Crow Creek Restoration Project
As-Built Monitoring Report – November 2007

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1.0 INTRODUCTION

AVISTA Corporation, in conjunction with U.S. Forest Service (USFS) and Green Mountain Conservation District (GMCD) retained River Design Group, Inc. (RDG) to design and implement stream restoration activities on approximately 0.25 miles of Crow Creek near Thompson Falls, Montana. An important bull trout and westslope cutthroat migratory corridor, Crow Creek has been substantially altered by the Bonneville Power Administration transmission line that extends up the lower valley bottom of the main stem from County Highway No. 471 to the confluence of the East and West Forks Crow Creek (upstream of project area). Commercial timber harvest has occurred across the Crow Creek watershed with the exception of the alpine glaciated valleys in the headwaters of both forks (RDG, USGS 2004).

Historically, the Crow Creek valley bottom was dominated by dense stands of large cedar (Figure 1-1). Large cedar stumps within the project area provide evidence of this historical condition. Riparian areas in Crow Creek and within the project area have experienced persistent loss of vegetation from maintenance of the road system and the transmission line. Within the project area, riparian harvest and encroachment on the floodplain have resulted in loss of vegetation, bank instability, lateral migration, downcutting and increased sediment supply.

Figure 1-1. Representative channel and riparian conditions in the project area. Note the BPA transmission line, lack of wood riparian species, and remnant cedar stumps.

There is marginal riparian vegetation in the project area due to the presence of the BPA transmission line. Prior to construction, the reach classified is an over-widened C stream type transitioning to an F channel type. The post construction condition is characterized by a moderately entrenched, riffle-pool, gravel-cobble dominated B3/4 stream type.

A comprehensive assessment and stream restoration design were completed by River Design Group, Inc. in February 2006. The design specified reconstructing the channel using natural channel design techniques. In October 2007, the project was implemented under the auspices of RDG in consultation with USFS, GMCD and the U.S. Fish & Wildlife Service. The following monitoring report describes the post-construction or “as-built” channel conditions of the project area. Future monitoring in 2008 after spring runoff will document channel conditions and

trends in channel geomorphology. These data will be compared to the as-built monitoring dimensions to evaluate channel response over time.

1.1 Construction Overview

During October 2007, approximately 1,200 ft of new channel was constructed within the project area. The design incorporated Natural Channel Design (NCD) methods and fundamental civil and hydraulic engineering principles to re-establish the expected dimension, pattern and profile of Crow Creek. Channel features observed in stable sections of Crow Creek such as riffles, runs, pools and glides were constructed, their dimension based on their naturally-occurring form as determined from empirical, analog, and analytical based methods. Grade control structures including native cobble patches, boulder clusters, log and rock cross-vanes, and log j-hook vanes were installed to maintain the design channel dimensions until riparian vegetation can establish and lend permanence to the constructed project. Large woody debris structures were added to dissipate energy in pools and meander bends and to enhance aquatic habitat.

Table 1-1 summarizes the types and quantities of structures constructed in the Crow Creek project area.

Table 1-1. Types and numbers of structures built in the Crow Creek project area.

Structure Type	Quantity
Log j-hook vane	1
Log vane	4
Engineered log jam	12
Cobble grade control	19
Log cross vane	2
Rock cross vane	4
Channel spanning log	3
Rootwad composite	12
Habitat pieces	8
Vegetated soil lift (LF)	669
Willow cuttings	~1750
Rooted plant stock	~1,250

1.2 Monitoring Goals and Objectives

The following monitoring objectives and performance standards are proposed to evaluate project success in achieving the stated project objectives. Project monitoring will occur in 2007 (as-built survey, this report), and in 2008 (post-runoff survey) assuming Crow Creek experiences a peak event approximating bankfull discharge. If a bankfull event is not realized in 2008, monitoring will be postponed. For the purposes of this monitoring program, stability will be defined as the ability of Crow Creek to adjust to hydrologic conditions and physical inputs within the watershed while maintaining its design dimensions, pattern and profile over time. Section 1.2.1 defines the monitoring objectives and performance standards. These

performance standards will be applied to evaluate the channel response following the first bankfull or greater runoff event (2008).

1.2.1 Channel Stability and Morphology

Objective 1: Channel cross-sections will remain within 20 percent of the as-built dimensions after three years.

Performance Standard 1: Four channel cross-sections were established in the reconstructed reach. Cross-sections are located at pool and riffle units. Cross-sections will be re-surveyed in 2008 if a bankfull discharge event occurs in that time span. Photo points were established at each channel cross-section, and in select areas to document overall reach conditions.

Objective 2: The design channel profile will remain within 20 percent of the as-built dimensions after three years.

Performance Standard 2: One longitudinal channel profile was established in the reconstructed reach. The profile encompasses a minimum of 20x the bankfull channel width of Crow Creek, or two meander wavelengths. The as-built survey captured all pertinent design thalweg points on the profile including top and bottom of riffle units, maximum pool depths, and pool crest/glide units. In addition to the physical channel bed, water surface and design bankfull elevations were surveyed. The post-runoff survey will be compared to the as-built profile to evaluate vertical bed stability.

1.2.2 Long-term Maintenance and Monitoring

The project is designed to require minimal maintenance. However, repairs to the new channel sections or plugs in the old channel may be necessary in the future. The participating sponsoring agencies and RDG will collaborate on future repairs.

2.0 CHANNEL DESIGN DIMENSIONS

Final design dimensions were determined from a variety of methods including reference reach data, analytical based procedures including hydraulic modeling, and empirically derived hydraulic geometry relationships. Longitudinal profile and cross-sectional dimensions were validated with HEC-RAS (USACE 2003). HEC-RAS computes water surface profiles and hydraulic variables in a one dimensional steady flow system, and also supports calculation of maximum scour based on the empirical methods of HEC-18. Design plan form, longitudinal profile, and cross-sectional channel dimensions are summarized in Tables 2-1, 2-2, and 2-3.

Table 2-1. The design bankfull cross-section dimensions for Crow Creek stratified by channel unit^.

Variable	Pool	Riffle	Run
Bankfull discharge (cfs)	180	180	180
Width (ft)	27.5-32.6 (30.0)	23.0-26.9 (25.0)	20.2-23.9 (21.9)
Average depth (ft)	1.0-1.2 (1.1)	1.2-1.4 (1.3)	1.4-1.7 (1.6)
Maximum depth (ft)	2.3-4.0 (3.3)	1.5-1.8 (1.7)	1.8-2.1 (2.0)
Predicted scour depth (ft)	4.2	2.1	2.4
Cross-sectional area (ft^2)	38.0	33.0	34.7
Bankfull velocity (ft/s)	4.8	5.3	5.0
Design Channel Type	B4c		

^River Design Group, Inc. 2007.

Table 2-2. The design plan form dimensions for Crow Creek^.

Variable	Range (Average Value)
Meander length (ft)	225-340 (286)
Radius of curvature (ft)	61.9-87.7 (69.4)
Belt width (ft)	50-104 (70.4)
Sinuosity	1.19

^River Design Group, Inc. 2007.

Table 2-3. The design longitudinal profile dimensions for Crow Creek^.

Variable	Range (Average Value)
Average bankfull slope (ft/ft)	0.0216
Riffle slope (ft/ft)	0.032-0.043 (0.037)
Pool slope (ft/ft)	0.0021-0.0049 (0.0026)

^River Design Group, Inc., 2007.

3.0 2007 AS-BUILT MONITORING SURVEY

3.1 Methods

As-built monitoring data collection metrics and methods are summarized in Table 3-1.

Table 3-1. Summary of as-built data collection metrics and methods.

Channel Metric	No. of Samples
Cross-sections (Harrelson et al., 1994)	4 (2 pools, 2 riffles)
Longitudinal profiles (Harrelson et al., 1994)	675 ft (10 pool-riffle sequences)
Substrate characterization (Wolman, 1954)	2 (100 count composite samples)
Photo Points (Hall, 2002)	6
Bank Erodibility Hazard Index (D. Rosgen, 2001)	3 sites

3.1.1 Longitudinal Channel Profile

As summarized in Table 3-1, the as-built longitudinal channel profile included 675 ft or 56% of the total project length. Approximately 10 contiguous pool and riffle sequences were sampled. Longitudinal profile and cross-sections were measured using a calibrated total station and rod. Upper and lower reach termini were monumented with rebar and benchmarks serving as horizontal and vertical reference points. Longitudinal profiles included thalweg or bed surface elevations that define the morphology of the channel bed features. Water surface elevations were obtained to derive individual channel facet slopes and to develop an energy grade line for the constructed channel. Bankfull elevations were determined from design indicators such as the tops of banks, floodplain extents, slope breaks, and other features.

3.1.2 Channel Cross-Sections

Four channel cross-sections were measured and monumented according to methods described by Harrelson et al. (1994). To establish a range of values for each feature, two cross-sections for riffle and pool units were measured in the project area. The lateral limits of each cross-section corresponded to the top of terraces, where feasible, and included all important features such as active floodplain, top of bank, bankfull elevation, water surface and channel bottom elevations.

3.1.3 Channel Substrate Composition

Channel materials were sampled in the project area to characterize existing bed material characteristics as well as to complement future hydraulic and sediment transport monitoring validation. The Wolman method (Wolman, 1954) was used to characterize the particle size distribution of channel materials. The material sampling locations were established on riffle habitat units. The intermediate axes of the particles were measured (Wolman, 1954).

3.1.4 Bank Erodibility Monitoring and Sediment Reduction Analysis

RDG will assess sediment load reductions resulting from the restoration project using methodologies outlined in Watershed Assessment of River Stability and Sediment Supply

(WARSS). Specifically, the Bank Assessment for Non-point Source Consequences of Sediment (BANCS) model will be used to predict pre and post bank erosion rates within the project area. The application evaluates the pre and post construction bank characteristics and flow distribution along the river reach and maps BEHI and NBS risk ratings commensurate with streambank and channel changes. Annual pre construction, predicted post-construction, and measured post-construction bank erosion rates and sediment loading estimates are presented in Section 4 of this report. Methods are further described in the Crow Creek Restoration Project: Project Monitoring Program Quality Assurance Project Plan (RDG, August 3, 2007).

3.1.5 Photo Points

Photo points will be established at all monitoring sites according to techniques outlined in Hall (2002). During each monitoring visit, photos will be taken from monumented photo point locations in addition to other locations. Photo number, numbered photo point location, and direction will be noted in the field notes.

3.1.6 Vegetation Monitoring

Site revegetation was a critical component of the restoration plan. The restoration plan included four primary revegetation components, including: 1) use of vegetated soil lifts to stabilize and promote woody shrub development on critical reconstructed streambanks, 2) planting of rooted shrub stock, 3) transplanting of existing mature shrubs, and 4) seeding of disturbed areas.

Vegetation survival will be assessed in 2008 as part of the year one monitoring report. Section 3.2.4 summarizes the implemented revegetation strategies in the project area.

3.2 Results

The monitoring reach extends from the top of riffle feature, approximately 400 ft downstream of the West Fork Crow Creek Road Bridge, to the lower terminus of the project, at station 12+00. The reach encompasses nearly 675 ft of reconstructed channel. This reach was previously characterized as an over-widened C stream type transitioning to an F channel type. The post construction condition is characterized by a slightly meandering, riffle pool, cobble dominated B4c channel type.

3.2.1 Channel Dimensions (Cross-sections)

As-built cross-section metrics are summarized in Table 3-2. Bankfull channel width was greater in pool features than in riffles, as expected. Floodprone width values derived from riffle cross-sections ranged from 90 ft to 100 ft. Corresponding entrenchment ratios at riffles ranged from 3.2 to 3.6. The variability in entrenchment ratios was related to the influence of the Holocene terraces on the floodplain width.

Table 3-2. As-built bankfull channel dimensions for riffle (n=2) and pool (n=2) cross-sections in Crow Creek. Range and average values reported.

Variable	Riffle	Pool
Bankfull Width (ft)	23.9-31.7 (27.8)	30.4-30.9 (30.7)
Floodprone Width (ft)	90.0-100 (95.0)	n/a
Entrenchment Ratio	3.2-3.6 (3.4)	n/a
Mean Depth (ft)	1.5-1.5 (1.5)	1.7-2.0 (1.9)
Maximum Depth (ft)	1.9-2.1 (2.0)	4.4-4.8 (4.6)
Width/Depth Ratio	16.3-21.6 (18.9)	16.1-18.5 (17.3)
Bankfull Area (sq ft)	35.1-46.7 (40.9)	51.5-61.5 (56.5)
Wetted Perimeter (ft)	24.8-32.5 (28.6)	32.5-33.2 (32.8)
Hydraulic Radius (ft)	1.4-1.4 (1.4)	1.6-1.9 (1.7)
Slope (ft/ft)	0.016-0.044 (0.030)	0.0005-0.0076 (0.0041)

As-built bankfull mean depths of constructed riffles averaged 1.5 ft with maximum depths ranging from 1.9 ft to 2.1 ft. Pool depths varied from a mean of 1.7 ft to 2.0 ft to maximum depths of 4.4 ft to 4.8 ft. Riffle features demonstrated marginally higher width-to-depth ratios than pools and ranged from 16.3 to 21.6. Pools width-to-depth ratios ranged from 16.1 to 18.5.

As-built, bankfull cross-sectional area was greater in pool features than in riffle features, averaging 56.5 ft^2 and 40.9 ft^2, respectively. Wetted perimeter values were greater in pool features with an average of 32.8 ft, compared to an average value of 28.6 ft for riffle units. Hydraulic radius averaged 1.4 and 1.7 for pool and riffle units, respectively. Local water surface slopes indicate average energy gradients in riffles of 0.030 ft/ft and 0.0041 ft/ft for pools.

Figure 3-1 and Figure 3-2 include plots of the monitored riffle cross-sections and photo points.

Riffle XS 2

Riffle cross-section 2 was located along the existing Crow Creek channel alignment. Restoration actions specific to this section included raising the channel invert by as much as 2.0 ft from existing conditions to reconnect the adjacent floodplain feature. As described in the RDG design report, this section of Crow Creek had downcut in response to downstream channelization of the creek. Construction techniques included raising the bed elevation with coarse cobble to fine gravel and installing a series of boulder clusters to increase bed roughness, stabilize the channel profile, and create pocket water habitat.

Riffle XS 4

Riffle cross-section 4 was located along the reactivated meander sequence which had been physically disconnected from the main Crow Creek channel due to downstream channelization. Construction activities included re-excavating the historical channel alignment and importing coarse rounded alluvium to increase bed roughness, stabilize the channel profile, and improve aquatic habitat for the target fish species. Numerous wood and rock-based structures were constructed to create pool habitat, increase channel margin complexity, and stabilize the vertical channel alignment.

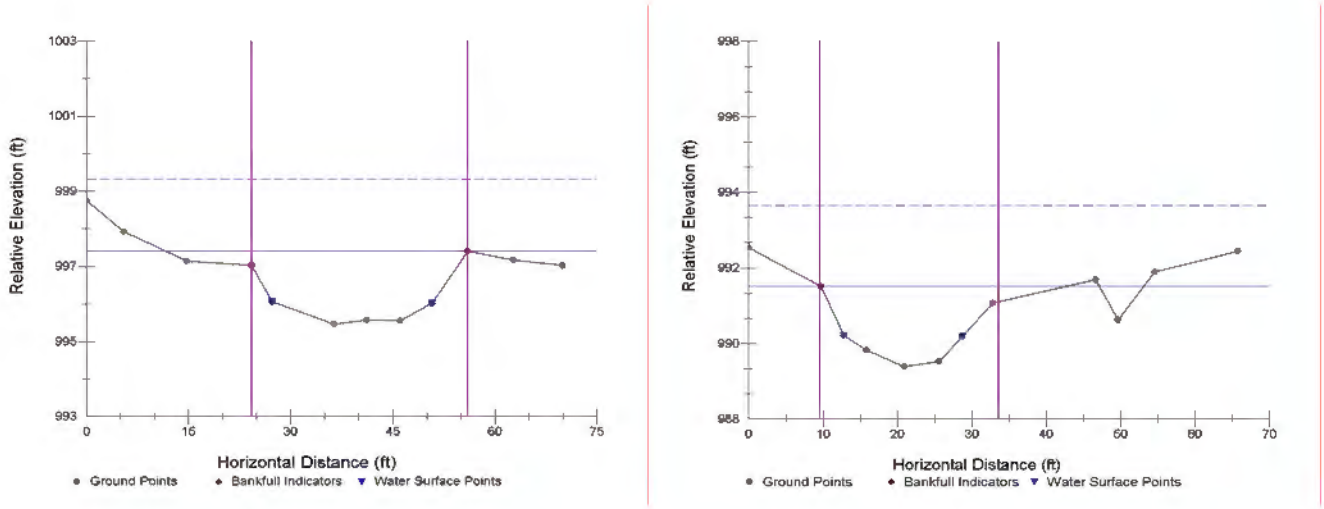

Figure 3-1. Monitoring riffle cross-sections 2 (left) and 4 (right) in the project area. The solid line denotes the design bankfull elevation and vertical lines provide limits for bankfull hydraulic calculations.

Figure 3-2. Monitoring riffle cross-sections 2 (left) and 4 (right) in the project area.

Figure 3-3 and Figure 3-4 include plots of the monitored riffle cross-sections and photo points.

Pool XS 1

Pool cross-section 1 is located in the upper reach of the project area. The pool structure consists of a wood-based engineered log jam located on an outside meander bend. The jam consists of approximately 4 rootwad complexes and is ballasted with a 24-inch diameter rootwad member to counter buoyancy and sliding forces. No rock was used in the structure. Future monitoring efforts will monitor both pool development and structure stability.

Pool XS 3

Pool cross-section 3 is located along the constructed avulsion channel plug in the middle reach of the project reach. The plug consists of earthen bill, a series of engineered log jams, and vegetated soil lift treatments to promote revegetation. As shown in Figure 3-3, the top of plug elevation was set approximately 1.5 feet in elevation higher than the opposing floodplain/point bar feature. Future monitoring efforts will evaluate channel plug stability and pool development.

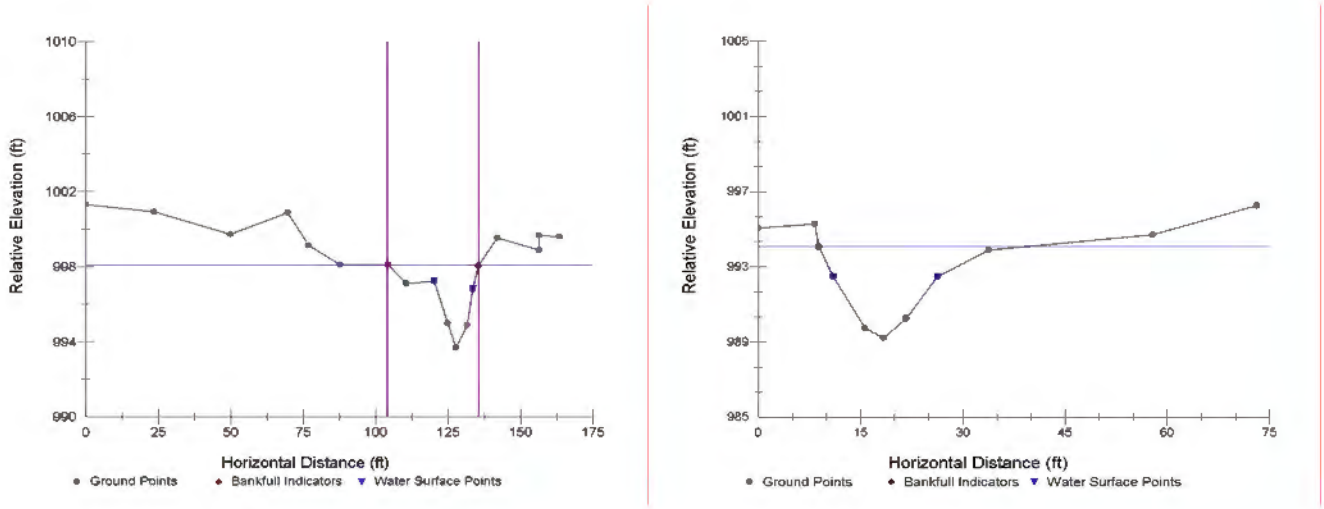

Figure 3-3. Monitoring pool cross-sections 1 (left) and 3 (right) in the project area. The solid line denotes the design bankfull elevation and vertical lines provide limits for bankfull hydraulic calculations.

Figure 3-4. Monitoring pool cross-sections 1 (left) and 3 (right) in the project area.

3.2.2 Channel Profile

The as-built longitudinal profile in the project area encompassed approximately 675 ft of reconstructed channel and is presented in Figure 3-5. Profile data including channel unit slopes, maximum depths, pool frequency and channel unit lengths are summarized in Table 3-3. Data are reported for actual values and in dimensionless ratio form.

Channel unit facet slopes were derived from the longitudinal profile (Figure 3-5) and reported as minimum, mean and maximum values for riffle, pool, run and glide features. Within the designed B4c channel, typical profile slopes occur in a range of values according to feature type. The predicted ranges of dimensionless ratios have been established based on measurement of stable, reference streams of similar valley, channel type and parent material. For this project, design ratios were established from the downstream reference reach in the Crow Creek watershed.

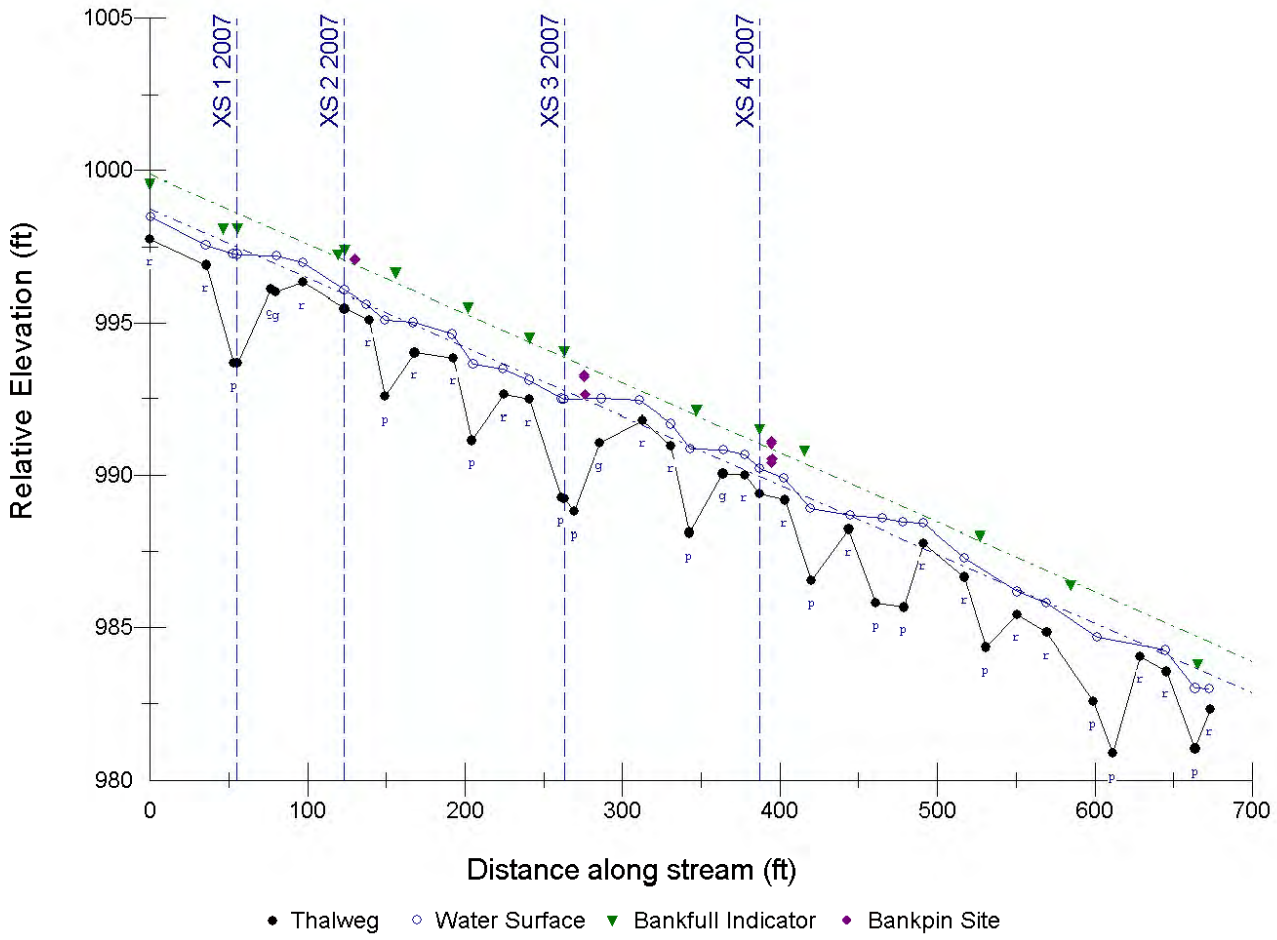

Figure 3-5. The as-built longitudinal channel profile of the Crow Creek project reach, a B4c stream type. The profile included measurement of approximately 10 pool and riffle channel sequences.

Figure 3-6. Typical photo points of the as-built channel conditions and restored channel and floodplain. A variety of habitat-forming and revegetation techniques are shown including large wood complexes, vegetated soil lifts, willow fascines and boulder clusters.

The as-built longitudinal channel profile data are summarized and presented by feature type in Table 3-3. Actual values are reported as well as their corresponding dimensionless ratio. The designed facet slopes exist as a range of values and demonstrate higher gradient riffle and run features, and lower gradient pools and glides. Review of the corresponding dimensionless ratios calculated for the Crow Creek reference reach, upon which the restoration design was based in part, indicate that the slope values for each feature type occur within the design range for the B4c channel type.

Maximum channel depths for the reconstructed reach are also reported in Table 3-3. As summarized, riffle maximum depths were less than values measured in pool features, as expected. The transitional run and glide features contain intermediary depth values. Review of the corresponding dimensionless ratios reveals that the maximum depths for each feature occur within the designed B4c range of values for each channel unit type.

Table 3-3. As-built longitudinal profile dimensions and dimensionless ratios for the Crow Creek project reach.

Profile Dimensions Metric	Min	Mean	Max	Profile Dimensionless Ratios[1]	Min	Mean	Max
S riffle (ft/ft)	0.0159	0.0290	0.0435	S riffle / Sbkf (ft/ft)	0.7	1.3	1.9
S pool (ft/ft)	0.0005	0.0041	0.0076	S pool / Sbkf (ft/ft)	0.0	0.2	0.3
S run (ft/ft)	0.0116	0.0152	0.0189	S run / Sbkf (ft/ft)	0.5	0.7	0.8
S glide (ft/ft)	0.0035	0.0060	0.0077	S glide / Sbkf (ft/ft)	0.2	0.3	0.3
P - P (ft)	41.6	67.2	94.5	P - P / Wbkf (ft)	1.5	2.4	3.4
P length (ft)	24.0	34.9	52.2	P length / Wbkf (ft)	0.9	1.3	1.9
Dmax riffle (ft)	1.4	1.7	2.1	Dmax riffle / Dbkf (ft)	1.0	1.2	1.4
Dmax pool (ft)	3.6	4.2	5.2	Dmax pool / Dbkf (ft)	2.4	2.9	3.5
Dmax run (ft)	2.5	2.7	3.2	Dmax run / Dbkf (ft)	1.7	1.9	2.1
Dmax glide (ft)	2.2	2.4	2.6	Dmax glide / Dbkf (ft)	1.5	1.6	1.8
Low Bank Ht (ft)	2.0	2.0	2.1	Low Bank Ht /Dmax riff (ft)	1.1	1.2	1.2
WS Slope (ft/ft)		0.023		Bankfull Slope (ft/ft)		0.023	

[1]Sbkf=0.023 ft/ft, Wbkf=27.8 ft, Dbkf=1.5 ft, Dmax=2.0 ft.

Pool frequency is reported in Table 3-3. Within the reconstructed reach, pool features occur approximately every 67.0 ft on average, for a resulting average pool to pool spacing to bankfull width ratio of 2.4. Constructed pool length is approximately 35.0 ft on average and ranges from 24.0 ft to 52.2 ft. Pool length varies based on the structure type. In general, shorter pool lengths were associated with mid-riffle structures such as rock cross vanes. Longer pools were associated with meander arc sequences and engineered log jams.

3.2.3 Channel Substrate Composition

Channel substrate composition was characterized using the Wolman pebble count method at three riffle features. Pebble counts data were collected at three locations in the project reach, including cross-section 2, Station 7+20 and cross-section 4. As-built data are summarized in Table 3-4.

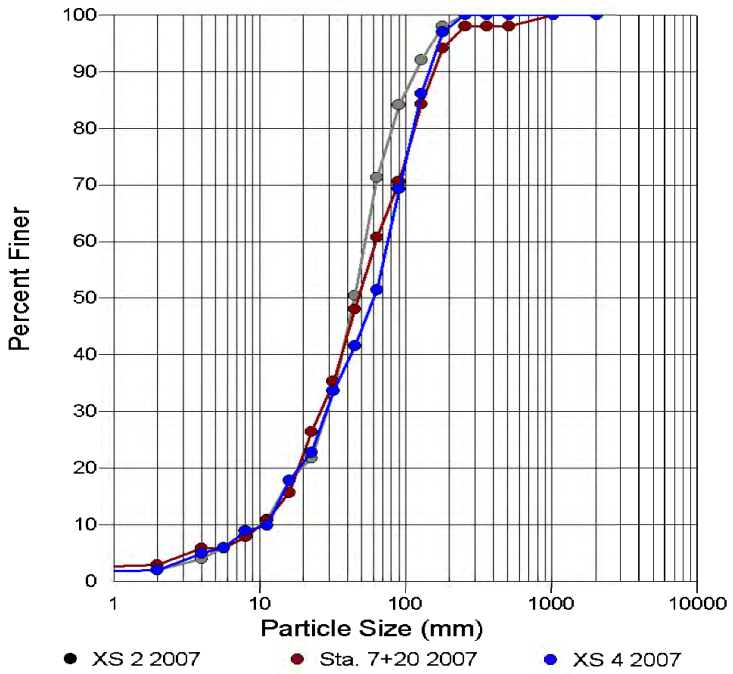

Figure 3-7. Channel particle size distributions for three as-built riffle features in the Crow Creek project area.

Table 3-4. As-built particle size distributions by size class for three riffle features in the Crow Creek project area.

Percentile	XS 2	Sta. 7+20	XS 4	Coefficient of Variance
D_{16}	15	16	15	0.04
D_{35}	33	32	34	0.03
D_{50}	45	48	61	0.17
D_{84}	90	127	123	0.18
D_{95}	154	197	170	0.13
D_{100}	256	1024	256	0.87

Figure 3-7 graphically displays the particle size distribution curves for the monitoring sections. Table 3-4 reports the actual values and the degree of variation between size classes. Results from the particle size analyses indicate less than 20% variation between samples. The exception is the D100 size particle. This may be reflective of the medium to large boulders at station 7+20 that were imported and utilized during construction of the new channel.

Pre-construction and post-construction substrate particle size analyses are displayed in Figure 3-8. Sample populations for riffles were grouped and reported as a single sample to evaluate changes in channel substrate composition for the pre and post construction condition.

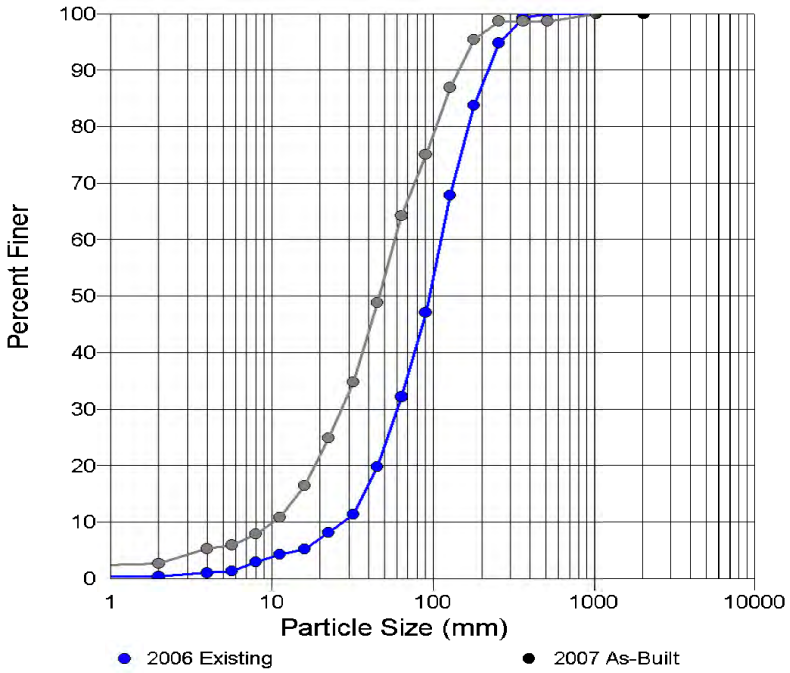

Figure 3-8. Substrate particle size distribution comparison for 2006 pre construction and 2007 post construction conditions (n=300).

Summary results are reported in Table 3-5. A general fining trend can be discerned for all size classes with the exception of the D100 class. As previously discussed, coarse boulder material was used to construct a variety of structures in the project area including boulder clusters and rock cross vanes. The increase in the D100 particle size is likely attributed to this factor.

Table 3-5. Substrate particle size distribution comparison between three riffle features in 2006 and three riffle features in 2007.

Percentile	2006 Cumulative	2007 Cumulative	Percent Change
D_{16}	39	16	-144
D_{35}	69	32	-115
D_{50}	95	46	-107
D_{84}	182	119	-53
D_{95}	260	178	-46
D_{100}	512	1024	50

3.2.4 Vegetation

Vegetation survival will be evaluated in 2008 as part of the year one post runoff survey. As described in Section 3.1.6, the restoration plan included four primary revegetation components, including: 1) use of vegetated soil lifts to stabilize and promote woody shrub development on critical reconstructed streambanks, 2) planting of rooted shrub stock, 3) transplanting of existing mature shrubs, and 4) seeding of disturbed areas.

Approximately 375 ft of single and double layer vegetated soil lifts (VSL) were installed in the project area (see RDG design report for locations of VSLs). The VSLs were planted with a

approximately ~1,250 rooted plants and ~1,750 dormant willow cuttings. The following rooted species were used:

- Alder (Alnus incana)
- Water birch (Betula occidentalis)
- Red-osier dogwood (Cornus sericea)
- Bebb willow (Salix bebbiana)
- Douglas hawthorne (Crataegus douglasii)
- Chokecherry (Prunus virginiana)
- Serviceberry (Amelanchier alnifolia)
- Rocky Mountain Maple (Acer glabrum)
- Ribes americanum
- Rose (Rosa woodsii)

Approximately 20 whole shrubs were transplanted from donor sites located in the project area to areas where added soil strength and rapid vegetation establishment was desired. Priority areas for shrub transplanting included abandoned channel plug surfaces and constructed wetland cells. Following transplant, the shrubs were cut down to within 1.5 ft of the ground surface to increase survival.

Monitoring in 2008 will focus on survival of transplanted shrubs, rooted plant stock, and willow cuttings. A second broadcast seed application will occur in Spring 2008 to ensure all disturbed areas are properly mitigated.

3.3 As-Built and Design Dimensions

A comparison between the designed riffle and pool channel dimensions and the as-built, constructed channel dimensions are presented in Table 3-6. Constructed pools were built to within 2.3% of designed bankfull channel width specification. However, constructed pools were excavated to depths greater than the design dimensions. Similarly, a constructed mean depth 42% greater than design depth was detected from the post construction survey. This in turn influences the cross-sectional area resulting in a departure from the design channel metrics.

Constructed riffle dimensions have remained within 20% of the design specification. Constructed bankfull riffle width and width-to-depth ratio are within 10% and 4.0% of the design specification, respectively.

Table 3-6. Pool and riffle design dimensions and reach averaged values for select morphological variables.

	Design Pool	As-Built Pool	Percent Difference	Design Riffle	As-Built Riffle	Percent Difference
Width (ft)	30.0	30.7	2.3	25.0	27.8	10.0
Mean Depth (ft)	NA	NA	NA	1.3	1.5	13.3
Max Depth (ft)	3.3	4.6	28.3[1]	1.7	2.0	15.0
XS Area (ft^2)	38.0	56.5	32.7[1]	33.0	40.9	19.3
Width/Depth (ft)	NA	16.2	NA	19.2	18.5	-3.8

4.0 SEDIMENT REDUCTION ANALYSIS

Annual streambank erosion rates in the Crow Creek project area were estimated using the Bank Erosion Hazard Index (BEHI) as described in Section 2.2 Sampling Methods in the Crow Creek Restoration Project Quality Assurance Project Plan (RDG, 2007). Bank conditions including bankfull height, bank length, BEHI score and near-bank stress ratings were evaluated for representative cross-section and BEHI conditions. For comparative purposes, BEHI analyses were completed before and after construction and in the Crow Creek reference reach, located approximately 0.25 miles downstream of the project area. The reference reach exhibits similar morphological characteristics to the project reach and was used as a field model for developing proposed design dimensions.

Established curves relating BEHI and near-bank stress to predicted annual streambank erosion rates were utilized. The first equation is from Yellowstone National Park, representing streams formed in alpine glaciated valley morphologies and/or volcanism geology (Rosgen 1996, 2001a). A second equation is based on Colorado streams formed in sedimentary and/or metamorphic geology and was also used to predict annual streambank erosion rates (Rosgen 1996, 2001a) for the project area.

Table 4-1 and Table 4-2 summarize the results of the pre and post-construction analyses within the project reach.

Table 4-1. Estimated pre-construction sediment loading (in tons/year) calculated for the Crow Creek restoration project area.

Bank ID	Bank Height (ft)	Bank Length (ft)	BEHI Score	BEHI Rating	Near Bank Stress	Colorado (tons/yr)	Yellowstone (tons/yr)
Bank 1	4.0	175	37.2	High	V High	10.8	22.9
Bank 2	3.6	125	38.7	High	V High	16.9	35.8
Bank 3	4.1	175	39.3	High	High	17.3	41.5
Bank 4	3.3	175	34.7	High	V High	22.6	48.0
Bank 5	2.4	200	39.8	High	V High	18.8	40.0
Bank 6	7.7	40	45.0	V. High	Extreme	19.3	37.1
Total						105.7	225.3

Table 4-2. Estimated post construction sediment loading (in tons/year) calculated for the Crow Creek restoration project area.

Bank ID	Bank Height (ft)	Bank Length (ft)	BEHI Score	BEHI Rating	Near Bank Stress	Colorado (tons/yr)	Yellowstone (tons/yr)
Bank 1	2.1	175	18.7	low	moderate	1.2	1.6
Bank 2	2.5	125	19.9	low	low	0.5	0.5
Bank 3	2.5	140	19.7	low	moderate	1.2	1.5
Bank 4	2.4	175	16.4	low	moderate	1.4	1.8
Bank 5	1.9	100	27.0	moderate	low	0.8	1.7
Bank 6	2.1	80	13.5	low	low	0.3	0.3
Total						5.4	7.4

Table 4-3 summarizes the predicted reduction in sediment loading from pre construction to post restoration conditions. The table identifies the measured variables and the corresponding percent change between 2006 (pre construction) and 2007 (post construction).

Table 4-3. Sediment reduction analysis for the Crow Creek restoration project reach, existing conditions versus as-built conditions.

Condition	Average Bank Height (ft)	Average Bank Protection (%)	Average BEHI Score	Average BEHI Rating	Average Near Bank Stress	Colorado (tons/yr)	Yellowstone (tons/yr)
2006 Existing Conditions	4.2	19	39.1	V. High	High	106	225
2007 As-built Conditions	2.2	64	19.2	Low	Low - Moderate	5.4	7.4
Percent Change	-91	70	-104	n/a	n/a	-1863	-2941

As summarized in Table 4-3, average BEHI ratings decreased from a very high-high rating in 2006 to a low-moderate rating in 2007, a 104% decrease. Estimated sediment loading reduction within the project area applying both the Colorado and Yellowstone curves is 1,863 tons/year and 2,941 tons/year, respectively. This is a prediction of sediment load reduction and will be validated during subsequent monitoring efforts in the project area.

5.0 DISCUSSION

An as-built monitoring survey was completed in the Crow Creek restoration project area to document post-construction channel dimensions, channel substrate composition and sediment loading characteristics. As-built data are valuable for comparing the design and constructed channel dimensions, as well as evaluating channel response to future runoff events. As such, the as-built survey provides baseline data for assessing future channel adjustments. This survey documents channel conditions immediately after construction and prior to the onset of any high flow events in the Crow Creek watershed.

The as-built survey data indicate some departure from the designed channel dimensions. Pools were constructed to the target width but excavated deeper than designed maximum scour depth. The measured departures in bankfull maximum pool depth and cross-sectional are attributed to the manner in which the “foundations” of the pool forming structures (e.g. footer logs and rock footers) are installed. In order for these types of structures to remain stable under high flow events, the bases of the structures are set below the predicted pool scour depth. The design analysis indicated potential scour depths averaging 4.5 ft. As a result, during construction, the excavator placed the bottom of the footer logs and/or rocks to depths of at least 4.5 ft relative to bankfull. This resulted in some deviation from the design maximum pool dimensions. We expected to observe some degree of pool filling during the 2008 runoff which will be detected and discussed in the year one post runoff survey and report.

Constructed riffle widths were built to within 10% of the design dimensions. Riffle mean and maximum depths were excavated to within 15% of the design depths. These as-built channel dimensions will be subject to adjustment in response to seasonal and other high flows. The 2008 post-runoff survey will determine the occurrence and extent of any channel adjustments and the results will be evaluated against the established performance standards.

Bed sediment data collected in the project area indicate a general fining trend in the post construction condition relative to the pre-restoration condition. As described in the RDG design report, one of the primary objectives of this project was re-establish hydrologic connectivity between the active channel and floodplain. This required raising the channel bed elevation by as much as 2.0 ft in locations along the profile with a graded mixture of boulders, cobble, gravel and sand. Due to the lack of pools and energy dissipating features associated with the pre-restoration condition, channel substrate was largely characterized by coarse particle sizes and limited finer substrate. Reintroducing pool and riffle sequences should result in a general fining of channel substrate over time as sorting processes are re-established and promote gravel retention in pool tailout areas.

The sediment reduction analysis using the BEHI protocol has proven to be effective in demonstrating the reduction in bank-derived sediment loading with improved bank conditions. Because increased bank erosion hazard is driven by high bank height ratios, sparse or shallow rooted riparian vegetation, over-steepened banks and high near bank stress, substantial decreases in bank erosion hazard can be obtained through natural channel design techniques which are engineered to moderate these conditions. It is anticipated that with time, as the reconstructed channel in the project area stabilizes and the planted vegetation matures, erosion rates and subsequent delivery of fine and coarse sediment to Crow Creek will decrease. The sediment response will be tracked during subsequent monitoring of the restoration project.

6.0 REFERENCES

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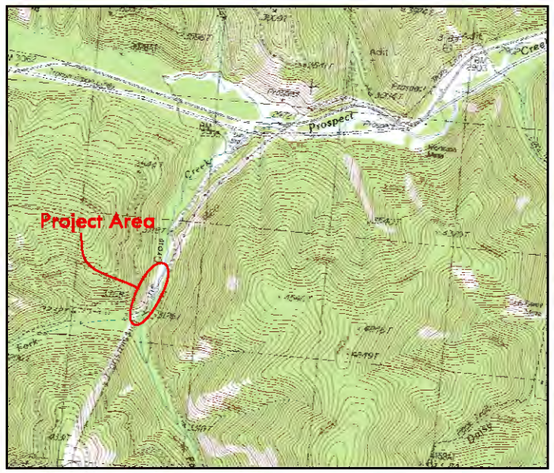
Thompson Falls
Sanders County, Montana



PROJECT VICINITY MAP
SCALE: 1" = 4000'

CONSTRUCTION PLAN SET

CROW CREEK RESTORATION PROJECT

NEAR THOMPSON FALLS, MONTANA

PREPARED FOR:

AVISTA Corp.

PREPARED BY:

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MT-1 MATERIALS LIST

NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
1	3-10-07	MSD	DESIGN

TITLE SHEET

CROW CREEK RESTORATION PROJECT

DRAWN BY:	NMW	SCALE: As Noted	
DESIGNED BY:	JMM/MSD		
CHECKED BY:	MSD	FILE NAME: Title Sheet.dwg	
PROJECT NO.:	RDG-06-017		

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PT#	LATITUDE	LONGITUDE	ELEVATION	DESCRIPTION
1	10000	10000	1000	SET RDG
2	10454.99	10241.92	984.65	SET RDG

NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
1	3-06-07	MSD	DESIGN

SURVEY CONTROL INDEX

CROW CREEK RESTORATION PROJECT

DRAWN BY: NMW
DESIGNED BY: MSD
CHECKED BY: MSD
PROJECT NO.: RDG-06-017
NOT TO SCALE
FILE NAME: SC-1.dwg

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SHEET SC-1

RIVER DESIGN GROUP, INC.

Site	BF Slope	Station	DS Dist.	BF Elev	Feature	TOR max d	POOL max d	BOR max d	TOP RUN max d	BOT RUN max d	Riffle Scour	Pool Scour	Run Scour	TW Elev	Scour Elev	Facet Slp	Riffle Length	Glide Length	Run Length	Pool Length
	0.0216	0		1008.25	START	1.30					2.10			1006.95	1006.15					
	0.0216	250	250	1002.85	TOR	1.25					2.10			1001.60	1000.75					
	0.0216	292.5	42.5	1001.93	BOR			1.80			2.10			1000.13	999.83	-0.0345	43			
	0.0216	302.5	10	1001.72	POOL		3.30					4.20		998.42	997.52	-0.0216		10		
A	0.0216	312.5	10	1001.50	TOP RUN				1.80				2.40	999.70	999.10				10	20
	0.0216	330	17.5	1001.12	BOT RUN					1.74			2.40	999.38	998.72	-0.0182	18			
	0.0216	339	9	1000.93	POOL		3.30					4.20		997.63	996.73	-0.0249		9		
	0.0216	348	9	1000.74	TOP RUN				1.80				2.40	998.94	998.34				9	18
	0.0216	368	20	1000.30	BOT RUN					1.80			2.40	998.50	997.90	-0.0216	20			
	0.0216	377	9	1000.11	POOL		3.30					4.20		996.81	995.91	-0.0020		9		
	0.0216	396.5	19.5	999.69	TOR	1.24					2.10			998.45	997.59				20	29
	0.0216	449.5	53	998.54	BOR			1.90			2.10			996.64	996.44	-0.0341	53			
	0.0216	459.5	10	998.33	POOL		3.30					4.20		995.03	994.13	-0.0166		10		
	0.0216	469.5	10	998.11	TOP RUN				1.80				2.40	996.31	995.71				10	20
B	0.0216	494.5	25	997.57	BOT RUN					2.00			2.40	995.57	995.17	-0.0296	25			
	0.0216	503.5	9	997.38	POOL		3.30					4.20		994.08	993.18	-0.0146		9		
	0.0216	523	19.5	996.96	TOP RUN				1.80				2.40	995.16	994.56				20	29
	0.0216	541	18	996.57	BOT RUN					1.80			2.40	994.77	994.17	-0.0216	18			
	0.0216	551	10	996.35	POOL		3.30					4.20		993.05	992.15	-0.0021		10		
	0.0216	561	10	996.14	TOR	1.41					2.10			994.73	994.04				10	20
	0.0216	579	18	995.75	BOR			1.80			2.10			993.95	993.65	-0.0433	18			
	0.0216	589	10	995.53	POOL		3.30					4.20		992.23	991.33	-0.0216		10		
	0.0216	599	10	995.31	TOP RUN				1.80				2.40	993.51	992.91				10	20
	0.0216	621	22	994.84	BOT RUN					1.80			2.40	993.04	992.44	-0.0216	22			
C	0.0216	631	10	994.62	POOL		3.30					4.20		991.32	990.42	-0.0216		10		
	0.0216	641	10	994.41	TOP RUN				1.80				2.40	992.61	992.01				10	20
	0.0216	659	18	994.02	BOT RUN					1.80			2.40	992.22	991.62	-0.0216	18			
	0.0216	669	10	993.80	POOL		3.30					4.20		990.50	989.60	-0.0027		10		
	0.0216	686	17	993.44	TOR	1.29					2.10			992.15	991.34				17	27
	0.0216	734	48	992.40	BOR			1.85			2.10			990.55	990.30	-0.0333	48			
	0.0216	744	10	992.18	POOL		3.30					4.20		988.88	987.98	-0.0021		10		
D	0.0216	754	10	991.97	TOR	1.46					2.10			990.51	989.87				10	20
	0.0216	815	61	990.65	BOR			2.10			2.10			988.55	988.55	-0.0321	61			
	0.0216	825	10	990.43	POOL		3.30					4.20		987.13	986.23	-0.0026		10		
	0.0216	835	10	990.22	TOP RUN				1.72				2.40	988.50	987.82				10	20
	0.0216	855	20	989.78	BOT RUN					1.97			2.40	987.81	987.38	-0.0341	20			
	0.0216	865	10	989.57	POOL		3.30					4.20		986.27	985.37	-0.0029		10		
	0.0216	894	29	988.94	TOR	1.24					2.10			987.70	986.84				29	39
	0.0267	924	30	988.14	BOR			1.79			2.10			986.35	986.04	-0.0450	30			
	0.0267	936.5	12.5	987.81	POOL		3.30					4.20		984.51	983.61	-0.0031		13		
	0.0267	949	12.5	987.47	TOR	1.20					2.10			986.27	985.37				13	25
E	0.0267	979	30	986.67	BOR			1.77			2.10			984.90	984.57	-0.0457	30			
	0.0267	989	10	986.41	POOL		3.30					4.20		983.11	982.21	-0.0282		10		
	0.0267	999	10	986.14	TOP RUN				1.80				2.40	984.34	983.74				10	20
	0.0267	1024	25	985.47	BOT RUN					1.95			2.40	983.52	983.07	-0.0327	25			
	0.0267	1036.5	12.5	985.14	POOL		3.30					4.20		981.84	980.94	-0.0049		13		
	0.0267	1063	26.5	984.43	TOR	1.10					2.10			983.33	982.33				27	39
	0.0267	1113	50	983.10	BOR			1.90			2.10			981.20	981.00	-0.0427	50			
	0.0267	1125.5	12.5	982.76	POOL		3.30					4.20		979.46	978.56	-0.0227		13		
F	0.0267	1138	12.5	982.43	TOP RUN				1.80				2.40	980.63	980.03				13	25
	0.0267	1163	25	981.76	BOT RUN					1.80			2.40	979.96	979.36	-0.0267	25			

NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
1	3-06-07	MSD	DESIGN

CHANNEL CENTERLINE ELEVATIONS

CROW CREEK RESTORATION PROJECT

DRAWN BY: NMW
DESIGNED BY: MSD/JM
CHECKED BY: MSD/JM
PROJECT NO.: RDG-06-017
NOT TO SCALE
FILE NAME: SC-1.dwg

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SHEET SC-2

RIVER DESIGN GROUP, INC.

GENERAL SPECIFICATIONS

1. The project shall be constructed according to the plan set. The Contractor shall notify the Construction Manager of any changes prior to implementation. The Construction Manager for this project shall be John Muhlfeld.

2. It is the Contractor's responsibility to identify all underground utilities prior to construction.

3. Costs incurred due to project delays resulting from failure of the Contractor to meet the requirements of the general specifications, contractor qualifications, construction specifications, materials specifications and revegetation specifications shall be the expense of the Contractor.

CONTRACTOR QUALIFICATIONS

1. The Contractor shall have at least two (2) years of river restoration construction experience and shall have completed at least five (5) river restoration projects. Or, the Contractor shall have at least one (1) year of river restoration experience, shall have completed at least three (3) river restoration projects, and shall have completed an approved river restoration training class. Approved training classes include those sponsored by Wildland Hydrology, Inc. or a similarly qualified practitioner of natural channel design stream restoration principles.

2. If the Contractor chooses to designate an employee without qualified stream restoration experience, the Contractor shall be on-site at all times when the employee is performing river restoration work. Failure to abide by this condition without previous agreement with the Construction Manager would be grounds for termination.

3. The Contractor shall maintain at least $1,000,000 in liability insurance and have proof of liability insurance on-site during the entirety of project construction.

4. The Contractor shall have proof of worker's compensation insurance on-site during the entirety of project construction.

5. The Contractor shall have posted at the site all regulatory permits including the U.S. Army Corps of Engineers 404, conservation district 310 permit and MDEQ 318 authorization.

EQUIPMENT SPECIFICATIONS

1. The Contractor shall furnish all equipment necessary to construct the project. The Contractor shall mobilize all equipment to the project area as directed by the Construction Manager.

2. At a minimum, the equipment for this project shall include:

Trackhoe/Excavator - One (1) excavator(s) shall be required. The equipment shall be minimum 300 class. The bucket volume shall be one (1) cubic yard(s). The bucket shall be equipped with a hydraulic thumb for grasping logs, rocks, and other materials. The equipment must be capable of crossing water and working on or adjacent to steep slopes. A chain shall be available for attaching culverts, pumps and other equipment or materials to the bucket for transport on-site.

Front End Loader - One (1) front end loader(s) shall be required. The equipment shall be minimum 300 class. The minimum bucket volume shall be four (4) cubic yards. The bucket must be equipped with forks for transporting logs, rocks and other materials. A chain shall be available for attaching culverts, pumps and other equipment or materials to the bucket for transport on-site.

Bulldozer - One (1) bulldozer(s) shall be required.

Dump Truck - One (1) dump truck shall be required for this project. Truck(s) shall have a minimum bed volume of eight (8) cubic yards. The truck(s) shall be capable of driving on non-asphalt surfaces and off-road surfaces.

Skid steer - One (1) skid-steer(s) all-surface loader shall be required. The equipment shall have sod tracks to minimize on-site disturbance.

Chainsaw - One (1) chainsaw shall be required. The chainsaw must be capable of completely sawing logs of the diameter specified in the material specifications. Also, the chainsaw must be capable of sawing HDPE or PVC culverts or pipes as noted in the material specifications.

3. All equipment shall be washed prior to mobilization to the site to minimize the introduction of foreign materials and fluids to the project site. All equipment shall be free of oil, hydraulic fluid, and diesel fuel leaks. To prevent invasion of noxious weeds or the spread of whirling disease spores, all equipment shall be power washed or cleaned to remove mud and soil prior to mobilization into the project area. It will be the Contractor's responsibility to insure that adequate measures have been taken.

Equipment shall be new or in a well-maintained condition to minimize the likelihood of a fluid leak. If a fluid leak does occur, the Construction Manager shall be notified immediately, and all work ceased until the leak has been rectified. At all times during the construction phase, fluid spill containment equipment shall be present on-site and ready for deployment should an accidental spill occur.

4. The Contractor shall maintain a complete tool set with commonly replaced parts (e.g. O-rings) to minimize downtime in the event of equipment malfunction.

CONSTRUCTION SPECIFICATIONS

1. Construction shall occur in accordance with the plan set, construction specifications, equipment specifications, material specifications, revegetation specifications and general specifications.

2. Prior to construction, construction areas will be staked out using a survey grade Global Positioning System (GPS), total station, or survey laser. The Construction Manager shall stake the locations of the construction access, stockpile locations, limits of disturbance, temporary diversion channels, temporary culverts, proposed channel centerline, proposed channel margins, channel bed features, floodplain extents, wetlands and all structures according to the plan set. Construction staking shall occur in accordance with the Survey Control Sheet. At a minimum, staking of features shall occur every 25 feet along the alignment. The Contractor shall minimize disturbance to grade stakes. If excessive disturbance to grade stakes by the Contractor occurs, it shall be the Contractor's expense to re-stake the project.

3. Stream crossings shall be minimized during construction. If multiple crossings (5 or more) are expected, the contractor shall provide and install temporary culverts so that equipment can cross the stream without generating excess turbidity. Temporary culvert sizes shall accommodate 150% of expected base flow during construction. The Construction Manager shall specify the sizes and locations of the temporary culverts.

4. Prior to construction, temporary diversion channels shall be constructed to divert water away from construction areas. Temporary diversion channels shall be located and constructed according to the plan set. Temporary diversion channels constructed in fine soils such as sand, silt, or organic material shall be completely lined with fabric to prevent erosion. The Contractor shall divert water incrementally into the temporary diversion channel to minimize turbidity and permit fish to move out of the dewatered channel segments.

5. Straw bales and silt fencing shall be available and installed by the Contractor if deemed necessary by the Construction Manager. Construction fencing (limits of disturbance) shall be installed by the Contractor if deemed necessary by the Construction Manager.

6. Initially, the Contractor shall excavate the channel to approximate design dimensions using the excavator, trackhoe or bulldozer. Excavation shall comply with construction stakes and the plan set. Excavation shall establish channel elevations within one-half foot of final elevations. The Construction Manager shall inspect the channel excavation for compliance with the plan set. All excavated materials shall be stockpiled on-site, above the bankfull channel until hauled off-site or used on-site. Disturbance to riparian vegetation, channel banks and sod shall be minimized. Excavated sod and riparian shrub transplants shall be carefully stockpiled and reused for revegetating floodplains or stream banks.

7. After excavating the channel, the Contractor shall install the grade control, bank stabilization and habitat structures. Each structure shall be constructed in accordance with the locations and specifications provided in the plan set. The Construction Manager shall inspect and approve all structures. Structures shall not be backfilled until the Construction Manager has inspected and approved all structures.

8. After all structures are installed, the channel will be shaped to within 0.2 feet of the final elevations specified on the plan set using an excavator, trackhoe or bulldozer. The Construction Manager shall check the final elevations for compliance with the plan set. All excavated materials shall be stockpiled on-site, above the bankfull channel until hauled off-site or used on-site. Disturbance to riparian vegetation, channel banks and sod shall be minimized.

9. Upon notification from the Construction Manager, the Contractor shall divert water incrementally into the new channel. Efforts shall be made to minimize turbidity and permit fish to move out of the dewatered channel segments.

10. After water is diverted into the new channel, soil stockpiled on site will be used to construct earthen channel plugs in the existing channel. Each plug shall be constructed in accordance with the locations and specifications provided in the plan set. Excess material shall be placed in the old channel or hauled off-site to a location approved by the Construction Manager. The Construction Manager shall inspect and approve all earthen channel plugs.

11. The Contractor shall remove excess materials, temporary culverts and equipment from the site. The Contractor shall regrade disturbed areas and construction access roads to their original grades. The Contractor shall treat compacted soil areas including access roads and material stockpile areas. The Contractor shall remove soil from the project site if the soil is tainted with petroleum-based fluids.

NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
1	3-06-07	MSD	DESIGN

SPECIFICATIONS

CROW CREEK RESTORATION PROJECT

DRAWN BY:	NMW	NOT TO SCALE	
DESIGNED BY:	MSD/JM		
CHECKED BY:	MSD/JM	FILE NAME: SP-1.dwg	
PROJECT NO.:	RDG-06-017		

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SHEET SP-1

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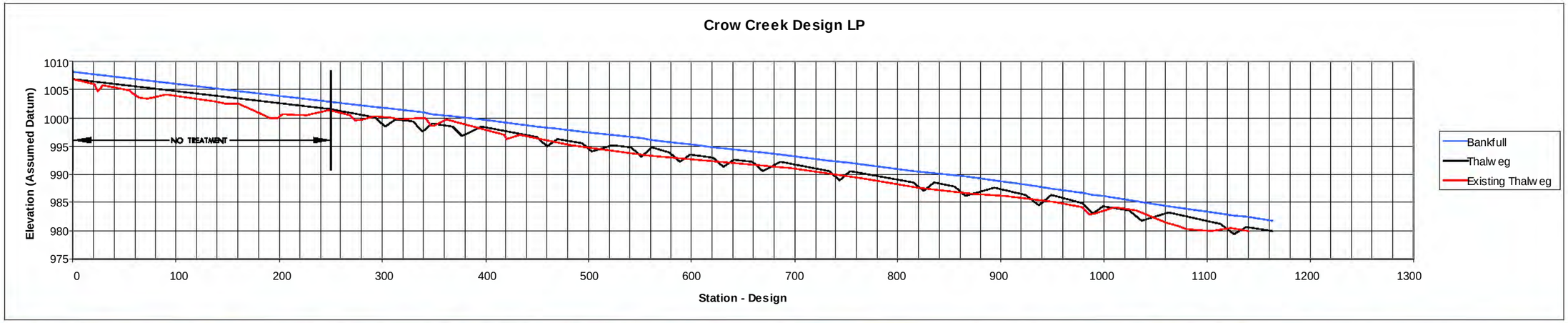

NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
1	3-06-07	MSD	DESIGN

PLAN VIEW INDEX

CROW CREEK RESTORATION PROJECT

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DESIGNED BY:	MSD/JM		
CHECKED BY:	MSD	FILE NAME: SC-1.dwg	
PROJECT NO.:	RDG-06-017		

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SHEET PP-1

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NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
1	3-06-07	MSD	DESIGN

STRUCTURE LOCATIONS

CROW CREEK RESTORATION PROJECT

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CHECKED BY:	MSD	FILE NAME: SC-1.dwg	
PROJECT NO.:	RDG-06-017		

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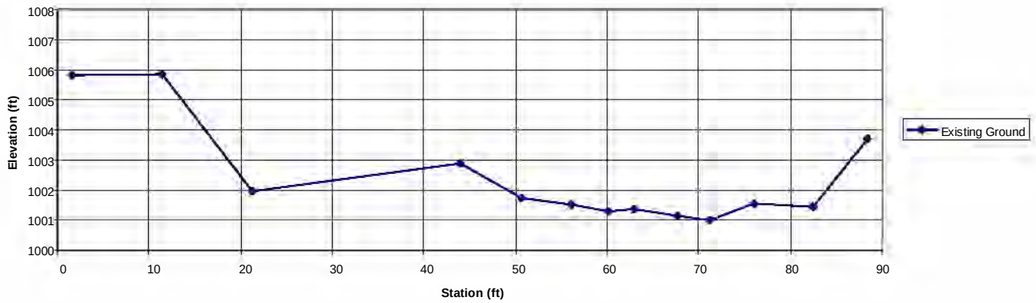
SHEET SL-1

RIVER DESIGN GROUP, INC.

Sta 2+50 - Riffle



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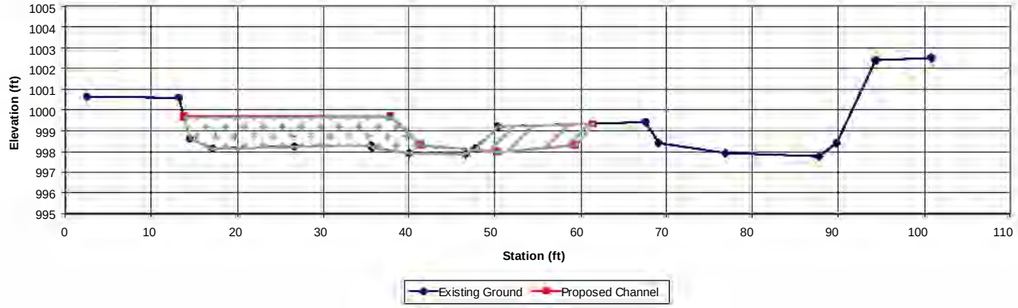

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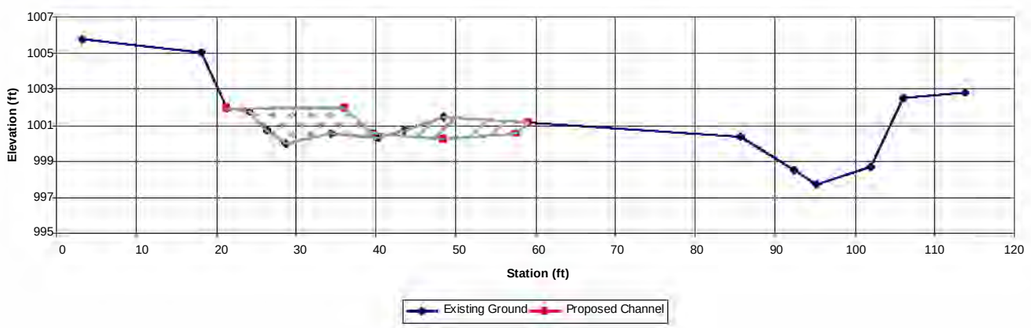

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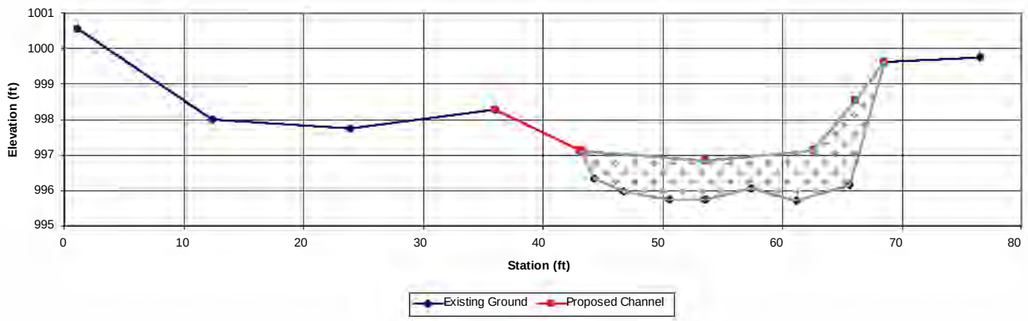

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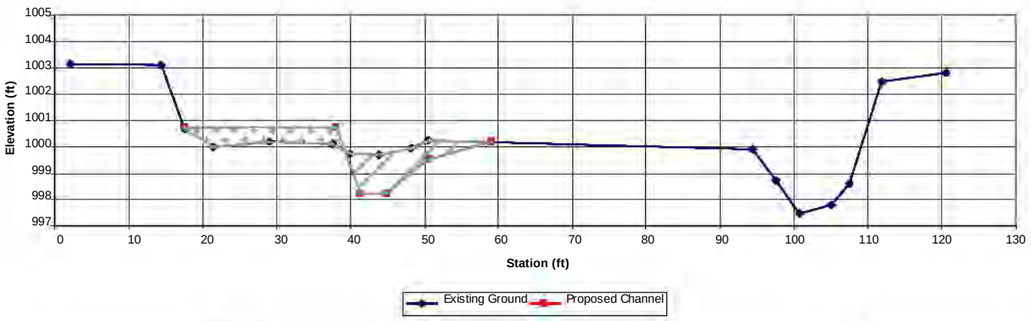

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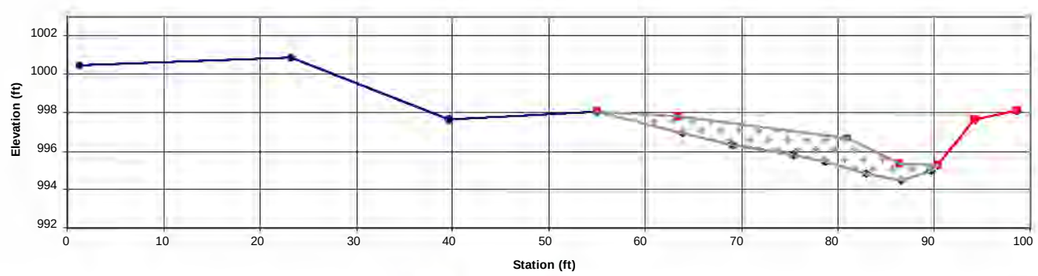

"CROSS SECTIONS ARE SHOWN LOOKING DOWNSTREAM"

Legend

Cut

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NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
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CROSS SECTIONS

CROW CREEK RESTORATION PROJECT

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PROJECT NO.:	RDG-06-017		

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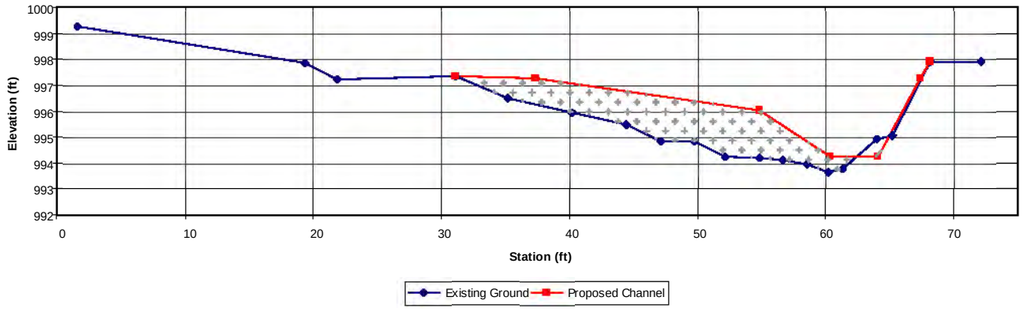
Sta 5+08 - Pool



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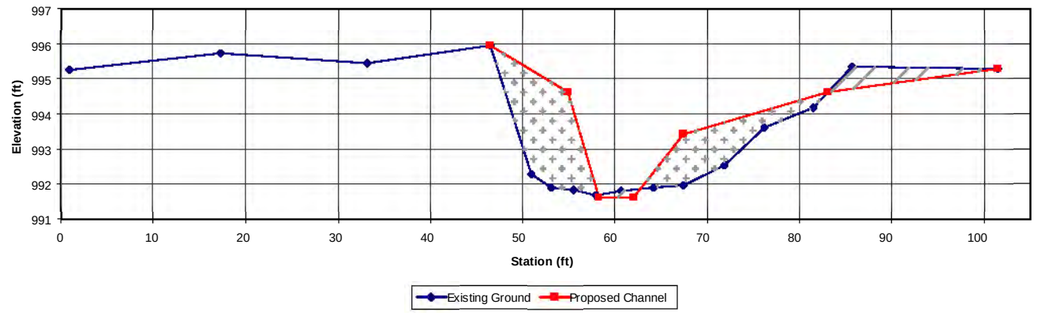

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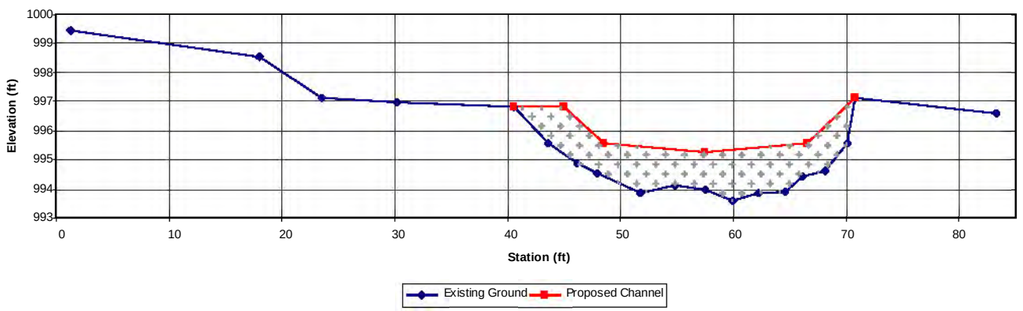

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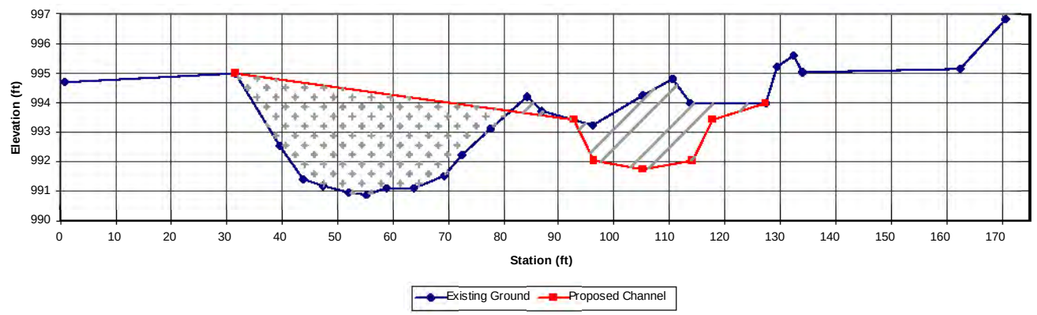

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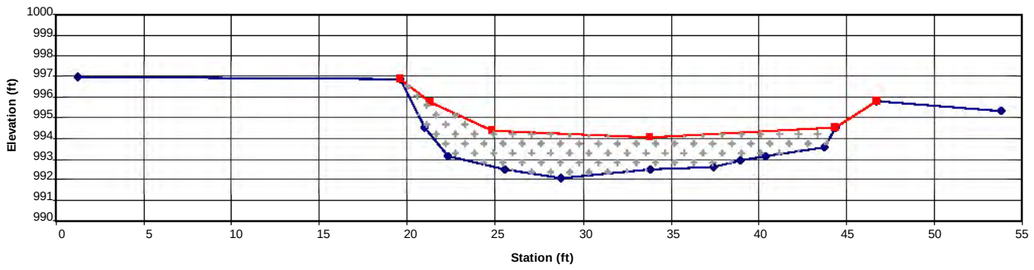

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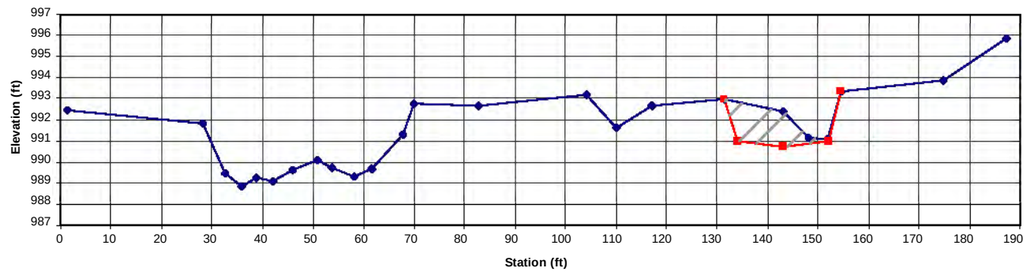

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NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
1	3-06-07	MSD	DESIGN

CROSS SECTIONS

CROW CREEK RESTORATION PROJECT

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PROJECT NO.:	RDG-06-017		

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SHEET XS-2

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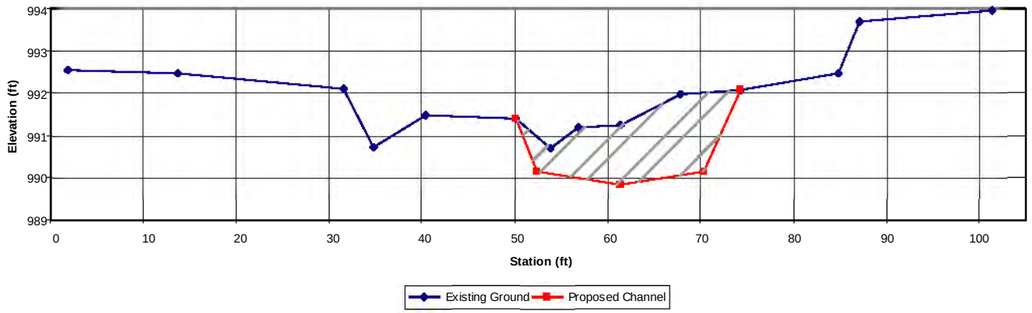
Sta 7+73 - Riffle



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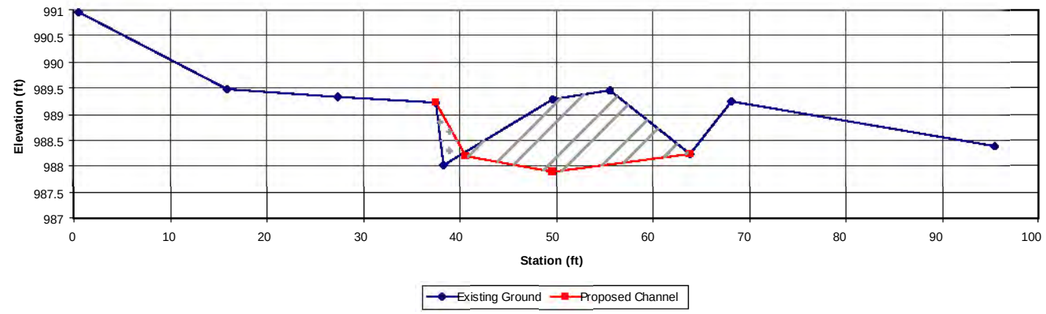

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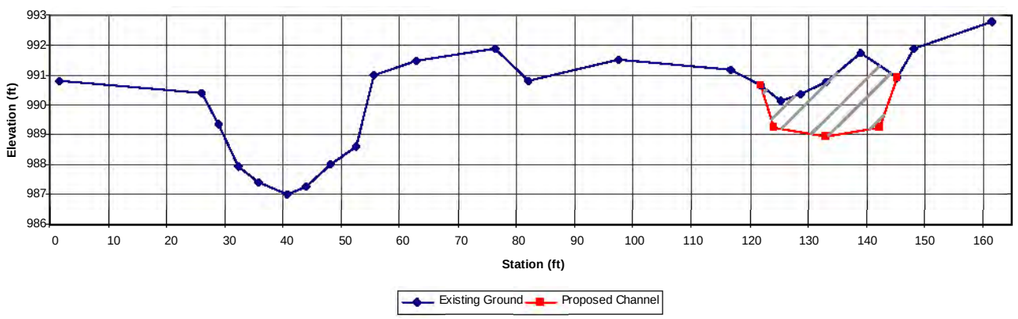

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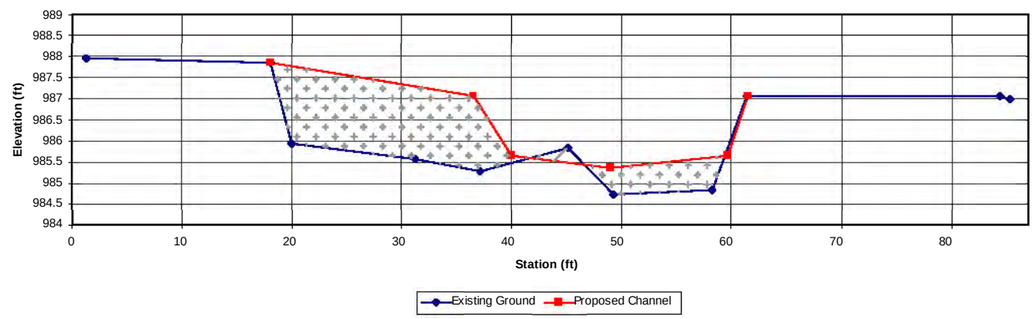

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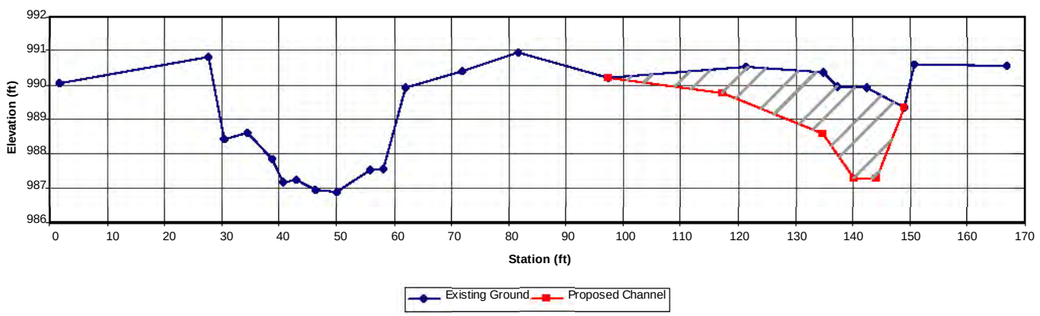

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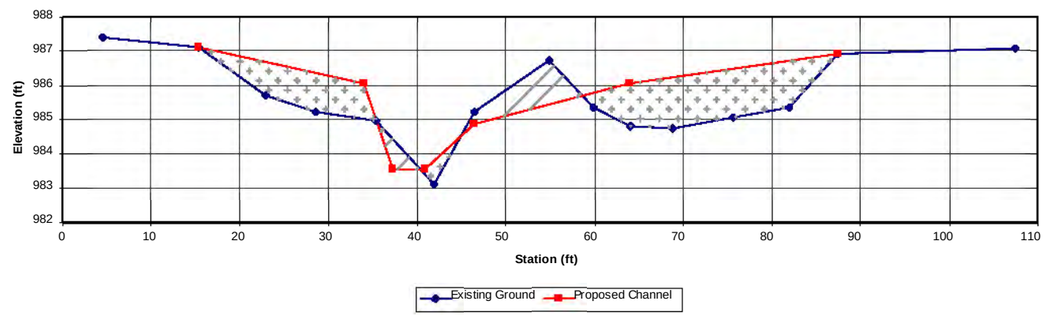

"CROSS SECTIONS ARE SHOWN LOOKING DOWNSTREAM"

Legend

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NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
1	3-06-07	MSD	DESIGN

CROSS SECTIONS

CROW CREEK RESTORATION PROJECT

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DESIGNED BY:	MSD/JM		
CHECKED BY:	MSD	FILE NAME: XS-1.dwg	
PROJECT NO.:	RDG-06-017		

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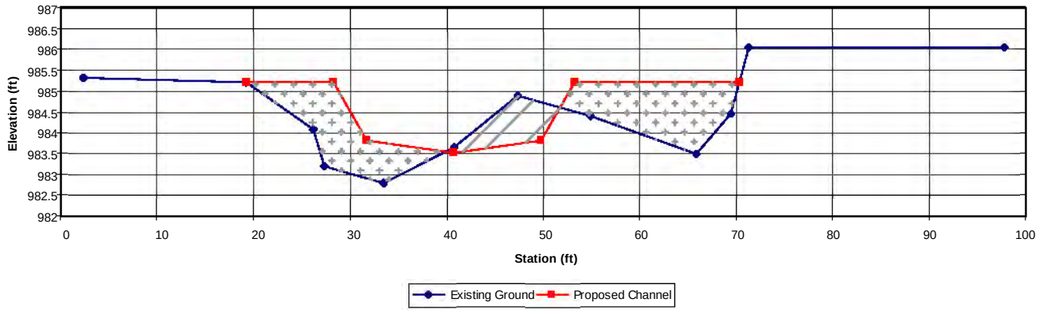
SHEET XS-3

Sta 10+65 - Riffle



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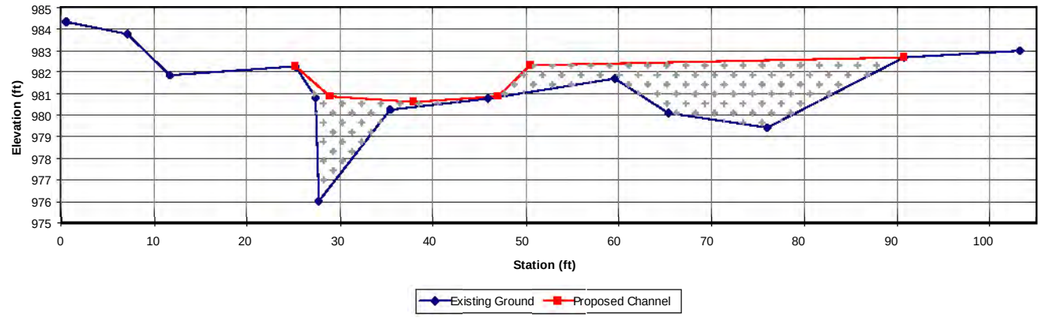

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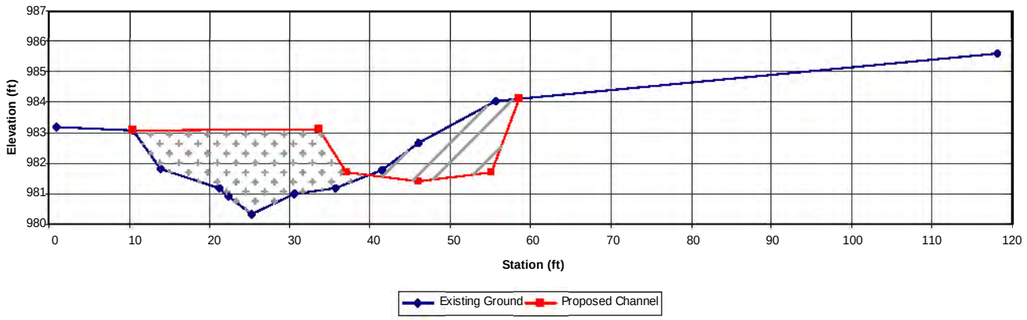
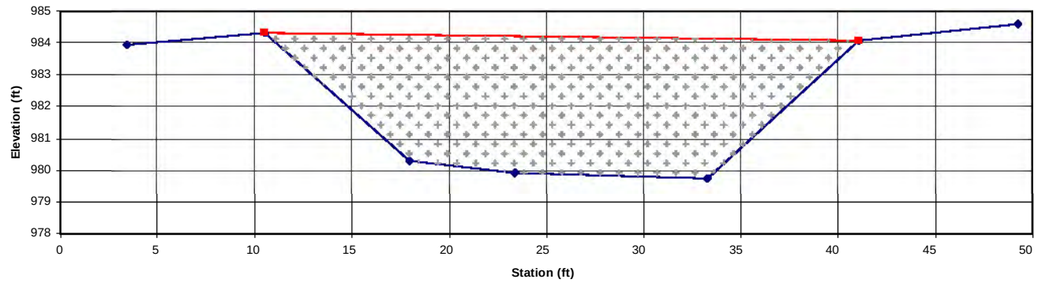


XS-23 - Fill



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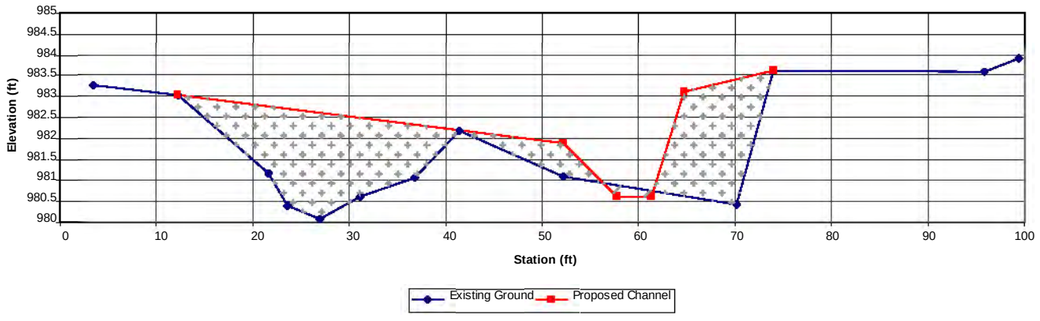

"CROSS SECTIONS ARE SHOWN LOOKING DOWNSTREAM"

Legend

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NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
1	3-06-07	MSD	DESIGN

CROSS SECTIONS

CROW CREEK RESTORATION PROJECT

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DESIGNED BY:	MSD/JM		
CHECKED BY:	MSD	FILE NAME: XS-1.dwg	
PROJECT NO.:	RDG-06-017		

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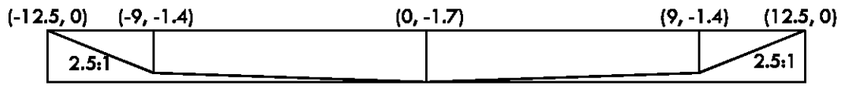
SHEET XS-4

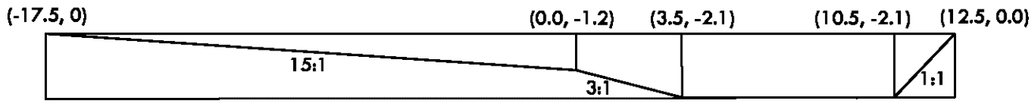
RIVER DESIGN GROUP, INC.

NOTE: COORDINATES ARE REFERENCED FROM THALWEG AND BANKFULL

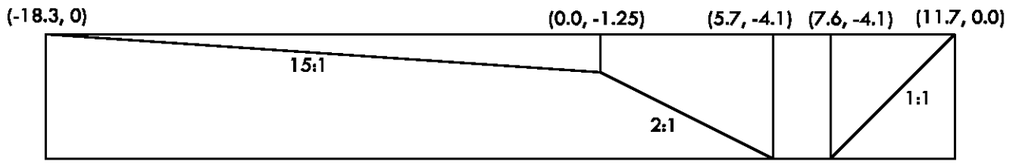
TYPICAL RIFFLE CROSS SECTION



TYPICAL RUN CROSS SECTION



TYPICAL POOL CROSS SECTION



BANKFULL CHANNEL DESIGN DIMENSIONS
B4 STREAM TYPE

PARAMETER / FEATURE	POOL	RIFFLE	RUN
DISCHARGE	170–180 cfs	170–180 cfs	170–180 cfs
WIDTH	27.5–32.6 ft	23–26.9 ft	20.2–23.9 ft
MEAN DEPTH	1.3–1.5 ft	1.2–1.4 ft	1.4–1.7 ft
MAX. DEPTH	2.3–4.1 ft	1.6–1.7 ft	1.8–2.1 ft
SCOUR DEPTH	5.0 ft	2.1 ft	2.4 ft
XS AREA	41 sq ft	33 sq ft	34.7 sq ft
WIDTH:DEPTH	N/A	16–22	N/A

5 2.5 0 2.5 5

SCALE: 1" = 5'

B4 STREAM TYPE DETAILS

CROW CREEK RESTORATION PROJECT

NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
1	3-06-07	MSD	DESIGN

DRAWN BY: NMW
DESIGNED BY: JMM
CHECKED BY: MSD
PROJECT NO.: RDG-06-017
FILE NAME: B4 Stream Type.dwg

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SHEET DT-1

RIVER DESIGN GROUP, INC.

CONSTRUCTION NOTES:

1. Place key piece(s) perpendicular to flow and anchor to existing stable strucutures. Spanning log tapered end may be anchored into the bank by excavating the streambank, placing the log, and backfilling with the excavated material. Stable array anchoring will be the preferred method of array anchoring.

2. Example stable structures include mature trees, boulders, established LWD, or placed LWD such as another key piece(s). Anchor key pieces by placing key pieces upstream of the established stable structure. Augment key piece(s) with additional stacked pieces. Place stacked pieces to interact with channel and anchor to key pieces and existing anchoring structures.

3. Place channel-spanning log arrays where the channel is more confined to ensure that channel-spanning log extends across the entire channel.

4. Channel-spanning logs may be placed at various elevations and angles relative to the channel bed. Array placement is up to the discretion of the Construction Manager.

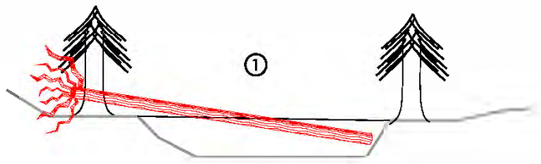
5. Limbs will be left intact on trees, although limbs are not depicted in the typical drawing for clarity.

STRUCTURE DIMENSIONS	
A, MAX. SCOUR DEPTH	4.2 ft
B, KEY PIECE MINIMUM ROOT FAN DIAMETER	OPTIONAL
C, KEY PIECE MINIMUM STEM DIAMETER	12-18 INCH
D, KEY PIECE MINIMUM STEM LENGTH	30 ft

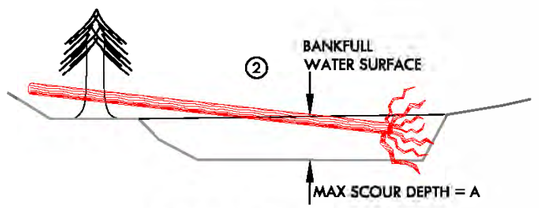
LEGEND

- STANDING MATURE TREE, BOULDER OR STABLE LWD ARRAY
- ANCHORING "KEY PIECE" LOG
- "STACKED PIECE" LOG

EXAMPLE CHANNEL-SPANNING LOG

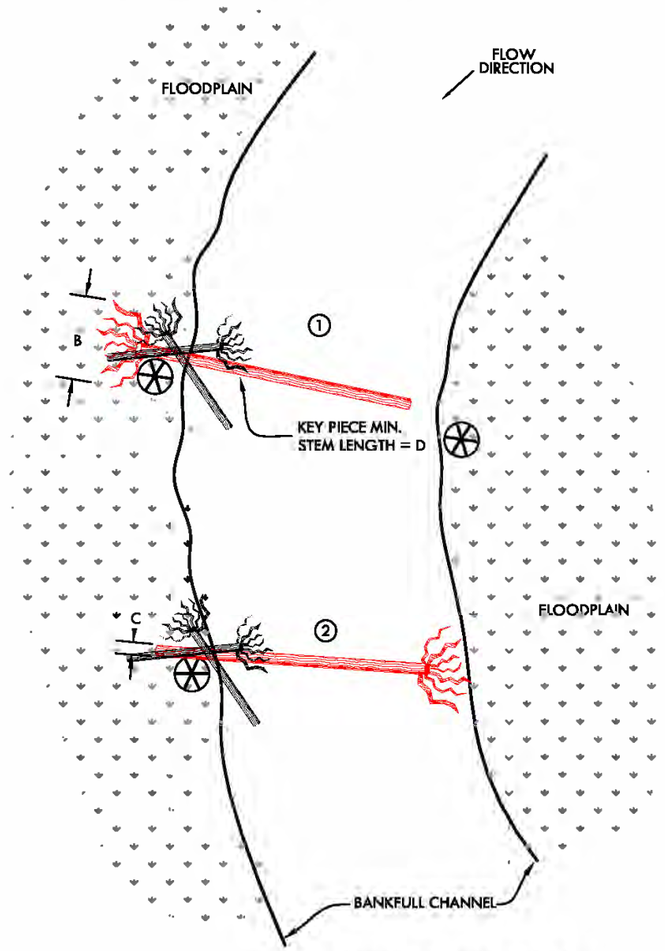


CHANNEL-SPANNING LOG
CROSS-SECTION



CHANNEL-SPANNING LOG
CROSS-SECTION

CHANNEL-SPANNING LOG ARRAY CONFIGURATIONS



CHANNEL-SPANNING LOG
PLAN VIEW

NO.	DATE	BY	REVISION DESCRIPTION
2	4-9-07	JM	FINAL
1	3-06-07	MSD	DESIGN

CHANNEL SPANNING LOG

CROW CREEK RESTORATION PROJECT

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DESIGNED BY:	MSD/JM		
CHECKED BY:	MSD	FILE NAME: Log Vane.dwg	
PROJECT NO.:	RDG-06-017		

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SHEET DT-2

RIVER DESIGN GROUP, INC.

CONSTRUCTION NOTES:

1. Construction shall begin at structure throat (upstream center) and proceed downstream toward banks. Use footer and sill rocks with minimum size as specified. Vane arm slope shall be between 4% and 7% as specified by the Construction Manager.

2. Excavate trench and stockpile excavated material for use as backfill. Place base of footer rocks at or below maximum scour depth. Minimize gaps between footer rocks. The Construction Manager shall inspect all footers prior to backfilling. Place geotextile fabric on upstream half of top side and upstream side of footer rocks. Backfill geotextile and sides of footer rocks with native gravel and cobble. Backfill shall be obtained from stockpiled material or excavated from downstream pool.

3. Place sill rocks on top of footer rocks. Sill rocks should be placed slightly upstream of footer rocks. Minimize gaps between sill rocks. The Construction Manager shall inspect the placement and elevation of sill rocks. The top of sill rocks shall not exceed the bankfull elevation.

4. Backfill voids around structure with native gravel and cobble to fill gaps and reduce piping of water. Backfill shall be obtained from stockpiled material or excavated from downstream pool.

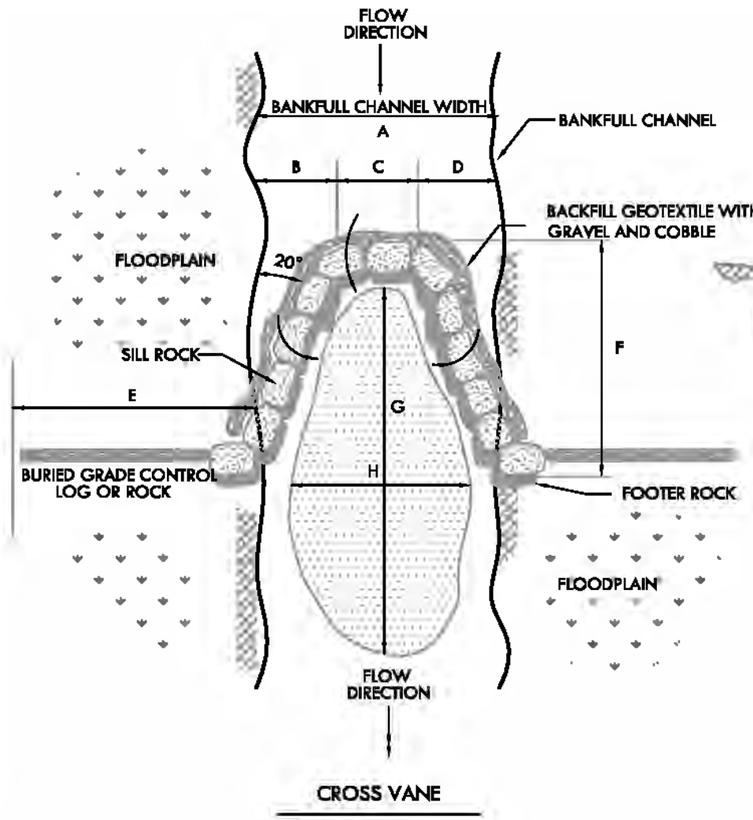
5. Floodplain grade control sills shall be constructed of log or rock and shall be keyed into the floodplain no less than 50% of the maximum riffle depth. Top of floodplain grade control sills shall be 0.5 feet below bankfull elevation and covered with 0.5 feet of sod/shrub transplants.

6. Excavate pool according to specified dimensions. Use excavated material to backfill structure or haul to a location approved by the Construction Manager.

7. Notify the Construction Manager of any proposed changes prior to implementation. The Construction Manager reserves the right to modify structure design specifications during construction, if warranted, due to unforeseen conditions.

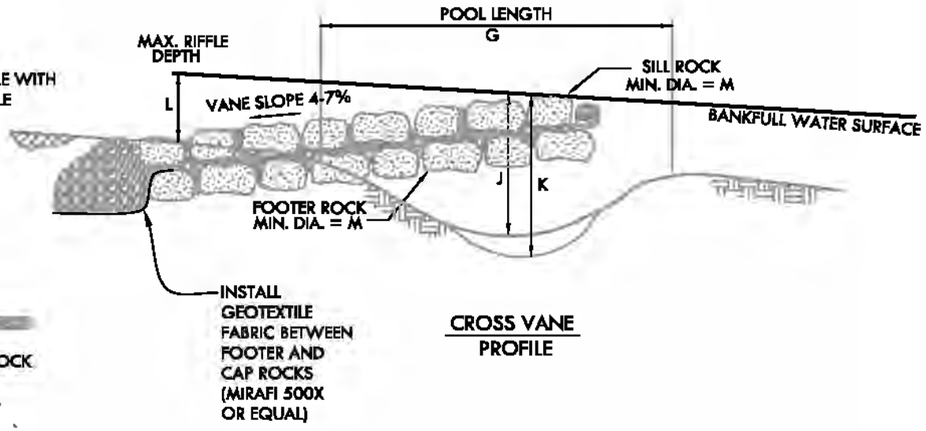
STRUCTURE DIMENSIONS	
A = BANKFULL WIDTH	25 ft
B = RIGHT ARM WIDTH	8.3 ft
C = THROAT WIDTH	8.3 ft
D = LEFT ARM WIDTH	8.3 ft
E = FLOODPLAIN GRADE CONTROL WIDTH	5 ft
F = LINEAR CROSS VANE LENGTH	24 ft
G = POOL LENGTH	27 ft
H = POOL WIDTH	17 ft
J = MAXIMUM POOL DEPTH	4.1 ft
K = MAXIMUM POOL SCOUR DEPTH	5.0 ft
L = MAXIMUM RIFFLE DEPTH	1.8 ft
M = MINIMUM ROCK DIAMETER	3.0 ft

EXAMPLE OF A CONSTRUCTED CROSS-VANE



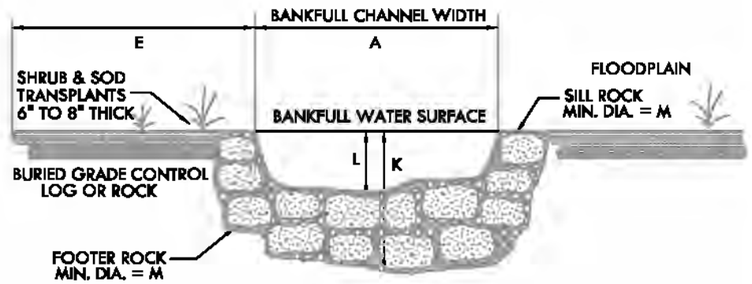
CROSS VANE

PLAN VIEW



CROSS VANE

PROFILE



CROSS VANE

CROSS SECTION

NO.	DATE	BY	REVISION DESCRIPTION
2	4-9-07	JM	FINAL
1	3-06-07	MSD	DESIGN

ROCK CROSS VANE

CROW CREEK RESTORATION PROJECT

DRAWN BY: NMW
DESIGNED BY: MSD/JM
CHECKED BY: MSD
PROJECT NO.: RDG-06-017
NOT TO SCALE
FILE NAME: rock cross vane.dwg

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SHEET DT-3

RIVER DESIGN GROUP, INC

CONSTRUCTION NOTES:

1. Use vane and backer logs with minimum dimensions as specified. Vane arm slope shall be between 4% and 7% as specified by the Construction Manager.

2. Excavate trench and stockpile excavated material for use as backfill. Place base of upstream end of log below maximum run scour depth. Anchor the upstream end of the vane log with footer rocks as specified. Place backing log behind/upstream of vane log.

3. Attach geotextile fabric and ledger to upstream side of vane log just below top of log so that fabric will not be exposed after backfilling. Nails shall be minimum 6-inch length sinker nails. Nail spacing shall be no more than 12 inches.

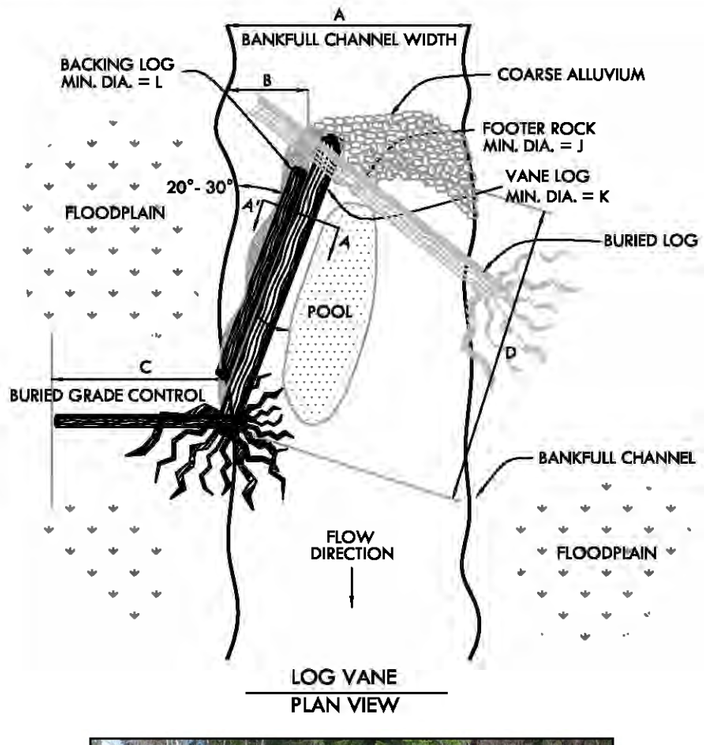
4. The Construction Manager shall inspect the orientation and elevation of the structure prior to backfilling. Backfill upstream side of vane log with native gravel and cobble. Backfill shall be obtained from stockpiled material or excavated from downstream pool.

5. A floodplain grade control sill shall be constructed of log or rock and shall be keyed into the floodplain no less than 50% of the maximum riffle depth. The vane log shall be placed on top of the sill log. Rootfans of the sill log and vane logs shall be placed at the edge of the bankfull channel. The top of floodplain grade control sill shall be 0.5 feet below bankfull elevation and covered with 0.5 feet of sod/shrub transplants.

6. Excavate pool according to typical pool dimensions. Use excavated material to backfill structure, or haul to a location approved by the Construction Manager.

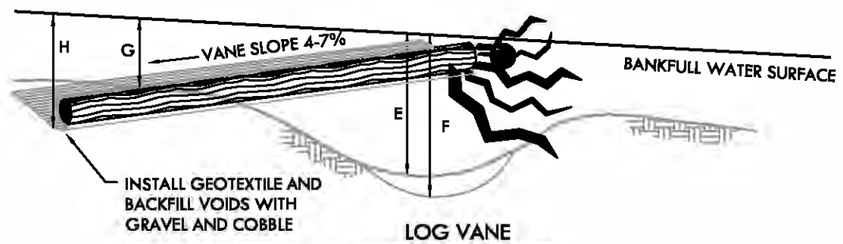
7. Notify the Construction Manager of any proposed changes prior to implementation. The Construction Manager reserves the right to modify structure design specifications during construction, if warranted, due to unforeseen conditions.

STRUCTURE DIMENSIONS	
A = BANKFULL WIDTH	25 ft
B = VANE ARM WIDTH	8.3 ft
C = FLOODPLAIN SILL WIDTH	5.0 ft
D = LINEAR VANE ARM LENGTH	24 ft
E = MAX. POOL DEPTH	4.1 ft
F = MAX. POOL SCOUR DEPTH	5.0 ft
G = THROAT DEPTH	1.8 ft
H = MAX. RUN SCOUR DEPTH	2.4 ft
J = MIN. ROCK DIAMETER	3.0 ft
K = MIN. VANE LOG DIA.	18-24 in
L = MIN. BACKING LOG DIA.	18-24 in

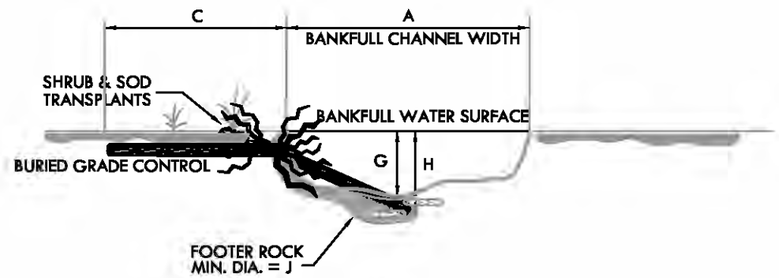


LOG VANE
PLAN VIEW

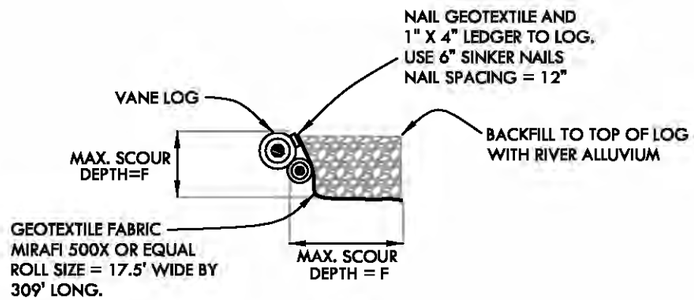
EXAMPLE OF A CONSTRUCTED LOG VANE



LOG VANE
PROFILE



LOG VANE
CROSS-SECTION



A-A' LOG VANE
GEOTEXTILE DETAIL

NO.	DATE	BY	REVISION DESCRIPTION
2	4-9-07	JM	FINAL
1	3-06-07	MSD	DESIGN

LOG VANE WITH COBBLE THROAT

CROW CREEK RESTORATION PROJECT

DRAWN BY: NMW
DESIGNED BY: MSD/JM
CHECKED BY: MSD
PROJECT NO.: RDG-06-017
NOT TO SCALE
FILE NAME: Log Vane.dwg

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SHEET DT-4

RIVER DESIGN GROUP, INC.

CONSTRUCTION NOTES:

1. Excavate trench to specified structure dimensions and stockpile excavated material for use as backfill. Use rounded material with D50 as specified.

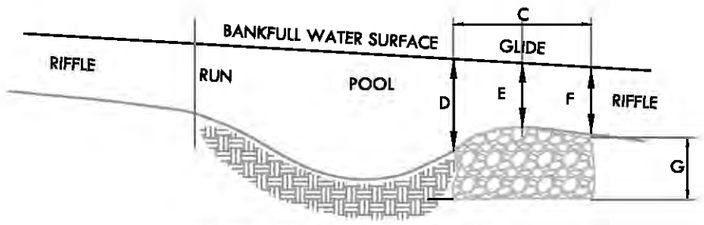
2. Shape the channel to the specified feature dimensions upstream and downstream of structure.

3. The Construction Manager shall inspect the orientation and elevation of the structure prior to backfilling.

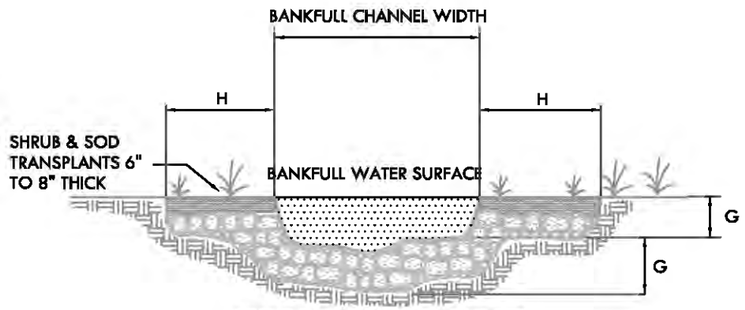
4. The top of floodplain grade control sill shall be 0.5 feet below bankfull elevation and covered with 0.5 feet of sod/shrub transplants.

5. Notify the Construction Manager of any proposed changes prior to implementation. The Construction Manager reserves the right to modify structure design specifications during construction, if warranted, due to unforeseen conditions.

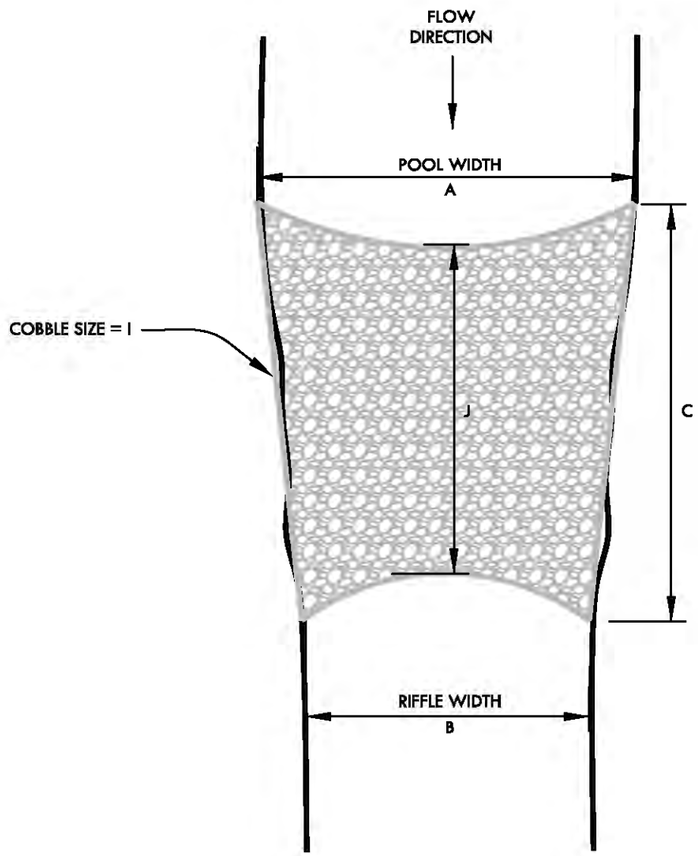
STRUCTURE DIMENSIONS	
A = POOL WIDTH	27.5-32.6 ft
B = RIFFLE WIDTH	23-26.9 ft
C = STRUCTURE LENGTH	20-30 ft
D - UPSTREAM DEPTH	2.3 - 4.0 ft
E = MAX. GLIDE DEPTH	1.2 ft
F = MAX. RIFFLE DEPTH	1.6-1.7 ft
G - STRUCTURE DEPTH	5.0 ft
H = BANK KEY-IN WIDTH	OPTIONAL
I = COBBLE D50	18 inches
J = THROAT WIDTH	23-26.9 ft



COBBLE GRADE CONTROL STRUCTURE
PROFILE



COBBLE GRADE CONTROL STRUCTURE
CROSS SECTION



COBBLE GRADE CONTROL STRUCTURE
PLAN VIEW

NO.	DATE	BY	REVISION DESCRIPTION
2	4-9-07	JM	FINAL
1	3-06-07	MSD	DESIGN

COBBLE GRADE CONTROL STRUCTURE

CROW CREEK RESTORATION PROJECT

DRAWN BY:	NMW	NOT TO SCALE	
DESIGNED BY:	MSD		
CHECKED BY:	MSD	FILE NAME: DT-5 Cobble.dwg	
PROJECT NO.:	RDG-06-017		

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SHEET DT-5

RIVER DESIGN GROUP, INC.

CONSTRUCTION NOTES:

1. Use vane and backing logs with minimum dimensions as specified. Vane arm slope shall be between 4% and 7% as specified by the Construction Manager.

2. Excavate trench and stockpile excavated material for use as backfill. Place base of upstream end of log below maximum run scour depth. Anchor the upstream end of the vane log with footer rocks as specified. Place backing log behind/upstream of vane log.

3. Attach geotextile fabric and ledger to upstream side of vane log just below top of log so that fabric will not be exposed after backfilling. Nails shall be minimum 6-inch length sinker nails. Nail spacing shall be no more than 12 inches. Also, install geotextile on upstream side of throat rocks.

4. Excavate trench at throat and place footer and sill rocks at specified elevations.

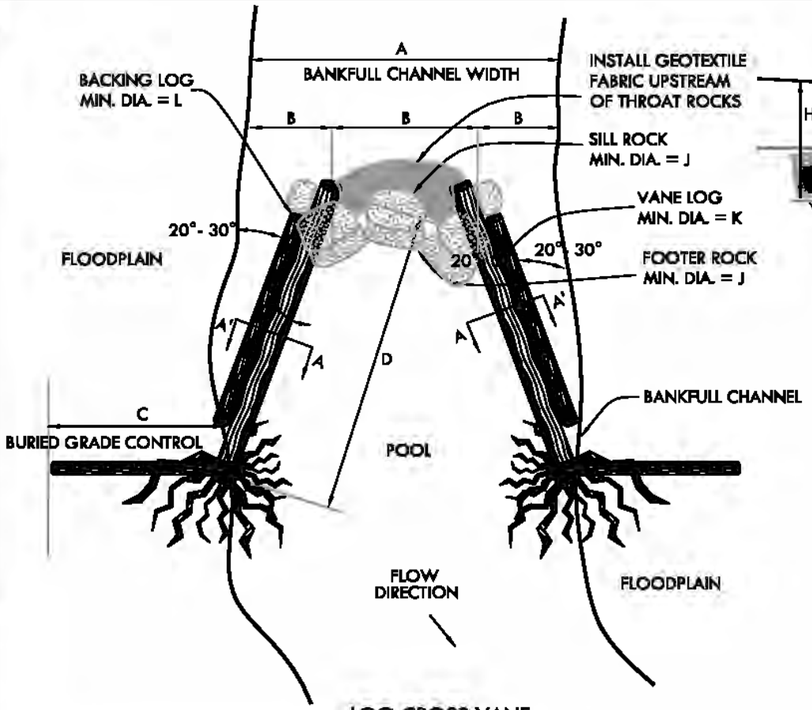
5. The Construction Manager shall inspect the orientation and elevation of the structure prior to backfilling. Backfill upstream side of vane log with native gravel and cobble. Backfill shall be obtained from stockpiled material or excavated from downstream pool.

6. A floodplain grade control sill shall be constructed of log or rock and shall be keyed into the floodplain no less than 50% of the maximum riffle depth. The vane log shall be placed on top of the sill log. Rootfans of the sill log and vane logs shall be placed at the edge of the bankfull channel. The top of floodplain grade control sill shall be 0.5 feet below bankfull elevation and covered with 0.5 feet of sod/shrub transplants.

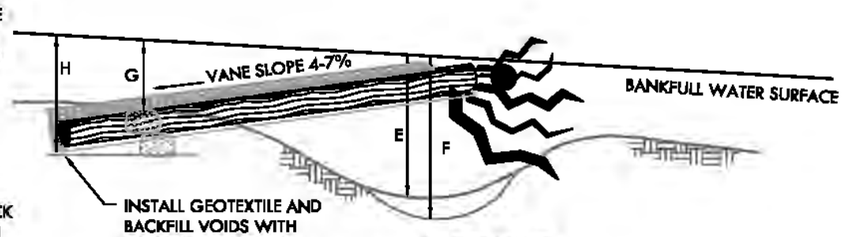
7. Excavate pool according to typical pool dimensions. Use excavated material to backfill structure, or haul to a location approved by the Construction Manager.

8. Notify the Construction Manager of any proposed changes prior to implementation. The Construction Manager reserves the right to modify structure design specifications during construction, if warranted, due to unforeseen conditions.

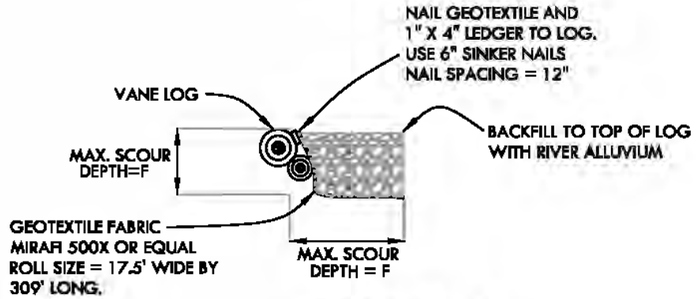
STRUCTURE DIMENSIONS	
A = BANKFULL WIDTH	25 ft
B = ARM/THROAT WIDTH	8.3 ft
C = FLOODPLAIN SILL WIDTH	5 ft
D = LINEAR VANE ARM LENGTH	24 ft
E = MAX. POOL DEPTH	4.1 ft
F = MAX. POOL SCOUR DEPTH	5.0 ft
G = THROAT DEPTH	1.8 ft
H = MAX. RUN SCOUR DEPTH	2.4 ft
J = MIN. ROCK DIA.	3 ft
K = MIN. VANE LOG DIA.	18-24 in
L = MIN. BACKING LOG DIA.	18 in



LOG CROSS VANE
PLAN VIEW

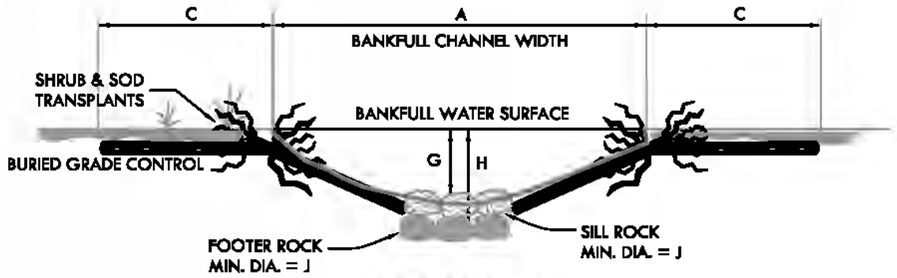


LOG CROSS VANE
PROFILE



A - A' LOG CROSS VANE
GEOTEXTILE DETAIL

EXAMPLE OF A CONSTRUCTED LOG CROSS VANE



LOG CROSS VANE
CROSS-SECTION

NO.	DATE	BY	REVISION DESCRIPTION
2	4-9-07	JM	FINAL
1	3-06-07	MSD	DESIGN

LOG CROSS VANE

CROW CREEK RESTORATION PROJECT

DRAWN BY:	NMW	NOT TO SCALE	
DESIGNED BY:	MSD		
CHECKED BY:	MSD	FILE NAME: Log Cross Vane.dwg	
PROJECT NO.:	RDG-06-017		

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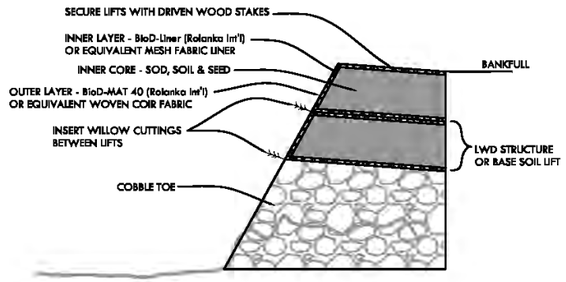
SHEET DT-6

RIVER DESIGN GROUP, INC

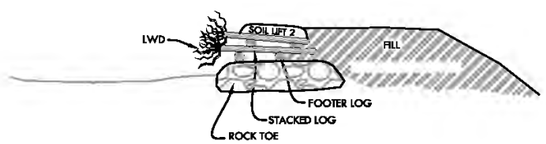
EXAMPLE OF A CONSTRUCTED SOIL LIFT

EXAMPLE OF A CONSTRUCTED SOIL LIFT AND LWD JAM

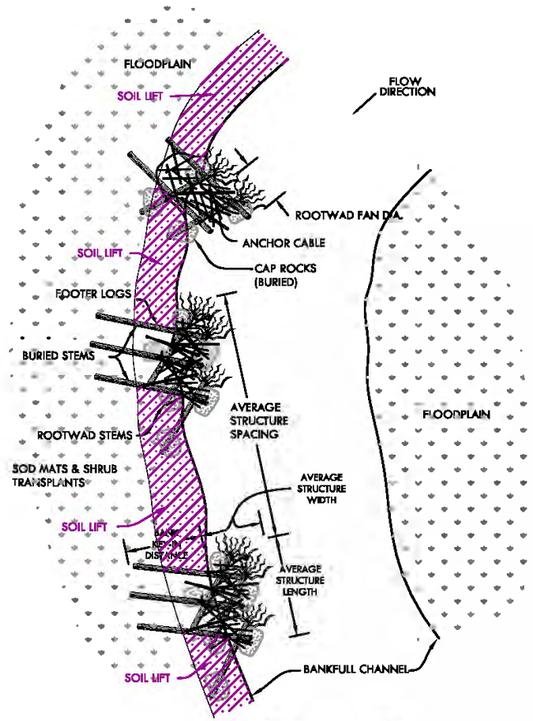
EXAMPLE OF A CONSTRUCTED ENGINEERED LOG JAM



ENGINEERED SOIL LIFT DETAIL
CROSS-SECTION
(TYPICAL)



LWD JAM W/ SOIL LIFT
CROSS-SECTION
(TYPICAL)



SERIES OF LWD JAMS
PLAN VIEW

CONSTRUCTION NOTES:

1. Excavate trench and set footer logs at maximum scour depth. Use footer logs with minimum diameter and stem length as specified.

2. Set rootwad logs on footer logs. Place logs stems sloping downward into bank from edge of water. Use rootwad logs with minimum fan diameter and stem length as specified.

3 Place additional logs and woody debris into trench to act as deflector logs and habitat cover. Number and size of habitat logs may vary from structures shown.

4. Ballast structure with cable and cap rocks of minimum diameter as specified. Set cap rocks below bankfull elevation on overlapping logs. The Construction Manager shall inspect and approve all structures prior to backfilling.

5. Backfill voids with native gravel and cobble to minimize gaps and piping of water. Cover with sod mats and shrub transplants at bankfull elevation.

6. Space structures as specified.

7. Notify Construction Manager of any proposed changes prior to implementation. The Construction Manager reserves the right to modify structure design specifications during construction if warranted due to unforeseen conditions.

STRUCTURE DIMENSIONS	
A, MAX. SCOUR DEPTH	5.0 ft
B, MIN. CAP ROCK DIA.	18 in
C, MIN. ROOT FAN DIA.	3 ft
D, MIN. FOOTER LOG DIA.	18 in
E, AVG. STRUCTURE SPACING	25 ft
F, AVG. STRUCTURE LENGTH	15 ft
G, AVG. STRUCTURE WIDTH	6 ft
H, ROOTWAD STEM LENGTH	15 ft
K, BANK KEY-IN DISTANCE	15 ft
J, FOOTER LOG STEM LENGTH	15 ft

NO.	DATE	BY	REVISION DESCRIPTION
2	4-9-07	JM	FINAL
1	3-06-07	MSD	DESIGN

BIOENGINEERED SOIL LIFT AND ENGINEERED DEBRIS JAM DETAIL

CROW CREEK RESTORATION PROJECT

DRAWN BY:	NMW	NOT TO SCALE	
DESIGNED BY:	MSD		
CHECKED BY:	MSD	FILE NAME: DT-7 Soil-Debris.dwg	
PROJECT NO.:	RDG-06-017		

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SHEET DT-7

RIVER DESIGN GROUP, INC.

CONSTRUCTION NOTES:

1. Plugs shall be constructed from a mixture of graded pitrun and native soils. The Construction Manager shall determine a suitable source for fill material.

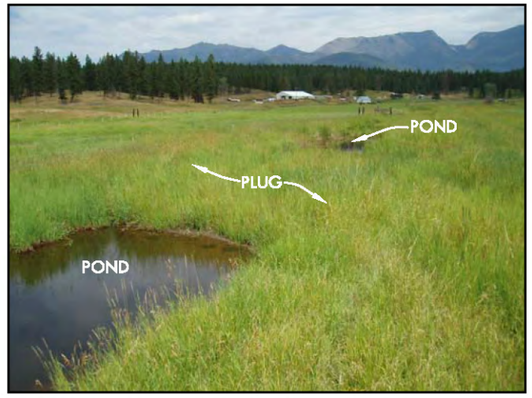
2. Fill material shall be compacted in one foot lifts. A sheeps foot roller shall be used to compact the fill material.

3. The ends of each plug shall have a slope of 3:1.

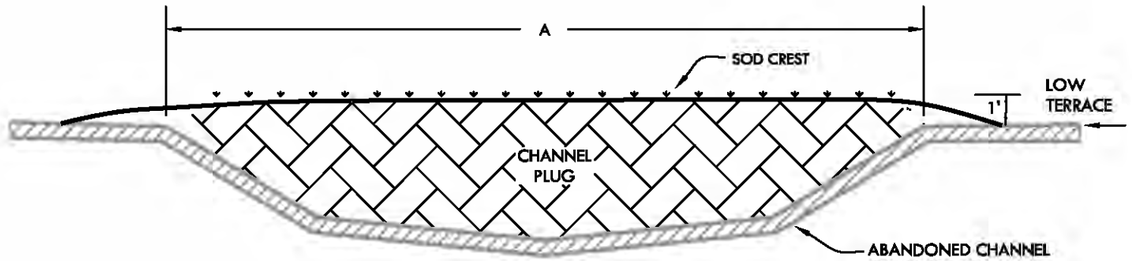
4. Crests of plug structures shall be one foot above adjacent ground/or floodplain elevation. Elevation differences of successive plug crests shall be no more than one foot.

5. The entire suface of the plug shall be sodded, seeded and/or planted with containerized shrubs.

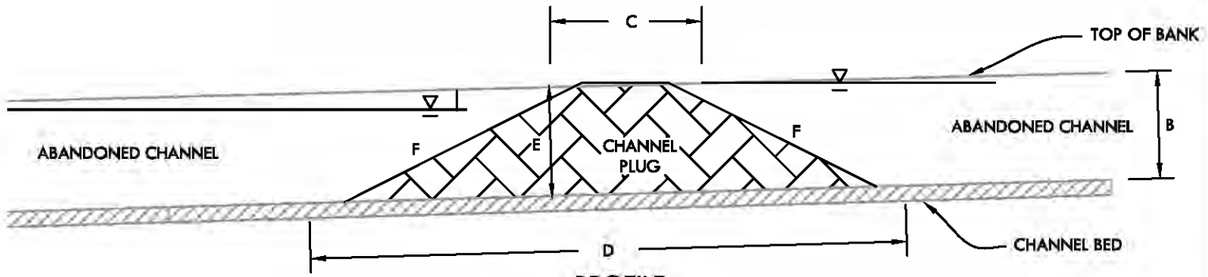
STRUCTURE DIMENSIONS	
A = CHANNEL WIDTH	VARIES 30' TO 45'
B = CHANNEL DEPTH	VARIES 3' TO 4'
C = CREST WIDTH	MIN. 12'
D = PLUG BOTTOM WIDTH	VARIES 36' TO 42'
E = PLUG HEIGHT	VARIES 4' TO 5'
F = PLUG SIDE SLOPES	3:1



EXAMPLE OF A CONSTRUCTED PLUG



CROSS SECTION
NOT TO SCALE



PROFILE
NOT TO SCALE

NO.	DATE	BY	REVISION DESCRIPTION
2	4-9-07	JM	FINAL
1	4-01-07	JM	DESIGN

TYPICAL CHANNEL PLUG DETAIL

CROW CREEK RESTORATION PROJECT

DRAWN BY: NMW
DESIGNED BY: JM
CHECKED BY: MSD/JM
PROJECT NO.: RDG-06-017
FILE NAME: Channel Plug.dwg

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SHEET DT-8

RIVER DESIGN GROUP, INC.

			ELJ Rootwads 12"-18" dia 15-ft.	ELJ Footers 18"-24" dia 15-ft.	Vane Logs 18"-24" dia 40-ft.	Backer Logs 18"-24" dia 40-ft.	Washed cobble Minimum 7-inch round alluvium	Rock rip rap d50=18"	Vegetated Soil Lift Material						Habitat pieces 12-inch dbh	Rock Boulders Min 3-ft. diam.
Site	Station-start	Channel Feature	Min. 3-ft. fan	No Rootwad	3' Rootwad	No.	CY	CY	Round Cobble 7-12 inch CY	NAG C125 LF	700 Coir Mat LF	Coir Log LF	Willow Cuttings No.	Wooden Stakes No.	30-ft. length	CY
	250	TOR	2	2				0								
	292.5	BOR	1		1	1	20	5								2
	302.5	MAX PL														
	312.5	TO RUN					20									
A	330	BO RUN	6	6				10								
	339	MAX PL														
	348	TO RUN														
	368	BO RUN	4	4				6								
	377	MAX PL														
	386	GLIDE					20									
	396.5	TOR														
	396.5 - 631						360									
	449.5	BOR	6	6				10							2	
	459.5	MAX PL														
	469.5	TO RUN					20									
B	494.5	BO RUN	6	6				10								
	503.5	MAX PL														
	512.5	GLIDE					20									
	523	TOR														
	541	BOR														30
C	551	MAX PL														
	561	TOR					20									
	579	BOR													2	
	589	MAX PL														
	599	TO RUN					20									
D	621	BO RUN	6	6				10								
	631	MAX PL														
	641	TO RUN														
	659	BO RUN	6	6				10								
	669	MAX PL														
	679	GLIDE					20									
	686	TOR					20									
	734	BOR			2	2									4	10
	744	MAX PL														
	754	TOR					20									
E	815	BOR					20	8								30
	825	MAX PL														
	835	TO RUN					20									
	855	BO RUN	6	6				10								
	865	MAX PL														
	880	GLIDE					20									
	894	TOR														
	924	BOR														30
F	936.5	MAX PL														
	949	TOR					20									
	979	BOR	4	4	1	1	20	8								2
	989	MAX PL														
	999	TO RUN					20									
G	1024	BO RUN	4	4				10								
	1036.5	MAX PL														
	1049	GLIDE					20									
	1063	TOR					20									
	1113	BOR	6	6				10								
	1125.5	MAX PL														
	1138	TO RUN					20									
H	1163	BO RUN	6	6				10								
	1173	MAX PL														
	1180	GLIDE					20									
	1190	TOR														
			63	62	4	4	760	117	221	669	669	669	3500	335	8	104

VSL Single	VSL Double
36	20
18	21
20	22
17	18
	10
	68
	30
	100
91	289

Earthwork	
XS 4 to XS 10 -	360 CY (FILL)
XS 11 to XS 17 -	353 CY (CUT)
Abandoned Channel Plugs -	700 CY (FILL)

NO.	DATE	BY	REVISION DESCRIPTION
2	4-7-07	JM	FINAL
1	3-06-07	MSD	DESIGN

MATERIALS LIST

CROW CREEK RESTORATION PROJECT

DRAWN BY: NMW
DESIGNED BY: MSD
CHECKED BY: MSD
PROJECT NO.: RDG-06-017
NOT TO SCALE
FILE NAME: Log Cross Vane.dwg

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SHEET MT-1

RIVER DESIGN GROUP, INC.