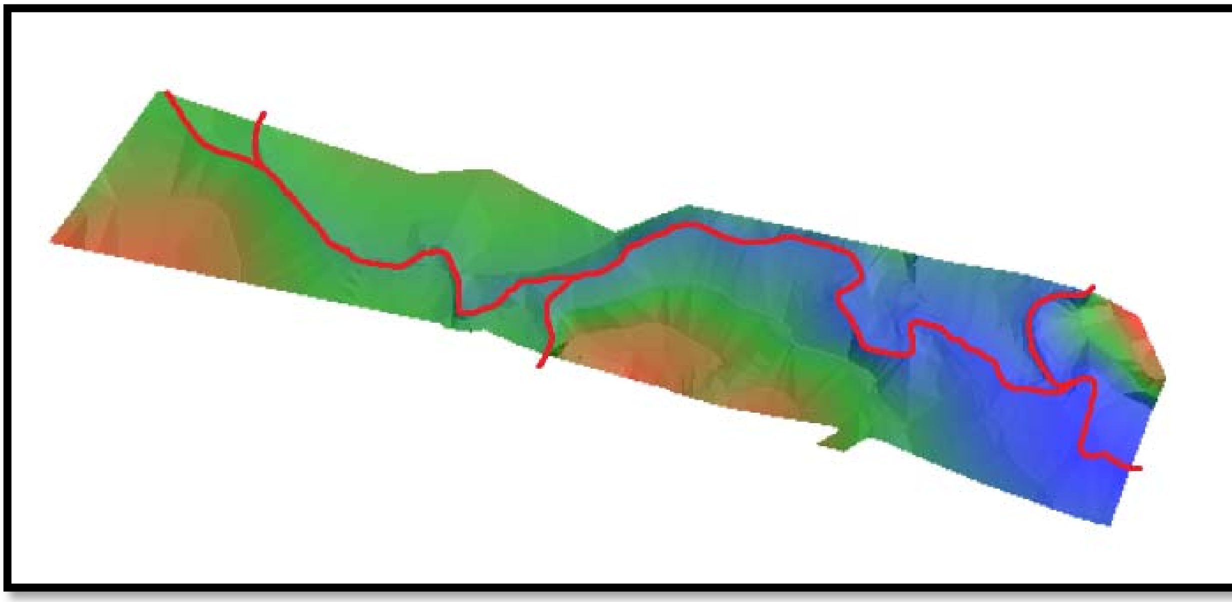
ATTACHMENT J-7

POSTMINE PAR 10A SFSC MAJOR CHANNEL DESIGN

Appendix J Volume 2 Attachment J-7

Post-mine PAR 10A
South Fork Spring Creek Major Channel Design

South Fork Spring Creek Channel Segment Design for PAR 10A
August 1, 2018



Introduction

The goal of stream reclamation is to approximate pre-mine channel morphology while meeting rule requirements in ARM 17.24.634(1)(e) that require reclaimed streams be able to safely pass the 100-year 6-hour runoff event. Appendix J of SMP C1979012 includes commitments for post-mine stream design and construction. Notably, major stream channel designs (includes South Fork Spring Creek) will be submitted to Montana DEQ for review and approval. This document details the PAR 10A South Fork Spring Creek channel design.

PAR 10A Setting

The designed stream segment that is the subject of this document is located in a reclaimed area known as PAR 10A and contains a segment of South Fork Spring Creek, as well as four minor tributaries. South Fork Spring Creek is an ephemeral stream, flowing only in response to precipitation and/or snow melt events. The PAR 10A reclaimed area is approximately 16 acres and the reclaimed segment (as designed) of South Fork Spring Creek is approximately 2,689 feet long. The contributing drainage basin area to PAR 10A is approximately 8,250 acres (12.9 square miles). PAR 10A is located just upstream of an undisturbed area that includes a broad flood plain and broad low-flow channel. Modeled runoff rates for each design storm event for the stream segment were taken from a SED-CAD study more fully documented in Appendix I of SMP C1979012.

Channel Design Terms and Definitions

Figure 1 depicts helpful terms and definitions used in this document.

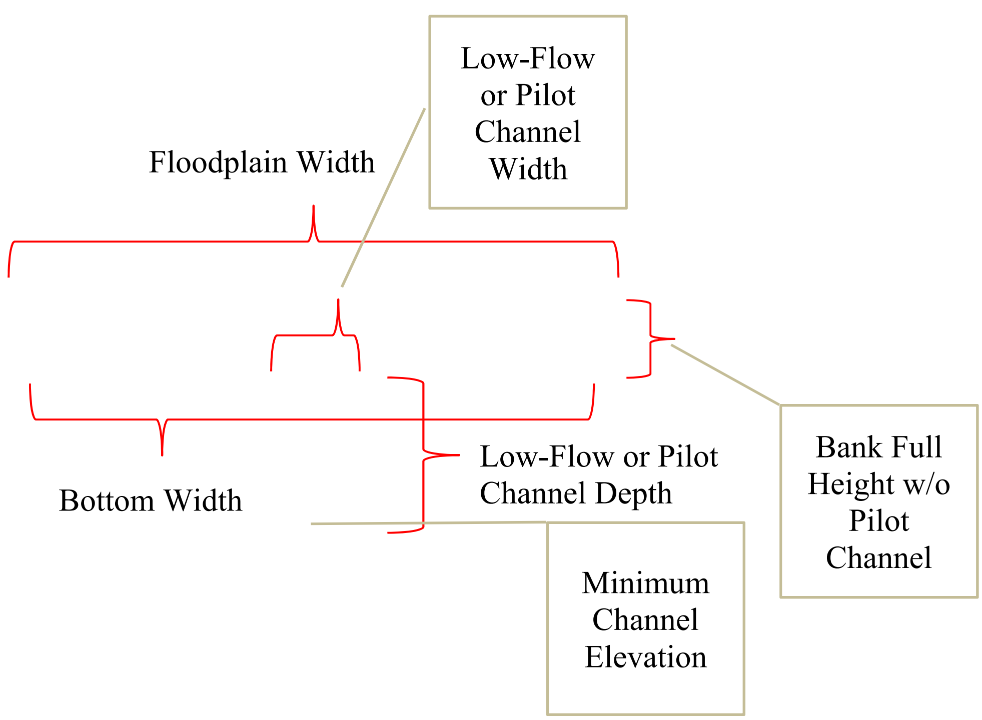


Figure 1. Stream Channel Cross-section Terms.

South Fork Spring Creek Characteristics (Pre-mine)
Detailed studies of the form and function of South Fork Spring Creek in the pre-mining condition have been completed and are fully documented in Appendix I of SMP C1979012. Studies completed include estimating storm flow runoff (done via SED-CAD software) for design storm events and estimating the subsequent elevations of each flow event (done via HEC-RAS software). Figure 2 depicts the pre-mine channel cross-sections in relation to where PAR 10A is located.

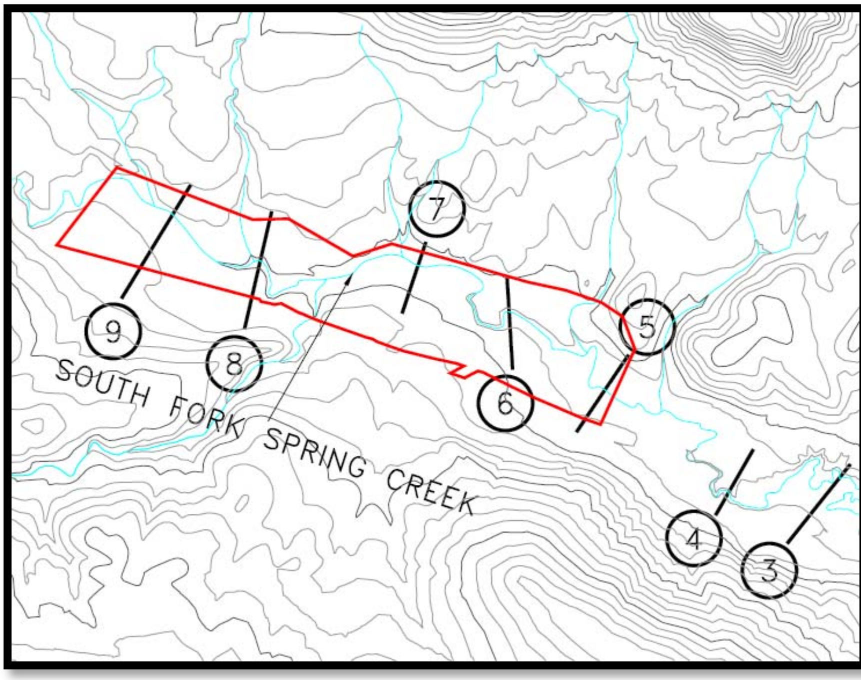


Figure 2. From Plate I-5, pre-mining HEC-RAS cross-section locations with PAR 10A boundary in red.

Table 1 below summarizes the modeled flow data of the seven most-relevant pre-mine stations from Appendix I Volume 2, Attachment I-5, page I-5-26 from the TR1 Major Revision (to SMP C1979012) currently being evaluated by the Department. Note that these data represent modeled flows on the pre-mining channel before any disturbance as described in Appendix I.

Table 1. HEC-RAS Station Flow Data 100-year 6-hour runoff event (pre-mining condition)

Station #	Flow Total (cfs)	Vel. (ft/s)	Flow Area (ft^2)	Top Flow Width (ft)	Froude # Chl	Water Surface Elev. (ft)	Minimum Channel Elev. (ft)
9	442.2	6.65	75.3	66.7	0.9	3594.0	3591.6
8	442.2	3.71	125.9	133.3	0.6	3592.0	3590.3
7	442.2	3.16	154.9	139.6	0.5	3589.0	3586.5
6	442.2	4.27	131.7	156.7	0.6	3585.3	3582.5
5	442.2	3.56	174.6	165.9	0.5	3582.3	3578.6
4	442.2	4.44	117.5	106.6	0.6	3578.8	3574.6
3	442.2	3.58	153.7	146.0	0.6	3576.3	3571.7
Average	**442.2**	**4.20**	**133.4**	**130.7**	Slope = 0.007 ft/ft		

Conceptual Spring Creek Characteristics (Post-mine)
Conceptual-level design work for the major post-mine channels is contained in Appendix J of SMP C1979012. The conceptual channel location contains a comparable longitudinal profile as the pre-mine channel. The conceptual channel consists of a flood plain (capable of passing the 100-year, 6-hour flow event) and an inner pilot channel. The inner pilot channel (also called low-flow channel) is generally capable of conveying the runoff from a 2-year, 24-hour runoff event. The conceptual-level channel design geometry is based on pre-mine channel characteristics to the extent practicable and these modeling results are helpful in identifying overall channel dimensions and general characteristics for use in the final channel design.

Studies completed include estimating storm flow runoff for design storm events and estimating the subsequent elevations of each flow event. Figure 3 depicts the conceptual post-mine channel cross-sections in relation to where PAR 10A is located. Actual cross-sections depicting flow elevations are contained in Appendix J, Volume 2, Attachment J-2 of TR1 Major Revision (to SMP C1979012).

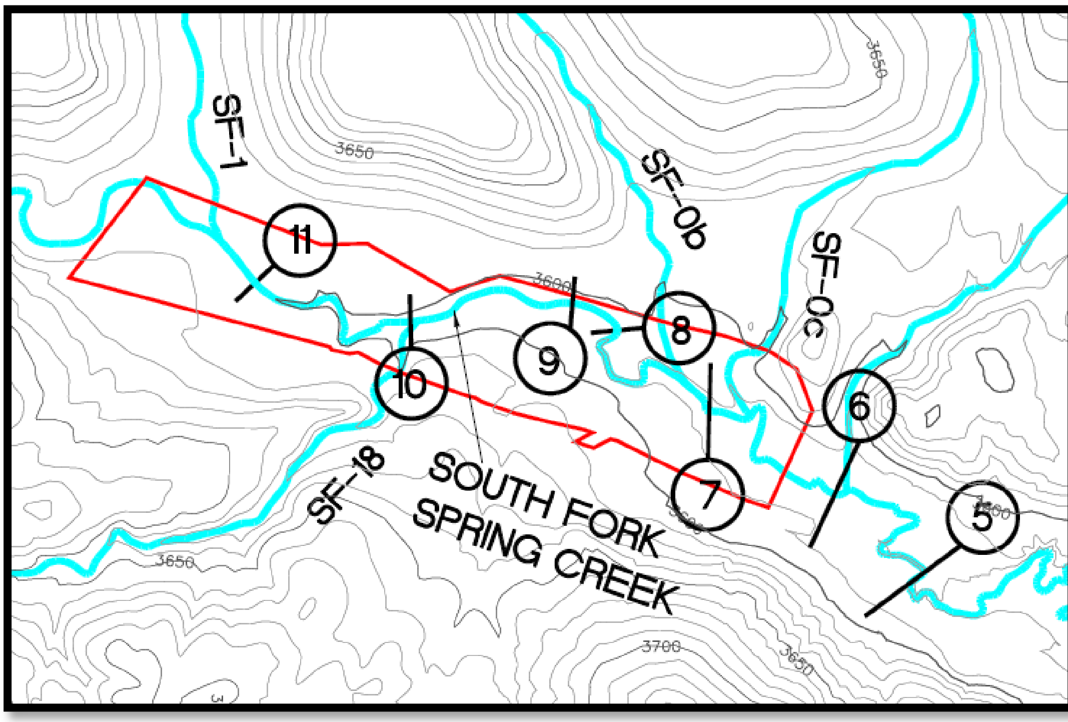


Figure 3. From Plate J-4, conceptual post-mining HEC-RAS cross-section locations with PAR 10A boundary in red.

Table 2 below summarizes the conceptual post-mine flow data of the seven most-relevant stations from Appendix J Volume 2, Attachment J-2, page J-2-30 from TR1. Note that these data represent modeled flows on a **conceptual** post-mining channel design described in Appendix J. Also note the stations do not correlate exactly with the pre-mining condition stations.

Table 2. HEC-RAS Station Flow Data 100-year 6-hour runoff event (conceptual channel design, post-mining)

Station #	Flow Total (cfs)	Vel. (ft/s)	Flow Area (ft^2)	Top Flow Width (ft)	Froude # Chl	Water Surface Elev. (ft)	Minimum Channel Elev. (ft)
11	442.2	6.39	113.4	125.8	0.8	3602.7	3600.4
10	442.2	4.32	119.6	80.5	0.5	3598.5	3595.7
9	442.2	6.65	75.3	66.7	0.9	3594.0	3591.6
8	442.2	3.71	125.9	133.3	0.6	3592.0	3590.3
7	442.2	3.16	155.0	139.6	0.5	3589.0	3586.5
6	442.2	4.27	131.6	156.7	0.6	3585.3	3582.5
5	442.2	3.56	174.6	165.9	0.5	3582.3	3578.6
Average	**442.2**	**4.58**	**127.9**	**124.1**	Slope = 0.007 ft/ft		

PAR 10A South Fork Spring Creek Channel Design

Figure 4 depicts the design finish grade topography for the reclaimed lands inside PAR 10A, including the segment of South Fork Spring Creek that is the subject of this document. In general, the topography resembles the approved post-mine topography contained in Plate 4 of SMP C1979012.

A low-flow channel was designed to model pre-mine channel invert geometry and will be able to handle a 2-year, 24-hour runoff event. The primary flood plain will be capable of handling the flow from a 100-year, 6-hour runoff event. Modeled runoff rates from the pending TR1 major revision were used, which contain higher rates than the current permit (for conservativeness). Using the higher flows, the design shows its ability to handle both runoff events. To demonstrate this, five cross-sections were developed for the channel segment inside PAR 10A. Surface topography and runoff data were then modeled using the HEC-RAS hydrology model. Note that one additional cross-section (cross-section 59+85.6) is actually located completely on undisturbed land downstream of PAR 10A as depicted in Figure 4.

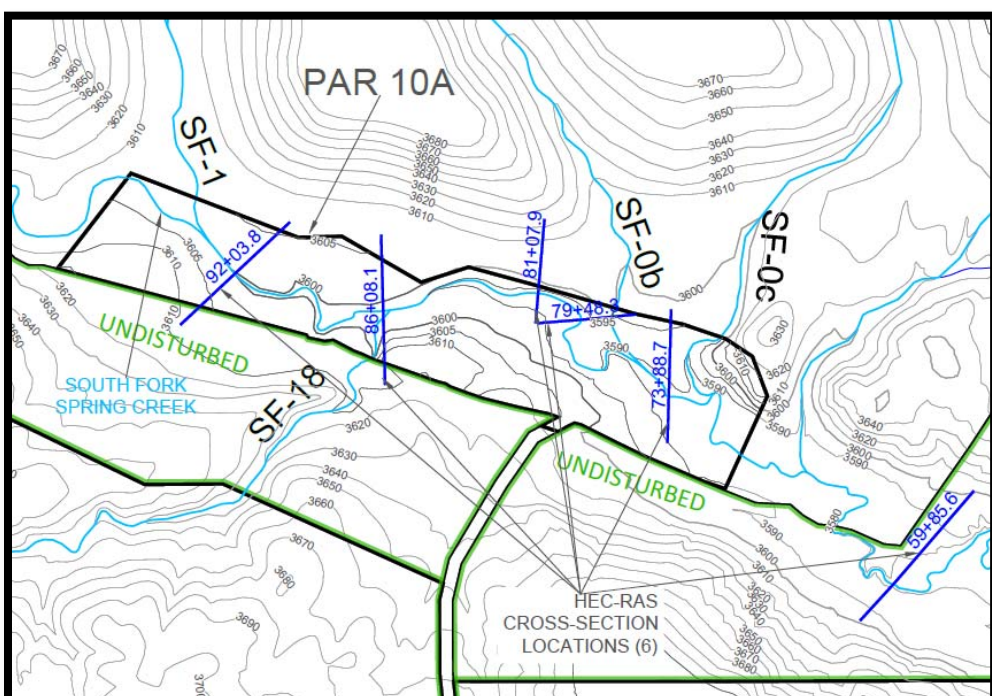


Figure 4. PAR 10A design topography with HEC-RAS cross-section locations in blue. Contour interval is five foot inside PAR 10A boundary and ten foot outside the PAR 10A boundary.

Table 3 below summarizes the modeled flow data of the six cross-sections using the runoff rates expected from the 100-year, 6-hour event from the post-mine TR1 data. Figures 5 and 6 depict the HEC-RAS cross-sections and the flow elevations expected for the 2-year, 24-hour and 100-year, 6-hour runoff events. It should be noted that cross-section 59+85.6 is native and the Froude number is not a result of PAR 10A design.

Table 3. HEC-RAS Station Flow Data 100-year 6-hour runoff event (PAR 10A channel design, post-mining)

Cross-section ID	Flow Total (cfs)	Vel. (ft/s)	Flow Area (ft^2)	Top Flow Width (ft)	Froude # Chl	Water Surface Elev. (ft)	Minimum Channel Elev. (ft)
92+03.8	442.2	4.02	110.1	107.3	0.7	3602.0	3599.9
96+08.1	442.2	4.46	99.2	65.5	0.6	3598.5	3596.0
81+07.9	442.2	4.35	101.6	77.6	0.7	3595.4	3592.7
79+48.3	442.2	5.78	77.1	79.9	1.0	3593.5	3591.7
73+88.7	442.2	3.37	138.1	166.0	0.6	3589.9	3588.0
59+85.6	442.2	4.91	92.2	140.3	1.1	3581.1	3578.1
Average	**442.2**	**4.48**	**103.1**	**106.1**	Slope = 0.007 ft/ft		

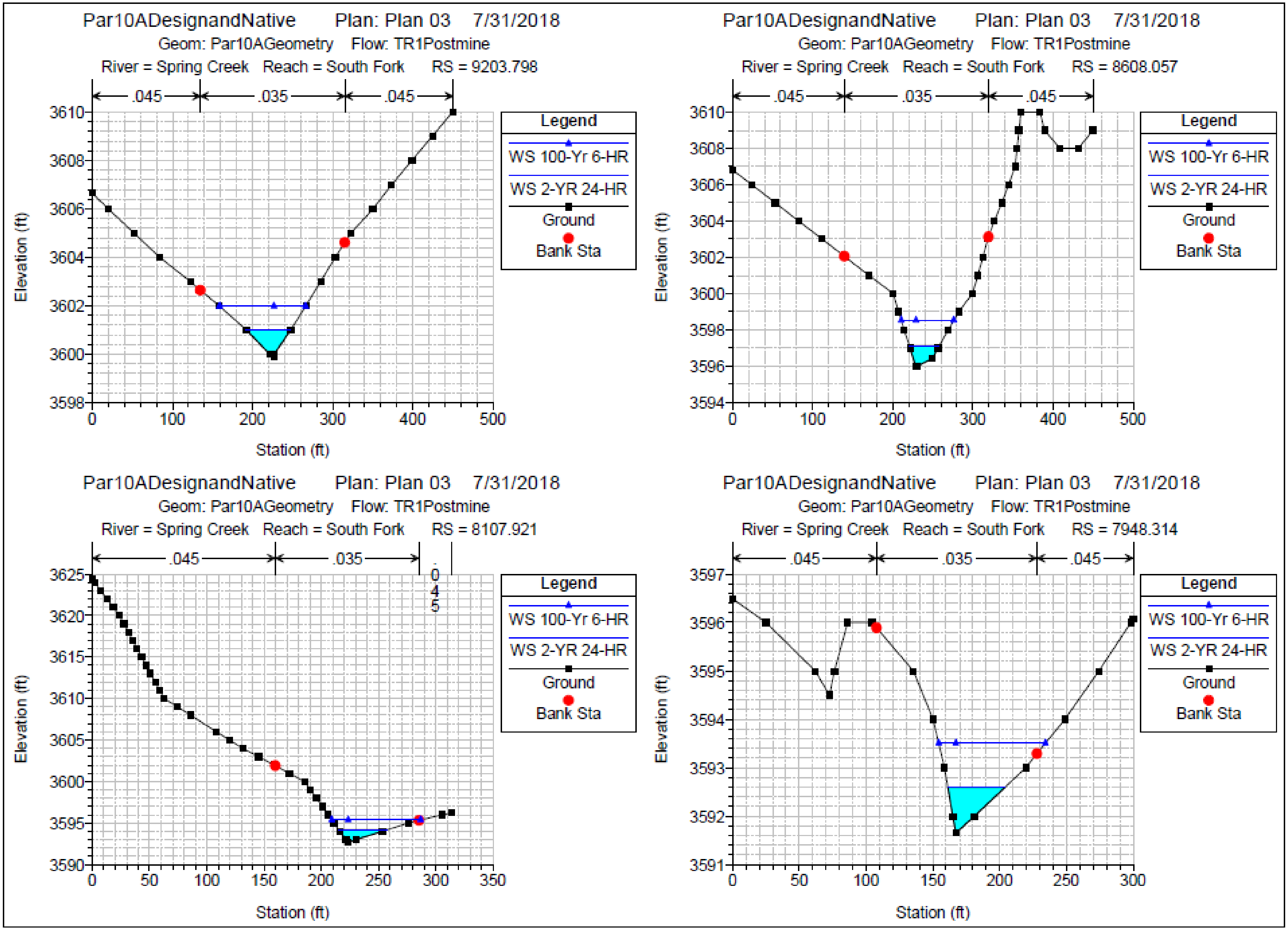


Figure 5. PAR 10A South Fork Spring Creek channel design segment HEC-RAS cross-sections

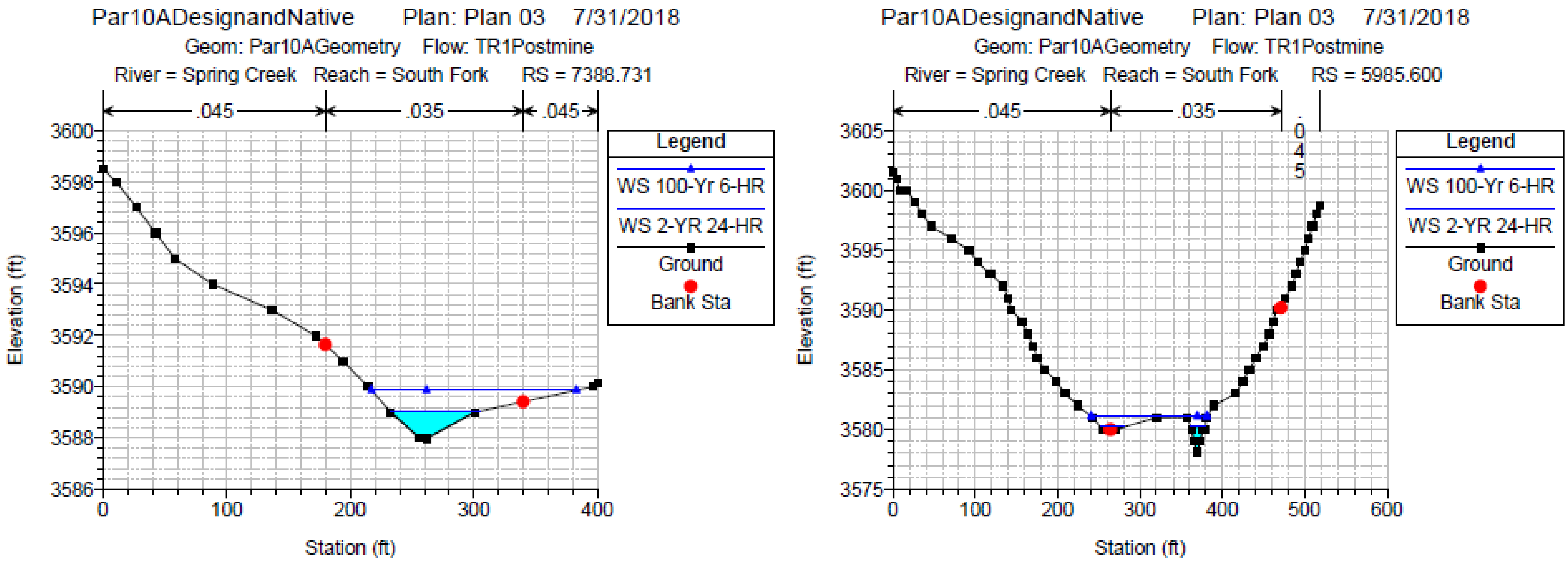


Figure 6. PAR 10A South Fork Spring Creek channel design segment HEC-RAS cross-sections

Channel Stability

The HEC-RAS software was used to ensure the final channel design would safely pass the 100-year, 6-hour and the 2-year, 24-hour storm event. Tables 4 and 5 compare pre-mine to post-mine flow conditions. Table 4 compares HEC-RAS model flow data for the most relevant pre-mine cross-sections with the five cross-sections inside the designed PAR 10A stream segment for the 100-year, 6-hour storm event. Table 5 compares HEC-RAS model flow data for the pre-mine cross-sections to the five cross-sections within the PAR 10A boundary for the 2-year 24 hour storm event.

Note the runoff rate for the pre-mine condition is from Appendix I, Volume 2, Attachment I-5, page I-5-26 from TR1, and the runoff rate for the post-mine condition is from Appendix J, Volume 2, Attachment J-2, page J-2-30 from TR1.

The design channel's flood plain longitudinal slope is the same slope as the pre-mine condition and ensures channel concavity in the longitudinal direction. With respect to channel length, a direct comparison of pre-mine (2,697 feet) to design post-mine (2,689 feet) for the low-flow channel was performed, showing the two lengths to be close in magnitude.

Table 4 shows the post-mine channel will be stable with a Froude number at or below 1.0 (indicating subcritical or slow/tranquil flow) using the modeled runoff flows from Appendix J in TR1.

Table 4. Comparison of HEC-RAS analysis for pre-mine and post-mine cross-sections in PAR 10A for a 100-year 6-hour storm event

Cross-Section		Q Total (cfs)	Min Ch. El (ft)	W.S. Elev. (ft)	Critical W.S. (ft)	E.G. Elev. (ft)	E.G. Slope (ft/ft)	Vel. Chnl (ft/s)	Flow Area (sq. ft)	Top Width (ft)	Froude # Chl
Pre-mine	9	442.2	3591.6	3594	3594.0	3594.6	0.0170	6.65	75.3	66.7	0.9
Pre-mine	8	442.2	3590.3	3592	3591.6	3592.2	0.0071	3.71	125.9	133.3	0.6
Pre-mine	7	442.2	3586.5	3589		3589.1	0.0050	3.16	154.9	139.6	0.5
Pre-mine	6	442.2	3582.5	3585.3	3585.1	3585.5	0.0087	4.27	131.7	156.7	0.6
Pre-mine	5	442.2	3578.6	3582.3	3581.9	3582.5	0.0040	3.56	174.6	165.9	0.5
Design	92+03.8	442.2	3599.9	3602.0		3602.2	0.0087	4.02	110.1	107.3	0.7
Design	96+08.1	442.2	3596.0	3598.5		3598.8	0.0064	4.46	99.2	65.5	0.6
Design	81+07.9	442.2	3592.7	3595.4	3595	3595.7	0.0072	4.35	101.6	77.6	0.7
Design	79+48.3	442.2	3591.7	3593.5	3593.5	3594.0	0.0177	5.78	77.1	79.9	1.0
Design	73+88.7	442.2	3588.0	3589.9	3589.5	3590.0	0.0060	3.37	138.1	166.0	0.6

Table 5 shows the post-mine channel invert (low-flow channel) within PAR 10A will be stable with a Froude number at or below 1.0 using the modeled runoff rates from Appendix J in TR1.

Table 5. Comparison of HEC-RAS analysis for pre-mine and post-mine cross-sections in PAR 10A for a 2-year, 24-hour storm event

Cross-section		Q Total	Min Ch. El	W.S. Elev.	Critical W.S.	E.G. Elev.	E.G. Slope	Vel. Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq. ft)	(ft)	
Pre-mine	9	81.4	3591.6	3592.9	3592.8	3593.1	0.0173	3.57	22.8	36.3	0.8
Pre-mine	8	81.4	3590.3	3591.1	3590.9	3591.2	0.0090	2.06	39.7	91.6	0.5
Pre-mine	7	81.4	3586.5	3587.7		3587.8	0.0044	2.13	41.2	60.7	0.4
Pre-mine	6	81.4	3582.5	3584.4		3584.5	0.0070	2.21	38.1	68.2	0.5
Pre-mine	5	81.4	3578.6	3581.0		3581.1	0.0047	2.64	30.8	28.5	0.5
Design	92+03.8	81.4	3599.9	3601.0	3600.8	3601.1	0.0087	2.67	30.5	55.1	0.6
Design	96+08.1	81.4	3596.0	3597.1		3597.3	0.0080	3.03	26.9	37.6	0.6
Design	81+07.9	81.4	3592.7	3594.2		3594.3	0.0051	2.52	32.4	42.7	0.5
Design	79+48.3	81.4	3591.7	3592.6	3592.6	3592.8	0.0234	3.97	20.5	43.0	1
Design	73+88.7	81.4	3588.0	3589.1	3588.8	3589.1	0.0050	2.02	40.3	72.9	0.5

As another comparison, Table 6 shows the designed cross-sections located within PAR 10A that correlate with conceptual post-mine cross-sections. The conceptual post-mine runoff rates and the design post-mine runoff rates are from Appendix J. The conceptual post-mine cross-section locations are shown in Figure 3, and the design post-mine cross-section locations are shown in Figure 4.

Top widths between the conceptual design and design vary for cross-sections such as 8 and 11 as seen in Table 6. In order to maintain a concave longitudinal profile for the minor tributary SF-0b, the surrounding topography around conceptual cross-section 8 was modified to accommodate the minor tributary joining South Fork Spring Creek. As for conceptual cross-section 11, this cross-section was conceptually designed with a basic trapezoidal channel shape, appearing manmade. The design cross-section 92+03.8 features a more natural channel design consistent with the pre-mine as surveyed topography, displaying a more sloping channel invert and floodplain. In general, the differences of cross-section top widths and flow areas between the conceptual design and design seen in Table 6 are due to the design attempting to closely match the as-surveyed pre-mine cross-sections of South Fork Spring Creek within PAR 10A.

Table 6. Comparison of HEC-RAS analysis for conceptual post-mine and designed post-mine cross-sections in PAR 10A

Cross-section		Q Total	Min Ch. El	W.S. Elev.	Critical W.S.	E.G. Elev.	E.G. Slope	Vel. Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq. ft)	(ft)	
2-Year, 24-Hour											
Conceptual	11	81.4	3600.4	3601.9	3601.7	3602.2	0.017	4.70	17.3	17.7	0.8
Design	92+03.8	81.4	3599.9	3601.0	3600.8	3601.1	0.009	2.67	30.5	55.1	0.6
Conceptual	10	81.4	3595.7	3597.2		3597.3	0.005	2.28	36	47.2	0.4
Design	96+08.1	81.4	3596.0	3597.1		3597.3	0.008	3.03	26.9	37.6	0.6
Conceptual	9	81.4	3591.6	3592.9	3592.8	3593.1	0.017	3.57	22.8	36.3	0.8
Design	81+07.9	81.4	3592.7	3594.2		3594.3	0.005	2.52	32.4	42.7	0.5
Conceptual	8	81.4	3590.3	3591.1	3590.9	3591.2	0.009	2.06	39.7	91.6	0.5
Design	79+48.3	81.4	3591.7	3592.6	3592.6	3592.8	0.023	3.97	20.5	43.0	1.0
Conceptual	7	81.4	3586.5	3587.7		3587.8	0.004	2.13	41.2	60.7	0.4
Design	73+88.7	81.4	3588.0	3589.1	3588.8	3589.1	0.005	2.02	40.3	72.9	0.5
100-Year, 6-Hour											
Conceptual	11	442.2	3600.4	3602.7	3602.7	3603.1	0.014	6.39	113.4	125.8	0.8
Design	92+03.8	442.2	3599.9	3602.0		3602.2	0.009	4.02	110.1	107.3	0.7
Conceptual	10	442.2	3595.7	3598.5		3598.8	0.005	4.32	119.6	80.5	0.5
Design	20+53.1	442.2	3596.0	3598.5		3598.8	0.006	4.46	99.2	65.5	0.6
Conceptual	9	442.2	3591.6	3594.0	3594.0	3594.6	0.017	6.65	75.3	66.7	0.9
Design	81+07.9	442.2	3592.7	3595.4	3595.0	3595.7	0.007	4.35	101.6	77.6	0.7
Conceptual	8	442.2	3590.3	3592.0		3592.2	0.007	3.71	125.9	133.3	0.6
Design	79+48.3	442.2	3591.7	3593.5	3593.5	3594.0	0.018	5.78	77.1	79.9	1.0
Conceptual	7	442.2	3586.5	3589.0		3589.1	0.005	3.16	155.0	139.6	0.5
Design	73+88.7	442.2	3588.0	3589.9	3589.5	3590.0	0.006	3.37	138.1	166.0	0.6

Channel Function

The cover page figure shows a three dimensional rendering of the PAR 10A area with the stream centerline traced in red and four minor tributaries feeding into South Fork Spring Creek.

Channel Construction and Topsoil Plan

The South Fork Spring Creek channel will be constructed to the lines and grades depicted on Figure 4. Following overburden grading (and after receiving topsoil laydown approval), the channel and reclamation area will be topsoiled in accordance with Section 313 of SMP C1979012 (specifically Table 313-2a). The South Fork Spring Creek channel has an approved typical cross section shown on Plate J-6 in Appendix J Volume 1 and depicted in Figure 7. Alluvial topsoil will be placed in the floodplain areas to a depth of 2.0 feet and general topsoil in all other places at a depth of 1.5 feet.

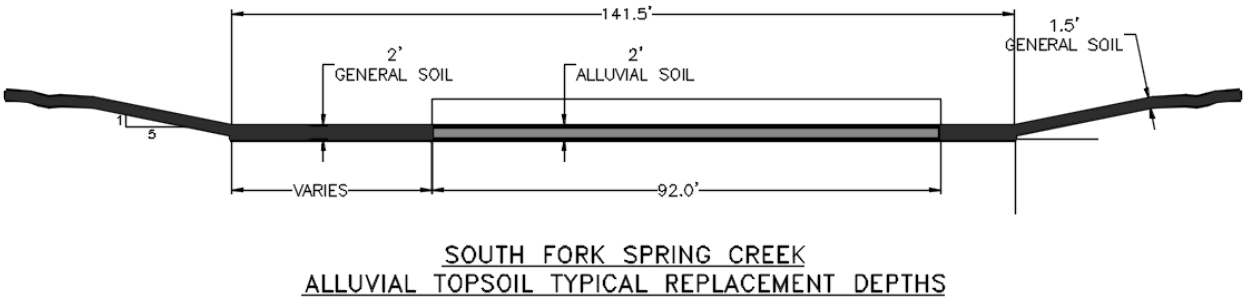


Figure 7. Appendix J, Volume 1, Plate J-6

Comparison of PAR 10A Segment Design to Minor Tributary Design Methodology
While the minor tributary design methodology does not necessarily apply to the design of major stream channel segments at Spring Creek Mine, it does serve as a useful comparison. Furthermore, the regression equation that is used in the minor tributary methodology can be used to approximate floodplain widths for drainages as large as 450 square miles (for Type C streams, see Table J-9 of Appendix J in SMP C1979012) (MDEQ 2002). Therefore, a brief comparison is constructive.

Using a drainage area of approximately 8,250 acres (12.9 square miles) and a Type C channel slope of 0.5%-1.0%, the calculated belt width of the PAR 10A South Fork Spring Creek channel segment (using the Table J-9 regression equation) results in a calculated belt width of 157 to 207 feet and a calculated low-flow (or pilot channel) top width of 13.0 feet. The designed PAR 10A channel segment floodplain width and invert width vary considerably. Primarily, the designed low-flow channel width and floodplain width match the pre-mine widths of the PAR as surveyed before disturbing the channel.

PAR 10A South Fork Spring Creek Minor Tributary Design

Four minor tributaries, SF-0b, SF-0c, SF-1, and SF-18 feed into South Fork Spring Creek within the PAR 10A boundary as shown in Figure 3.

Belt Width and Floodplain Width Determination
The drainage areas for each minor tributary were determined using Appendix J, Volume 2, Attachment 3, page J-3-93 for SF-0b, page J-3-84 for SF-0c, page J-3-96 for SF-1, and page J-3-171 for SF-18. Utilizing Tables J-7 through J-10 included in Appendix J Volume 1 of the current permit, the resulting floodplain widths and belt widths are shown in Table 7 below.

Table 7. Minor Tributary Calculated Belt Widths and Floodplain Widths

Drainage	Area (acres)	Upper Elevation (ft)	Lower Elevation (ft)	Stream Length (ft)	Slope (%)	Channel Type	Belt Width (ft)	Floodplain Width Range (ft)
SF-0b	12.8	3650	3589	1345	4.6%	A	1.8	4-5
SF-0c	57.6	3666	3587	3243	2.4%	B	2.8	17-23
SF-1	32.0	3630	3600	1325	2.2%	B	2.4	14-19
SF-18	167.7	3717	3596	3761	3.2%	B	3.9	16-24

Figure 4 shows how the four minor tributaries will connect into South Fork Spring Creek within PAR 10A. All four tributaries maintain a concave longitudinal profile and will be constructed as close as feasible to the calculated belt widths and floodplain widths displayed in Table 7.

References

Montana Department of Environmental Quality (MDEQ), 2002. Guideline for Reclamation of Drainage Basins and Channels Disturbed by Surface Coal Mining. July.