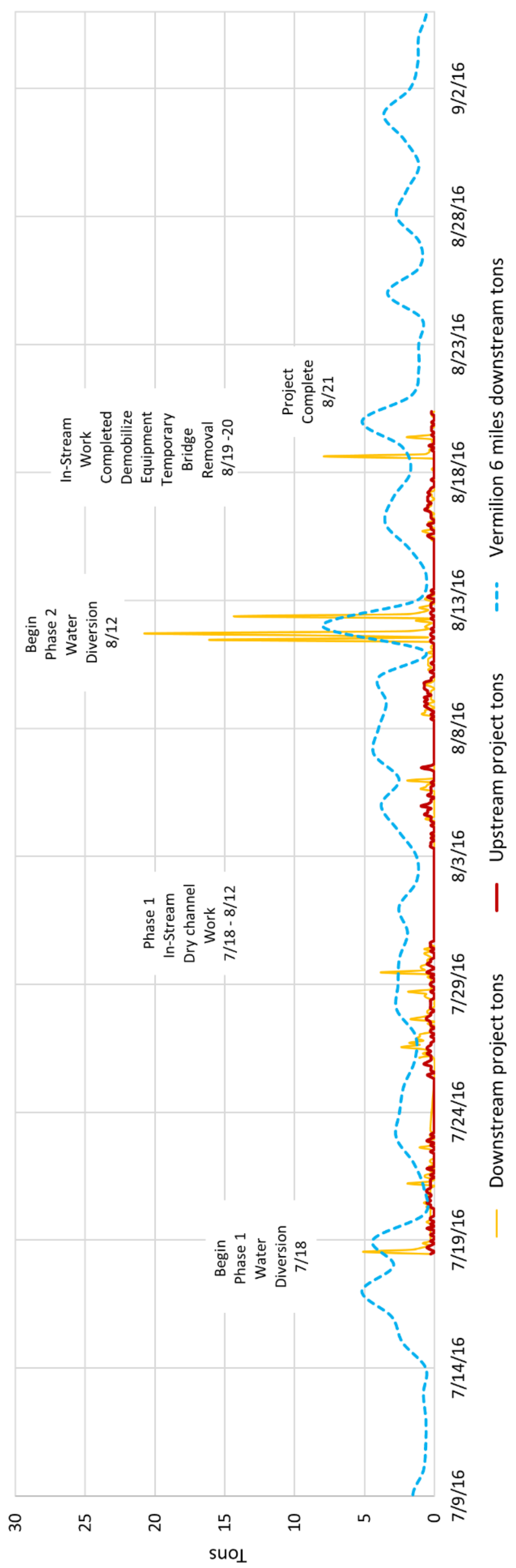
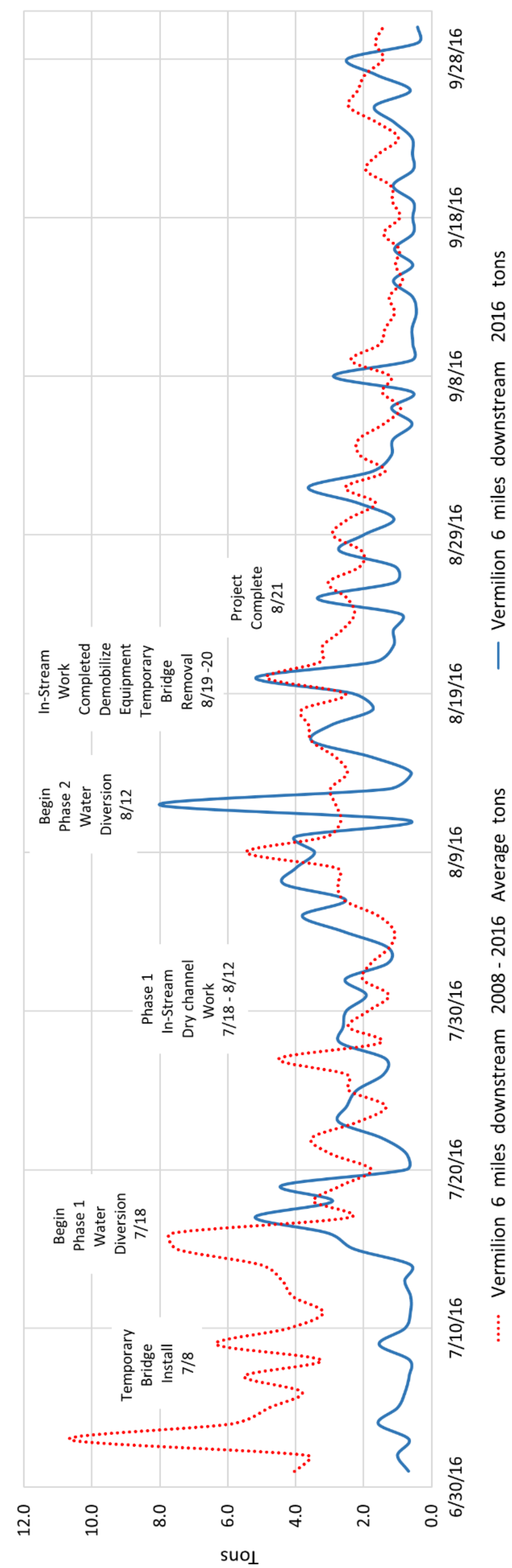


Figure 4.4 Phase 1 and Phase 2 temporary water diversion utilized for the Miners gulch reach restoration.

Instream suspended sediment monitoring was ongoing for the length of the project. Automated sediment sampling equipment was installed above and below the project reach to capture project related contributions. Samples were obtained every 2 hours for roughly 35 days beginning July 18th. Alongside this effort a temporary stream gaging station was installed just above the project site. Stream discharge measurements were obtained periodically to complement the sediment sampling in the reach. Additional sediment and discharge sampling was ongoing close to the mouth of the Vermilion approximately 6 miles downstream at the historic USFS gaging station. These two data sets together helped to attain the total amount of project related tons of fine sediment being transported directly below the project reach and 6 miles downstream.

Figure 4.5 Downstream suspended sediment contributions from project construction activities.





Using the Wentworth (1922) classification system, sediment was characterized by particle size as mud and silt (<0.0625 mm) and sand (0.0625-2 mm). During normal flow conditions, suspended sediment is dominated by particles less than 0.0625 mm and can include colloids, clay, mud and silt. These smallest particles form part of the deposited sediment, and can be collectively referred to as 'suspended sediments'. Larger particles, that are less mobile, are deposited on the streambed and collectively referred to as 'bed load'. Although the activities did produce low levels of bedload which subsequently have been incorporated into the system, this project level sediment analysis captured only the volume of particles less than 0.0625 mm in size.

Table 4.0 Tons of fine sediment produced from project activities within the project site

Miners Gulch reach natural tons - Upstream 7/18 - 8/20	56	Vermilion @ USFS gaging station - 2016 total tons 7/18 - 8/20	88
Miners Gulch reach project tons - Downstream 7/18 - 8/21	166	Vermilion @ USFS gaging station - 2008 - 2016 average total tons 7/18 - 8/20	91
Total project related tons	110	Change in tons from average	-3

From 7/18 to 8/20 a total of 110 tons were captured directly below the project reach. These contributions were mostly from a few isolated events during different phases of construction. Although fine sediment was being introduced throughout the entire timeline, the larger events took place between phases, such as when the diversion water reentered the newly constructed semi-dry streambed. The immediate flushing of this "construction silt" was mobilized within the water column. Increases were occurring directly below the work as anticipated, and slightly muted surges were observed at the lower monitoring location 6 miles downstream (see Figure 4.5). Sediment spikes of 15-20 tons in a two-hour period were happening directly below the project for approximately 1 day, whereas loses in transit only allowed for 3-5 ton spikes at the lower location during this time.

The 2016 sediment budget at the lower gaging station was similar to average. Combined with the one larger event that occurred on 8/12, the total suspended sediment contributions for this time of year were slightly below average.

5.0 Riparian Revegetation

During the spring and fall of 2017 stream banks through the reach were further stabilized using native seed mixes, bare root seedlings, and live vegetation stakes. Floodplain plantings consisted mostly of Black Cottonwood with some Ponderosa Pine, Woods Rose, Serviceberry, Lewis' Mockorange, Thinleaf Alder, and Sandbar Willow. All disturbed areas were seeded in the fall of 2016 shortly after construction with a cover crop of Annual Rye and Sitka Alder. During the spring of 2017 field crews imported local topsoil from adjacent floodplain areas to the site and mixed it directly with the coarse alluvium at each individual planting site. To protect the vegetation from browse a fenced riparian buffer was established in strategic locations. An extensive irrigation system was installed during the summers of 2017 and 2018 and provided for supplementary water throughout the dry seasons.

Irrigation was considered critical to the survival of the plantings on the well-drained alluvial floodplain. A watering target of 1" of water per week was applied to the riparian area. Approximately 4 hours of pump run-time were needed to apply this quantity of water. Various gravity fed and drip systems were considered but due to the coarse soil texture little lateral spread of moisture from emitters was expected. To provide water to directly seeded species as well as encourage natural seedling establishment, a sprinkler system was required to distribute the water over the entire planting area. Sampling cups were used to ensure adequate water was applied at each watering. Roughly 7 acres were irrigated during the summers of 2017 and 2018.

Figure 5.0 Irrigation of the planted riparian vegetation with fenced enclosures on the constructed floodplain.

6.0 Water Years 2017 and 2018 Runoff Monitoring

A USFS stream gaging station exists roughly 6 miles below the project reach towards the mouth of the Vermilion River. The water years of 2017 and 2018 have been represented from the calibration of discrete manual measurements and automated 30 minute data. The hydrographs are displayed below (Figure 6.0). In 2017 most streams in northwestern Montana experienced average runoff and slightly above average in 2018 with the Vermilion being no exception (USFS Cabinet Ranger District 2017, USFS Cabinet Ranger District 2018).

Water Year 2017

During the 2017 water year spring snowmelt occurred slightly earlier than most years in the period of record (2002 – present). The initial rising limb of the hydrograph began in early March. Peak events occurred shortly thereafter with sustained discharges of roughly 1200 cfs ($Q_{1.5}$) for a few days in March and May of 2017. Overall, it was an average water year in terms of flood frequency and water volume.

Water Year 2018

Toward the end of November a rain on snow event occurred that elevated baseflows to roughly half bankfull. A similar event occurred towards the beginning of February. For the remainder of the year an average runoff occurred. Peakflows related to the highest event surpassed the bankfull discharge for approximately 5 days. The peak flow of 2018 at the gaging station was 1,430 cfs, which equates to the approximate 3 year return interval flow ($Q_{2.1}$). Flows above the bankfull discharge were sustained for roughly 1 week in May within the project site. Peak flows at the project site approached roughly 850 cfs.

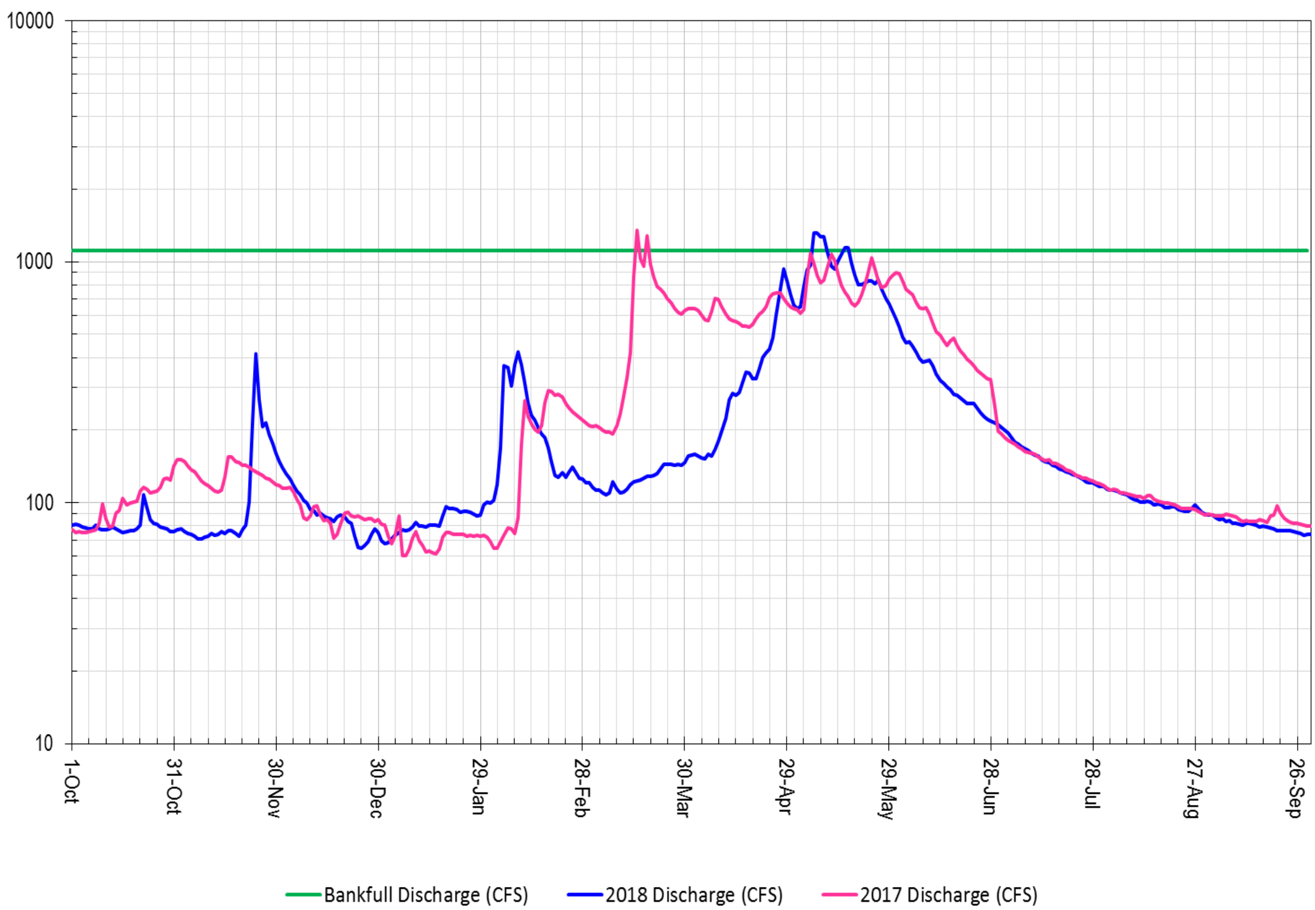


Figure 6.0 Hydrographs of the Vermilion River for the 2017 and 2018 water years.

Figure 6.1 Peak flow runoff (top – May 2018) and low flow runoff (bottom – October 2018) at station 4+00

7.0 Dimension, Profile, Channel Substrate, Pool Tail Fines, LWD and Vegetation Monitoring

Upon completion of the construction activities in the late summer of 2016, as-built channel dimensions and profiles were surveyed within the project reach. In 2017 and 2018 this monitoring was repeated in the previous monumented locations as well as those associated with the upstream reference reach. The bankfull elevations estimated from the 2016 surveys acted as a datum to provide for a static location to evaluate change in dimensions over time. Along with this, a suite of pebble counts, pool tail fines and LWD quantity and type were surveyed.

Table 7.0 Trend monitoring items for the Vermilion River Miners Gulch reach

Monitoring Item	Quantity
Channel Cross Sections (Harrelson et al., 1994)	18 (4 riffles, 5 runs, 5 pools, 4 glides)
Channel Longitudinal Profile (Harrelson et al., 1994)	1 (the majority of the project reach, approx. 1420 ft.)
Wolman Pebble Counts (Harrelson et al., 1994)	9 (4 riffles, 3 runs, 2 glides)
LWD and Pool tail % fines (Archer et al. 2016(b))	1 (the majority of the project reach, approx. 1420 ft.)
Riparian Vegetation Mortality (Archer et al. 2016)	1 (the majority of the planted floodplain area, approx. 7 acres)

Table 7.1 Trend monitoring items for the Vermilion River Reference reach

Monitoring Item	Quantity
Channel Cross Sections (Harrelson et al., 1994)	10 (3 riffles, 3 runs, 2 pools, 2 glides)
Channel Longitudinal Profile (Harrelson et al., 1994)	1 (the entire length of the reach, approx. 660 ft.)
Wolman Pebble Counts (Harrelson et al., 1994)	7 (2 riffles, 2 runs, 3 glides)
LWD and Pool tail % fines (Archer et al. 2016(b))	1 (the majority of the project reach, approx. 1420 ft.)
Riparian Vegetation Mortality (Archer et al. 2016)	1 (the majority of the planted floodplain area, approx. 7 acres)

7.1 Reference and Project Channel Dimensions

Eighteen channel cross-sections were measured and monumented within the project reach according to methods described by Harrelson et al. 1994. To establish a range of values for each feature and encompass the majority of the project area dimensions, representative riffle, run, pool and glide units were measured immediately after project completion and two following years post run-off (2016-2018). These results are displayed below in Table 7.2 and Appendix A.

Changes in the mean dimension reach variables of the project ranged in the first two runoff seasons. The magnitude of adjustment was greater in the first season of runoff with the subsequent season allowing for lesser change. As was noticed in similar monitoring of the previous Chapel Slide project, the first season of runoff through a newly constructed channel may have a slight adjustment period related to the settling and sealing of the grade control and bank stabilization structures. No transition towards an unstable channel type is actively occurring. A few of the monitored cross sections displayed slight aggradation (mostly pool features) while others displayed deepening of the channel (mostly run features) from 2016 to 2018 (Table 7.2).

Ten channel cross-sections were measured during the same time period within the reference reach upstream of the project site. These results are displayed below in Table 7.3 and Appendix B.

Changes in the mean dimension reach variables of the reference reach ranged from 0 to 3 percent through the 2017 runoff season and 0 to 1 in 2018. This is slightly lower than what was monitored in the project reach (0 to 9 percent (2017), 0 to 3 (2018)). The magnitude of adjustment was monitored to capture the natural changes within the reference reach directly upstream of the project site. Throughout this time period there was no transition towards an unstable channel type within the reference reach. The riffles within the reach saw minimal change within all dimension variables. The mean and maximum depths changed slightly within the pools. This reach maintained resilient bank and bed dimensions through these two runoff cycles which briefly provided for bankfull flows ($Q_{1.5}$) and above.

Table 7.2 Percent change in channel dimensions for the Vermilion River Miners Gulch project reach

Dimension Variables	XS#1 Pool	XS#2 Glide	XS#3 Run	XS#4 Rif	XS#5 Run	XS#6 Pool	XS#7 Glide	XS#8 Rif	XS#9 Rif	XS#10 Run	XS#11 Pool	XS#12 Run	XS#13 Run	XS#14 Pool	XS#15 Glide	XS#16 Riffle	XS#17 Pool	XS#18 Glide	**Mean Reach**
BFA (2016)	241.4	152.1	115.0	131.1	102.6	189.9	145.1	130.6	139.0	112.2	219.7	121.4	81.0	194.0	105.9	96.6	224.3	115.2	
BFA (2017)	207.7	131.1	112.9	121.5	130.5	199.1	159.5	140.6	117.3	125.0	196.5	132.0	105.0	195.5	134.1	107.9	176.6	126.8	
BFA (2018)	213.7	137.9	110.4	126.1	144.2	191.5	168.0	133.3	120.4	126.5	192.0	137.3	107.7	195.1	139.0	107.0	167.8	128.9	
% Change in BFA (2016-2017)	-14	-14	-2	-7	27	5	10	8	-16	11	-11	9	30	1	27	12	-21	10	**4**
% Change in BFA (2017-2018)	3	5	-2	4	10	-4	5	-5	3	1	-2	4	3	0	4	-1	-5	2	**1**
Width/Depth(2016)	19.0	23.2	26.4	32.8	18.1	11.9	16.5	32.6	18.2	18.7	9.9	19.1	32.8	24.8	39.5	23.5	10.4	15.1	
Width/Depth(2017)	21.8	29.2	26.7	27.1	17.5	15.4	19.2	32.1	21.3	14.6	10.8	19.0	23.8	25.2	32.0	20.4	15.5	29.3	
Width/Depth(2018)	22.4	28.2	26.8	24.9	15.4	15.1	19.0	30.9	21.6	14.2	8.6	19.1	22.7	25.6	32.2	24.0	13.2	28.9	
% Change in W/D (2016-2017)	14	26	1	-18	-3	29	17	-1	17	-22	9	-1	-27	2	-19	-13	49	94	**9**
% Change in W/D (2017-2018)	3	-3	0	-8	-12	-2	-1	-4	1	-2	-20	1	-5	2	1	18	-14	-1	**-3**
ENT (2016)	1.48	1.68	1.82	1.52	2.32	2.11	2.05	1.54	1.99	2.19	2.14	2.08	1.95	1.44	1.54	2.10	2.07	2.40	
ENT (2017)	1.49	1.61	1.82	1.74	2.11	1.81	1.81	1.49	2.00	2.34	2.17	2.00	2.00	1.43	1.52	2.12	1.91	1.64	
ENT (2018)	1.45	1.60	1.84	1.78	2.12	1.86	1.77	1.56	1.98	2.36	2.46	1.96	2.02	1.41	1.49	1.98	2.12	1.64	
% Change in ER (2016-2017)	1	-4	0	14	-9	-14	-12	-3	1	7	1	-4	3	-1	-1	1	-8	-32	**-3**
% Change in ER (2017-2018)	-3	-1	1	2	0	3	-2	5	-1	1	13	-2	1	-1	-2	-7	11	0	**1**
BFW (2016)	67.8	59.5	55.1	65.6	43.1	47.5	48.9	65.2	50.3	45.7	46.7	48.2	51.4	69.3	64.8	47.6	48.3	41.7	
BFW (2017)	67.3	62.0	54.9	57.4	47.3	55.3	55.4	67.1	50.0	42.7	46.1	50.1	50.0	70.2	65.6	47.0	52.3	61.0	
BFW (2018)	69.1	62.4	54.3	56.1	47.1	53.8	56.6	64.2	50.9	42.4	40.6	51.2	49.5	70.7	67.0	50.6	47.1	61.0	
% Change in BFW (2016-2017)	-1	4	0	-13	10	16	13	3	-1	-7	-1	4	-3	1	1	-1	8	46	**5**
% Change in BFW (2017-2018)	3	1	-1	-2	-1	-3	2	-4	2	-1	-12	2	-1	1	2	8	-10	0	**-1**
BFDMN (2016)	3.56	2.56	2.09	2.00	2.38	4.00	2.97	2.00	2.76	2.45	4.70	2.52	1.57	2.80	1.64	2.03	4.65	2.76	
BFDMN (2017)	3.09	2.12	2.06	2.12	2.76	3.60	2.88	2.09	2.35	2.93	4.26	2.64	2.10	2.79	2.05	2.30	3.38	2.08	
BFDMN (2018)	3.09	2.21	2.03	2.25	3.06	3.56	2.97	2.08	2.36	2.98	4.72	2.68	2.18	2.76	2.08	2.11	3.56	2.11	
% Change in BFDMN (2016-2017)	-13	-17	-1	6	16	-10	-3	4	-15	20	-9	5	34	0	25	13	-27	-25	**0**
% Change in BFDMN (2017-2018)	0	4	-1	6	11	-1	3	0	0	2	11	2	4	-1	1	-8	5	1	**2**
BFDMX (2016)	7.38	4.36	3.25	4.28	4.89	9.38	6.06	3.77	4.48	4.66	8.58	4.30	3.28	7.74	4.08	3.02	8.64	4.47	
BFDMX (2017)	5.42	4.56	2.92	3.70	6.42	7.88	5.92	3.83	4.14	4.90	7.51	4.41	4.30	7.04	4.52	3.35	6.83	4.16	
BFDMX (2018)	5.08	4.85	2.80	3.98	6.37	7.62	5.71	3.59	4.16	4.71	8.03	4.27	4.04	7.61	5.26	3.39	6.08	4.52	
% Change in BFDMX (2016-2017)	-27	5	-10	-14	31	-16	-2	2	-8	5	-12	3	31	-9	11	11	-21	-7	**-2**
% Change in BFDMX (2017-2018)	-6	6	-4	8	-1	-3	-4	-6	0	-4	7	-3	-6	8	16	1	-11	9	**0**

Table 7.3 Percent change in channel dimensions for the Vermilion River Miners Gulch reference reach

Dimension Variables	XS#1 Pool	XS#2 Glide	XS#3 Run	XS#4 Riffle	XS#5 Run	XS#6 Pool	XS#7 Glide	XS#8 Riffle	XS#9 Riffle	XS#10 Run	**Mean Reach**
BFA (2016)	111.2	156.9	119.5	118.9	104.7	176.5	138.0	137.0	122.8	116.1	
BFA (2017)	106.7	144.7	119.6	119.6	99.0	172.3	132.3	128.9	124.9	112.0	
BFA (2018)	99.8	134.8	119.5	115.5	96.4	172.7	137.3	132.9	124.2	113.3	
% Change in BFA (2016-2017)	-4	-8	0	1	-5	-2	-4	-6	2	-4	**-3**
% Change in BFA (2017-2018)	-6	-7	0	-3	-3	0	4	3	-1	1	**-1**
Width/Depth(2016)	25.5	18.8	29.9	28.6	30.3	25.3	28.2	27.1	15.4	26.1	
Width/Depth (2017)	25.9	20.6	29.3	32.4	31.0	22.8	25.9	25.7	16.5	27.5	
Width/Depth (2018)	25.2	21.7	28.5	34.0	31.2	25.4	25.7	25.0	17.1	26.9	
% Change in W/D (2016-2017)	2	9	-2	13	2	-10	-8	-5	7	5	**1**
% Change in W/D (2017-2018)	-3	5	-3	5	1	11	-1	-3	3	-2	**1**
Entrenchment (2016)	1.88	1.84	1.68	1.71	1.78	1.50	1.60	1.64	2.30	1.82	
Entrenchment (2017)	1.90	1.83	1.69	1.61	1.80	1.59	1.71	1.74	2.20	1.80	
Entrenchment (2018)	1.99	1.85	1.71	1.60	1.82	1.51	1.68	1.74	2.17	1.81	
% Change in ER (2016-2017)	1	-1	1	-6	1	6	7	6	-4	-1	**1**
% Change in ER (2017-2018)	5	1	1	-1	1	-5	-2	0	-1	1	**0**
BFW (2016)	53.3	54.4	59.7	58.4	56.3	66.8	62.3	61.0	43.5	55.0	
BFW (2017)	52.7	54.6	59.2	62.2	55.5	62.8	58.5	57.6	45.4	55.5	
BFW (2018)	50.2	54.1	58.4	62.6	54.9	66.2	59.4	57.6	46.0	55.2	
% Change in BFW (2016-2017)	-1	0	-1	6	-1	-6	-6	-6	4	1	**-1**
% Change in BFW (2017-2018)	-5	-1	-1	1	-1	6	2	0	1	0	**0**
BFDMN (2016)	2.09	2.89	2.00	2.04	1.86	2.64	2.21	2.25	2.82	2.11	
BFDMN (2017)	2.03	2.65	2.02	1.92	1.79	2.75	2.26	2.24	2.75	2.02	
BFDMN (2018)	1.99	2.49	2.05	1.84	1.76	2.61	2.31	2.31	2.70	2.05	
% Change in BFDMN (2016-2017)	-3	-8	1	-6	-4	4	2	0	-2	-4	**-2**
% Change in BFDMN (2017-2018)	-2	-6	1	-4	-2	-5	2	3	-2	1	**-1**
BFDMX (2016)	4.31	7.42	3.67	3.38	3.75	4.96	4.23	3.96	4.72	4.02	
BFDMX (2017)	3.93	6.82	3.70	3.28	3.45	4.86	4.14	3.96	4.87	3.93	
BFDMX (2018)	3.82	5.91	3.82	3.38	3.28	4.94	4.28	4.20	4.72	3.79	
% Change in BFDMX (2016-2017)	-9	-8	1	-3	-8	-2	-2	0	3	-2	**-3**
% Change in BFDMX (2017-2018)	-3	-13	3	3	-5	2	3	6	-3	-4	**-1**

Table 7.4 Comparison of reference reach vs. as-built mean dimensions 2016 - 2017

Dimension Variables	Mean Reach Vermilion Reference (2016-2017)	Mean Reach Vermilion Reference (2017-2018)	Mean Reach Miners Gulch Restoration (2016-2017)	Mean Reach Miners Gulch Restoration (2017-2018)
% Change in BFA	**1**	**1**	**4**	**1**
% Change in W/D	**3**	**1**	**9**	**3**
% Change in Entrenchment	**1**	**0**	**3**	**1**
% Change in BFW	**1**	**0**	**5**	**1**
% Change in BFDMN	**2**	**1**	**0**	**2**
% Change in BFDMX	**0**	**1**	**2**	**0**

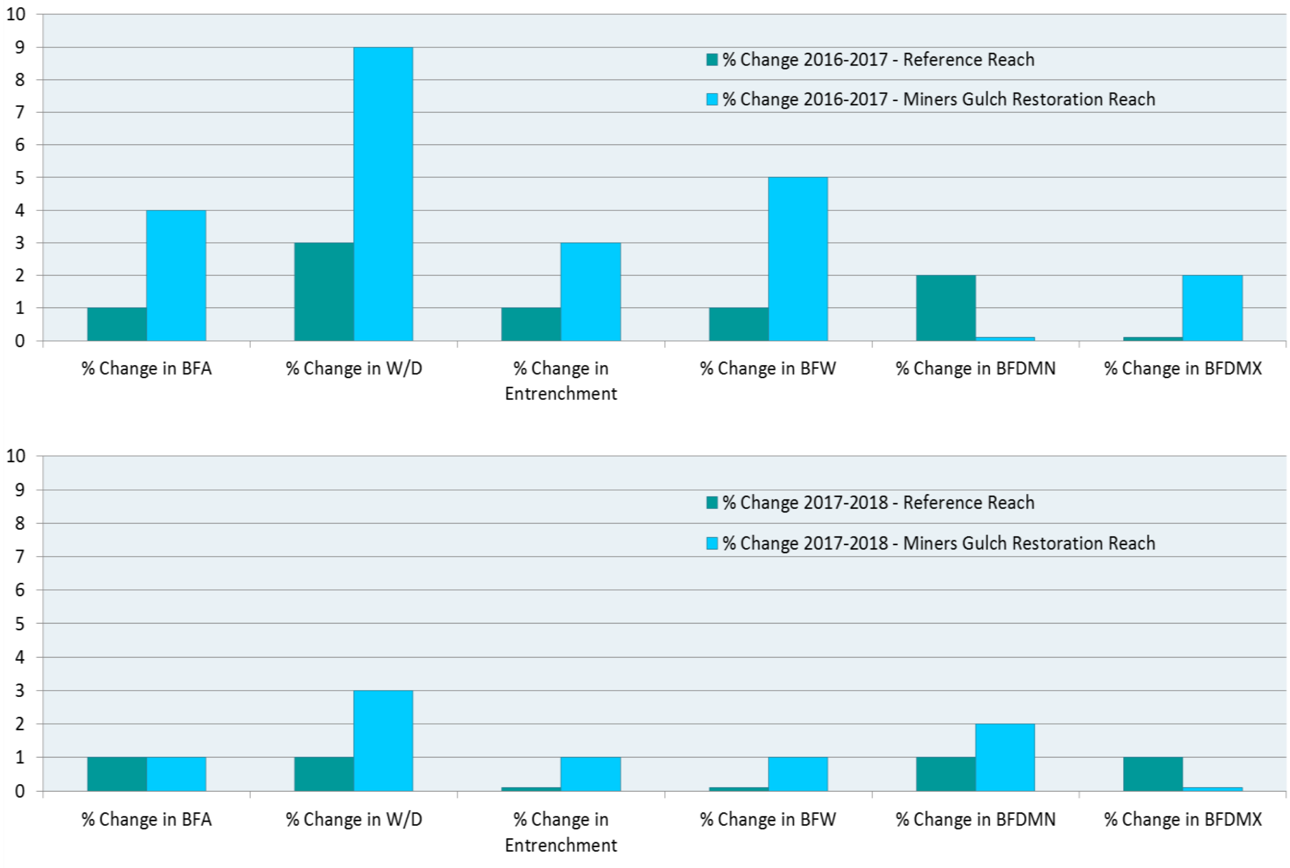


Figure 7.0. Dimension variable percent change within the project and reference reaches from 2016 to 2018.

Natural channel fluctuations are expected within most fluvial systems in the Lower Clark Fork drainage. Within stable channels major shifts in channel dimension variables generally occur during low frequency high intensity flood events. These can happen at any time but are largely related to Rain On Snow (ROS) events in this area of Northwest Montana. Monitoring throughout the Lower Clark Fork region suggests flood frequencies above 10 -20 year return interval flows could exacerbate stream channels with good stability and most likely those displaying poor stability. In general terms dimension variables that drastically change under average runoff years or bankfull type flows point to severe instability or unnatural stream channel succession.

Based on the differences between the percent change within the reference and project reach, the small fluctuations in dimension variables noticed are similar to what is naturally expected, especially those related to the second year post-project.

As expected the changes in reference reach dimension variables were slightly less than the project reach, especially those associated with the first runoff post build. This could be related to a combination of things, such as a more imbricated well developed channel and/or a more established riparian component. As the second season variables suggest, over time the project reach dimension fluctuations should more closely relate to those of the reference reach directly upstream.

7.2 Stream Channel Succession through the Project Reach

Reference reach information similar to that obtained for the project reach has been collected from the Cabinet and Libby Ranger Districts since 1998. Dimensionless mean values have been stratified by stream type and threshold values where channel succession is most likely to occur have been developed. The Miners Gulch project reach has Rosgen “B/C” channel types as the desired design type. The local reference derived threshold values surrounding the possible morphological changes in a “C” channel type are represented below in Table 7.5.

Table 7.5 Stream successional thresholds derived from local reference reaches.

Dimension Variables	C to B	C to G	C to F	C to D
Dimensionless W/D	> 1.31	< 0.54	> 1.47	> 6.76
Dimensionless Entrenchment	< 0.43	< 0.56	< 0.32	< 0.72
Dim BFW/Dim BFDMN	> 1.37	< 0.57	> 1.71	> 7.26
Dim BFW/Dim BFDMX	> 1.23	< 0.61	> 1.40	> 3.72

Should these variables be monitored through the project reach and dimensionless variables exist around 1.0, this would mean the stream channel dimensions are within the natural range of variability, are currently maintaining stability and not in a state of transition or further channel succession. Should the dimensionless variables approach the thresholds listed in Table 7.5 it can be expected that channel succession is actively occurring.

As Table 7.6 suggests, no active channel succession is or has occurred within the project reach. In terms of channel dimensions the restoration techniques employed have proven effective in terms of maintaining a stable channel as designed that display minimal signs of premature transitions through two average runoff seasons. Pending no short-term high intensity flood damage, the planted riparian vegetation should continue to flourish and add to floodplain function and bank stability.

Table 7.6 Dimensionless project reach variables 2016 - 2017 - 2018

Dimension Variables	XS#1 Pool	XS#2 Glide	XS#3 Run	XS#4 Rif	XS#5 Run	XS#6 Pool	XS#7 Glide	XS#8 Rif	XS#9 Rif	XS#10 Run	XS#11 Pool	XS#12 Run	XS#13 Run	XS#14 Pool	XS#15 Glide	XS#16 Rif	XS#17 Pool	XS#18 Glide	**Mean Reach**
BFA (2016 As-Built)	241.4	152.1	115.0	131.1	102.6	189.9	145.1	130.6	139.0	112.2	219.7	121.4	81.0	194.0	105.9	96.6	224.3	115.2	
BFA (2017)	207.7	131.1	112.9	121.5	130.5	199.1	159.5	140.6	117.3	125.0	196.5	132.0	105.0	195.5	134.1	107.9	176.6	126.8	
BFA (2018)	213.7	137.9	110.4	126.1	144.2	191.5	168.0	133.3	120.4	126.5	192.0	137.3	107.7	195.1	139.0	107.0	167.8	128.9	
Dimensionless BFA (2016-2017)	0.86	0.86	0.98	0.93	1.27	1.05	1.10	1.08	0.84	1.11	0.89	1.09	1.30	1.01	1.27	1.12	0.79	1.10	**1.04**
Dimensionless BFA (2017-2018)	1.03	1.05	0.98	1.04	1.10	0.96	1.05	0.95	1.03	1.01	0.98	1.04	1.03	1.00	1.04	0.99	0.95	1.02	**1.01**
Width/Depth(2016 As-Built)	19.0	23.2	26.4	32.8	18.1	11.9	16.5	32.6	18.2	18.7	9.9	19.1	32.8	24.8	39.5	23.5	10.4	15.1	
Width/Depth (2017)	21.8	29.2	26.7	27.1	17.5	15.4	19.2	32.1	21.3	14.6	10.8	19.0	23.8	25.2	32.0	20.4	15.5	29.3	
Width/Depth (2018)	22.4	28.2	26.8	24.9	15.4	15.1	19.0	30.9	21.6	14.2	8.6	19.1	22.7	25.6	32.2	24.0	13.2	28.9	
Dimensionless W/D (2016-2017)	1.14	1.26	1.01	0.82	0.97	1.29	1.17	0.99	1.17	0.78	1.09	0.99	0.73	1.02	0.81	0.87	1.49	1.94	**1.09**
Dimensionless W/D (2017-2018)	1.03	0.97	1.00	0.92	0.88	0.98	0.99	0.96	1.01	0.98	0.80	1.01	0.95	1.02	1.01	1.18	0.86	0.99	**0.97**
Entrenchment (2016 As-Built)	1.5	1.7	1.8	1.5	2.3	2.1	2.1	1.5	2.0	2.2	2.1	2.1	2.0	1.4	1.5	2.1	2.1	2.4	
Entrenchment (2017)	1.5	1.6	1.8	1.7	2.1	1.8	1.8	1.5	2.0	2.3	2.2	2.0	2.0	1.4	1.5	2.1	1.9	1.6	
Entrenchment (2018)	1.5	1.6	1.8	1.8	2.1	1.9	1.8	1.6	2.0	2.4	2.5	2.0	2.0	1.4	1.5	2.0	2.1	1.6	
Dimensionless ER (2016-2017)	1.01	0.96	1.00	1.14	0.91	0.86	0.88	0.97	1.01	1.07	1.01	0.96	1.03	0.99	0.99	1.01	0.92	0.68	**0.97**
Dimensionless ER (2017-2018)	0.97	0.99	1.01	1.02	1.00	1.03	0.98	1.05	0.99	1.01	1.13	0.98	1.01	0.99	0.98	0.93	1.11	1.00	**1.01**
BFW (2016 As-Built)	67.8	59.5	55.1	65.6	43.1	47.5	48.9	65.2	50.3	45.7	46.7	48.2	51.4	69.3	64.8	47.6	48.3	41.7	
BFW (2017)	67.3	62.0	54.9	57.4	47.3	55.3	55.4	67.1	50.0	42.7	46.1	50.1	50.0	70.2	65.6	47.0	52.3	61.0	
BFW (2018)	69.1	62.4	54.3	56.1	47.1	53.8	56.6	64.2	50.9	42.4	40.6	51.2	49.5	70.7	67.0	50.6	47.1	61.0	
Dimensionless BFW (2016-2017)	0.99	1.04	1.00	0.87	1.10	1.16	1.13	1.03	0.99	0.93	0.99	1.04	0.97	1.01	1.01	0.99	1.08	1.46	**1.05**
Dimensionless BFW (2017-2018)	1.03	1.01	0.99	0.98	0.99	0.97	1.02	0.96	1.02	0.99	0.88	1.02	0.99	1.01	1.02	1.08	0.90	1.00	**0.99**
BFDMN (2016 As-Built)	3.6	2.6	2.1	2.0	2.4	4.0	3.0	2.0	2.8	2.5	4.7	2.5	1.6	2.8	1.6	2.0	4.7	2.8	
BFDMN (2017)	3.1	2.1	2.1	2.1	2.8	3.6	2.9	2.1	2.4	2.9	4.3	2.6	2.1	2.8	2.1	2.3	3.4	2.1	
BFDMN (2018)	3.1	2.2	2.0	2.3	3.1	3.6	3.0	2.1	2.4	3.0	4.7	2.7	2.2	2.8	2.1	2.1	3.6	2.1	
Dimensionless BFDMN (2016-2017)	0.87	0.83	0.99	1.06	1.16	0.90	0.97	1.05	0.85	1.20	0.91	1.05	1.34	1.00	1.25	1.13	0.73	0.75	**1.00**
Dimensionless BFDMN (2017-2018)	1.00	1.04	0.99	1.06	1.11	0.99	1.03	1.00	1.00	1.02	1.11	1.02	1.04	0.99	1.01	0.92	1.05	1.01	**1.02**
BFDMX (2016 As-Built)	7.4	4.4	3.3	4.3	4.9	9.4	6.1	3.8	4.5	4.7	8.6	4.3	3.3	7.7	4.1	3.0	8.6	4.5	
BFDMX (2017)	5.4	4.6	2.9	3.7	6.4	7.9	5.9	3.8	4.1	4.9	7.5	4.4	4.3	7.0	4.5	3.4	6.8	4.2	
BFDMX (2018)	5.1	4.9	2.8	4.0	6.4	7.6	5.7	3.6	4.2	4.7	8.0	4.3	4.0	7.6	5.3	3.4	6.1	4.5	
Dimensionless BFDMX (2016-2017)	0.73	1.05	0.90	0.86	1.31	0.84	0.98	1.02	0.92	1.05	0.88	1.03	1.31	0.91	1.11	1.11	0.79	0.93	**0.98**
Dimensionless BFDMX (2017-2018)	0.94	1.06	0.96	1.08	0.99	0.97	0.96	0.94	1.00	0.96	1.07	0.97	0.94	1.08	1.16	1.01	0.89	1.09	**1.00**

7.3 Project and Reference Channel Profile

Project Channel Profile

The 2017 and 2018 post runoff longitudinal profiles encompassed all of the 1500 feet of channel which was reconstructed in 2016. The vertical stability of the newly constructed channel can be assessed in relation to the runoff events experienced in the related water years. As well as sediment entrainment, the vertical stability of a reach lends inferences about vegetative potential and the static groundwater elevation in the hyporheic regions of the floodplain.

Water facet slopes have been measured by feature type from the 2016 as-built profile as well as the 2017 and 2018 post runoff profiles. Table 2.4 below displays the % change from as-built in terms of profile and pattern related to water years 2017 and 2018.

Table 7.7 Project reach summary of monitored pattern and profile 2016 -2017 – 2018

Dimension Variables	Riffles	Runs	Pools	Glides	All Features	Mean Reach
Average Slope (2016 As-Built)	0.022	0.119	0.004	0.012		.017
Average Slope (2017 Post run-off)	0.021	0.057	0.004	0.004		.017
Average Slope (2018 Post run-off)	0.023	0.075	0.003	0.009		.017
% Change in Slope (2016-2017)	5	52	0	67	**31**	**0**
% Change in Slope (2017-2018)	9	24	25	56	**28**	**0**
Sinuosity (2016 As-Built)						1.13
Sinuosity (2017 Post run-off)						1.13
Sinuosity (2018 Post run-off)						1.13
% Change in Sinuosity (2016-2017)						**0**
% Change in Sinuosity (2017-2018)						**0**

Changes in channel elevation were noticed in certain design features. The as-built channel went through a cleansing flow upon the first substantial run-off event post construction in 2016. None of these changes led to loss of integrity in structure or bank strength. In the more constricted areas changes led to the slight down cutting around the mid-channel boulder features. These areas were constructed to narrow the channel and provide for the “run” type features that aide in pool maintenance and function. The boulder and cobble placements in these areas have moved slightly and margin elevations have deepened. The cobble “throats” were designed to move under bankfull or higher flow and have slightly. These areas were further monitored through the next event cycle of 2018 and little change is occurring. Additional pool habitat formed in areas below the constructed cobble pool tails in 2017 while maintaining the same water surface elevation. The glide or pool tail areas seem to be sorting material. Very little deposition occurred throughout the reach. Most other changes related to the ebb and flow of natural sediment transport and was expected. Although very similar in terms of water year to that of 2017 (see Figure 7.1) the channel bottom within the project reach seemed to have somewhat sustained through the 2018 runoff season. Slight changes in channel features were observed mostly within the 1st year of runoff. A few pools and glides noticed some filling of material leading to less overall depth. All of the pools seem to have stabilized after the second runoff cycle of 2018. Riffles maintained grade and dimensions such as width and depth. Wood structures at the lower end of the project reach seemed to have collected more material and created additional lateral pool volume from that of the previous two years.

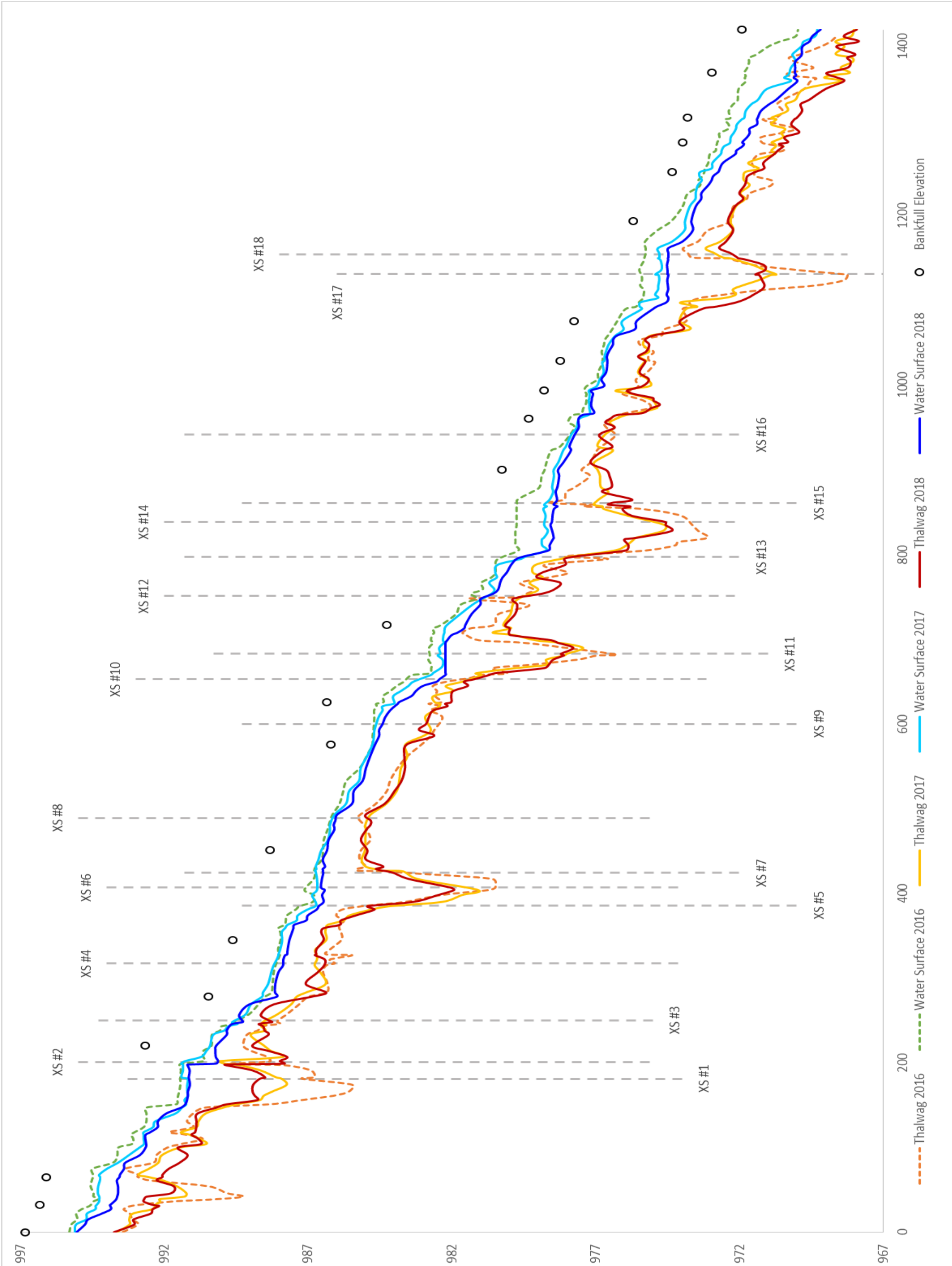


Figure 7.1 Vermilion Miners Gulch project reach longitudinal profile of 2016, 2017 and 2018.

It could be expected that as long as sediment is being transported through the system some degree of channel fluctuation will occur through each runoff cycle. The descriptor that explains whether or not the channel elevation has maintained through the monitored flow events is the overall change in reach slope post run-off. As is displayed in Table 7.7 the mean slope of the channel did not change with the 2017 or 2018 flow events and related sediment transport, nor did the planned structures create active headcutting or channel avulsions.

Reference Channel Profile

The vertical stability of the reference channel upstream of the project site was assessed in relation to the runoff events experienced in the water years of 2017 and 2018.

Facet slopes have been measured from the monitored post runoff profiles within the reference reach. Table 2.5 below displays the % change in terms of profile and pattern related to water years 2017 and 2018.

Table 7.8 Reference reach summary of monitored pattern and profile 2016 -2017 – 2018

Dimension Variables	Riffles	Runs	Pools	Glides	All Features	Mean Reach
Average Slope (2016)	0.018	0.060	0.005	0.011		.024
Average Slope (2017 Post run-off)	0.027	0.090	0.003	0.005		.024
Average Slope (2018 Post run-off)	0.023	0.044	0.002	0.010		.024
% Change in Slope (2016-2017)	33	33	40	55	**40**	**0**
% Change in Slope (2017-2018)	15	51	33	50	**37**	**0**
Sinuosity (2016 As-Built)						1.17
Sinuosity (2017 Post run-off)						1.17
Sinuosity (2018 Post run-off)						1.17
% Change in Sinuosity (2016-2017)						**0**
% Change in Sinuosity (2017-2018)						**0**

Vertical stability measured by water surface facet slopes within the reference reach changed slightly through the monitored runoff period. All changes were within expected tolerances and very similar to changes monitored within the as-built project reach. Both reaches were subject to the same flow regime in both 2017 and 2018.

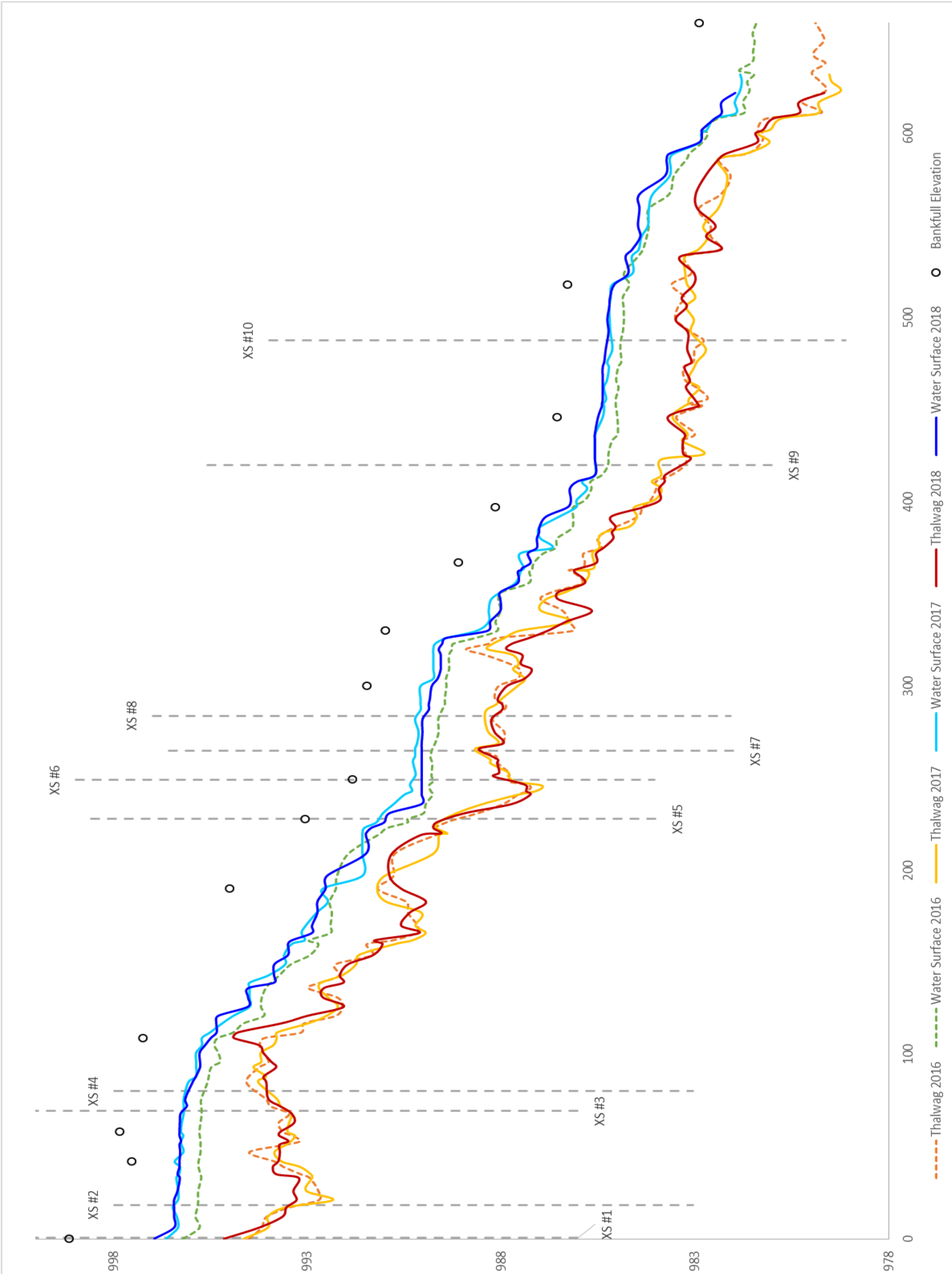


Figure 7.2 Vermilion reference reach longitudinal profile of 2016, 2017 and 2018.

7.4 Substrate Monitoring – Reference and Project Reaches

Wolman pebble counts were completed at 6 cross sections within the project reach and 7 within the reference reach in the summer of 2017. All were repeated in the exact locations following the peakflow events of 2018. Most of the counts were completed directly atop the monumented cross sections in representative riffle, run, and glide units. As-built pebble counts were not surveyed immediately after construction in 2016 as it was thought that these samples would be biased from the related instream silt and sand bedload produced from activities (see section 4.0). The runoff events that occurred in water year 2017 are thought to have transported the majority of this “construction silt” out of the project reach.

In terms of the channel substrate below the bankfull elevation, slight fluctuations were noticed within the riffles, glides and the entire reach. These changes corresponded well with the minor dimension fluctuations noticed in the surveyed transects and profiles. A certain level of variability can be expected within this type of survey as the protocol requires random particles to be measured annually. Changes in substrate remained at a low level and further supported the other observation trends throughout the project reach.

Slight shifts in channel substrate have occurred in the reference reach just upstream of the project. None of these shifts however are influencing channel function and stability of the reference or the project reach. Although still a small percentage of the total composition, both the reference and project reaches noticed changes in the percent sand. Reductions occurred within the reference channel while slight increases occurred within the project reach. Although the percent sand size material increased in 2018, mostly in glide features, the low percentage is not concerning in terms of the overall material composition and effects to fisheries and aquatic habitat. This was most likely associated with a seasonal flush of upstream fines, with slight deposition through the project reach.

Table 7.9 Combined (C), Riffle (R) and Glide (G) particle size distributions within the project and reference reaches.

Cumulative % and Finer	**2017 Reference Reach**			**2018 Reference Reach**			**2017 Miners Gulch Project Reach**			**2018 Miners Gulch Project Reach**		
	C	**R**	**G**	**C**	**R**	**G**	**C**	**R**	**G**	**C**	**R**	**G**
D16	6	2	4	10	6	8	17	17	19	11	8	11
D50	43	33	35	53	47	39	53	48	46	56	52	63
D84	152	131	119	183	168	136	153	136	130	202	174	163
D95	310	260	305	372	336	318	302	256	254	473	421	315
%Silt / Clay (<.062 mm)	0	0	0	0	0	0	0	0	0	0	0	0
%Sand (.062 – 2.0 mm)	13	14	13	8	9	7	2	3	2	5	8	5
%Gravel (2.0 – 64 mm)	51	55	55	51	54	59	57	58	59	48	48	45
%Cobble (64 – 256 mm)	27	22	26	29	26	25	35	35	35	36	36	42
%Boulder(256-2048 mm)	9	8	6	11	10	8	7	4	5	10	9	8
%Bedrock (> 2048 mm)	0	0	0	0	0	0	0	0	0	0	0	0

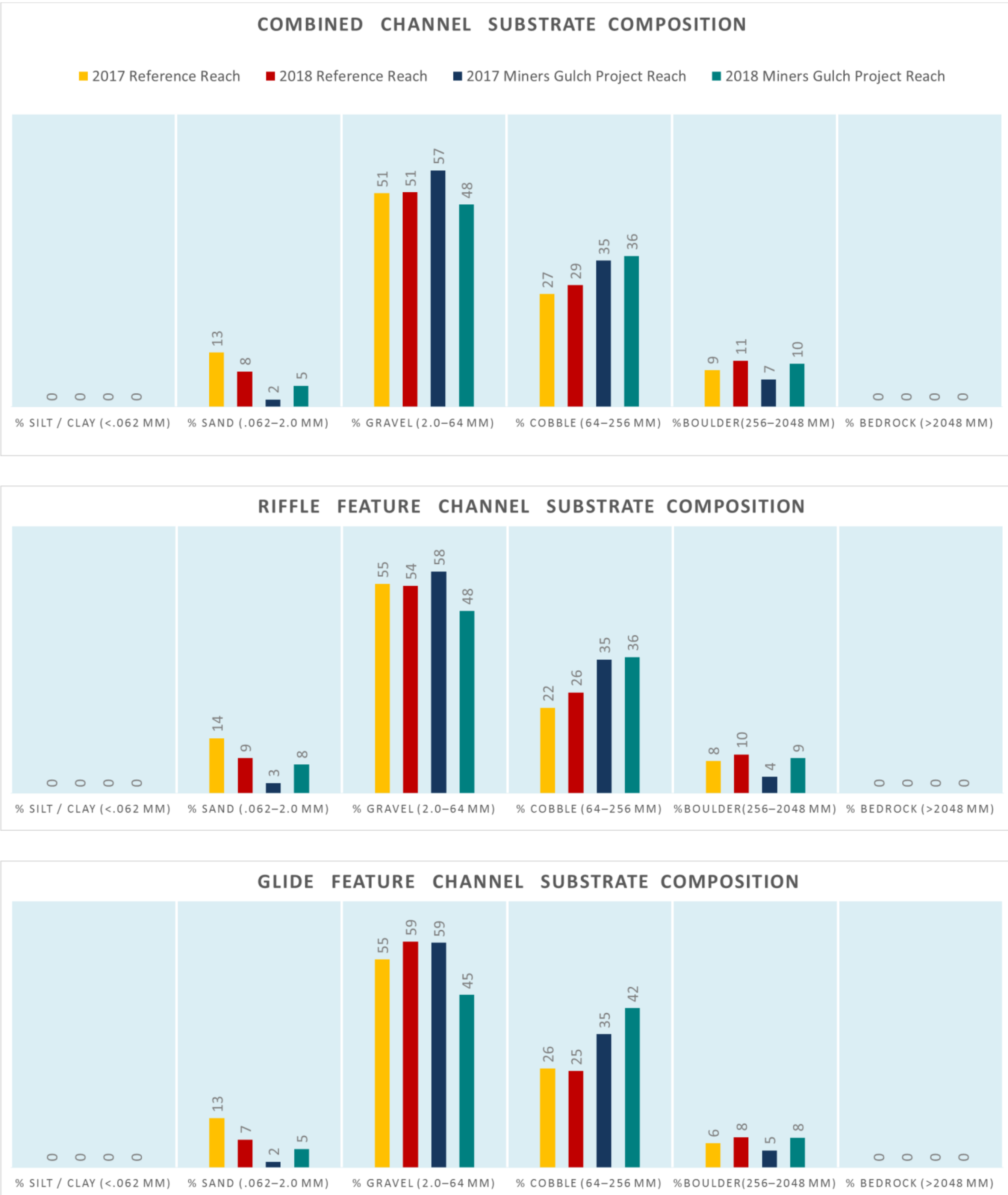


Figure 7.3 Composite, Riffle and Glide feature substrate composition 2017 and 2018.

7.5 Pool Tail Fines

Pool tail fines less than 6 mm were measured within the project and upstream reference reach. Values remained between 7-11% throughout the reference reach, which is considered low. Immediately post-project pool tail fines were measured within the rebuilt channel and thought to be at roughly 15%. Although not considered high in terms of habitat impairment (Weaver and Fraley (1991), Bryce et al (2010)), initially this higher value was thought to be directly related to the construction activities, all of which allowed for in-channel fine sediment (see section 4.0), especially in the depositional features such as the pool tail glide areas. These areas were measured again in 2018 and after two runoff cycles the substrate less than 6mm lowered to 11%.

7.6 Large Wood Additions

After the project was completed in 2016 an aquatic habitat survey (Archer et al. 2016(b)) was initiated to monitor additional characteristics such as the amount and types of Large Woody Debris (LWD). An existing condition survey of wood was not completed pre-project as the reach was practically void of woody material that could potentially create or maintain an array of channel features.

The 2016 survey of the project reach captured a total of 327 pieces of LWD which equaled 1485 pieces per mile. The average length of each piece was 19 feet with a diameter of 8 inches. Almost all of these additions were a product of project activities. During the summer of 2018 the reach was re-examined and wood tallies at that time displayed an additional 33 pieces that had been recruited and transported from upstream sources during two average runoff cycles. These additions had average lengths of 7 feet and a diameter of 7 inches. The initial project related wood structures were intended to provide for LWD additions that not only created channel complexity but also provided an assembly for capturing and retaining upstream woody material that historically would pass through this reach during flood flows. In terms of retaining large wood the designs employed are yielding positive results.

Figure 7.4 Example of the large wood additions within the project subsequent two runoff cycles in the Vermilion River (white wood).

7.7 Project Reach Tree Planting and Riparian Vegetation Site Monitoring

Tree plantings included Black Cottonwood and Ponderosa Pine. A very small percentage of naturally recruited Black Cottonwood trees existed in the reach with the majority occurring from planting operations. Although the PIBO riparian vegetation survey completed prior to the project (Table 2.1) has yet to be reproduced (4 year survey cycle), a floodplain assessment on both the north and south banks of the reach has been done to assess the percent tree mortality and associated damage from browsing and/or other causes.

Table 7.10 Planted riparian vegetation mortality within the project reach.

Species	Number	Browsing Damage	Survival %	Damaged %	Primary cause of damage
Black Cottonwood (planted)	388	Low	99	55	Snow damage
Black Cottonwood (natural)	2	Low	100	0	--
Ponderosa Pine (planted)	9	Low	100	0	--

Almost all of the plantings survived within the first season after planting. Approximately 55% of the planted Black Cottonwood trees were slightly compressed from heavy snow within the constructed browse enclosures. Although all of these trees survived, maintenance was needed to help prop the plantings upright. Observations during the fall of 2018 confirmed these techniques helped to maintain the integrity of the stand.

Figure 7.5 Example of a bent cottonwood bole related to heavy snowfall in the immediate floodplain.

8.0 Conclusions

This report provides for the monitoring of the Miners Gulch project reach in the mainstem of the Vermilion River. The effort has given understanding of not only channel stability but the overall trend of hydrologic processes in relation to applied designs directly linked to a representative reference reach. The channel morphology has been assessed, and monitoring has demonstrated that the project improvements function as designed through multiple runoff events. Revegetation of native trees and shrubs that were completed in 2017 are responding well and will be further monitored. The floodplain and nearbank riparian vegetation surveys completed prior to the project will be reproduced in the near future to assess trends. The current results display that the project reach is functioning similar to that of a reference condition and trending towards a stable self-sustaining riparian corridor.

Avista Utilities and Montana Fish Wildlife and Parks (MTFWP) have supported this monitoring effort by continuing to sample fish population density and diversity within this reach of the Vermilion River. Initial pre-project evaluations were made within this reach in 2016 and a repeat assessment is planned for 2019. Eventually the expectation is to link these two data sets over time in a hydro ecological setting to arrive at conclusions surrounding the impacts of this type of work in a priority Bull Trout watershed.

The next downstream project is the Sims reach which is currently in the planning and design phase. Approaches and lessons learned through this and past monitoring efforts will help evolve designs in hopes of assisting the natural processes in the Vermilion River.

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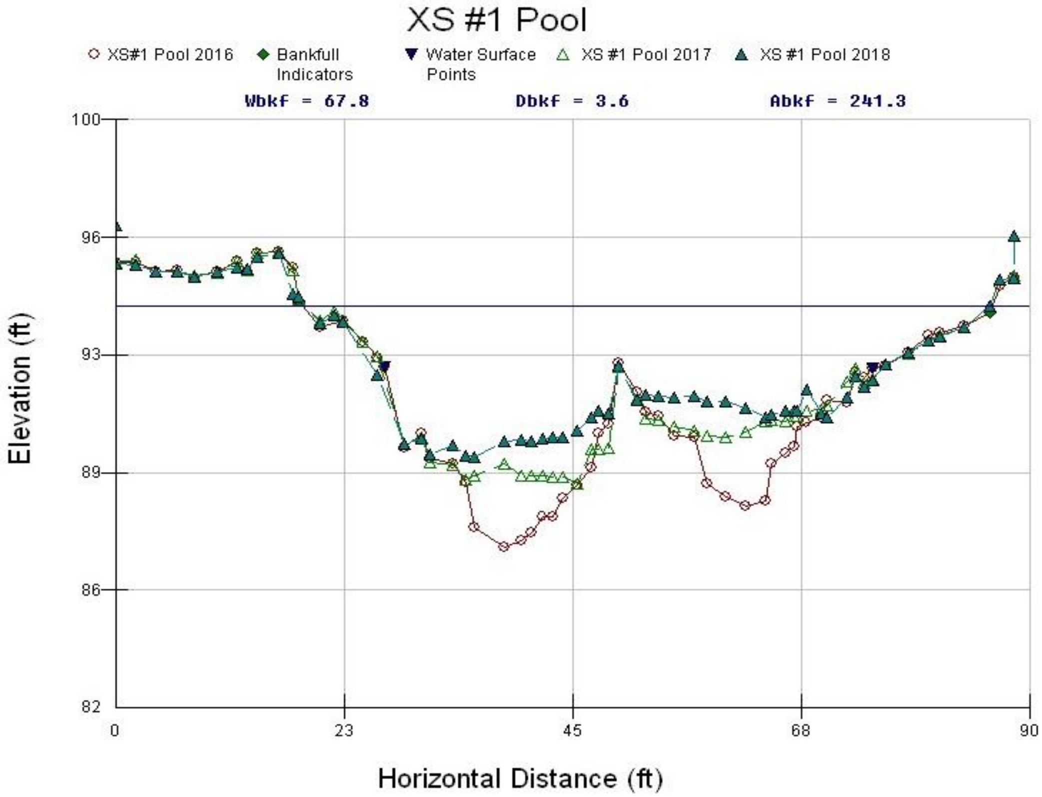
Appendix A. Miners Gulch reach as-built cross section plots and associated photos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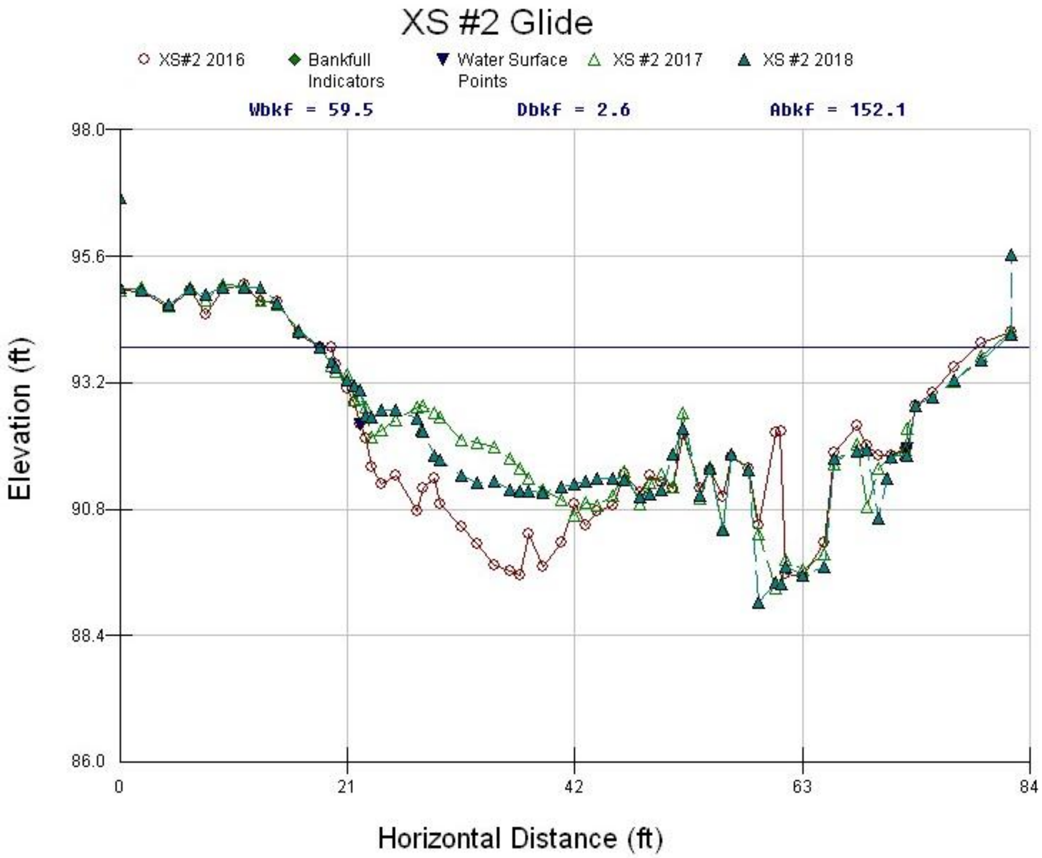
XS#1 Pool 2016
Bankfull Indicators
Water Surface Points
XS #1 Pool 2017
XS #1 Pool 2018
Wbkf = 67.8
Dbkf = 3.6
Abkf = 241.3
Elevation (ft)
100
96
93
89
86
82
0
23
45
68
90
Horizontal Distance (ft)


XS #2 Glide
XS#2 2016
Bankfull Indicators
Water Surface Points
XS #2 2017
XS #2 2018
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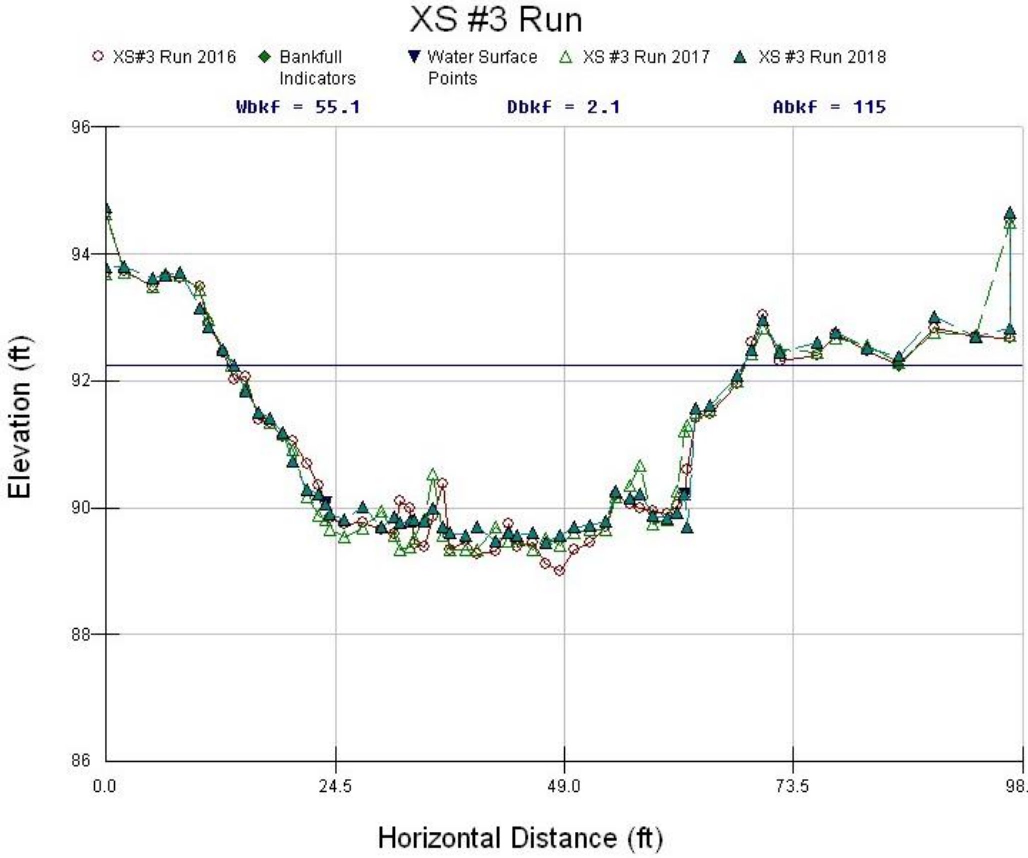
Dbkf = 2.6
Abkf = 152.1
98.0
95.6
93.2
90.8
88.4
86.0
Elevation (ft)
0
21
42
63
84
Horizontal Distance (ft)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XS#3 Run 2016
Bankfull Indicators
Water Surface Points
XS #3 Run 2017
XS #3 Run 2018
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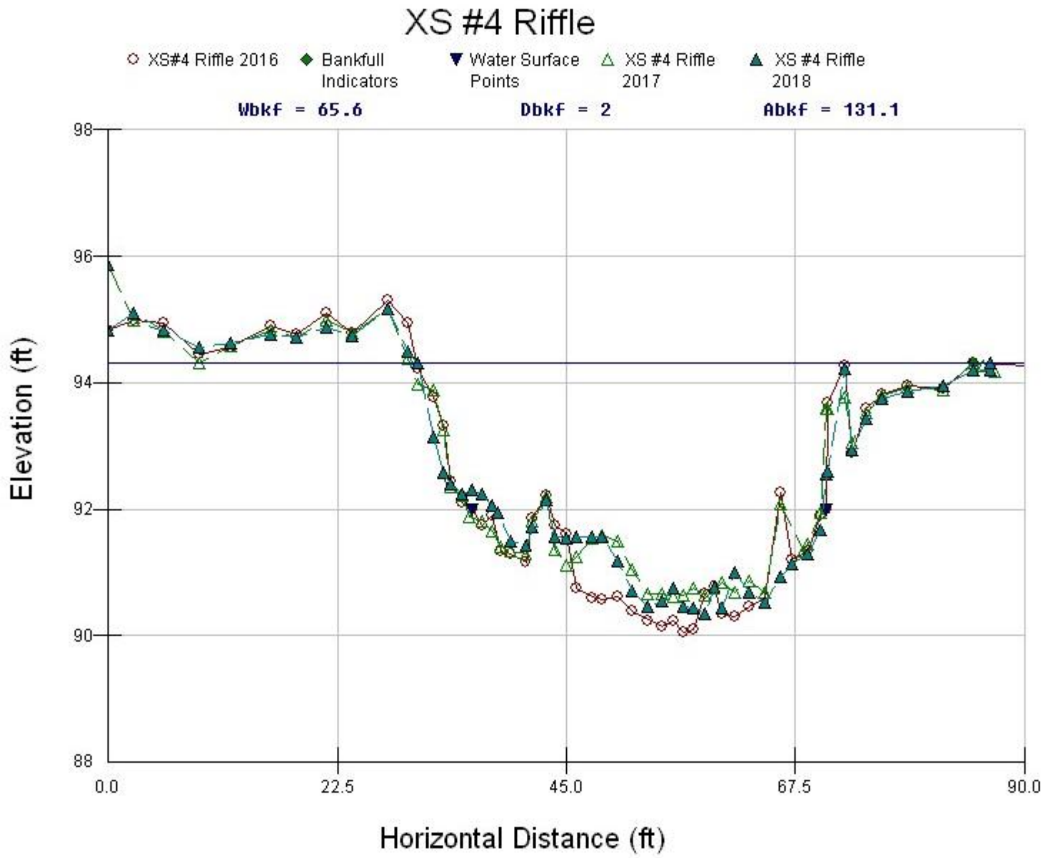
Dbkf = 2.1
Abkf = 115
Elevation (ft)
96
94
92
90
88
86
0.0
24.5
49.0
73.5
98.0
Horizontal Distance (ft)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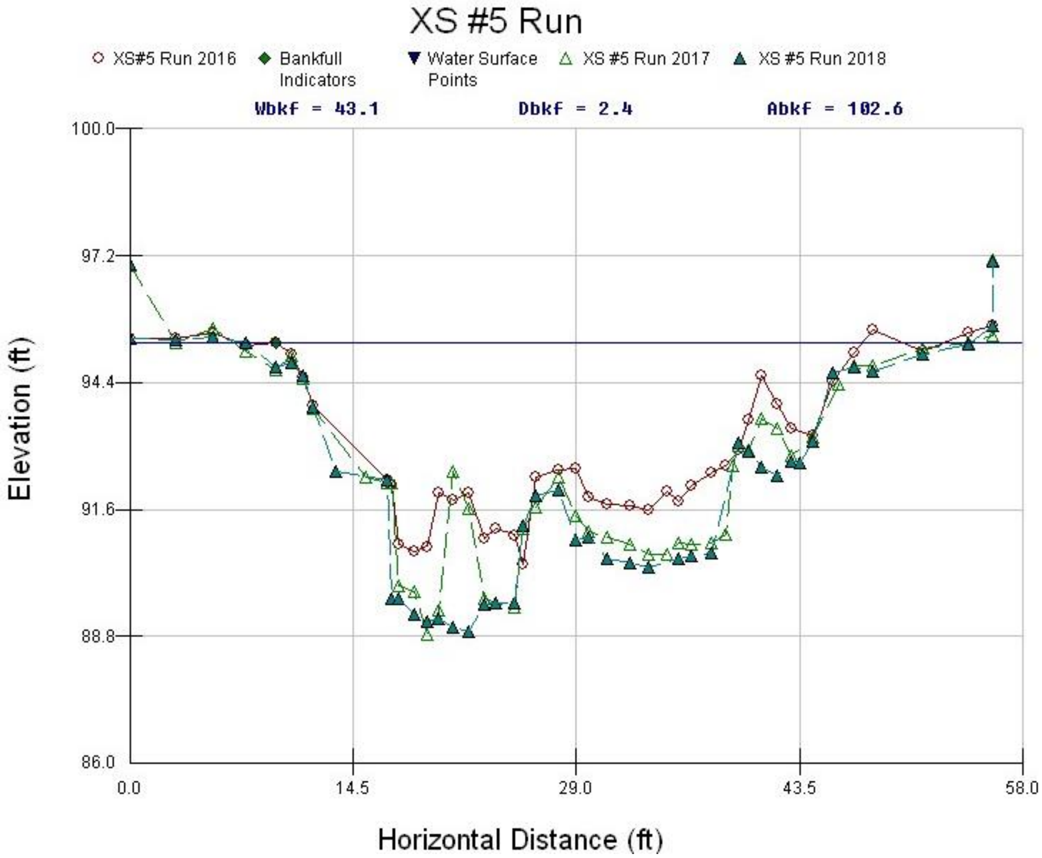
XS#4 Riffle 2016
Bankfull Indicators
Water Surface Points
XS #4 Riffle 2017
XS #4 Riffle 2018
Wbkf = 65.6
Dbkf = 2
Abkf = 131.1
Elevation (ft)
98
96
94
92
90
88
0.0
22.5
45.0
67.5
90.0
Horizontal Distance (ft)


XS #5 Run
XS#5 Run 2016
Bankfull Indicators
Water Surface Points
XS #5 Run 2017
XS #5 Run 2018
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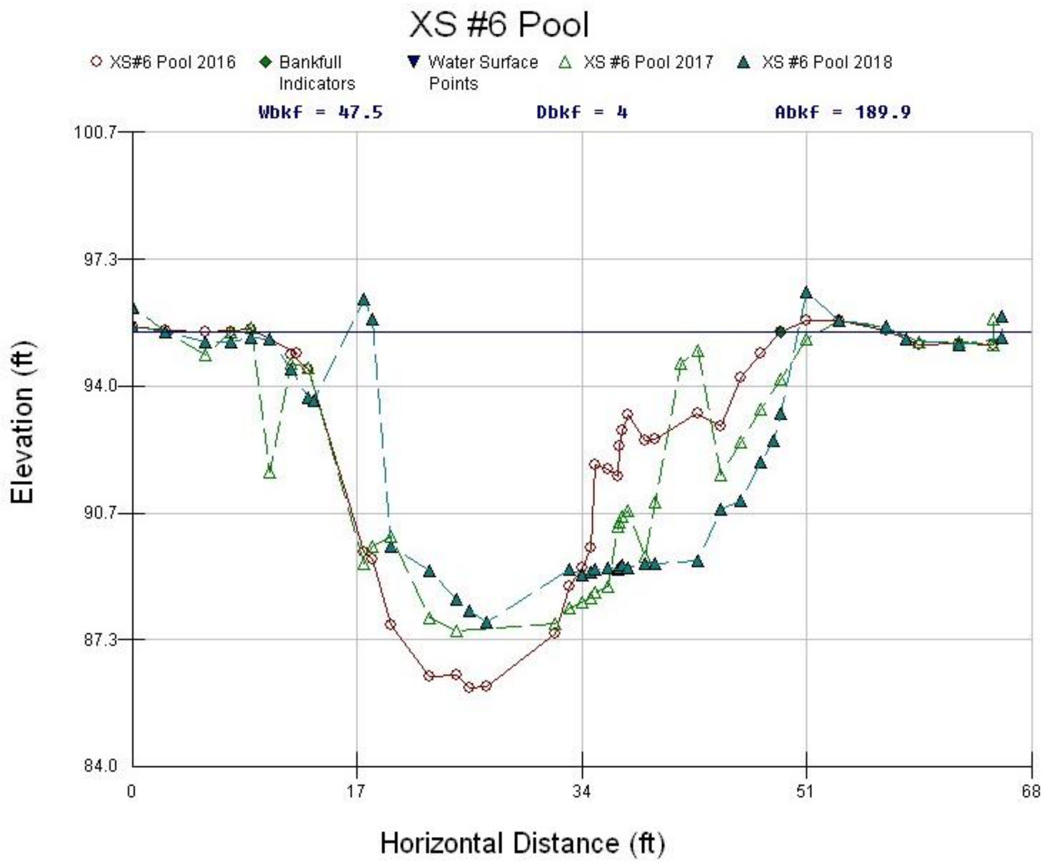
Dbkf = 2.4
Abkf = 102.6
Elevation (ft)
100.0
97.2
94.4
91.6
88.8
86.0
0.0
14.5
29.0
43.5
58.0
Horizontal Distance (ft)


XS #6 Pool
XS#6 Pool 2016
Bankfull Indicators
Water Surface Points
XS #6 Pool 2017
XS #6 Pool 2018
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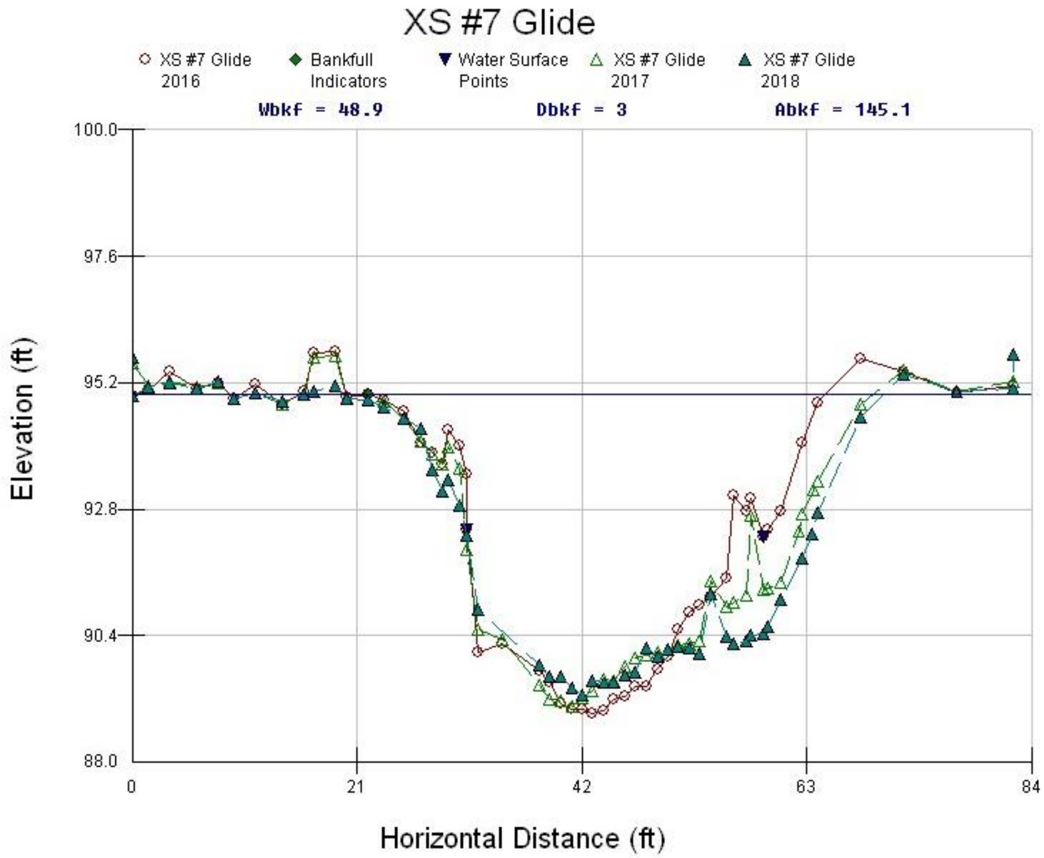
Dbkf = 4
Abkf = 189.9
100.7
97.3
94.0
90.7
87.3
84.0
0
17
34
51
68
Elevation (ft)
Horizontal Distance (ft)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XS #7 Glide 2016
Bankfull Indicators
Water Surface Points
XS #7 Glide 2017
XS #7 Glide 2018
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Dbkf = 3
Abkf = 145.1
100.0
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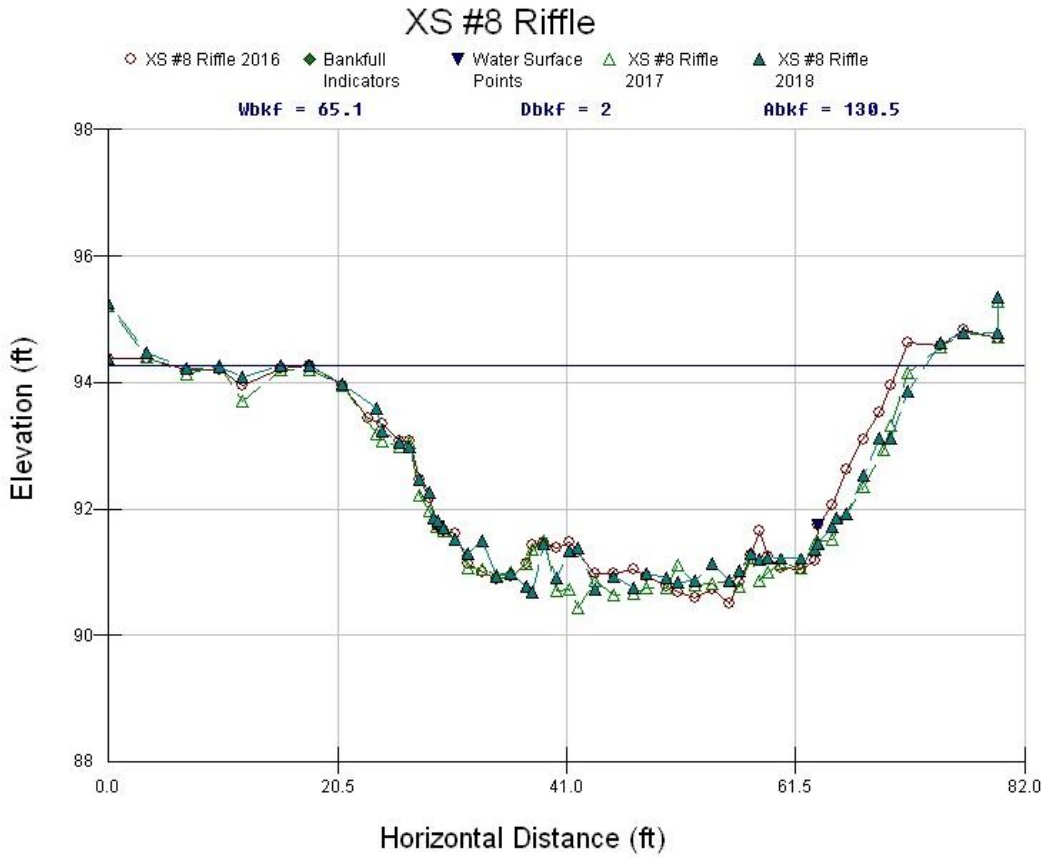
95.2
92.8
90.4
88.0
0
21
42
63
84
Elevation (ft)
Horizontal Distance (ft)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XS #8 Riffle 2016
Bankfull Indicators
Water Surface Points
XS #8 Riffle 2017
XS #8 Riffle 2018
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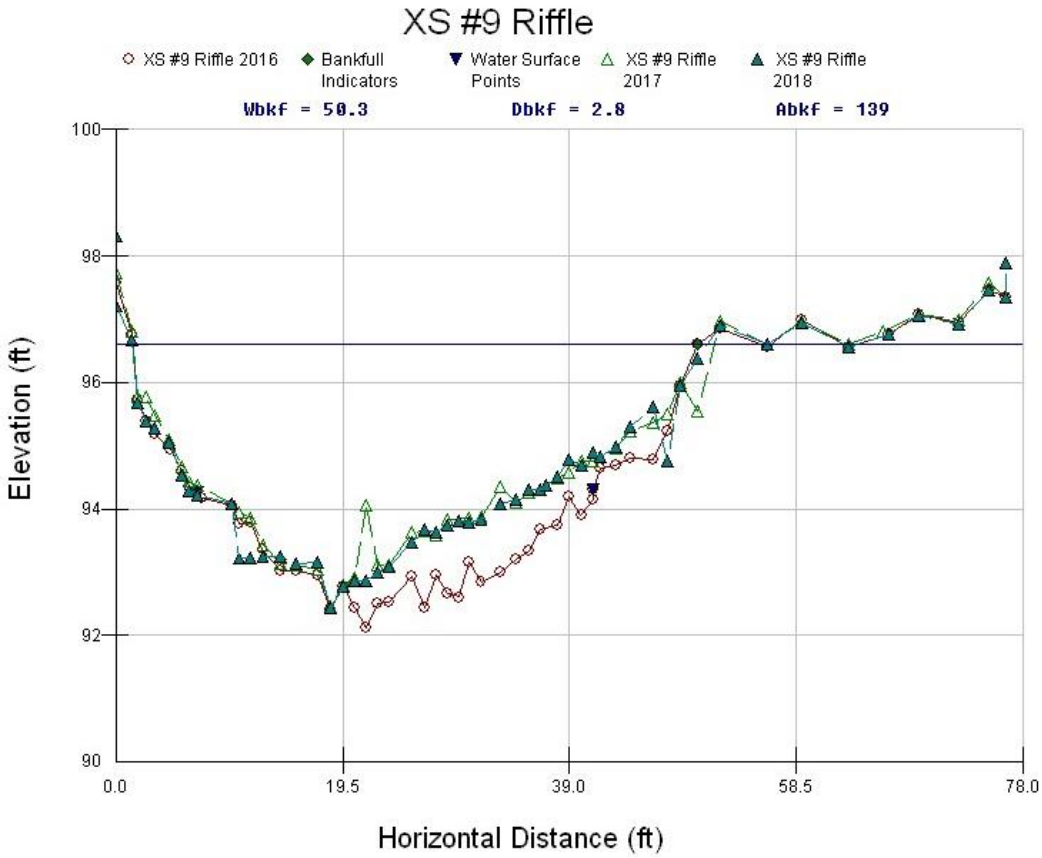
Dbkf = 2
Abkf = 130.5
Elevation (ft)
Horizontal Distance (ft)
98
96
94
92
90
88
0.0
20.5
41.0
61.5
82.0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Bankfull Indicators
Water Surface Points
XS #9 Riffle 2017
XS #9 Riffle 2018
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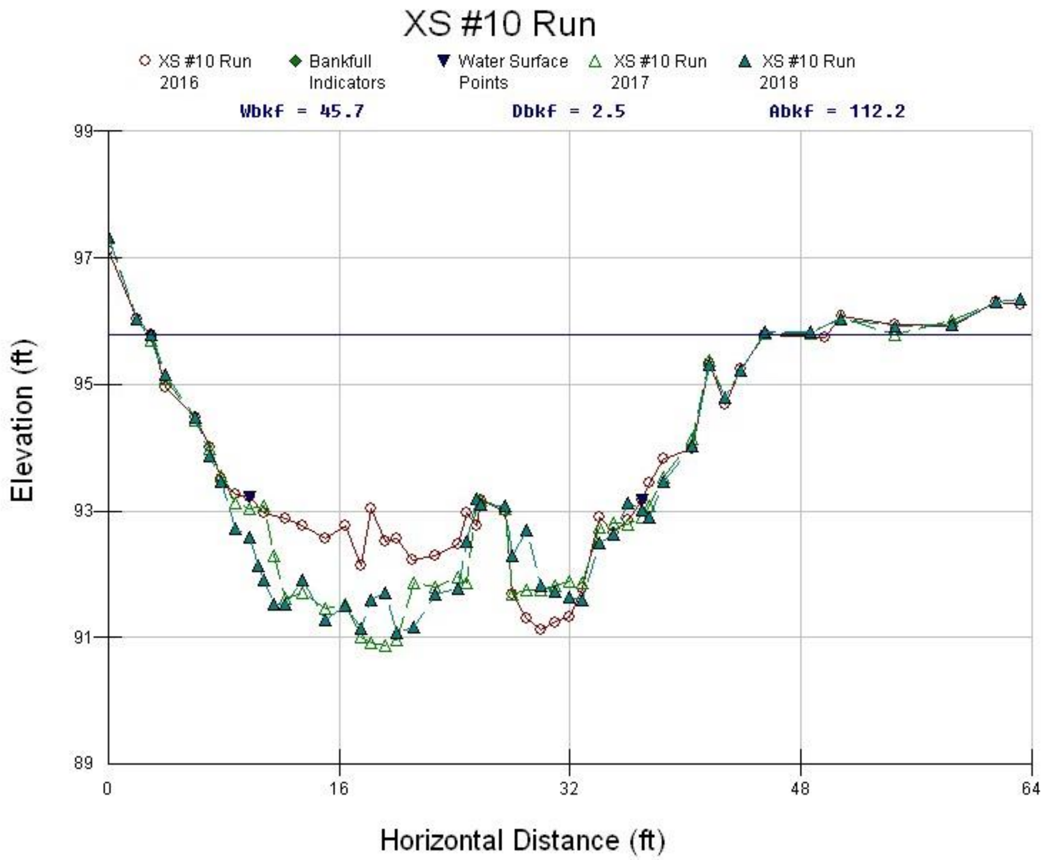
Dbkf = 2.8
Abkf = 139
Elevation (ft)
100
98
96
94
92
90
0.0
19.5
39.0
58.5
78.0
Horizontal Distance (ft)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XS #10 Run 2016
Bankfull Indicators
Water Surface Points
XS #10 Run 2017
XS #10 Run 2018
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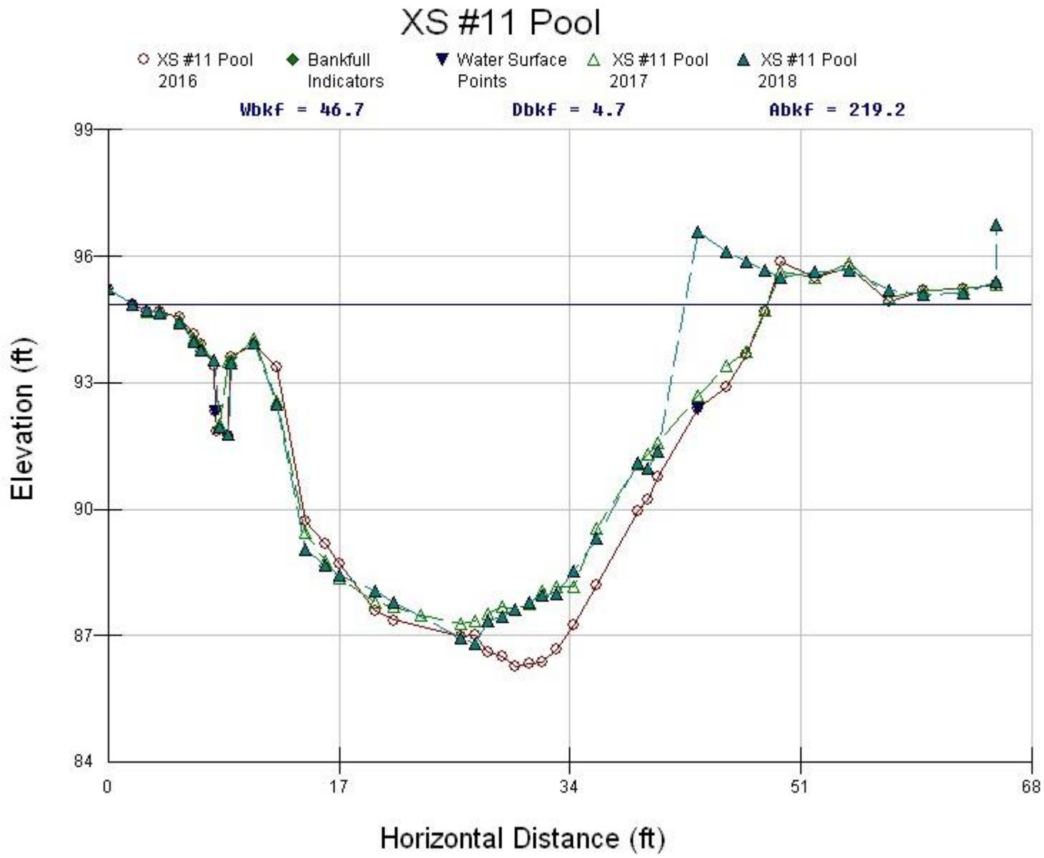
Dbkf = 2.5
Abkf = 112.2
Elevation (ft)
99
97
95
93
91
89
0
16
32
48
64
Horizontal Distance (ft)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XS #11 Pool 2016
Bankfull Indicators
Water Surface Points
XS #11 Pool 2017
XS #11 Pool 2018
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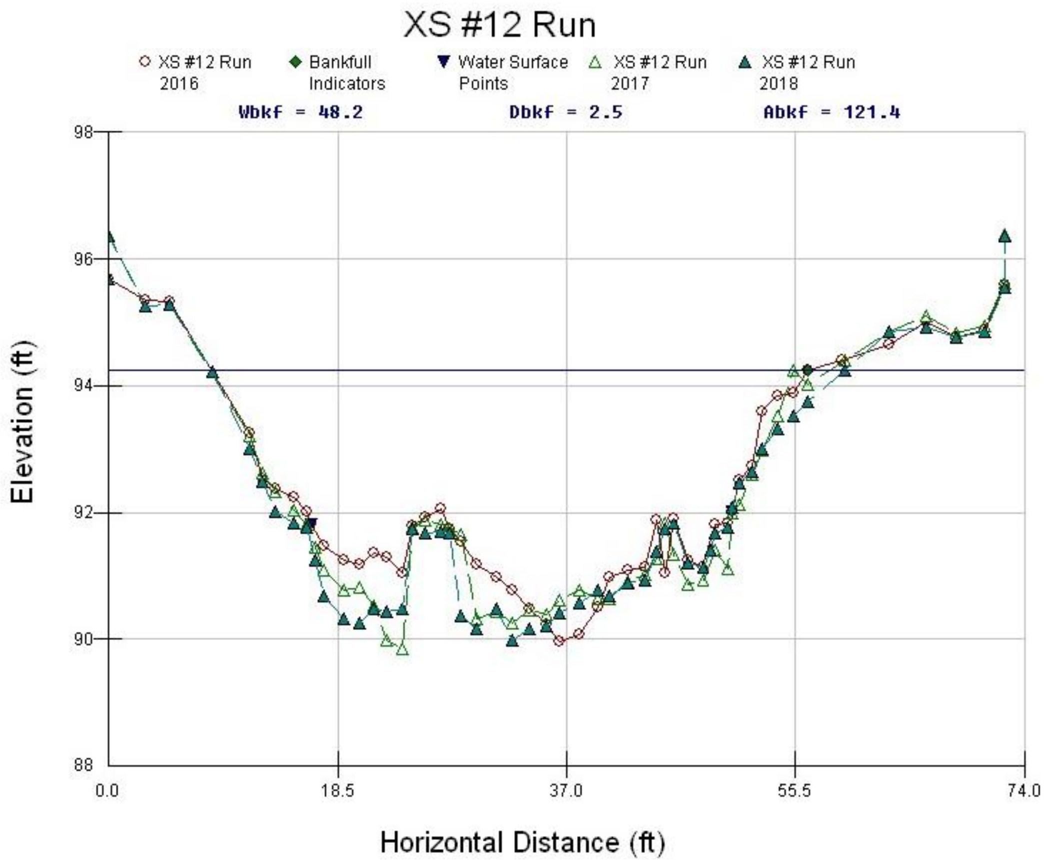
Dbkf = 4.7
Abkf = 219.2
Elevation (ft)
Horizontal Distance (ft)
99
96
93
90
87
84
0
17
34
51
68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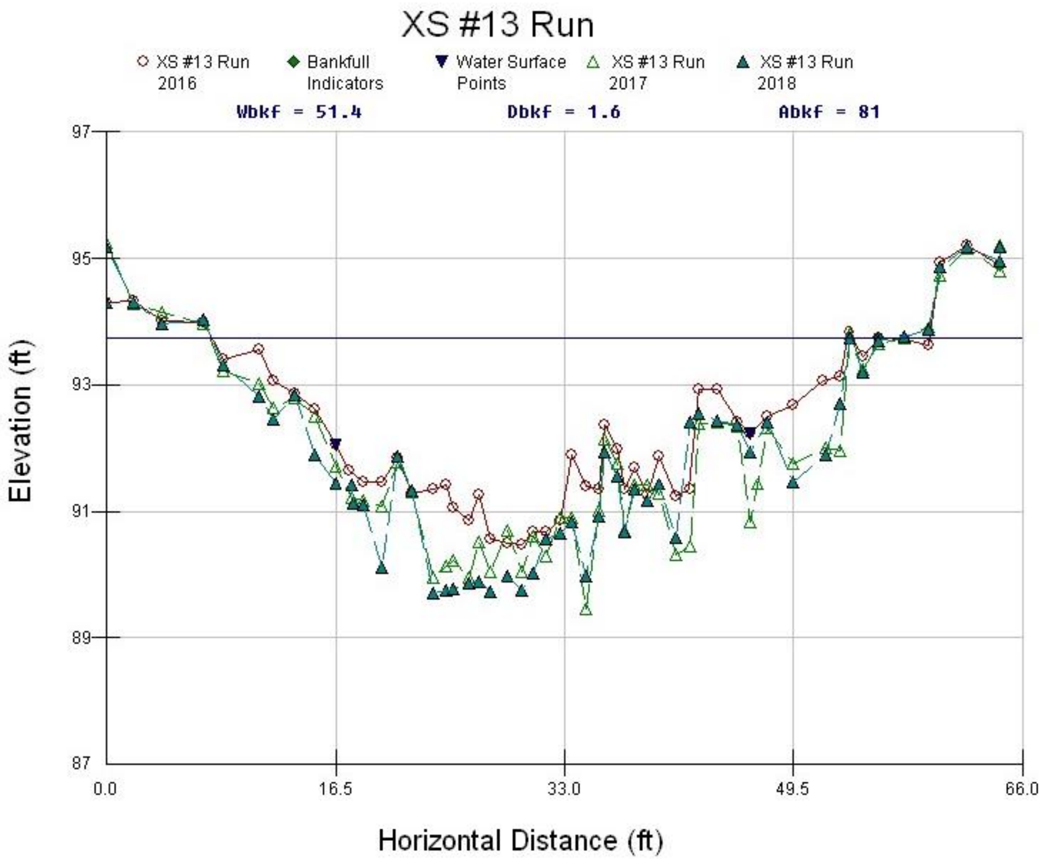
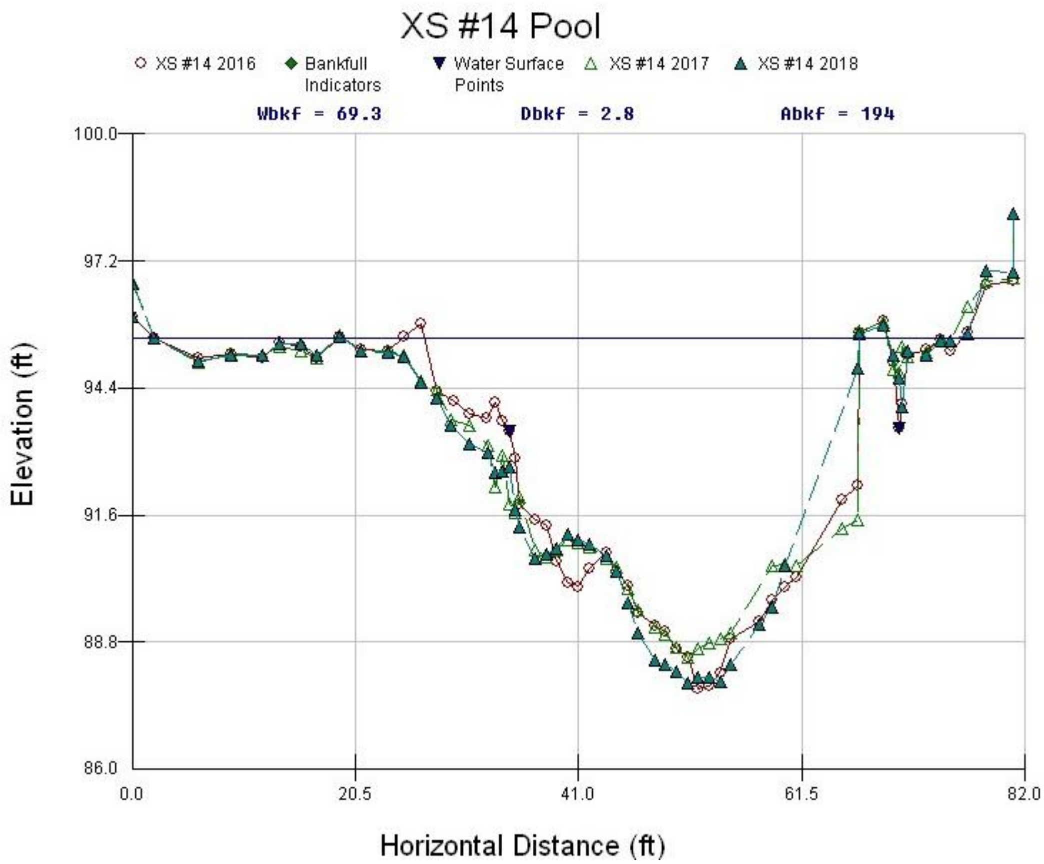
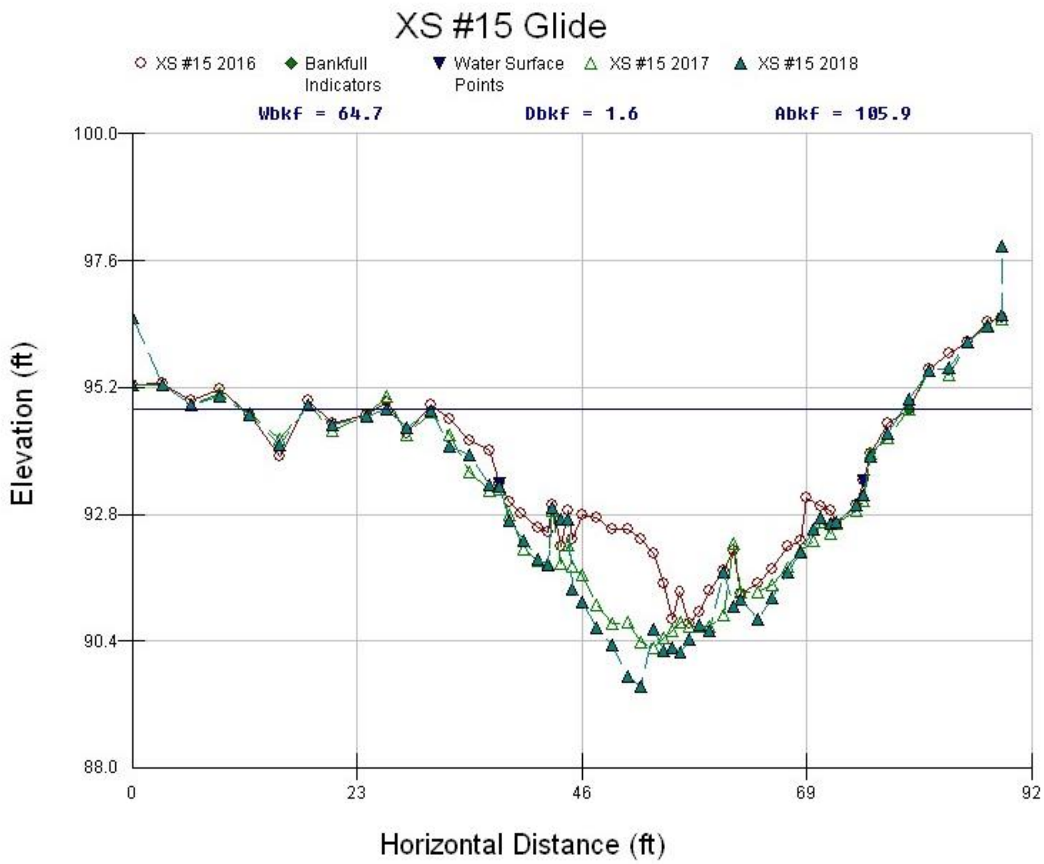
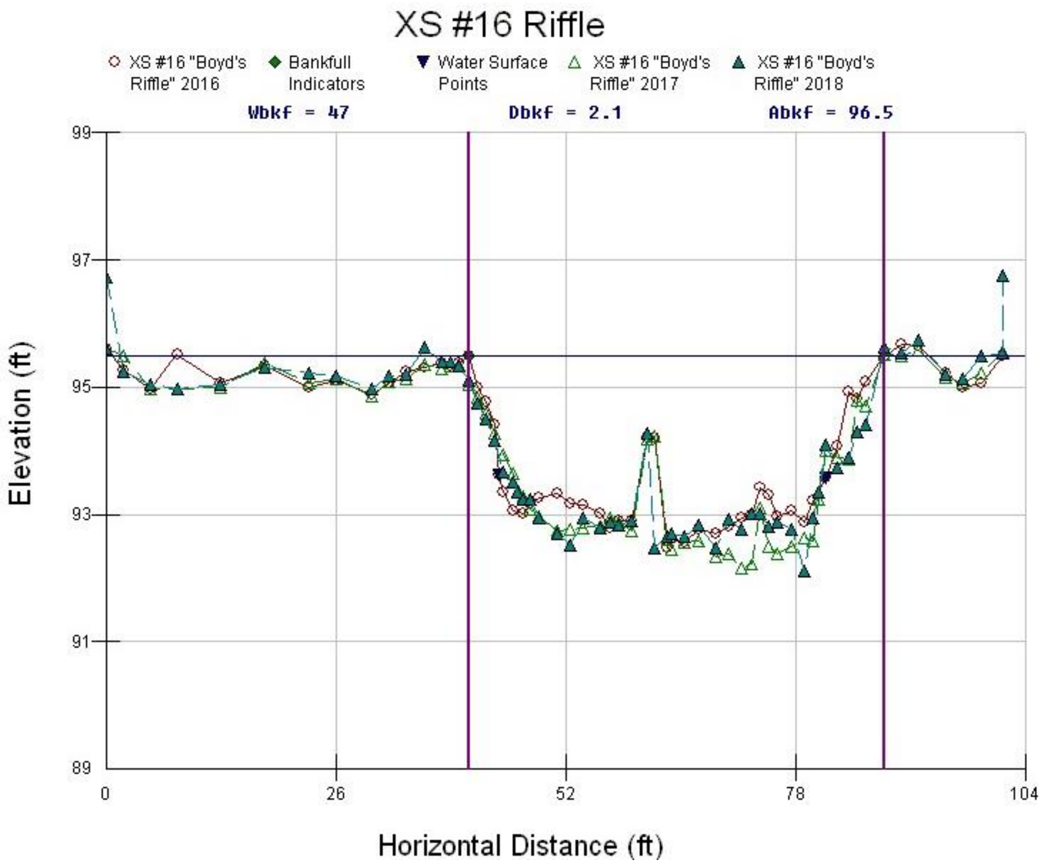
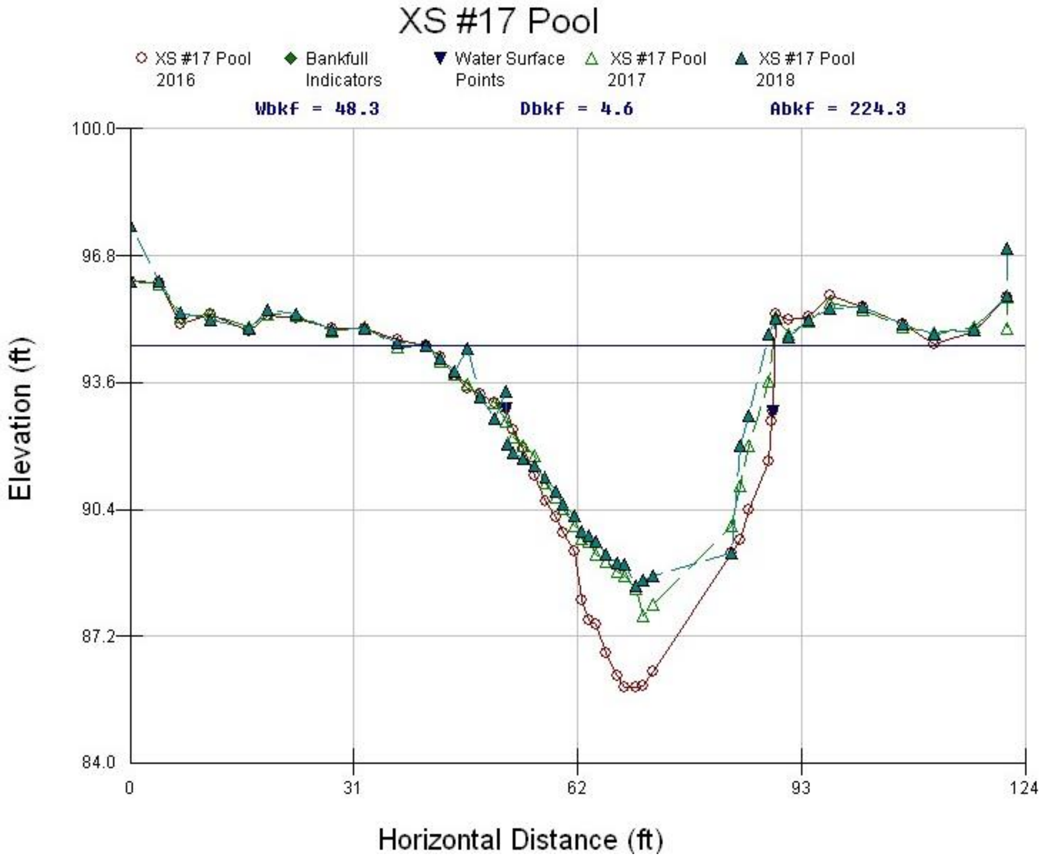
XS #12 Run 2016
Bankfull Indicators
Water Surface Points
XS #12 Run 2017
XS #12 Run 2018
Wbkf = 48.2
Dbkf = 2.5
Abkf = 121.4
Elevation (ft)
Horizontal Distance (ft)
98
96
94
92
90
88
0.0
18.5
37.0
55.5
74.0

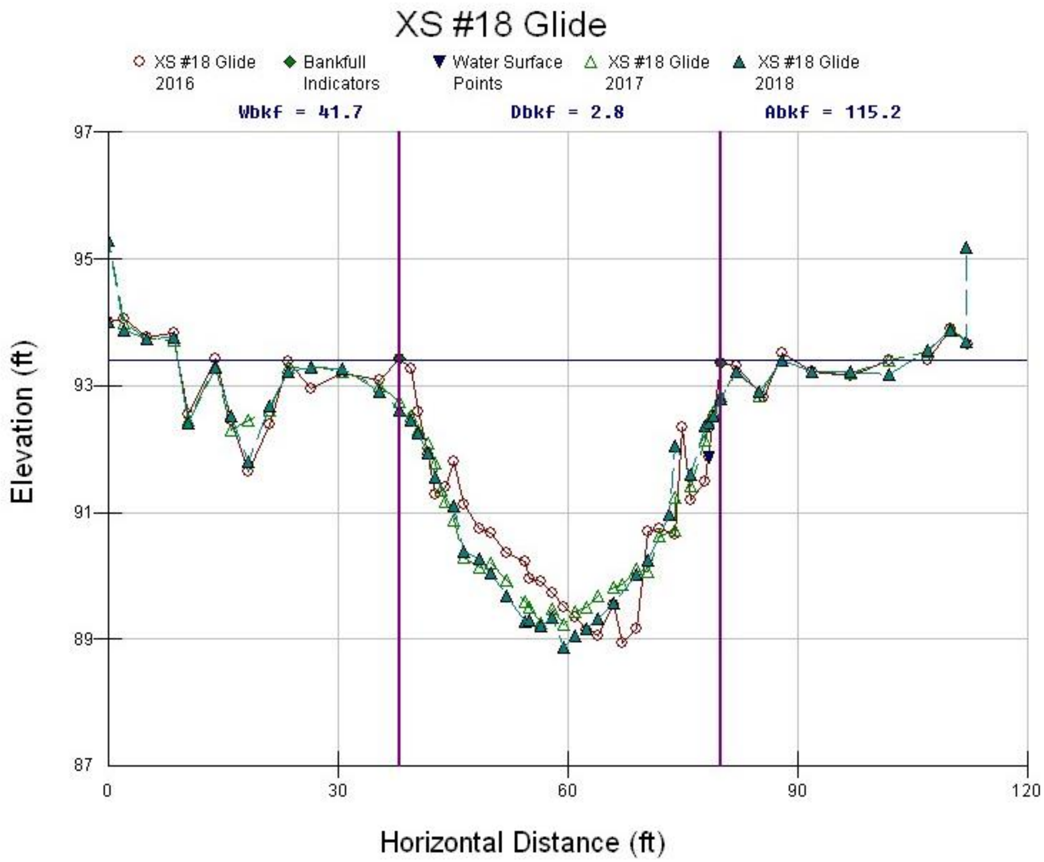

XS #13 Run
XS #13 Run 2016
Bankfull Indicators
Water Surface Points
XS #13 Run 2017
XS #13 Run 2018
Wbkf = 51.4
Dbkf = 1.6
Abkf = 81
Elevation (ft)
Horizontal Distance (ft)
97
95
93
91
89
87
0.0
16.5
33.0
49.5
66.0


XS #14 Pool
XS #14 2016
Bankfull Indicators
Water Surface Points
XS #14 2017
XS #14 2018
Wbkf = 69.3
Dbkf = 2.8
Abkf = 194
Elevation (ft)
100.0
97.2
94.4
91.6
88.8
86.0
0.0
20.5
41.0
61.5
82.0
Horizontal Distance (ft)

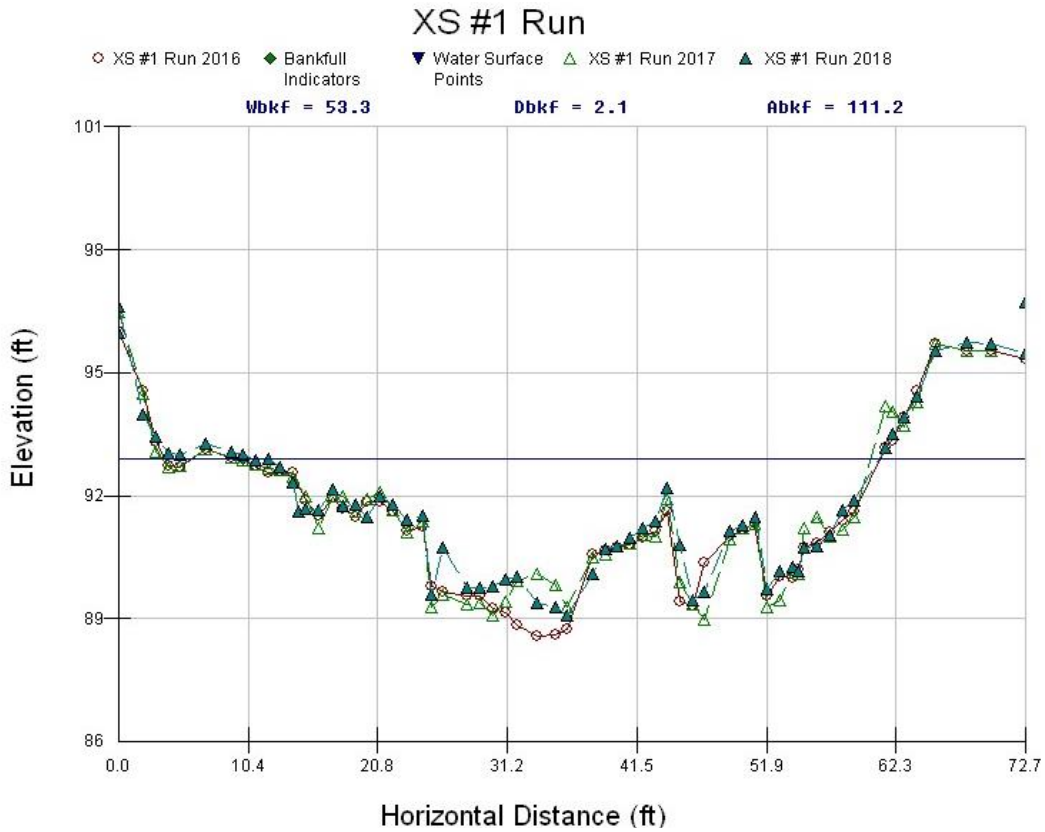

XS #15 Glide
XS #15 2016
Bankfull Indicators
Water Surface Points
XS #15 2017
XS #15 2018
Wbkf = 64.7
Dbkf = 1.6
Abkf = 105.9
Elevation (ft)
Horizontal Distance (ft)
100.0
97.6
95.2
92.8
90.4
88.0
0
23
46
69
92

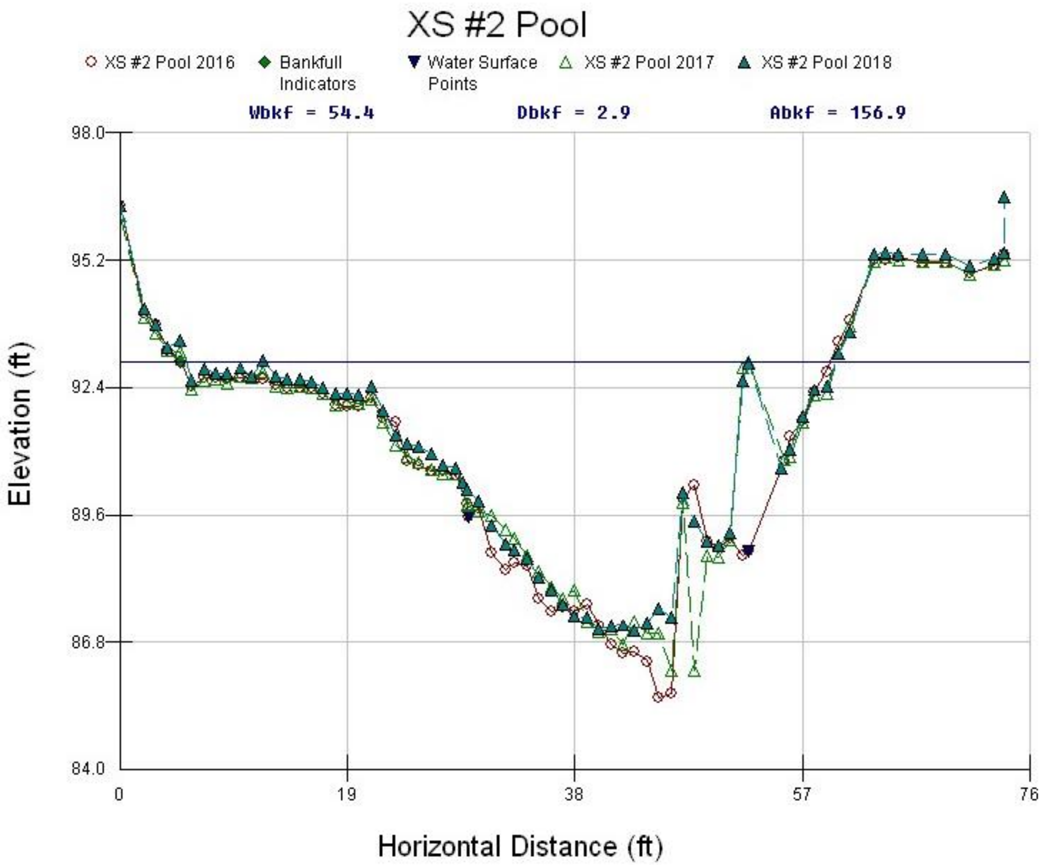

XS #16 Riffle
XS #16 "Boyd's Riffle" 2016
Bankfull Indicators
Water Surface Points
XS #16 "Boyd's Riffle" 2017
XS #16 "Boyd's Riffle" 2018
Wbkf = 47
Dbkf = 2.1
Abkf = 96.5
Elevation (ft)
99
97
95
93
91
89
0
26
52
78
104
Horizontal Distance (ft)


XS #17 Pool
XS #17 Pool 2016
Bankfull Indicators
Water Surface Points
XS #17 Pool 2017
XS #17 Pool 2018
Wbkf = 48.3
Dbkf = 4.6
Abkf = 224.3
100.0
96.8
93.6
90.4
87.2
84.0
Elevation (ft)
0
31
62
93
124
Horizontal Distance (ft)

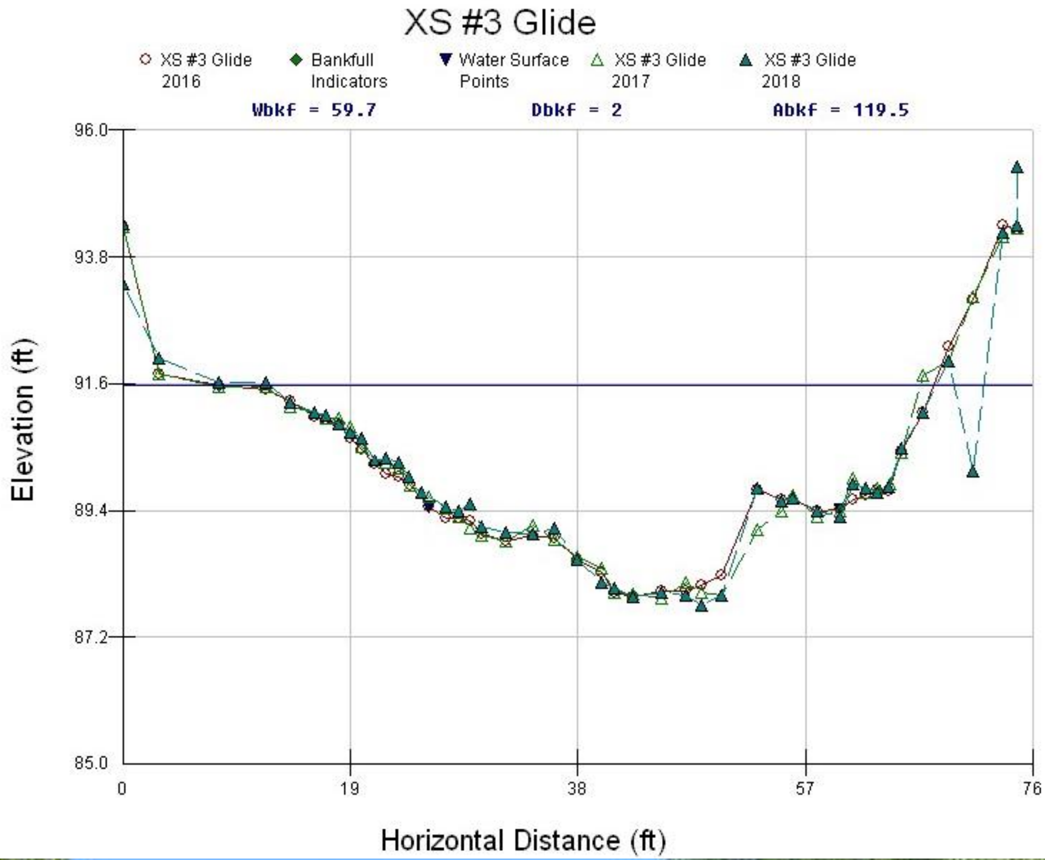

XS #18 Glide
XS #18 Glide 2016
Bankfull Indicators
Water Surface Points
XS #18 Glide 2017
XS #18 Glide 2018
Wbkf = 41.7
Dbkf = 2.8
Abkf = 115.2
Elevation (ft)
Horizontal Distance (ft)
97
95
93
91
89
87
0
30
60
90
120

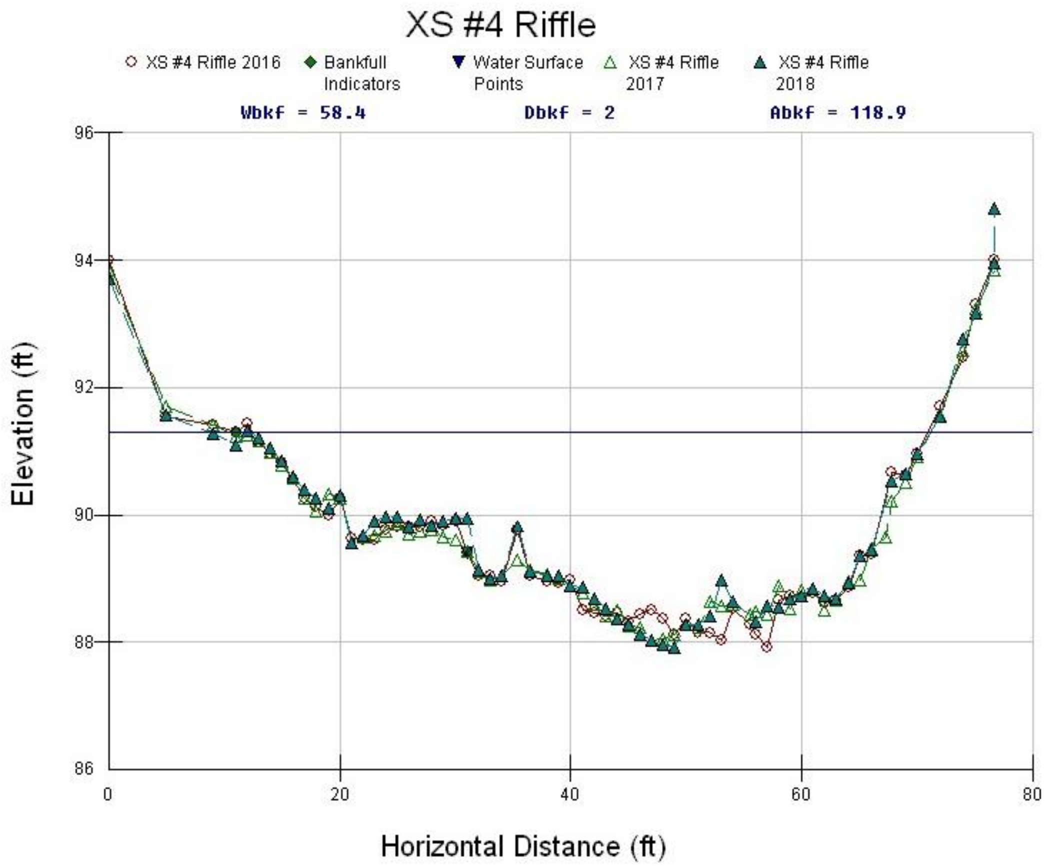
Appendix B.   Miners Gulch reference reach cross section plots and associated photos

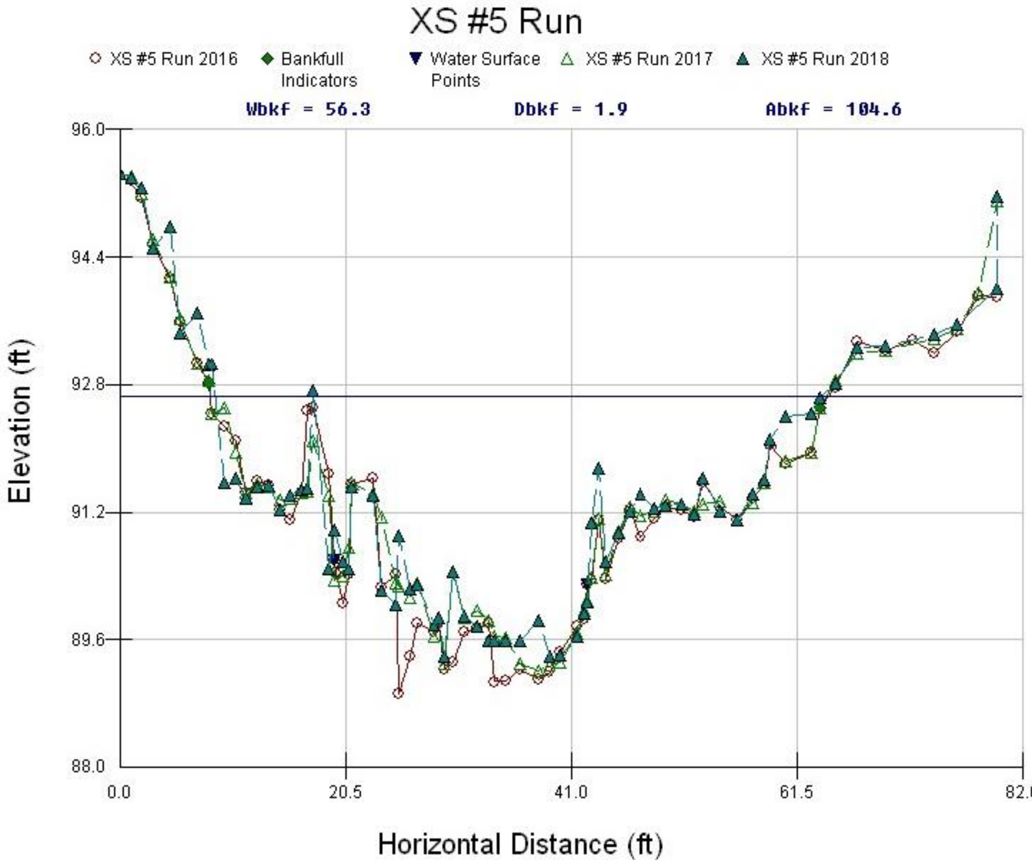

XS #1 Run
XS #1 Run 2016
Bankfull Indicators
Water Surface Points
XS #1 Run 2017
XS #1 Run 2018
Wbkf = 53.3
Dbkf = 2.1
Abkf = 111.2
Elevation (ft)
101
98
95
92
89
86
0.0
10.4
20.8
31.2
41.5
51.9
62.3
72.7
Horizontal Distance (ft)

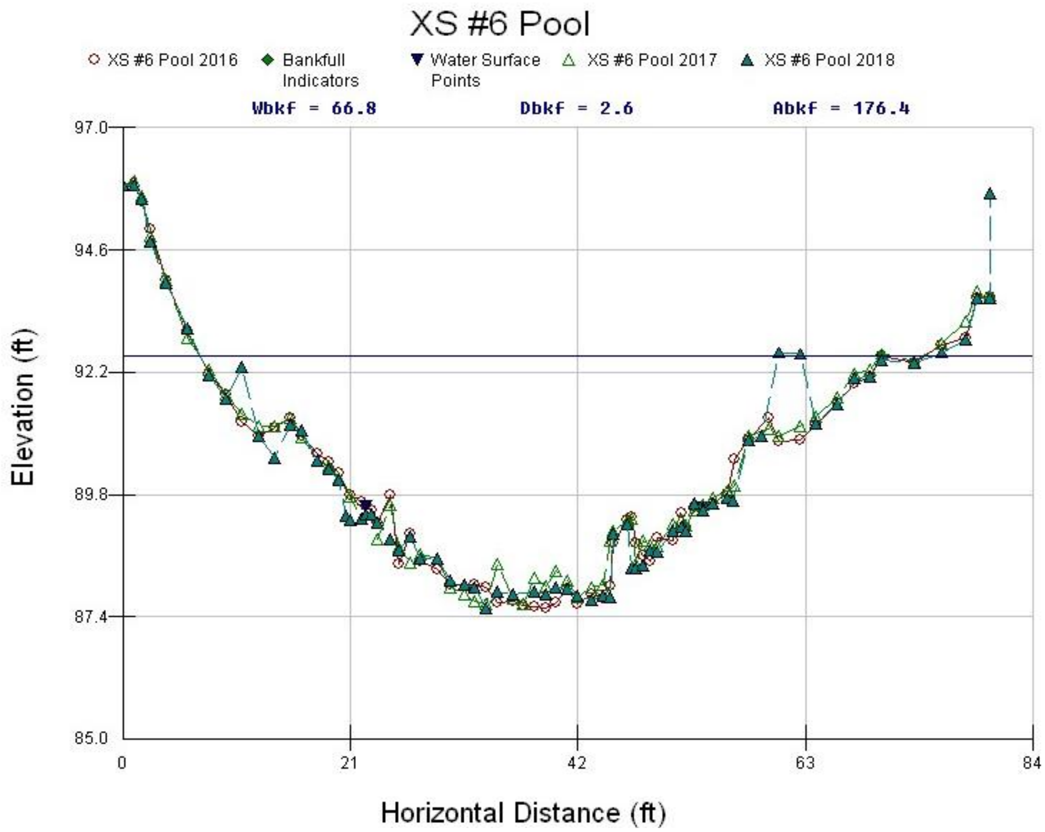


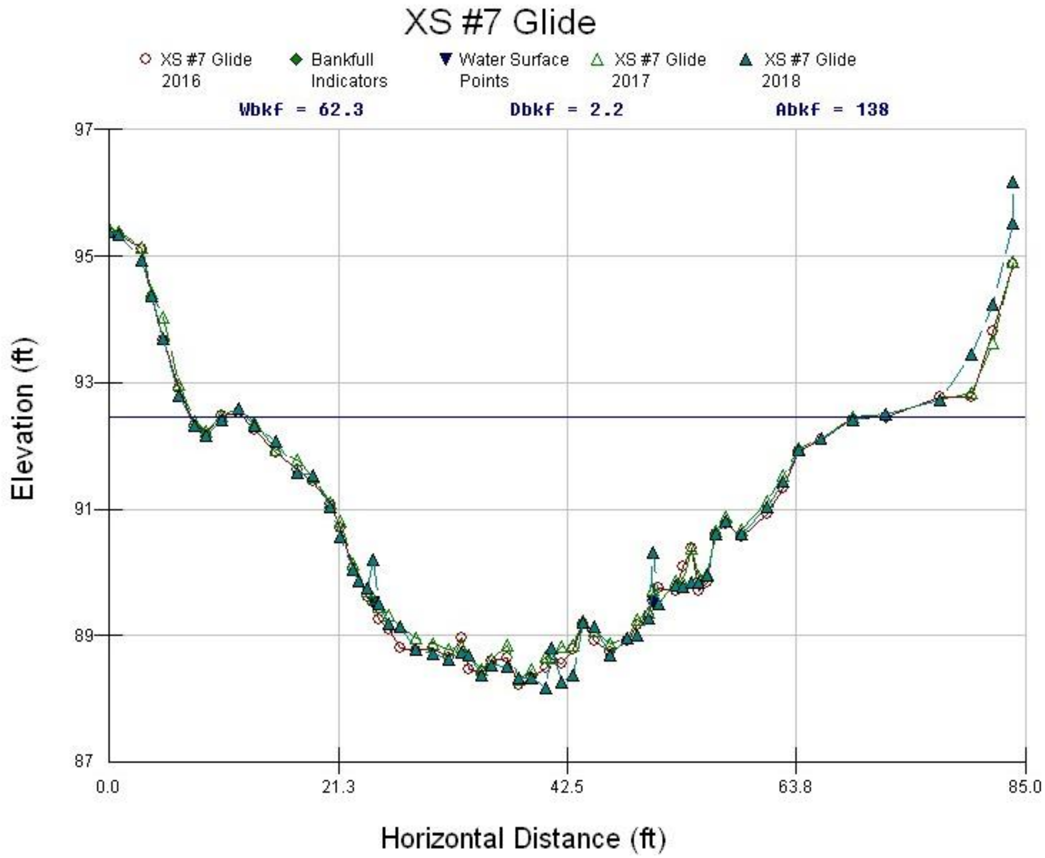
XS #2 Pool
XS #2 Pool 2016
Bankfull Indicators
Water Surface Points
XS #2 Pool 2017
XS #2 Pool 2018
Wbkf = 54.4
Dbkf = 2.9
Abkf = 156.9
Elevation (ft)
98.0
95.2
92.4
89.6
86.8
84.0
0
19
38
57
76
Horizontal Distance (ft)

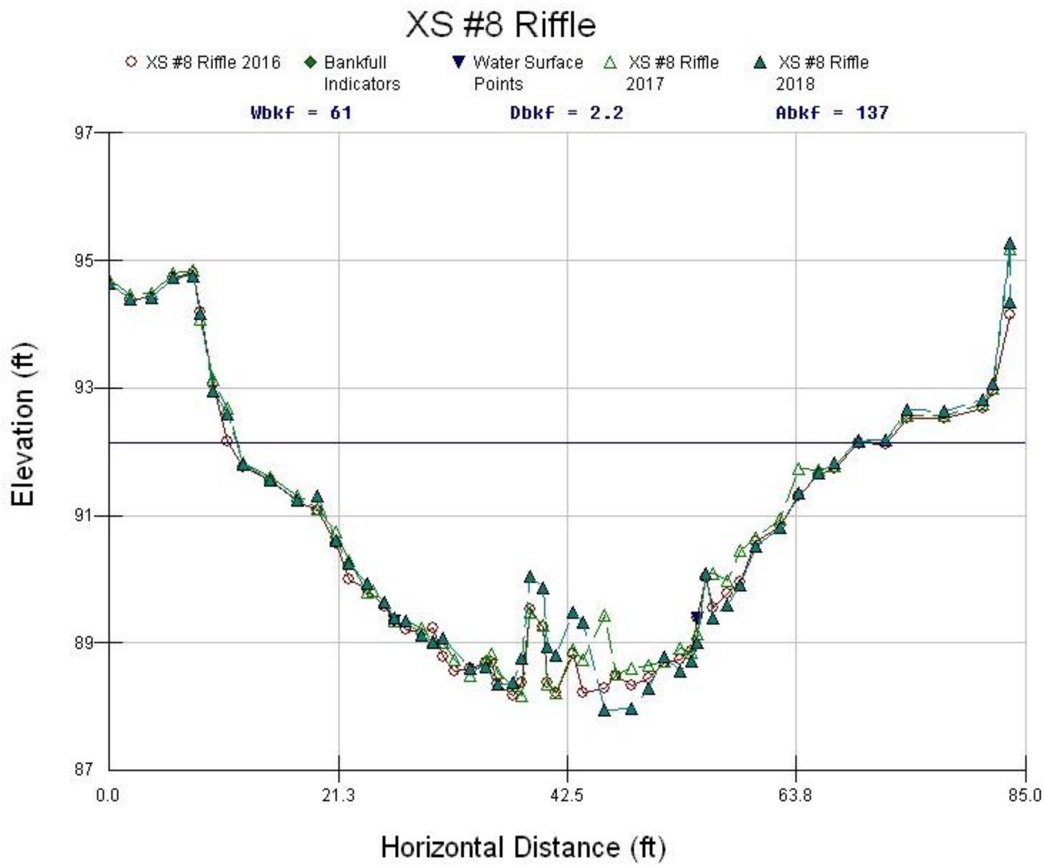

XS #3 Glide
XS #3 Glide 2016
Bankfull Indicators
Water Surface Points
XS #3 Glide 2017
XS #3 Glide 2018
Wbkf = 59.7
Dbkf = 2
Abkf = 119.5
96.0
93.8
91.6
89.4
87.2
85.0
Elevation (ft)
0
19
38
57
76
Horizontal Distance (ft)


XS #4 Riffle
XS #4 Riffle 2016
Bankfull Indicators
Water Surface Points
XS #4 Riffle 2017
XS #4 Riffle 2018
Wbkf = 58.4
Dbkf = 2
Abkf = 118.9
Elevation (ft)
Horizontal Distance (ft)
96
94
92
90
88
86
0
20
40
60
80

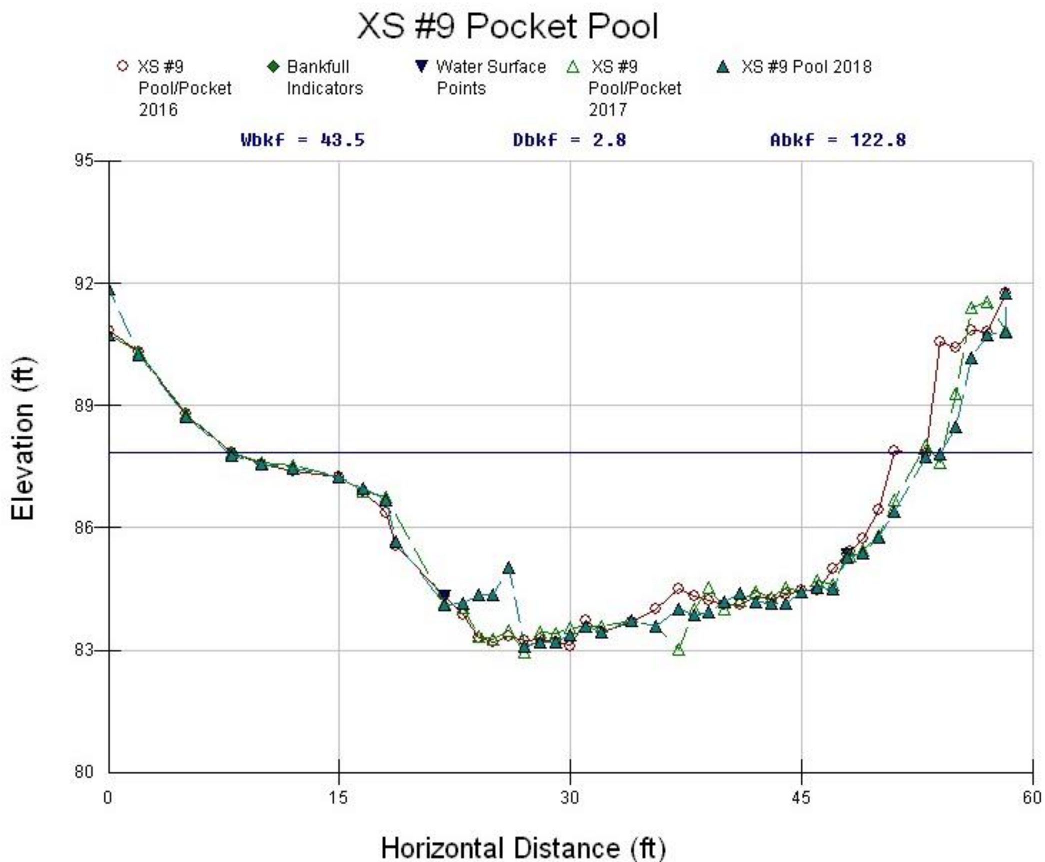

XS #5 Run
XS #5 Run 2016
Bankfull Indicators
Water Surface Points
XS #5 Run 2017
XS #5 Run 2018
Wbkf = 56.3
Dbkf = 1.9
Abkf = 104.6
Elevation (ft)
96.0
94.4
92.8
91.2
89.6
88.0
0.0
20.5
41.0
61.5
82.0
Horizontal Distance (ft)

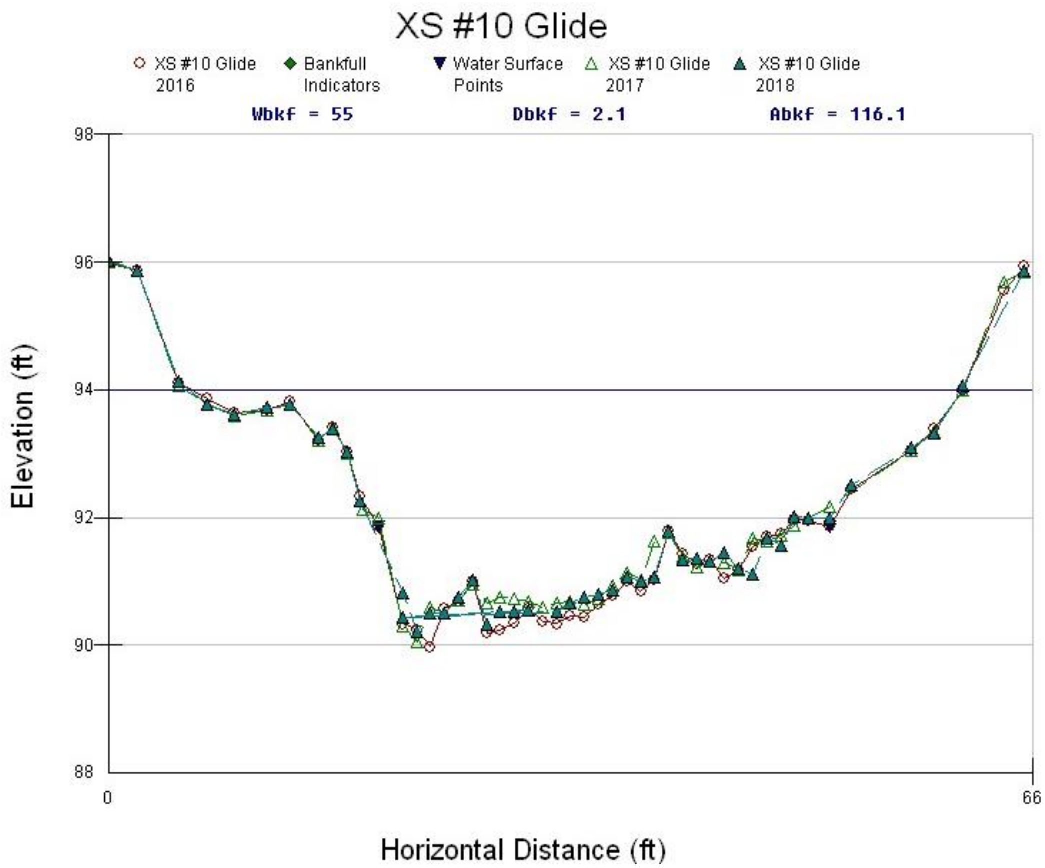

XS #6 Pool
XS #6 Pool 2016
Bankfull Indicators
Water Surface Points
XS #6 Pool 2017
XS #6 Pool 2018
Wbkf = 66.8
Dbkf = 2.6
Abkf = 176.4
Elevation (ft)
97.0
94.6
92.2
89.8
87.4
85.0
0
21
42
63
84
Horizontal Distance (ft)


XS #7 Glide
XS #7 Glide 2016
Bankfull Indicators
Water Surface Points
XS #7 Glide 2017
XS #7 Glide 2018
Wbkf = 62.3
Dbkf = 2.2
Abkf = 138
Elevation (ft)
97
95
93
91
89
87
0.0
21.3
42.5
63.8
85.0
Horizontal Distance (ft)



XS #8 Riffle
XS #8 Riffle 2016
Bankfull Indicators
Water Surface Points
XS #8 Riffle 2017
XS #8 Riffle 2018
Wbkf = 61
Dbkf = 2.2
Abkf = 137
Elevation (ft)
97
95
93
91
89
87
0.0
21.3
42.5
63.8
85.0
Horizontal Distance (ft)


XS #9 Pocket Pool
XS #9 Pool/Pocket 2016
Bankfull Indicators
Water Surface Points
XS #9 Pool/Pocket 2017
XS #9 Pool 2018
Wbkf = 43.5
Dbkf = 2.8
Abkf = 122.8
Elevation (ft)
Horizontal Distance (ft)
95
92
89
86
83
80
0
15
30
45
60


XS #10 Glide
XS #10 Glide 2016
Bankfull Indicators
Water Surface Points
XS #10 Glide 2017
XS #10 Glide 2018
Wbkf = 55
Dbkf = 2.1
Abkf = 116.1
98
96
94
92
90
88
0
66
Elevation (ft)
Horizontal Distance (ft)

Appendix C. Miners Gulch reach existing condition PIBO Greenline & Riparian Cross-section Field Data Collection Form

Greenline & Riparian Cross-section Data Collection Form

Stream: Vermilion **Group:** **Date:** 8/18/2015

Project: Miners Gulch Pre-construction **Valley Bottom Width (ft):** 300

Order: 4 **Reach Type:**

Crew: Pfalzer

Data Type	Bank	Transect	Quadrat Location	Quadrat Position	Layer	Species	% Cover	
GL/XS	L/R	Number	3,6, or 9	Valley/Upland	Lower/Upper		Code	% Cover
GL	L	1		VB	L	*Epilobium minutum*	4	30
GL	L	1		VB	L	rock	5	45
GL	L	1		VB	L	moss spp.	1	1
GL	L	1		VB	L	*Equisetum arvense*	2	10
XS	L	1	3	VB	L	sand	7	85
XS	L	1	3	VB	L	rock	2	10
XS	L	1	3	VB	L	*Epilobium minutum*	1	1
XS	L	1	6	VB	L	gravel	7	85
XS	L	1	6	VB	L	cobble	1	1
XS	L	1	6	VB	L	*Phacelia hastata*	1	1
XS	L	1	6	VB	L	*Agrostis exarata*	1	1
XS	L	1	9	VB	L	gravel	8	98
XS	L	1	9	VB	L	sand	1	1
XS	L	1	9	VB	L	*Centaurea stoebe*	2	10
GL	L	2		VB	L	*Salix drummondiana*	8	98
GL	L	2		VB	L	rock	1	1
GL	L	2		VB	U	*Salix drummondiana*	4	30
GL	L	3		VB	L	rock	4	30
GL	L	3		VB	L	gravel	3	20
GL	L	3		VB	L	*Epilobium brachycarpum*	2	10
GL	L	3		VB	L	*Agrostis exarata*	1	1
GL	L	4		VB	L	*Arabis spp*	1	1
GL	L	4		VB	L	*Leucanthemum vulgare*	2	10
GL	L	4		VB	L	*Agrostis exarata*	2	10
GL	L	4		VB	L	*Poa compressa*	2	10
GL	L	4		VB	L	rock	7	85
GL	L	5		VB	L	*Populus trichocarpa*	8	98
GL	L	5		VB	L	*Centaurea stoebe*	1	1
GL	L	5		VB	L	rock	1	1
GL	L	5		VB	U	*Populus trichocarpa*	4	30
GL	L	5	3	VB	L	rock	4	30
GL	L	5	3	VB	L	wood	3	20

GL	L	5	3	VB	L	gravel	2	10
GL	L	5	3	VB	L	*Centaurea stoebe*	1	1
GL	L	5	6	VB	L	rock	8	98
GL	L	5	6	VB	L	*Centaurea stoebe*	1	1
GL	L	5	9	VB	L	*Populus trichocarpa*	3	20
GL	L	5	9	VB	L	rock	4	30
GL	L	5	9	VB	L	litter	2	1
GL	L	5	9	VB	U	*Populus trichocarpa*	2	10
GL	L	6		VB	L	*Salix drummondiana*	4	30
GL	L	6		VB	L	rock	6	65
GL	L	6		VB	L	gravel	1	1
GL	L	6		VB	L	*Poa compressa*	1	1
GL	L	7		VB	L	rock	2	10
GL	L	7		VB	L	*Rumex salicifolius*	2	10
GL	L	7		VB	L	*Alnus incana*	2	10
GL	L	7		VB	L	*Epilobium minutum*	1	1
GL	L	7		VB	L	gravel	2	10
GL	L	7		VB	L	moss spp.	1	1
GL	L	8		VB	L	rock	5	45
GL	L	8		VB	L	*Equisetum arvense*	2	10
GL	L	8		VB	L	gravel	2	10
GL	L	8		VB	L	*Mimulus guttatus*	1	1
GL	L	8		VB	L	*Hieracium aurantiacium*	1	1
GL	L	8		VB	L	*Poa compressa*	1	1
GL	L	8		VB	L	*Trifolium hybridum*	1	1
GL	L	8		VB	L	*Leucanthemum vulgare*	1	1
GL	L	8		VB	L	moss spp.	1	1
GL	L	8		VB	L	litter	1	1
GL	L	9		VB	L	*Populus trichocarpa*	7	85
GL	L	9		VB	L	rock	2	10
GL	L	9		VB	L	litter	3	20
GL	L	9		VB	U	*Populus trichocarpa*	7	85
GL	L	10		VB	L	rock	7	85
GL	L	10		VB	L	gravel	1	1
GL	L	10		VB	L	*Populus trichocarpa*	2	10
GL	L	10		VB	L	*Centaurea stoebe*	1	1
GL	L	10		VB	L	moss spp.	1	1
GL	L	10		VB	L	*Poa compressa*	1	1
XS	L	10	3	VB	L	gravel	6	65
XS	L	10	3	VB	L	wood	3	20
XS	L	10	3	VB	L	*Achillea millefolium*	2	20
XS	L	10	6	VB	L	moss spp.	4	30
XS	L	10	6	VB	L	gravel	2	10
XS	L	10	6	VB	L	litter	1	1

XS	L	10	6	VB	L	*Centaurea stoebe*	2	10
XS	L	10	9	VB	L	moss spp.	6	65
XS	L	10	9	VB	L	gravel	5	45
XS	L	10	9	VB	L	*Centaurea stoebe*	2	10
XS	L	10	9	VB	L	*Fragaria vesca*	1	1
GL	L	11		VB	L	*Populus trichocarpa*	7	80
GL	L	11		VB	L	rock	1	1
GL	L	11		VB	L	moss spp.	1	1
GL	L	12		VB	L	*Salix drummondiana*	7	80
GL	L	12		VB	L	*Populus trichocarpa*	1	1
GL	L	12		VB	L	rock	1	1
GL	L	12		VB	U	*Salix drummondiana*	1	1
GL	L	13		VB	L	*Salix drummondiana*	8	98
GL	L	13		VB	L	rock	1	1
GL	L	13		VB	U	*Salix drummondiana*	1	1
GL	L	14		VB	L	rock	6	65
GL	L	14		VB	L	gravel	4	30
GL	L	14		VB	L	*Centaurea stoebe*	1	1
GL	L	14		VB	L	*Elymus glaucus*	1	1
GL	L	15		VB	L	*Cerastium glomeratum*	2	10
GL	L	15		VB	L	*Mimulus guttatus*	1	1
GL	L	15		VB	L	*Agrostis exarata*	1	1
GL	L	15		VB	L	rock	6	65
GL	L	15		VB	L	*Epilobium brachycarpum*	1	1
XS	L	15	3	VB	L	rock	6	65
XS	L	15	3	VB	L	gravel	5	45
XS	L	15	3	VB	L	moss spp.	1	1
XS	L	15	3	VB	L	*Centaurea stoebe*	1	1
XS	L	15	6	VB	L	rock	6	65
XS	L	15	6	VB	L	gravel	5	45
XS	L	15	6	VB	L	sand	1	1
XS	L	15	6	VB	L	*Centaurea stoebe*	1	1
XS	L	15	9	VB	L	rock	6	65
XS	L	15	9	VB	L	gravel	4	30
XS	L	15	9	VB	L	moss spp.	2	10
GL	L	16		VB	L	*Populus trichocarpa*	5	45
GL	L	16		VB	L	rock	4	30
GL	L	16		VB	L	*Poa compressa*	1	1
GL	L	16		VB	L	*Epilobium minutum*	2	10
GL	L	16		VB	L	*Elymus glaucus*	1	1
GL	L	16		VB	U	*Populus trichocarpa*	1	1
GL	L	17		VB	L	*Salix drummondiana*	8	98
GL	L	17		VB	L	rock	1	1
GL	L	17		VB	U	*Salix drummondiana*	1	1

GL	L	18		VB	L	*Salix drummondiana*	2	10
GL	L	18		VB	L	rock	7	85
GL	L	18		VB	L	moss spp.	2	10
GL	L	18		VB	U	*Salix drummondiana*	3	20
GL	L	18		VB	L	*Populus trichocarpa*	3	20
GL	L	18		VB	L	*Philadelphis lewissii*	2	10
GL	L	19		VB	L	rock	6	65
GL	L	19		VB	L	moss spp.	2	10
GL	L	19		VB	L	*Salix drummondiana*	2	10
GL	L	19		VB	L	*Canadanthus modestus*	1	1
GL	L	20		VB	L	rock	7	85
GL	L	20		VB	L	*Canadanthus modestus*	3	20
GL	L	20		VB	L	*Senecio triangularus*	1	1
XS	L	20	9	VB	L	litter	7	85
XS	L	20	9	VB	L	moss spp.	1	1
XS	L	20	9	VB	L	*Centaurea stoebe*	2	10
XS	L	20	6	VB	L	wood	3	20
XS	L	20	6	VB	L	litter	3	20
XS	L	20	6	VB	L	gravel	1	1
XS	L	20	6	VB	L	*Centaurea stoebe*	4	30
XS	L	20	3	VB	L	*rock*	7	85
XS	L	20	3	VB	L	moss spp.	2	10
XS	L	20	3	VB	L	*Canadanthus modestus*	1	1
XS	L	20	3	VB	L	*Anaphalis margaritacea*	1	1
GL	L	21		VB	L	rock	6	65
GL	L	21		VB	L	*Salix drummondiana*	3	20
GL	L	21		VB	L	gravel	1	1
GL	L	21		VB	L	sand	2	10
GL	L	22		VB	L	rock	6	65
GL	L	22		VB	L	moss spp.	1	1
GL	L	22		VB	L	sand	1	1
GL	L	22		VB	L	gravel	1	1
GL	L	22		VB	L	*Salix drummondiana*	3	20
GL	L	22		VB	L	*Equisetum arvense*	2	10
GL	L	23		VB	L	rock	5	45
GL	L	23		VB	L	gravel	6	65
GL	L	23		VB	L	sand	1	1
GL	L	23		VB	L	litter	1	1
GL	L	24		VB	L	rock	7	85
GL	L	24		VB	L	*Elymus glaucus*	2	10
GL	L	24		VB	L	*Centaurea stoebe*	1	1
XS	L	24	3	UL	L	gravel	8	98
XS	L	24	3	UL	L	sand	1	1
XS	L	24	6	UL	L	gravel	5	45

XS	L	24	6	UL	L	sand	4	30
XS	L	24	6	UL	L	rock	4	30
XS	L	24	6	UL	L	moss spp.	1	1
XS	L	24	6	UL	L	*Centaurea stoebe*	1	1
XS	L	24	9	UL	L	gravel	7	85
XS	L	24	9	UL	L	sand	3	20
GL	R	24		VB	L	rock	6	65
GL	R	24		VB	L	moss spp.	3	20
GL	R	24		VB	L	*Epilobium minutum*	2	10
XS	R	24	3	VB	L	rock	5	45
XS	R	24	3	VB	L	moss spp.	2	10
XS	R	24	3	VB	L	litter	2	10
XS	R	24	3	VB	L	*Canadanthus modestus*	1	1
XS	R	24	3	VB	L	*Centaurea stoebe*	1	1
XS	R	24	3	VB	L	*Achillea millefolium*	2	10
XS	R	24	3	VB	L	*Leucanthemum vulgare*	1	1
XS	R	24	6	VB	L	rock	5	45
XS	R	24	6	VB	L	moss spp.	3	20
XS	R	24	6	VB	L	litter	3	20
XS	R	24	6	VB	L	*Centaurea stoebe*	4	30
XS	R	24	6	VB	L	*Achillea millefolium*	1	1
XS	R	24	9	VB	L	rock	5	45
XS	R	24	9	VB	L	gravel	3	20
XS	R	24	9	VB	L	moss spp.	2	10
XS	R	24	9	VB	L	*Achillea millefolium*	2	10
GL	R	23		VB	L	*Senecio triangularus*	6	65
GL	R	23		VB	L	*Alnus incana*	2	10
GL	R	23		VB	L	*Canadanthus modestus*	3	20
GL	R	23		VB	U	*Alnus incana*	2	10
GL	R	22		VB	L	*Salix drummondiana*	5	45
GL	R	22		VB	L	rock	5	45
GL	R	22		VB	L	*Canadanthus modestus*	2	10
GL	R	22		VB	U	*Salix drummondiana*	1	1
GL	R	21		VB	L	rock	6	65
GL	R	21		VB	L	*Salix drummondiana*	2	10
GL	R	21		VB	L	*Canadanthus modestus*	2	10
GL	R	21		VB	L	litter	1	1
GL	R	21		VB	L	hair grass	1	1
GL	R	21		VB	L	*Salix drummondiana*	1	1
GL	R	20		VB	L	rock	4	30
GL	R	20		VB	L	*Salix drummondiana*	4	30
GL	R	20		VB	L	gravel	4	30
GL	R	20		VB	L	moss spp.	2	10
GL	R	20		VB	U	*Salix drummondiana*	1	1

XS	R	20	3	VB	L	*Populus trichocarpa*	4	30
XS	R	20	3	VB	L	rock	5	45
XS	R	20	3	VB	L	litter	5	45
XS	R	20	6	VB	L	rock	3	20
XS	R	20	6	VB	L	wood	4	30
XS	R	20	6	VB	L	litter	5	45
XS	R	20	6	VB	L	*Centaurea stoebe*	1	1
XS	R	20	6	VB	L	*Populus trichocarpa*	7	85
XS	R	20	9	VB	L	gravel	7	85
XS	R	20	9	VB	L	*Centaurea stoebe*	3	20
GL	R	18		VB	L	rock	8	98
GL	R	18		VB	L	gravel	1	1
GL	R	18		VB	L	*Elymus glaucus*	1	1
GL	R	18		VB	L	*Salix drummondiana*	1	1
GL	R	17		VB	L	rock	7	85
GL	R	17		VB	L	sand	1	1
GL	R	17		VB	L	*Agrostis exarata*	1	1
GL	R	16		VB	L	rock	7	85
GL	R	16		VB	L	gravel	1	1
GL	R	16		VB	L	sand	3	20
GL	R	16		VB	L	*Agrostis exarata*	1	1
GL	R	16		VB	L	*Salix drummondiana*	1	1
GL	R	15		VB	L	rock	7	85
GL	R	15		VB	L	gravel	1	1
GL	R	15		VB	L	moss spp.	2	10
GL	R	15		VB	L	*Agrostis exarata*	1	1
XS	R	15	3	VB	L	rock	7	85
XS	R	15	3	VB	L	moss spp.	3	20
XS	R	15	3	VB	L	*Populus trichocarpa*	1	1
XS	R	15	3	VB	L	*Centaurea stoebe*	1	1
XS	R	15	6	VB	L	rock	3	20
XS	R	15	6	VB	L	wood	2	10
XS	R	15	6	VB	L	*Centaurea stoebe*	2	10
XS	R	15	6	VB	L	litter	3	20
XS	R	15	6	VB	L	moss spp.	2	10
XS	R	15	6	VB	L	gravel	2	10
XS	R	15	9	UL	L	moss spp.	5	45
XS	R	15	9	UL	L	litter	4	30
XS	R	15	9	UL	L	*Pseudotsuga menziesii*	1	1
XS	R	15	9	UL	L	wood	1	1
GL	R	12		VB	L	*Salix drummondiana*	5	45
GL	R	12		VB	L	moss spp.	3	20
GL	R	12		VB	L	rock	3	20
GL	R	12		VB	L	*Cornus stolonifera*	3	20

GL	R	12		VB	U	*Salix drummondiana*	5	45
GL	R	12		VB	U	*Cornus stolonifera*	5	45
GL	R	11		VB	L	*Salix drummondiana*	5	45
GL	R	11		VB	L	rock	4	30
GL	R	11		VB	L	moss spp.	2	10
GL	R	11		VB	L	gravel	1	1
GL	R	11		VB	L	litter	1	1
GL	R	10		VB	L	rock	4	30
GL	R	10		VB	L	moss spp.	3	20
GL	R	10		VB	L	*Epilobium minutum*	2	10
GL	R	10		VB	L	*Alnus incana*	1	1
GL	R	10		VB	L	*Epilobium brachycarpum*	1	1
GL	R	10		VB	L	*Agrostis exarata*	1	1
GL	R	10		VB	L	grass spp.	1	1
GL	R	13		VB	L	*Salix drummondiana*	5	45
GL	R	13		VB	L	rock	5	45
GL	R	13		VB	L	moss spp.	1	1
GL	R	13		VB	L	*Epilobium minutum*	1	1
GL	R	13		VB	L	*Agrostis exarata*	1	1
GL	R	13		VB	L	wood	1	1
GL	R	13		VB	U	*Salix drummondiana*	1	1
XS	R	13	3	VB	L	wood	6	65
XS	R	13	3	VB	L	litter	3	20
XS	R	13	3	VB	L	*Epilobium minutum*	1	1
XS	R	13	3	VB	L	moss spp.	3	20
XS	R	13	3	VB	L	*Agrostis exarata*	2	10
XS	R	13	3	VB	L	*Symphoricarpos albus*	1	1
XS	R	13	3	VB	L	*Hieracium umbellatum*	2	10
XS	R	13	6	VB	L	litter	7	85
XS	R	13	6	VB	L	wood	2	10
XS	R	13	6	VB	L	rock	2	10
XS	R	13	6	VB	L	*Alnus incana*	2	10
XS	R	13	6	VB	L	*Taraxicum officinale*	1	1
XS	R	13	9	VB	L	litter	7	85
XS	R	13	9	VB	L	rock	2	10
XS	R	13	9	VB	L	moss spp.	1	1
XS	R	13	9	VB	L	*Agrostis exarata*	1	1
GL	R	14		VB	L	rock	4	30
GL	R	14		VB	L	moss spp.	3	20
GL	R	14		VB	L	*Epilobium minutum*	3	20
GL	R	14		VB	L	*Agrostis exarata*	1	1
GL	R	19		VB	L	rock	6	65
GL	R	19		VB	L	gravel	4	30
GL	R	19		VB	L	*Populus trichocarpa*	2	10

GL	R	5		VB	L	*Alnus incana*	6	65
GL	R	5		VB	L	rock	4	30
GL	R	5		VB	L	moss spp.	2	10
GL	R	5		VB	L	*Soladigo canadensis*	1	1
GL	R	5		VB	L	*Alnus incana*	3	20
XS	R	5	3	VB	L	rock	5	45
XS	R	5	3	VB	L	gravel	4	30
XS	R	5	3	VB	L	sand	2	10
XS	R	5	6	VB	L	rock	2	10
XS	R	5	6	VB	L	gravel	6	65
XS	R	5	6	VB	L	sand	1	1
XS	R	5	9	VB	L	rock	3	20
XS	R	5	9	VB	L	gravel	6	65
XS	R	5	9	VB	L	sand	3	20
XS	R	5	9	VB	L	*Agrostis exarata*	1	1
XS	R	5	9	VB	L	*Centaurea stoebe*	1	1
GL	R	4		VB	L	*Salix drummondiana*	3	20
GL	R	4		VB	L	rock	2	10
GL	R	4		VB	L	gravel	2	10
GL	R	4		VB	L	moss spp.	3	20
GL	R	4		VB	L	wood	2	10
GL	R	4		VB	L	*Senecio triangularus*	1	1
GL	R	4		VB	L	*Carex spp.*	1	1
GL	R	4		VB	L	unknown forb seedlings	2	10
GL	R	3		VB	L	rock	6	65
GL	R	3		VB	L	wood	2	10
GL	R	3		VB	L	*Senecio triangularus*	3	20
GL	R	3		VB	L	*Canadanthus modestus*	1	1
GL	R	3		VB	L	gravel	1	1
GL	R	3		VB	L	*Agrostis exarata*	1	1
GL	R	2		VB	L	rock	2	10
GL	R	2		VB	L	*Salix drummondiana*	4	30
GL	R	2		VB	L	*Populus trichocarpa*	2	10
GL	R	2		VB	L	moss spp.	3	20
GL	R	2		VB	L	wood	3	20
GL	R	2		VB	L	*Agrostis exarata*	1	1
GL	R	2		VB	L	*Epilobium minutum*	2	10
XS	R	10	3	VB	L	rock	6	65
XS	R	10	3	VB	L	gravel	3	20
XS	R	10	3	VB	L	moss spp.	3	20
XS	R	10	3	VB	L	*Centaurea stoebe*	1	1
XS	R	10	6	VB	L	wood	8	98
XS	R	10	6	VB	L	rock	1	1
XS	R	10	9	VB	L	rock	5	45

XS	R	10	9	VB	L	gravel	6	65
XS	R	10	9	VB	L	*Centaurea stoebe*	1	1
GL	R	9		VB	L	rock	4	30
GL	R	9		VB	L	gravel	3	20
GL	R	9		VB	L	*Epilobium minutum*	3	20
GL	R	8		VB	L	Populus trichocarpa	5	45
GL	R	8		VB	L	moss spp.	3	20
GL	R	8		VB	L	rock	2	10
GL	R	8		VB	L	gravel	1	1
GL	R	8		VB	L	grass spp.	1	1
GL	R	8		VB	L	*Epilobium minutum*	2	10
GL	R	7		VB	L	rock	3	20
GL	R	7		VB	L	gravel	3	20
GL	R	7		VB	L	sand	2	10
GL	R	7		VB	L	*Salix drummondiana*	2	10
GL	R	7		VB	L	*Agrostis exarata*	1	1
GL	R	6		VB	L	rock	6	65
GL	R	6		VB	L	gravel	4	30
GL	R	6		VB	L	*Agrostis exarata*	2	10
GL	R	6		VB	L	*Epilobium minutum*	1	1
GL	R	1		VB	L	rock	7	85
GL	R	1		VB	L	*Epilobium minutum*	1	1
GL	R	1		VB	L	moss spp.	1	1
GL	R	1		VB	L	*Agrostis exarata*	1	1
GL	R	1		VB	L	*Mimulus guttatus*	1	1
XS	R	1	3	VB	L	rock	6	65
XS	R	1	3	VB	L	litter	4	30
XS	R	1	3	VB	L	*Centaurea stoebe*	2	10
XS	R	1	6	VB	L	rock	7	85
XS	R	1	6	VB	L	litter	2	10
XS	R	1	6	VB	L	wood	1	1
XS	R	1	9	VB	L	gravel	4	30
GL	R	1	9	VB	L	litter	3	20
GL	R	1	9	VB	L	moss spp.	4	30
GL	R	1	9	VB	L	*Alnus incana*	1	1
GL	R	1	9	VB	U	*Alnus incana*	7	85