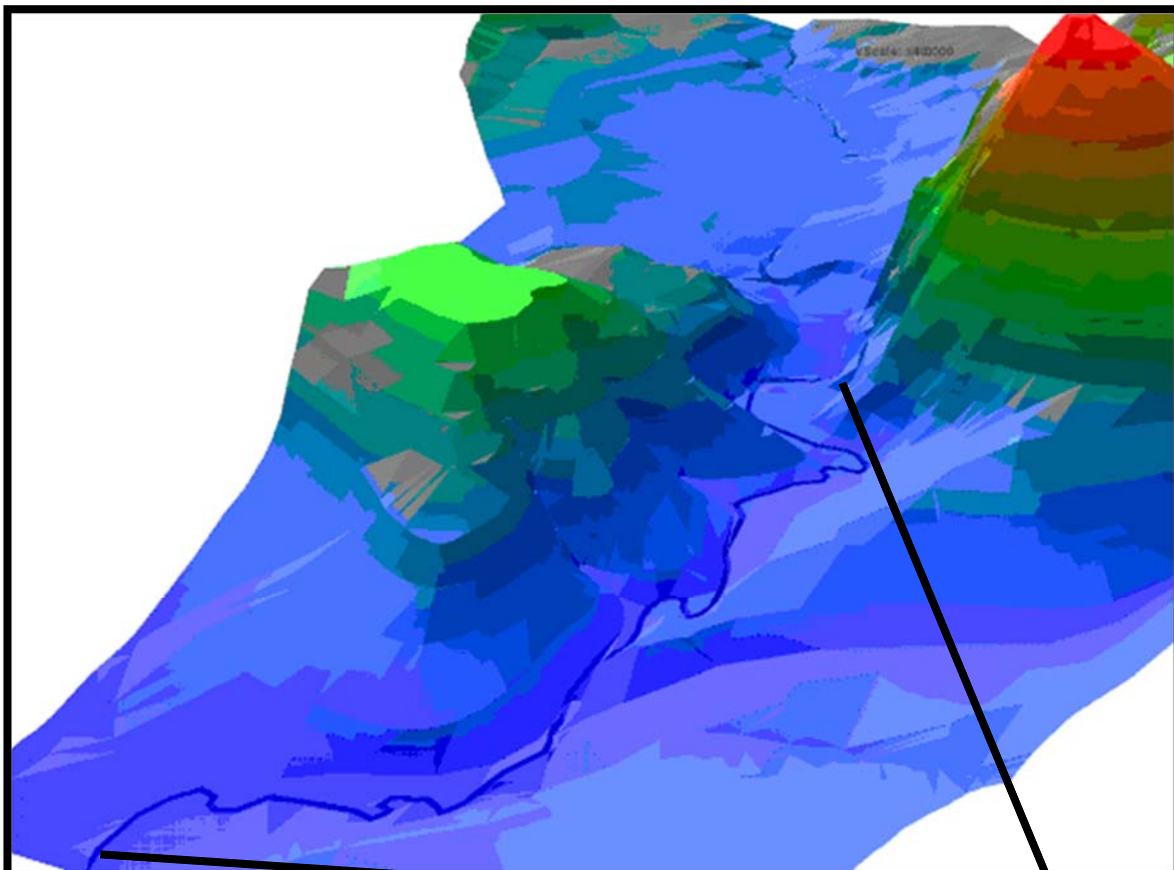
Appendix J Volume 2 Attachment J-8

Post-mine North Fork Spring Creek
(Downstream of PAR 9B to Confluence with Spring Creek)

North Fork Spring Creek Channel Segment Design
March 6, 2019



Post-mine design and 3-D rendering of segment of North Fork Spring Creek (that segment downstream of existing reclamation area PAR 9B to its confluence with Spring Creek).

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 North Fork Spring Creek) will be submitted to Montana DEQ for review and approval. This document details the channel design for a segment of North Fork Spring Creek, from the downstream point of PAR 9B to the confluence with Spring Creek.

Reclaimed North Fork Spring Creek Setting
The designed stream segment that is the subject of this document comprises North Fork Spring Creek from the downstream boundary of PAR 9B to its confluence with Spring Creek. The purpose of this document is to have a completed stream design that will allow Spring Creek Coal to construct any portion of North Fork Spring Creek as reclamation advances and opportunities arise. North Fork Spring Creek is an ephemeral stream, flowing only in response to precipitation and/or snow melt events. The designed segment of North Fork Spring Creek is approximately 2,300 feet long. The contributing drainage basin area to the subject channel segment is approximately 4,300 acres (6.7 square miles). The designed stream *segment is located downstream of the Carbone Flood Control Reservoir and existing recla*mation known as PAR 9B. In general, the pre-mine setting of the stream involved a broad flood plain with an incised low flow channel that meandered across a portion of the flood plain. Modeled runoff rates for each design storm event for the stream segment were taken from a SED-CAD study and are 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.

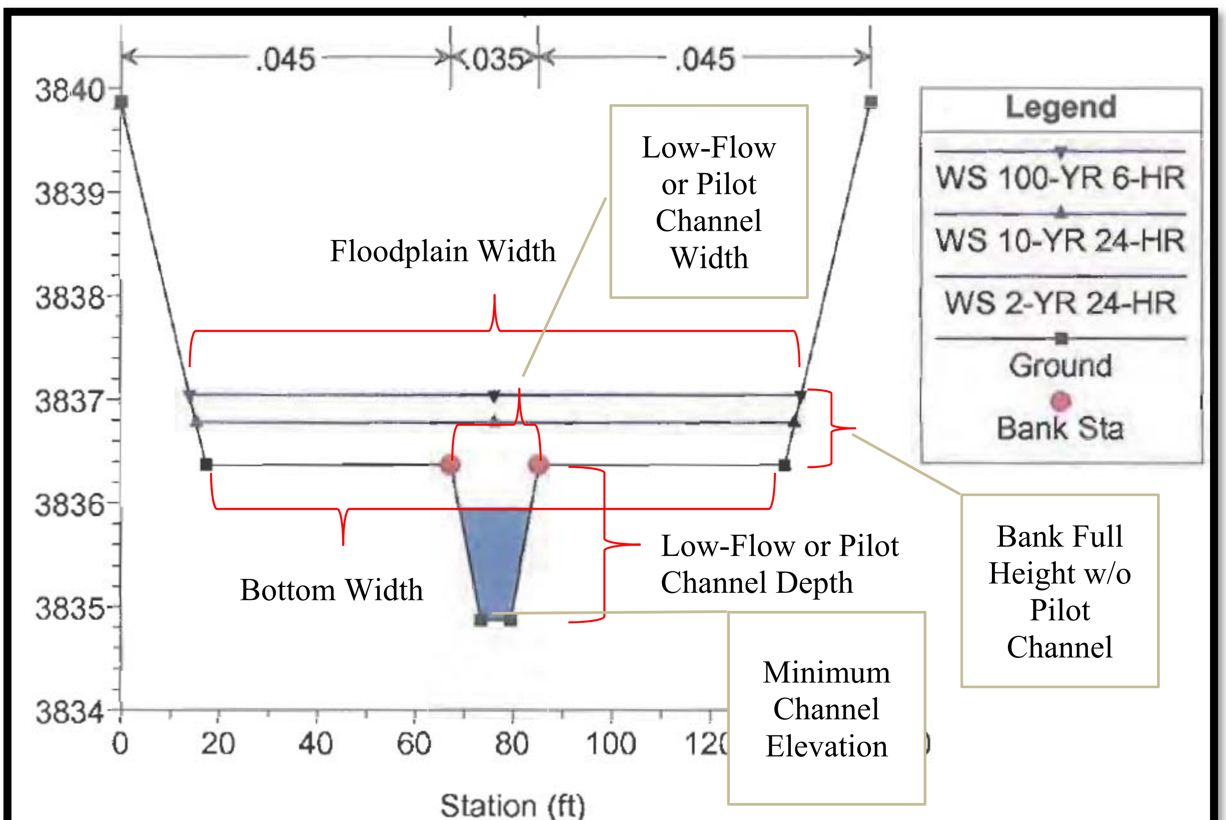


Figure 1. Stream Channel Cross-section Terms.

North Fork Spring Creek Characteristics (Pre-mine)
Detailed studies of the form and function of North 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 the designed channel segment is located.

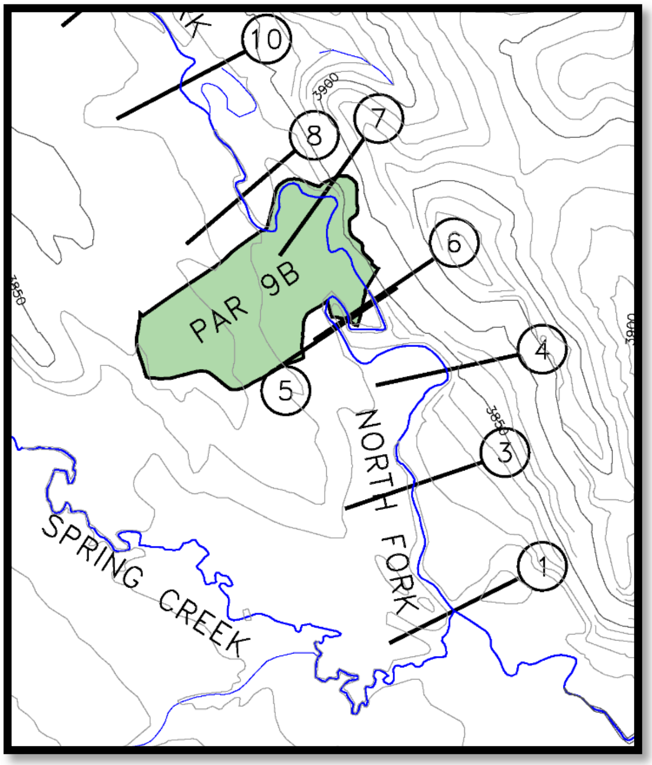


Figure 2. From Plate I-5, pre-mining topography and HEC-RAS cross-section locations (with existing PAR 9B reclamation area in green for reference).

Table 1 below summarizes the modeled flow data of the five most-relevant pre-mine stations from Appendix I Volume 2, Attachment I-5, Page I-5-4 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)
6	434.97	1.69	304.2	189.0	0.3	3821.1	3819.4
5	434.97	5.51	136.8	179.0	0.6	3820.3	3815.7
4	434.97	7.01	100.5	102.4	0.9	3816.5	3814.0
3	434.97	2.42	185.6	103.8	0.3	3811.2	3808.3
1	434.97	6.21	70.0	59.2	1.0	3806.6	3804.8
Average	**434.97**	**4.57**	**159.4**	**126.7**	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 (slightly steeper) longitudinal profile than 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 the channel segment that is the subject of this document (North Fork Spring Creek downstream of reclaimed PAR 9B). Actual cross-sections depicting flow elevations are contained in Appendix J, Volume 2, Attachment J-2 of SMP C1979012.

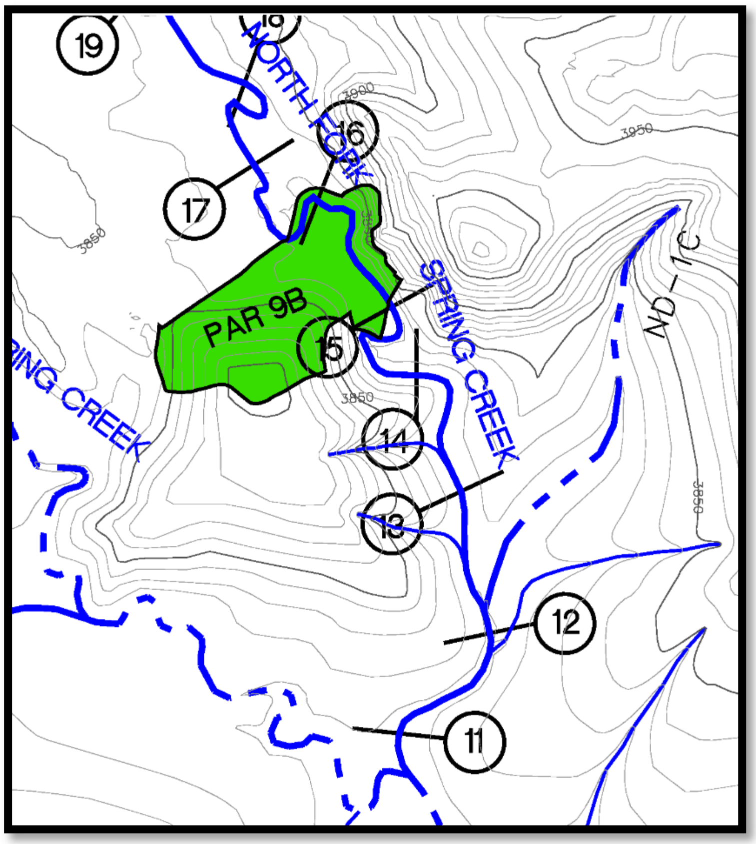


Figure 3. From Plate J-4, conceptual post-mining topography and HEC-RAS cross-section locations (with existing PAR 9B reclamation area in green for reference).

Table 2 below summarizes the conceptual post-mine flow data of the six most-relevant stations from Appendix J Volume 2, Attachment J-2, page J-2-5 (current permit, not 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)
16	266.3	5.77	80.7	125.8	0.9	3827.0	3825.4
15	266.3	4.93	93.0	127.7	0.7	3822.4	3820.7
14	266.3	4.91	93.4	127.8	0.7	3818.4	3816.7
13	266.3	5.85	79.6	125.6	0.9	3814.3	3812.8
12	266.3	4.19	107.6	130.0	0.6	3810.6	3808.8
11	266.3	5.77	80.7	125.8	0.9	3806.2	3804.6
Average	**266.3**	**5.24**	**89.2**	**127.1**	**Slope = 0.008 ft/ft**		

North Fork Spring Creek Channel Design

Figure 4 depicts the design topography for the design stream segment of North 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. In some locations, channel features have been modified to increase site topographic diversity.

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 TR1 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 (same locations as cross-sections used from Figure 3 and Table 2) were developed for the channel segment. Surface topography and runoff data were then modeled using the HEC-RAS hydrology model.

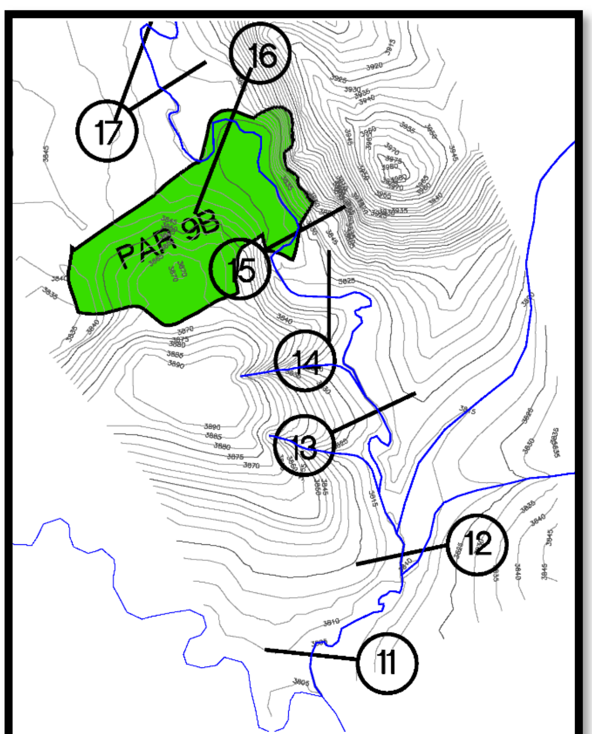


Figure 4. North Fork Spring Creek stream segment design topography with HEC-RAS cross-section locations (note existing reclaimed area PAR 9B shown in green for reference). Contour interval is five foot.

Table 3 below summarizes the modeled flow data of 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.

Table 3. HEC-RAS Station Flow Data 100-year 6-hour runoff event (North Fork Spring Creek channel design, post-mining)

Cross-section ID (River 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)
16 (2924.2’)	434.1	4.83	92.4	134.3	1.0	3825.6	3824.8
15 (2423.3’)	434.1	3.53	172.2	111.5	0.4	3821.7	3818.9
14 (2029.4’)	434.1	6.26	116.7	85.9	0.7	3820.6	3816.3
13 (1385.6’)	434.1	8.61	75.3	47.6	0.8	3816.9	3812.2
12 (750.8’)	434.1	4.78	147.9	116.6	0.6	3811.6	3808.1
11 (153.1’)	434.1	7.29	112.6	122.7	0.8	3808.1	3804.3
Average	**434.1**	**5.88**	**119.5**	**103.1**	**Slope = 0.007 ft/ft**		

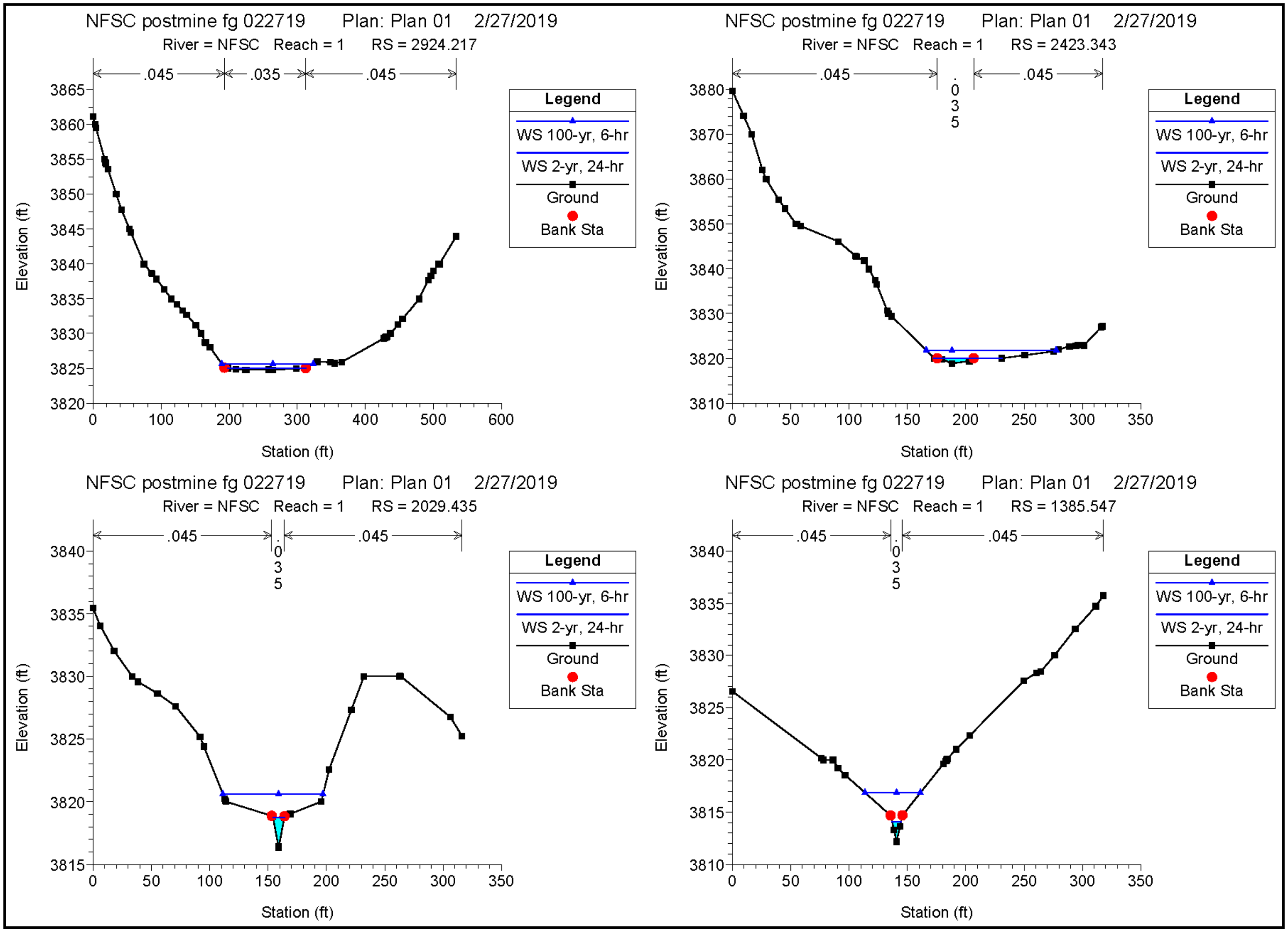
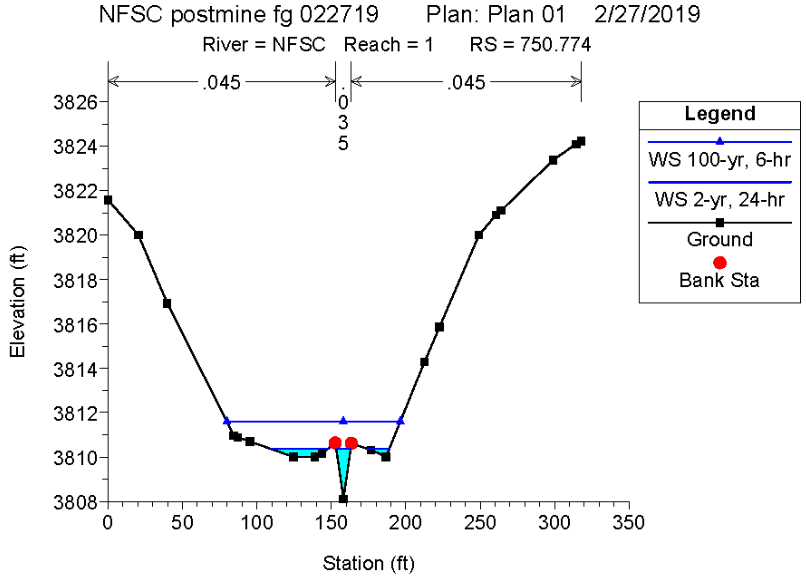


Figure 5. North Fork Spring Creek channel design segment HEC-RAS cross-sections



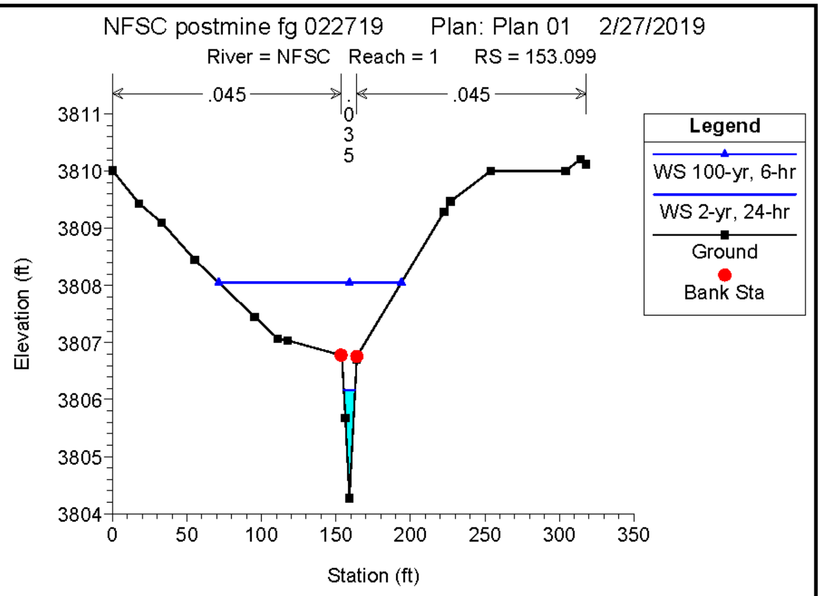


Figure 6. North Fork Spring Creek channel design segment HEC-RAS cross-sections

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. Table 4 compares HEC-RAS model flow data for the most relevant pre-mine cross-sections with the five cross-sections inside the designed North Fork Spring Creek stream segment for the 100-year 6-hour storm event. Table 5 compares HEC-RAS model flow data for the most relevant pre-mine cross-sections to the five cross-sections 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-5-4 from TR1, and the runoff rate for the post-mine condition is from Appendix J, Volume 2, Attachment J-2, Pages J-2-5 and J-2-6 from TR1. Note the post-mine TR1 runoff rate was used for designing the channel and floodplain within design stream segment instead of the pre-mine TR1 runoff rate as the design is to hold the runoff after all the disturbed land has been reclaimed. The post-mine topography differs very slightly from the pre-mine topography, resulting in an insignificantly lower runoff rate (0.9 cfs for the 100-year 6-hour and 0.1 cfs for the 2-year 24-hour storm event) for each condition.

The design channel's longitudinal flood plain slope (0.007 ft/ft) is similar to the pre-mine condition as the approved profile of North Fork Spring Creek in Appendix J, Volume 1, Plate J-5. Note that the longitudinal slope of the native flood plain above existing PAR 9B reclamation as surveyed is 0.005 ft/ft. Any slope differences are within the range of natural variability on major channels (in their native condition) at the Spring Creek Mine.

Table 4 shows the post-mine channel will be stable with Froude numbers 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 post-mine designed North Fork Spring Creek segment for a 100-year 6-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	6	435.0	3819.4	3821.1	3820.0	3821.2	0.0009	1.7	304.2	189.0	0.3
Pre-mine	5	435.0	3815.7	3820.3	3820.1	3820.6	0.0057	5.5	136.8	179.0	0.6
Pre-mine	4	435.0	3814.0	3816.5	3816.5	3817.0	0.0107	7.0	100.5	102.4	0.9
Pre-mine	3	435.0	3808.3	3811.2	--	3811.3	0.0013	2.4	185.6	103.8	0.3
Pre-mine	1	435.0	3804.8	3806.6	3806.6	3807.2	0.0173	6.2	70.0	59.2	1.0
Design	15	434.1	3818.9	3821.8	--	3821.9	0.0021	3.5	172.2	111.5	0.4
Design	14	434.1	3816.3	3820.6	3820.4	3821.0	0.0060	6.3	116.7	85.9	0.7
Design	13	434.1	3812.2	3816.9	3816.9	3817.7	0.0092	8.6	75.3	47.6	0.8
Design	12	434.1	3808.1	3811.6	--	3811.8	0.0050	4.8	147.9	116.6	0.6
Design	11	434.1	3804.3	3808.1	3808.1	3808.5	0.0102	7.3	112.6	122.7	0.8

Table 5 also shows the post-mine channel invert (low-flow channel) 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 post-mine designed North Fork Spring Creek segment 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	6	40.5	3819.4	3820.0	3820.0	3820.0	0.0004	0.4	96.2	177.1	0.1
Pre-mine	5	40.5	3815.7	3818.2	3817.4	3818.3	0.0029	2.5	16.2	23.3	0.4
Pre-mine	4	40.5	3814.0	3815.1	3815.1	3815.3	0.0184	4.0	10.3	21.9	0.9
Pre-mine	3	40.5	3808.3	3809.1	--	3809.2	0.0086	2.2	18.3	43.5	0.6
Pre-mine	1	40.5	3804.8	3805.3	3805.3	3805.5	0.0251	3.5	11.7	31.6	1.0
Design	15	40.4	3818.9	3820.0	--	3820.1	0.0036	1.9	20.9	58.0	0.4
Design	14	40.4	3816.3	3818.7	3818.2	3818.9	0.0061	3.5	11.6	9.6	0.6
Design	13	40.4	3812.2	3814.1	3814.1	3814.6	0.0207	5.5	7.4	7.7	1.0
Design	12	40.4	3808.1	3810.4	3810.2	3810.5	0.0042	2.8	23.1	62.4	0.5
Design	11	40.4	3804.3	3806.2	3806.2	3806.7	0.0217	5.6	7.2	7.6	1.0

Channel Function

Additional stream meander features were added to improve topographic and stream channel diversity. The cover page figure shows a three dimensional rendering of the designed North Fork Spring Creek area with the stream centerline traced in dark blue. Spring Creek Mine also commits to enhancing topographic diversity in the surrounding upland areas at the time of reclamation. These enhancements may include additional hills, swales, and depressions to provide increased cover opportunities for wildlife.

Channel Construction and Topsoil Plan

The North 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). Alluvial topsoil will be placed in the floodplain areas to a depth of 2.0 feet and general topsoil in all other places.

Comparison of PAR 9B 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 4,300 acres (6.72 square miles) and a Type C channel slope of 0.5%-1.0%, the calculated belt width of the designed North Fork Spring Creek channel segment (using the Table J-9 regression equation) results in a calculated belt width of 127 to 170 feet and a calculated low-flow (or pilot channel) top width of 10.6 feet. The calculated low-flow channel width of 10.6 feet compares reasonably well to the actual low-flow top width (7 to 63 feet) of the designed cross-sections located inside the stream segment areas that are the subject of this document as shown in Figure 4. The designed channel segment floodplain width varies considerably but generally conforms to the calculated belt width using the minor tributary methodology.

References

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