APPENDIX J POST MINE HYDROLOGY
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EXECUTIVE SUMMARY

Spring Creek Coal LLC operates an open-pit surface coal mine in Big Horn County, Montana, under Surface Mining Permit Number 79012. As a part of the mining process, Spring Creek Coal LLC will be temporarily mining through drainages and streams within the permit area. A study of the baseline characteristics of the hydrologic features at Spring Creek Mine (SCM) is presented in Appendix I to provide Montana Department of Environmental Quality (MDEQ) with sufficient data to determine the functions of the hydrologic system. This appendix has been provided to demonstrate the processes necessary to establish successful reclamation of the disturbed areas. The information presented in this appendix is a compilation of previous and new studies performed in and around the SCM. This document is meant to replace sections of Appendix M and Appendix I, which discuss postmining hydrologic features at SCM.

1.0 INTRODUCTION

This report summarizes SCM's plans for the reclamation of the SCM permit area, located in Big Horn County, Montana. This document replaces previously approved Appendix M, and portions of Appendix I.

SCM is committed to reclaiming the areas within the permit boundary that are disturbed by mining, in order to prevent material damage to offsite areas and re-establish the premine land use. The primary goal of the reclamation plan design is to restore the drainage system in the disturbed area to closely resemble the original system in terms of channel and floodplain hydraulics and sediment balance. The restoration plan presented in this appendix describes how, by restoring the characteristics of the surface water drainage system, the essential functions of the hydrologic system will be restored.

The hydrologic restoration plan is divided into sections. Section 2.0 reviews the postmine topography of the SCM permit area. Section 3.0 describes the plans for restoration of the surface water functions within the disturbed area, and Section 4.0 describes the plans for restoration of the groundwater functions.

2.0 POSTMINE TOPOGRAPHY

Postmining contours for the SCM area are shown in Volume 3, Plate 4. The postmining topography (PMT) was designed to be as similar as possible to premining topography given the constraints of earthmoving equipment, economics, contemporaneous reclamation, and stripping ratio. A discussion of the backfilling and regrading plan is contained in section 313.1(d). The premining topography consists of erosion-resistant ridges paralleling the major stream channels. These ridges are dissected by steep gullies that transition to the broad, low-gradient valley floors. During reclamation, smooth transitions will be constructed between undisturbed and reclaimed land to restore erosional stability and surface drainage patterns.

Diversification of vegetation and wildlife habitat will be promoted by a mixture of uniform and varied topography, restored in the same general areas as premining features. The terrain will readily support both wildlife and livestock, in conformance with the proposed postmining land use. The PMT was designed to meet the regulatory definition of restoring approximate original contours. The final surface configuration closely resembles the premining configuration and blends into and complements the drainage pattern of the surrounding terrain. A discussion of postmining slopes is included in the following section.

2.1 Slope Studies

Slope studies were conducted for the pre- and postmining surface within the SCM mining disturbance area. The results of these studies are located in 313 Addendum D, Volume 1B. The analyses include slope aspect, slope intensity, slope cumulative frequency and a map that shows the slope locations. The locations of steep slopes (slopes greater than 4H:1V) are located on a separate exhibit. The methods used for the analyses are included in the narrative of 313 Addendum D.

3.0 SURFACE WATER RESTORATION

The watershed reclamation plan for SCM was designed to produce postmining watersheds with hydrologic functions and erosional stability closely approximating those of the corresponding original watersheds. This restoration plan addresses major stream and tributary channel design, drainage density and topographic restoration. One of the primary goals in plan development was the restoration of a drainage system that will closely resemble the characteristics of the original system in terms of channel and floodplain hydraulics, geomorphology and sediment balance.

The following design sequence was utilized in the design of the postmining drainage system:

- The macrotopography of the graded spoil surface was refined to include stream channels with appropriate gradients.
- Major tributary basins were delineated and tie points were located where tributary channels will cross the disturbance boundaries.
- Watershed parameters were determined for postmining drainage basins. The parameters included drainage area, flow path length and slope, hydrologic soil types, and land cover and condition. The postmining parameters were compared with premining characteristics.

- Major tributary basins were populated with successively lower order subbasins to approximate premining drainage density.

- Topography was modified to conform to the lower-order basin drainage network.

- Rainfall runoff characteristics of watersheds were determined using the SCS triangular hydrograph method.

- The HEC-RAS program was used to determine the premining hydraulic response of major channels and floodplains to various discharge rates (see Appendix I).

- Successive HEC-RAS computer runs were used to evaluate postmining channel and floodplain cross sections and profiles to approximate premining channel and floodplain morphology and hydraulics.

- All drainages were designed in accordance with Section 3.5.2, to provide reclaimed floodplains that will allow the natural development of bankfull channels.

- Postmining topography was revised to accommodate drainages designed in the preceding step.

3.1 Drainage Basin Characteristics

The SCM property lies within the Tongue River drainage system. Three dominant drainages exist within the permit area. These three drainages include Spring Creek, South Fork Spring Creek, and Pearson Creek.

Premining and postmining longitudinal profiles of tributary streams to be reconstructed are shown on Plate J-2. A comparison of the postmining profiles with the premining profiles, demonstrate that postmining channel lengths and average gradients are similar to the premining streams. The characteristics of each of these three major watersheds are discussed below.

The reclaimed drainages will be designed using the methods presented in Section 3.5.2 and will be constructed to safely pass the peak discharge from the 100-year, 6-hour precipitation event. After construction, more frequent events such as the 1.5-year precipitation event, will occur and allow for the natural formation of a channel within the constructed floodplain.

3.1.1 Spring Creek

Plate 4, Postmining Topography with Drainage Divides, shows the Spring Creek drainage area with the postmining topography. Spring Creek has a drainage area of 37.7 square miles from its headwaters to its confluence with the Tongue River. Disturbance to the Spring Creek Drainage (8.87 square miles) will affect approximately 23.5% percent of the Spring Creek Drainage area. Comparison of geomorphic characteristics for pre- and postmining drainage basins is provided in tables provided on Plate 4b and Plate 4, respectively. Overall, the postmining basins are similar to the premine basins. Only one basin is significantly different after mining. Drainage ND-1 prior to mining was a tributary to Spring Creek below North Fork Spring Creek. Following mining ND-1 will be a tributary to North Fork Spring Creek.

In addition to Spring Creek and North Fork Spring Creek, portions of Draws SD1, ND1, ND2, and ND5 will be reconstructed in the mine backfill area and connected to existing undisturbed channel reaches at mine disturbance boundaries.

3.1.2 South Fork Spring Creek

Plate4, Postmine Drainage Basins, shows the South Fork Spring Creek Drainage with the postmine topography in the South Fork Spring Creek area. Restoration plans for the main channel of South Fork Spring Creek are included below. South Fork Spring Creek has a drainage area of 14.0 square miles above its confluence with Spring Creek. Disturbance to the South Fork Spring Creek drainage (4.33 square miles) will affect approximately 30.9% of the South Fork Spring Creek drainage basin area.

Comparison of geomorphic characteristics for pre- and postmining drainage basins is provided in tables on Plate 4b and Plate 4, respectively. Overall, the comparison shows the postmine basin area for South Fork Spring Creek will increase over the premine basin area. The drainage density will also increase for South Fork Spring Creek tributary basins.

3.1.3 Pearson Creek

Plate 4, Postmine Drainage Basins, shows the Pearson Creek drainage with the postmine topography in the Pearson Creek area. Pearson Creek has a drainage area of 8.70 square miles above its confluence with the Tongue River. Disturbance to the Pearson Creek drainage (1.82 square miles) will affect approximately 20.9% of the Pearson Creek drainage basin area.

Comparison of geomorphic characteristics for pre- and postmining drainage basins is provided in tables located on Plate 4B and Plate 4, respectively. Overall, the comparison shows the postmine basin area will increase over the premine basin area. The drainage density for this basin will also increase slightly.

3.2 Channel Characteristics

A watershed modeling study was conducted using the SEDCAD© 4.0 watershed modeling program. SEDCAD© was used to model both the premining and postmining Spring Creek watersheds from the headwaters to the east permit boundary. The premining watershed modeling study is discussed in Appendix I. This model uses the drainage pattern in conjunction with the topography, soil type, vegetation, and land use to provide calculated, site-specific, rainfall runoff data. The SEDCAD© model routes runoff due to precipitation through the drainage network. The runoff simulation routine within the SEDCAD© program is based on the SCS TR-55 triangular hydrograph procedure and uses input data similar to other triangular hydrograph methods (precipitation, CN, DA, Tc, etc.). The program provides hydrologic output consisting of runoff volume and peak discharge at designated points within the study watershed.

In ephemeral and intermittent streams, runoff volumes and peaks are dependent on precipitation frequency-duration relationships and on the characteristics of the contributing drainage basin. Basin characteristics that were considered during modeling included: basin area, relief, soil type, vegetative cover, and stream routing influences. These characteristics are each subject to change due to mining and reclamation activities. Input parameters for the SEDCAD© watershed model include drainage area, curve number, time of concentration, travel time to watershed outlet, channel routing coefficients, hydrologic surface condition, precipitation amount, and precipitation distribution.

Precipitation values associated with various return periods used in this model are illustrated in Table J-1 and were taken from Volume II of the NOAA Precipitation Frequency Atlas of the Western United States (Miller, et al., 1973). The precipitation distribution recommended for the western United States by the U.S. Soil Conservation Service is the Type II distribution, which was used in this study to generate flood estimates for the various return periods. Precipitation frequency-duration values for the SCM are shown in Table J-1.

Table J-1. SCM Precipitation Frequency Values

Duration		**Precipitation in Inches**						
		Return Period						
Hours	**Minutes**	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**500-yr**
0.08	5	0.16	0.23	0.28	0.34	0.39	0.44	0.55
0.17	10	0.25	0.36	0.43	0.53	0.61	0.68	0.86
0.25	15	0.32	0.45	0.55	0.67	0.77	0.86	1.09

0.50	30	0.44	0.63	0.76	0.93	1.06	1.20	1.50
1.00	60	0.56	0.80	0.96	1.18	1.35	1.51	1.90
2.00	120	0.66	0.93	1.11	1.35	1.54	1.73	2.17
3.00	180	0.75	1.04	1.24	1.50	1.71	1.92	2.40
6.00	360	0.98	1.32	1.56	1.88	2.19	2.38	2.96
12.00	720	1.18	1.59	1.87	2.26	2.56	2.87	3.56
24.00	1,440	1.38	1.86	2.19	2.65	3.00	3.35	4.16

Curve numbers developed by the Natural Resources Conservation Service (NRCS) represent the runoff potential for various watershed hydrologic soil-cover complexes. A higher CN indicates that a higher portion of precipitation contributes to direct runoff. Determination of a CN applicable to a specific drainage basin is a function of soil type, antecedent moisture condition (AMC), plant cover, and precipitation intensity. CNs were assigned to the various hydrologic cover-soil complexes assuming various cover complexes based on vegetation type and hydrologic soil groups as agreed upon with MDEQ personnel.

To determine the postmining CNs for North Fork Spring Creek, Spring Creek and South Fork Spring Creek, numerous contacts with MDEQ personnel were made, including telephone conversations, meetings and interim submittals from April 22, 1999 through October 9, 2000. Post-mining CNs were taken from a list of assigned composite CNs agreed to and published in a letter from MDEQ to SCM in February 2001 (See attachment J-3). In summary, the drainage area location and corresponding CN for postmine drainages are as follows:

DRAINAGE AREA	CURVE NUMBER
North Side of Spring Creek	64
South Side of Spring Creek and North side of South Fork Spring Creek	77
South side of the South Fork Spring Creek	81

The postmine CN's listed reflect only the basin area that will be disturbed and subsequently reclaimed. Postmine CN's were adjusted for individual basins where only a portion of the basin was disturbed. CNs were selected for undisturbed areas as explained in Appendix I.

The curve number for the Pearson Creek drainage area was developed using NRCS's Soil Survey database (websoilsurvey.sc.egov.usda.gov). Soil polygons were overlaid by the disturbed area using GIS. By area-weighting the CN for postmine topography was developed. Since many of the different soil types will be combined in the postmine topography, it was determined that a composite CN would be representative of the postmine conditions. A CN of 74 was determined to be representative for the Pearson Creek postmine area. The weighted average was found to be 73.3 and was rounded up to 74.

The postmining watershed dissection for the SEDCAD© model is shown on Plate J-3. The plate shows the dissection of the watershed into junctions, branches, and structures for which runoff values are calculated. Table J-2 shows the input parameters for the postmining watershed model.

3.3 Postmining Runoff Estimates

Postmining runoff calculations were performed using the SCS triangular hydrograph methodology utilized in the SEDCAD© watershed model. The same precipitation frequency values used in the premining analysis were used in the postmining analysis and include the 2-year, 10-year, and 100-year precipitation events. Postmining flood peaks and volumes were computed using the SCS Type II, 24-hour and 6-hr precipitation distribution. The postmining flood peaks and volumes are presented in Table J-4. The postmining SEDCAD© analysis results are presented in Attachments J-1.

3.4 Comparison of Premining and Postmining Floods

The premining and postmining watershed models allow comparison of contributing drainage area and watershed response at corresponding locations within the SCM. These comparisons can be made from Tables I-4 through I-6 of Appendix I and J-3 through J-5 of this appendix. Differences in premining and postmining hydrologic response can be determined for any corresponding location at which a structure has been placed, using this method of comparison. Watersheds included in the tables listed above represent tributary basins within the SCM permit boundary where the watershed and tributary channel will both be affected by mining and reclamation operations. Basins where the tributary channel is not disturbed have not been included in the tables.

The flood estimates for selected basins within the SCM, can only be used for general comparisons between the premining and postmining floods because the premining and postmining basins do not exactly correspond due to changes as a result of mining. However, the number and size of the postmining basins roughly correspond to the number and size of premining basins for the SCM. The locations of the premining basins are presented on Plate I-4 and the locations of the proposed postmining basins are presented on Plate J-3.

Table J-2. Postmine SEDCAD© Inputs

Structure	Subwatershed	Drainage Area DA (ac)	Curve Number CN	Travel Time Tt (hr)	Muskingum K (hr)	Muskingum X
Spring Creek						
1	1	917.10	71	0.83	0.00	0.00
2	1	869.10	77	1.30	0.00	0.00
3	1	958.90	76	1.35	0.00	0.00
4	1	694.00	73	1.10	0.00	0.00
5	1	893.20	72	2.04	0.00	0.00
6	1	744.50	73	1.92	0.00	0.00
7	1	674.10	70	0.47	0.00	0.00
8	1	0.00	0	0.00	0.00	0.00
9	1	541.70	68	1.40	0.00	0.00
10	1	573.50	72	1.55	0.00	0.00
11	1	586.00	76	2.05	0.00	0.00
12	1	0.00	0	0.00	0.00	0.00
13	1	944.90	65	1.64	0.00	0.00
14	1	554.00	64	1.83	0.00	0.00
15	1	670.40	75	1.41	0.00	0.00
16	1	630.70	73	2.93	0.00	0.00
17	1	808.10	76	1.09	0.00	0.00
18	1	583.40	74	1.36	0.00	0.00
19	1	828.30	73	1.46	0.00	0.00
20	1	872.00	66	1.52	0.00	0.00
21	1	944.40	62	2.74	0.00	0.00
South Fork Spring Creek						
1	1	959.20	78	1.25	0.00	0.00
2	1	816.60	71	1.21	0.00	0.00
3	1	629.60	76	1.19	0.00	0.00
4	1	633.20	76	0.96	0.00	0.00
5	1	822.90	75	1.84	0.00	0.00
	2	507.50	75	1.35	0.00	0.00
6	1	361.80	78	1.15	0.00	0.00
7	1	0.00	0	0.00	0.00	0.00
8	1	866.30	78	1.97	0.00	0.00
9	1	837.30	79	2.97	0.00	0.00
10	1	933.00	77	3.27	0.00	0.00
11	1	640.20	66	2.11	0.00	0.00
12	1	889.90	75	1.84	0.00	0.00
Pearson Creek						
1	1	839.60	71	1.51	0.00	0.00
2	1	327.00	75	0.71	0.00	0.00
3	1	372.40	74	0.97	0.00	0.00
4	1	360.80	74	2.09	0.00	0.00
5	1	0.00	0	0.00	0.00	0.00
6	1	126.60	72	0.59	0.00	0.00
7	1	0.00	0	0.00	0.00	0.00
8	1	523.20	75	0.82	0.00	0.00
9	1	511.50	76	0.97	0.00	0.00
	2	444.90	75	0.67	0.00	0.00
10	1	453.40	75	0.95	0.00	0.00
11	1	389.80	75	0.65	0.00	0.00
12	1	0.00	0	0.00	0.00	0.00
13	1	281.70	74	1.33	0.00	0.00

Table J-3. Postmine Spring Creek SEDCAD© Results

SEDCAD Structure Designation	Precipitation Distribution		Recurrence Interval 2-yr, 24-hr	10-yr, 24-hr	100-yr, 6-hr
1	SCS Type II	Peak (cfs)	7.71	87.09	174.66
		Vol (ac-ft)	4.15	21.03	26.34
2	SCS Type II	Peak (cfs)	31.63	200.51	370.51
		Vol (ac-ft)	13.52	52.96	64.75
3	SCS Type II	Peak (cfs)	50.19	285.22	521.61
		Vol (ac-ft)	22.64	85.72	104.38
4	SCS Type II	Peak (cfs)	55.64	305.02	559.47
		Vol (ac-ft)	26.99	104.52	127.58
5	SCS Type II	Peak (cfs)	60.51	322.77	593.87
		Vol (ac-ft)	31.77	126.81	155.27
6	SCS Type II	Peak (cfs)	64.65	334.91	605.86
		Vol (ac-ft)	36.44	146.98	180.16
7	SCS Type II	Peak (cfs)	64.92	328.29	579.41
		Vol (ac-ft)	38.99	161.15	198.05
8	SCS Type II	Peak (cfs)	92.68	453.58	793.16
		Vol (ac-ft)	59.59	256.78	317.49
9	SCS Type II	Peak (cfs)	92.34	450.34	779.96
		Vol (ac-ft)	60.93	266.19	329.59
10	SCS Type II	Peak (cfs)	93.22	451.59	773.32
		Vol (ac-ft)	64.00	280.50	347.38
11	SCS Type II	Peak (cfs)	11.01	53.83	94.96
		Vol (ac-ft)	5.57	20.01	24.22
12	SCS Type II	Peak (cfs)	95.97	458.80	773.52
		Vol (ac-ft)	69.58	300.51	371.59
13	SCS Type II	Peak (cfs)	96.10	461.31	769.07
		Vol (ac-ft)	70.59	312.46	387.50
14	SCS Type II	Peak (cfs)	95.44	458.84	765.37
		Vol (ac-ft)	70.59	312.46	387.50
15	SCS Type II	Peak (cfs)	95.57	459.21	764.42
		Vol (ac-ft)	76.18	333.71	413.37
16	SCS Type II	Peak (cfs)	95.19	457.59	760.12
		Vol (ac-ft)	80.13	350.79	434.45
17	SCS Type II	Peak (cfs)	21.29	114.69	201.86
		Vol (ac-ft)	7.69	27.62	33.41
18	SCS Type II	Peak (cfs)	34.37	195.40	351.22
		Vol (ac-ft)	13.89	52.66	64.09
19	SCS Type II	Peak (cfs)	41.59	230.64	419.17
		Vol (ac-ft)	19.08	75.09	91.78
20	SCS Type II	Peak (cfs)	42.00	239.81	443.66
		Vol (ac-ft)	20.36	87.42	107.98
21	SCS Type II	Peak (cfs)	40.35	236.45	434.05
		Vol (ac-ft)	20.60	95.63	119.44

Table J-4. Postmine South Fork Spring Creek SEDCAD© Results

SEDCAD Structure Designation	Precipitation Distribution		Recurrence Interval 2-yr, 24-hr	10-yr, 24-hr	100-yr, 6-hr
1	SCS Type II	Peak (cfs)	34.00	150.30	254.60
		Vol (ac-ft)	11.65	37.84	45.26
2	SCS Type II	Peak (cfs)	38.91	177.86	311.16
		Vol (ac-ft)	15.35	56.55	68.70
3	SCS Type II	Peak (cfs)	46.76	205.68	362.57
		Vol (ac-ft)	21.34	78.06	94.72
4	SCS Type II	Peak (cfs)	53.63	228.30	404.44
		Vol (ac-ft)	27.36	99.69	120.90
5	SCS Type II	Peak (cfs)	63.47	260.51	433.51
		Vol (ac-ft)	38.46	141.86	172.23
6	SCS Type II	Peak (cfs)	65.30	263.56	427.84
		Vol (ac-ft)	42.85	156.13	189.30
7	SCS Type II	Peak (cfs)	71.83	284.85	441.22
		Vol (ac-ft)	50.27	184.33	223.63
8	SCS Type II	Peak (cfs)	76.94	297.22	441.11
		Vol (ac-ft)	60.79	218.49	264.50
9	SCS Type II	Peak (cfs)	81.40	307.58	442.21
		Vol (ac-ft)	72.19	253.87	306.59
10	SCS Type II	Peak (cfs)	82.62	310.75	438.00
		Vol (ac-ft)	82.24	288.14	347.82
11	SCS Type II	Peak (cfs)	82.18	309.65	436.61
		Vol (ac-ft)	83.18	297.19	359.71
12	SCS Type II	Peak (cfs)	14.65	79.70	143.57
		Vol (ac-ft)	7.42	28.20	34.33

Table J-5. Postmine Pearson Creek SEDCAD© Results

SEDCAD Structure Designation	Precipitation Distribution		Recurrence Interval 2-yr, 24-hr	10-yr, 24-hr	100-yr, 6-hr
1	SCS Type II	Peak (cfs)	5.88	54.30	108.98
		Vol (ac-ft)	3.80	19.24	24.10
2	SCS Type II	Peak (cfs)	10.03	73.72	144.93
		Vol (ac-ft)	6.53	29.61	36.72
3	SCS Type II	Peak (cfs)	14.33	89.50	174.56
		Vol (ac-ft)	9.23	40.54	50.11
4	SCS Type II	Peak (cfs)	17.80	103.66	193.51
		Vol (ac-ft)	11.85	51.12	63.08
5	SCS Type II	Peak (cfs)	54.95	288.25	527.67
		Vol (ac-ft)	29.52	117.74	144.11
6	SCS Type II	Peak (cfs)	55.06	286.92	523.58
		Vol (ac-ft)	30.20	120.90	148.04
7	SCS Type II	Peak (cfs)	59.65	301.76	545.31
		Vol (ac-ft)	34.57	137.50	168.24
8	SCS Type II	Peak (cfs)	12.76	79.62	143.51
		Vol (ac-ft)	4.37	16.60	20.20
9	SCS Type II	Peak (cfs)	25.77	146.64	261.08
		Vol (ac-ft)	8.58	31.60	38.34
10	SCS Type II	Peak (cfs)	31.14	165.49	296.19
		Vol (ac-ft)	12.37	45.97	55.84
11	SCS Type II	Peak (cfs)	10.52	68.26	122.71
		Vol (ac-ft)	3.26	12.37	15.06
12	SCS Type II	Peak (cfs)	36.83	188.64	339.37
		Vol (ac-ft)	15.62	58.35	70.90
13	SCS Type II	Peak (cfs)	38.08	189.26	341.22
		Vol (ac-ft)	17.67	66.61	81.03

3.5 Conceptual Reclaimed Channel Design

To determine general channel dimensions for major drainages (e.g. South Fork Spring Creek), to determine flood plain widths, and verify that adequate flood irrigable land replacement areas are provided in the postmine setting, conceptual designs of the reclaimed channels have been evaluated and described in this section. The goal of the evaluation was to determine a conceptual design for the postmine channel and floodplain that would approximate premine. In general, these conceptual designs include an inner pilot channel designed to convey the flow from a 2-year, 24-hour peak flow and a floodplain designed to safely convey the 100-year, 6-hour peak discharge. While these conceptual designs help to identify overall channel dimensions and general characteristics, it is SCM's intent to ultimately design and construct the channels to allow for natural channel development (e.g., build the flood plain but not the inner pilot channel). Regardless, all major channel designs will be submitted to MDEQ for review and approval prior to construction; however, the general approach will be similar to that described in Section 3.5.2.

Reclaimed channels and floodplains for Spring Creek, North Fork Spring Creek, South Fork Spring Creek, and Pearson Creek were evaluated using peak runoff from the 2-year, 24-hr and 100-year, 6-hour storms.

Hydraulic properties of portions of Spring Creek and Pearson Creek in the premining and conceptual postmining states were compared using the HEC-RAS computer model (U.S. Army Corps of Engineers, 1997) to reach the goal of a conceptual postmine channel and floodplain that would approximate the premine hydraulic characteristics. HEC-RAS analyses were not completed on the lower portion of Spring Creek within the permit boundary since this section of the channel would not be disturbed. Primary inputs to the HEC-RAS model are as follows: peak discharge; Manning's roughness value "n" for the channel and overbank areas; and station/elevation data for conceptual stream cross sections within the study reach. . Again, detailed designs for all channels will be submitted to MDEQ for review and approval prior to construction in accordance with Section 3.5.2.

The conceptual channel dimensions used in evaluation of the restored major channels within the SCM area PMT involved a comprehensive approach utilizing hydrologic and hydraulic design principles. Discharges were determined for postmining drainages as previously described and are tabulated in Tables J-3 through J-5. Studies presented in the previous sections together with baseline geomorphic and watershed parameters, were utilized in the process along with the results obtained from a HEC-RAS computerized flood analysis. Although this method was used for analysis of the restored major channels, the design of the reconstructed floodplains will conform to the method presented in Section 3.5.2.

The computer flood studies were used as a basis of comparison for the pre- and postmining channel and floodplain to evaluate similar hydraulic characteristics for each major channel. In addition to other hydraulic parameters, the HEC-RAS program calculates flow area, water surface elevation, mean channel velocity, left overbank velocity and right overbank velocity at specified cross-sections.

The final stage of analysis consisted of editing the premining HEC-RAS data file to model the postmining conceptual channel gradient and geometry. The postmining conceptual geometry was then optimized by trial and error to approximate the premine hydraulic parameters, through successive HEC-RAS iterations. The procedure included adjustment of channel length and cross-section geometry until pre- and postmining HEC-RAS computed hydraulics were similar for corresponding discharge events.

The postmining HEC-RAS cross-section locations are illustrated on Plate J-4. The computer water surface elevation for the 2-year and 100-year events are tabulated and shown in representative cross sections in Attachment J-2. Table J-6 shows the average HEC-RAS values determined by this analysis.

Table J-6. Postmine HEC-RAS Averages

Stream Channel	Recurrence Interval	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # In Channel
North Fork Spring Creek	2-yr, 24-hr	40.4	3829.8	3830.9	3829.5	3831.0	0.012	3.3	19.4	56.4	0.7
North Fork Spring Creek	10-yr, 24-hr	236.5	3829.8	3831.5	3832.3	3831.7	0.009	4.5	85.2	117.8	0.7
North Fork Spring Creek	100-yr, 6-hr	434.1	3829.8	3831.9	3832.6	3832.1	0.009	5.3	128.2	126.7	0.7
Spring Creek	2-yr, 24-hr	82.8	3791.8	3793.3	3784.9	3793.5	0.008	3.4	43.6	166.5	0.6
Spring Creek	10-yr, 24-hr	411.8	3791.8	3794.0	3792.6	3794.2	0.007	4.6	162.4	212.7	0.6
Spring Creek	100-yr, 6-hr	727.3	3791.8	3794.4	3800.7	3794.7	0.007	5.4	238.9	227.4	0.7
South Fork Spring Creek	2-yr, 24-hr	75.0	3702.8	3704.5	3697.7	3704.7	0.009	3.5	31.2	75.4	0.6
South Fork Spring Creek	10-yr, 24-hr	291.5	3702.8	3705.3	3719.7	3705.6	0.008	4.9	96.8	108.0	0.7
South Fork Spring Creek	100-yr, 6-hr	440.1	3702.8	3705.6	3722.5	3706.0	0.009	5.6	127.9	113.9	0.7
Pearson Creek	2-yr, 24-hr	12.7	3680.8	3681.3	3766.0	3681.3	0.019	2.3	5.3	14.2	0.7
Pearson Creek	10-yr, 24-hr	84.6	3680.8	3682.1	3719.3	3682.3	0.016	4.1	22.6	28.5	0.8
Pearson Creek	100-yr, 6-hr	164.5	3680.8	3682.5	3682.4	3682.8	0.015	4.9	44.1	75.1	0.8
South Fork Pearson Creek	2-yr, 24-hr	36.1	3626.7	3627.6	3601.1	3627.7	0.014	3.2	11.7	16.9	0.7
South Fork Pearson Creek	10-yr, 24-hr	185.6	3626.7	3628.5	3628.5	3628.8	0.010	4.6	60.4	113.6	0.7
South Fork Pearson Creek	100-yr, 6-hr	333.6	3626.7	3628.8	3628.8	3629.2	0.011	5.5	96.3	125.6	0.7

The conceptual geometry was considered a premine approximation when the depths of flow and mean channel velocities were approximately the premining HEC-RAS parameters. Please note that the values shown in Table J-6 are hydraulic parameters and not construction dimensions. For example the top width shown is the top width of the water at the peak discharge during a specific storm event and not the top width of the reconstructed floodplain cross section.

Table J-6a provides a comparison of the premine and estimated postmine hydraulic characteristics: velocity, flow area, and top width. The postmine channel design of the major SCM drainages will conform with the method presented in Section 3.5.2. Although the channels were evaluated with consistent channel cross sections, the belt widths will vary with the inner pilot channel allowed to develop naturally. Final designs will be submitted to MDEQ for review and approval prior to construction.

Table J-6a. HEC-RAS Average Comparison For 100-yr, 6-hr Storm Event

Stream Channel	Q Total (cfs)			Vel Chnl (ft/s)			Flow Area			Top Width (ft)		
	Pre	Post	Percent Difference	Pre	Post	Percent Difference	Pre	Post	Percent Difference	Pre	Post	Percent Difference
Spring Creek	401.00	375.21	6.87%	4.20	4.63	-9.36%	141.50	146.36	-3.32%	159.60	196.57	-18.81%
South Fork Spring Creek	316.10	355.84	-11.17%	5.20	5.44	-4.41%	87.30	107.78	-19.00%	85.20	118.75	-28.25%
Pearson Creek	382.10	354.63	7.75%	5.20	5.61	-7.31%	84.80	97.78	13.27%	78.90	112.98	-34.16%

As discussed above, the 2-year inner pilot channel will not be constructed when the reclamation is constructed. The pilot channel will be allowed to establish naturally as described in Section 3.5.2, Minor Tributaries. However, based upon modeling the following pilot channel sizes may establish over time. The following conceptual dimensions were used in the HEC-RAS analysis to estimate the flood irrigable land for comparison to premine values. The conceptual channel and floodplain geometry for Spring Creek consisted of a 6-foot wide inner low-flow channel with 4H:1V side slopes to a depth of 1.5 feet and an approximate 200-foot wide floodplain. The conceptual channel and floodplain geometry for South Fork Spring Creek consisted of a 6-foot wide inner low-flow channel with 4H:1V side slopes to a depth of 1.5 feet and an approximate 100-foot wide floodplain as shown on Plate J-6. The conceptual channel and floodplain geometry for North Fork Spring Creek consisted of a 6-foot wide inner low-flow channel with 4H:1V side slopes to a depth of 1.0-foot and an approximate 100-foot wide floodplain. The conceptual channel and floodplain geometry for Pearson Creek and South Fork Pearson Creek consisted of a 6-foot wide inner low-flow channel with 4H:1V side slopes to a depth of 1.5-foot and an approximate 100-foot wide floodplain.

The restored North Fork Spring Creek channel will flow north to south through the Spring Creek Drainage area PMT in a gentle meandering pattern to the NE¼ SE¼ Section 15 where it will join Spring Creek. The channel has been designed with a slope that is similar to premining conditions.

The premine South Fork Spring Creek channel and floodplain had a potential for flood irrigation of 38 acres. The premine 2-yr flood had an average top width of 24 feet over a channel length of approximately 37,000 feet inside the disturbance boundary. Therefore, the 2-yr flood would inundate approximately 20 acres. The remaining lands would be irrigable through irrigation systems along the premine flood plain. The conceptual geometry for the postmining South Fork Spring Creek during the 2-yr flood as shown on Plate J-6 has an average top width of 18 feet over a channel length of approximately 40,700 feet inside the disturbance boundary, which provides 17 acres of inundation. The average belt width for the postmine channel is 141.5-feet wide (Plate J-6). Therefore, the reclaimed South Fork Spring Creek channel exceeds the 38 acres of potential flood irrigable lands that were there present premining.

Plates 4 and 4B show comparisons of the premine and postmine geomorphology. These plates have comparisons of geomorphology parameters such as: drainage density, channel sinuosity, and valley length. The geomorphology parameters shown were used comparing the overall postmine watershed to the premine watershed to optimize the postmine topography design to be as similar as possible to the premine topography.

3.5.1 Topsoil Replacement Within the Major Channels

The soil balance calculations for replacement depths within the Spring Creek and North Fork Spring Creek included two soil series as mapped on Plate A1-1 in Appendix A-1. These are Harlake and Alluvial soils, loamy. The soil balance calculations for replacement depths within the South Fork channel included the alluvial soil series as mapped on Plate 24, (Volume 4). The reclaimed channel configuration for the major reclaimed channels is shown on Plate 4. SCM proposes replacing alluvial soil and suitable plant growth medium within the major reclaimed drainages as shown in Table

313-3a. Addendum 313A also shows the estimated overall alluvial and topsoil balance.

3.5.2 Reconstructed Channels

Minor channels will be constructed according to Tables I-7, I-8, and I-9. These tables display construction criteria for the three common channel types at SCM. Tables J-7 through J-9 were developed using the design principles outlined in MDEQ's "Guideline for Reclamation of Drainage Basins and Channels Disturbed by Surface Coal Mining" and the channel characteristics described in "Catena, Geoecology and Landscape Evolution" (Rosgen, 1994).

Bankfull widths versus drainage area for southeastern Montana are shown on Appendix B, Figure 1 of the MDEQ guidelines. The bankfull width occurs during bankfull discharge, which is described as "the momentary maximum peak flow; one which occurs several days in a year and is often related to the 1.5 year recurrence interval discharge" (Rosgen 1994). Using the regression equation for southeast Montana, as presented in Appendix B, Figure 1 of the MDEQ guidelines, bankfull widths for different drainage areas can be calculated. The calculated bankfull widths are presented on Tables J-7 through J-9. Constructed valley bottom/floodplain side slopes will vary, generally with 2-3H:1V side slopes, but may be steeper or gentler to fit adjacent topography and/or approximate similar premine or undisturbed conditions. Natural channel development within constructed floodplains is expected to result in smaller, generally steeper side slopes.

Reclaimed drainage basins, valleys, floodplains, and channels will approximate relevant premine characteristics and natural variability. As necessary, the dimensions shown on Tables J-7 through J-9 may be adjusted to blend with adjacent native drainage basins and channel features.

Table J-7. Type A Stream Reclamation Standards

TYPE A (4%-6%)			
DRAINAGE AREA (acres)	BANKFULL WIDTH (ft)	BELT WIDTH (ft)	
		Min	Max
1	0.8	**2**	**2**
10	1.7	**4**	**5**
20	2.0	**5**	**6**
30	2.3	**6**	**7**
40	2.5	**6**	**8**
50	2.7	**6**	**8**
60	2.9	**7**	**9**
70	3.0	**7**	**9**
80	3.1	**8**	**9**
90	3.2	**8**	**10**
100	3.3	**8**	**10**
150	3.8	**9**	**11**
200	4.1	**10**	**12**
250	4.4	**11**	**13**
300	4.7	**11**	**14**

TYPE A (6%-8%)			
DRAINAGE AREA (acres)	BANKFULL WIDTH (ft)	BELT WIDTH (ft)	
		Min	Max
1	0.8	**1**	**2**
10	1.7	**3**	**4**
20	2.0	**3**	**5**
30	2.3	**4**	**6**
40	2.5	**4**	**6**
50	2.7	**5**	**6**
60	2.9	**5**	**7**
70	3.0	**5**	**7**
80	3.1	**5**	**8**
90	3.2	**6**	**8**
100	3.3	**6**	**8**
150	3.8	**6**	**9**
200	4.1	**7**	**10**
250	4.4	**8**	**11**
300	4.7	**8**	**11**

TYPE A (8%-10%)			
DRAINAGE AREA (acres)	BANKFULL WIDTH (ft)	BELT WIDTH (ft)	
		Min	Max
1	0.8	**1**	**1**
10	1.7	**2**	**3**
20	2.0	**2**	**3**
30	2.3	**2**	**4**
40	2.5	**3**	**4**
50	2.7	**3**	**5**
60	2.9	**3**	**5**
70	3.0	**3**	**5**
80	3.1	**3**	**5**
90	3.2	**3**	**6**
100	3.3	**3**	**6**
150	3.8	**4**	**6**
200	4.1	**4**	**7**
250	4.4	**4**	**8**
300	4.7	**5**	**8**

* The bankfull width was estimated using the following regression equation: $y = 5.9148x^{0.3068}$ (MDEQ, 2002) The regression equation only shows drainages from 1 to 300 acres it will approximate bankfull widths for drainages as large as approximately 450 square miles.

**The belt width (approximate floodplain width) was estimated using Rosgen's range of meander width ratios for each channel type (e.g. Figure 3; Rosgen 1994). It has been assumed that the developed flood plain width will be capable of safely passing the 100-year, 6-hour flood.

Table J-8. Type B Stream Reclamation Standards

TYPE B (2%-2.7%)				TYPE B (2.7%-3.3%)				TYPE B (3.3%-4%)			
		BELT WIDTH (ft)				BELT WIDTH (ft)				BELT WIDTH (ft)	
DRAINAGE AREA (acres)	BANKFULL WIDTH (ft)	Min	Max	DRAINAGE AREA (acres)	BANKFULL WIDTH (ft)	Min	Max	DRAINAGE AREA (acres)	BANKFULL WIDTH (ft)	Min	Max
1	0.8	**5**	**7**	1	0.8	**3**	**5**	1	0.8	**2**	**3**
10	1.7	**10**	**13**	10	1.7	**7**	**10**	10	1.7	**3**	**7**
20	2.0	**12**	**16**	20	2.0	**8**	**12**	20	2.0	**4**	**8**
30	2.3	**14**	**19**	30	2.3	**9**	**14**	30	2.3	**5**	**9**
40	2.5	**15**	**20**	40	2.5	**10**	**15**	40	2.5	**5**	**10**
50	2.7	**16**	**22**	50	2.7	**11**	**16**	50	2.7	**5**	**11**
60	2.9	**17**	**23**	60	2.9	**11**	**17**	60	2.9	**6**	**11**
70	3.0	**18**	**24**	70	3.0	**12**	**18**	70	3.0	**6**	**12**
80	3.1	**19**	**25**	80	3.1	**13**	**19**	80	3.1	**6**	**13**
90	3.2	**19**	**26**	90	3.2	**13**	**19**	90	3.2	**6**	**13**
100	3.3	**20**	**27**	100	3.3	**13**	**20**	100	3.3	**7**	**13**
150	3.8	**23**	**30**	150	3.8	**15**	**23**	150	3.8	**8**	**15**
200	4.1	**25**	**33**	200	4.1	**17**	**25**	200	4.1	**8**	**17**
250	4.4	**27**	**35**	250	4.4	**18**	**27**	250	4.4	**9**	**18**
300	4.7	**28**	**38**	300	4.7	**19**	**28**	300	4.7	**9**	**19**
350	4.9	**29**	**39**	350	4.9	**20**	**29**	350	4.9	**10**	**20**
400	5.1	**31**	**41**	400	5.1	**20**	**31**	400	5.1	**10**	**20**
450	5.3	**32**	**42**	450	5.3	**21**	**32**	450	5.3	**11**	**21**
500	5.5	**33**	**44**	500	5.5	**22**	**33**	500	5.5	**11**	**22**
600	5.8	**35**	**46**	600	5.8	**23**	**35**	600	5.8	**12**	**23**
700	6.1	**36**	**49**	700	6.1	**24**	**36**	700	6.1	**12**	**24**

* The bankfull width was estimated using the following regression equation: $y = 5.9148x^{0.3068}$ (MDEQ, 2002) The regression equation only shows drainages from 1 to 700 acres it will approximate bankfull widths for drainages as large as approximately 450 square miles.

**The belt width (approximate floodplain width) was estimated using Rosgen's range of meander width ratios for each channel type (e.g. Figure 3; Rosgen 1994). It has been assumed that the developed flood plain width will be capable of safely passing the 100-year, 6-hour flood.

Table J-9. Type C Stream Reclamation Standards

TYPE C (0.5%-1%)				TYPE C (1%-1.5%)				TYPE C (1.5%-2%)			
DRAINAGE AREA (acres)	BANKFULL WIDTH (ft)	BELT WIDTH (ft)		DRAINAGE AREA (acres)	BANKFULL WIDTH (ft)	BELT WIDTH (ft)		DRAINAGE AREA (acres)	BANKFULL WIDTH (ft)	BELT WIDTH (ft)	
		Min	Max			Min	Max			Min	Max
1	0.8	**10**	**14**	1	0.8	**7**	**10**	1	0.8	**4**	**7**
10	1.7	**20**	**27**	10	1.7	**14**	**20**	10	1.7	**7**	**14**
20	2.0	**25**	**33**	20	2.0	**17**	**25**	20	2.0	**9**	**17**
30	2.3	**28**	**38**	30	2.3	**19**	**28**	30	2.3	**10**	**19**
40	2.5	**31**	**41**	40	2.5	**21**	**31**	40	2.5	**11**	**21**
50	2.7	**33**	**44**	50	2.7	**22**	**33**	50	2.7	**11**	**22**
60	2.9	**35**	**46**	60	2.9	**23**	**35**	60	2.9	**12**	**23**
70	3.0	**36**	**48**	70	3.0	**24**	**36**	70	3.0	**12**	**24**
80	3.1	**38**	**51**	80	3.1	**26**	**38**	80	3.1	**13**	**26**
90	3.2	**39**	**52**	90	3.2	**26**	**39**	90	3.2	**13**	**26**
100	3.3	**41**	**54**	100	3.3	**27**	**41**	100	3.3	**14**	**27**
150	3.8	**46**	**61**	150	3.8	**31**	**46**	150	3.8	**16**	**31**
200	4.1	**50**	**67**	200	4.1	**34**	**50**	200	4.1	**17**	**34**
250	4.4	**54**	**71**	250	4.4	**36**	**54**	250	4.4	**18**	**36**
300	4.7	**57**	**76**	300	4.7	**38**	**57**	300	4.7	**19**	**38**
350	4.9	**59**	**79**	350	4.9	**40**	**59**	350	4.9	**20**	**40**
400	5.1	**62**	**82**	400	5.1	**41**	**62**	400	5.1	**21**	**41**
450	5.3	**64**	**85**	450	5.3	**43**	**64**	450	5.3	**22**	**43**
500	5.5	**66**	**88**	500	5.5	**44**	**66**	500	5.5	**22**	**44**
600	5.8	**70**	**93**	600	5.8	**47**	**70**	600	5.8	**24**	**47**
700	6.1	**73**	**98**	700	6.1	**49**	**73**	700	6.1	**25**	**49**

* The bankfull width was estimated using the following regression equation: $y = 5.9148x^{0.3068}$ (MDEQ, 2002) The regression equation only shows drainages from 1 to 700 acres it will approximate bankfull widths for drainages as large as approximately 450 square miles.

**The belt width (approximate floodplain width) was estimated using Rosgen's range of meander width ratios for each channel type (e.g. Figure 3; Rosgen 1994). It has been assumed that the developed flood plain width will be capable of safely passing the 100-year, 6-hour flood.

The system for the classification of natural rivers (Rosgen, 1994) was used to classify the streams at SCM. A type-A channel will generally have slopes that range from 4% to 10%, a type-B channel will have slopes that range from 2% to 4%, and a type-C channel will have slopes less than 2%. These slope ranges represent all of the postmine channels at SCM. The method (Rosgen, 1994) also outlines the meander width ratios for each stream type. The meander width ratio (MWR) is described as the ratio of the beltwidth to the bankfull width. The MWR values used for each stream type are shown in Table J-10.

Table J-10. Meander Width Ratios for Different Stream Types

	Slope		**Meander/Width Ratio**	
Stream Type	**Minimum**	**Maximum**	**Minimum**	**Maximum**
A	8.0%	10.0%	1.0	1.7
A	6.0%	8.0%	1.7	2.4
A	4.0%	6.0%	2.4	3.0
B	3.3%	4.0%	2.0	4.0
B	2.7%	3.3%	4.0	6.0
B	2.0%	2.7%	6.0	8.0
C	1.5%	2.0%	4.0	8.0
C	1.0%	1.5%	8.0	12.0
C	0.5%	1.0%	12.0	16.0

Three generic channel design tables for type-A, type-B, and type-C channels, were developed for SCM. The slopes corresponding to each stream type were divided into three groups to create more variation in construction at SCM.

Tables J-7 to J-9 were developed using 10-acre, 50-acre, and 100-acre increments for each channel type. Using the drainage area for the channel and the bankfull width regression equation discussed above, anticipated bankfull widths were calculated for each channel type.

It was determined through discussions with MDEQ, that channels with a more gradual slope will have more meander and a larger MWR. The range of MWR presented by Rosgen was divided into three representative values, which were then multiplied by the bankfull widths determined for the various drainage areas. As the slope for each channel type increases, the MWR multiplier is decreased. The resulting belt width is displayed in each table. SCM will construct their minor channel according to the range of belt widths displayed in the three tables. A single channel may require multiple belt width ranges depending on the slope of the channel and the size of the upstream drainage area.

Through discussions with MDEQ, it was determined that SCM will be required to construct the belt width for all channels. The belt width will have a flat bottom, constructed at a range of widths as specified in Tables J-7 through J-9. A flat channel bottom will not be required when the maximum belt width is narrower than the width of available reclamation equipment. To determine the appropriate belt width, the channel slope and the drainage area will have to be determined. To develop a channel that has more natural appearance, the sides of the channel will be blended into the approved postmining topography, as necessary. As requested by MDEQ, the low-flow channel will be allowed to develop naturally within the constructed belt width, through geomorphic and erosional processes. Since this process will produce sediment at times (mostly topsoil), the sediment will be collected and used at other locations around the mine. The mine does not intend (as agreed by MDEQ) to repair the normal channel erosional feature developed as part of the natural development of the bankfull channel.

Tables J-7 through J-10 are not intended for the design of major channels, but will be used as a guide in the final design of the major channel designs. SCM commits to submitting drainage designs for Spring Creek, North Fork Spring Creek, South Fork Spring Creek, Pearson Creek and South Fork Pearson Creek to the Department prior to construction.

3.6 Reclamation Hydrologic Control

See Appendix K, Section 8.0 for the Postmine Hydrologic Control Plan.

3.7 Postmining Ponds and Impoundments

Postmining impoundments may be necessary within the Spring Creek Drainage area PMT. In general, permanent postmining ponds and impoundments will be reduced from the operational sediment control design volumes to minimize disturbance to the premine hydrologic balance. In this way permanent ponds and impoundments will provide more frequent (e.g., annual) discharges to minimize impacts to downstream hydrologic and vegetative characteristics. Pond and impoundment details will be determined after the basin above is reclaimed and normal flows and ponding levels are more apparent.

All permanent ponds and impoundments will be approved by the Department prior to construction and will meet the requirements of ARM 17.24.639, and 17.24.642. The final design and location of any postmining pond or impoundment will be determined after discussing the location with the landowner, MDEQ and the Army Corp of Engineers. Refer to Section 17.24.642 for a more detailed discussion on postmining impoundments.

4.0 GROUNDWATER RESTORATION

See Appendix L, Probable Hydrologic Consequences Update, for a detailed discussion of groundwater impacts and restoration.

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