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TECHNICAL REPORT SURFACE-WATER AND GROUNDWATER RESOURCES IN THE FLAT CANYON AREA

Submitted to:

MANTI-LA SAL NATIONAL FOREST

AND

BUREAU OF LAND MANAGEMENT, UTAH STATE OFFICE

October 21, 2000

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OCT 24 2000

October 21, 2000

Carter Reed
Forest Geologist
USDA Forest Service
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Price, UT 84501

Dear Carter:

Enclosed are four copies of the Final Technical Report on Hydrology. The other copy will be delivered to BLM.

Our responses to each of your comments is attached to this letter.

We will look forward to your final approval of this report. It makes sense for us to wait and provide you with the electronic version of the reports and the hard copy of references until you have declared the three technical reports to be final.

Please contact me if you have any questions.

Yours truly
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1.0 INTRODUCTION

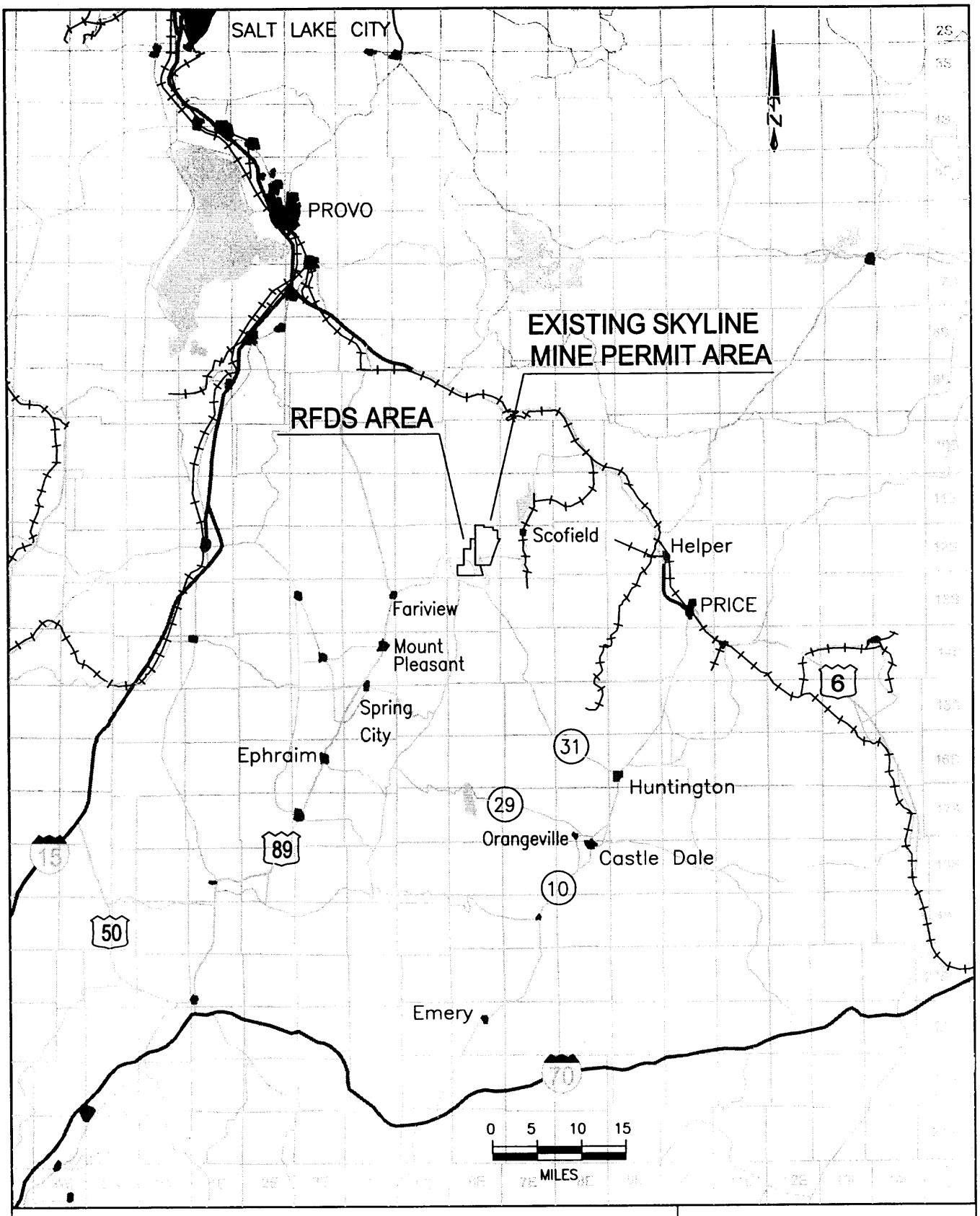
Canyon Fuel Company, LLC (CFC), submitted a Federal Lease Application to the Bureau of Land Management (BLM) for the Flat Canyon Tract (Tract) in March of 1998. A joint Manti-LaSal Forest Service (FS)/BLM Tract Delineation Team (TDT) ratified the Tract boundaries as submitted by CFC in August 1999.

The Tract is just west of the Wasatch Plateau Known Recoverable Coal Resource Area. The surface of the area is managed by the FS and the mineral estate by the BLM. The FS and BLM (Utah State Office) jointly determined that an Environment Impact Statement would be required as a basis for leasing decisions. The Office of Surface Mining (OSM) and Bureau of Reclamation (BOR) will participate as co-operating agencies.

The Tract encompasses some 2,692 acres immediately west of the existing CFC Skyline Mine as shown generally on Figure 1.1 and more particularly on Figure 1.2. Effects of mining the Tract may spill over into neighboring areas. The greater area of influence is termed the Reasonably Foreseeable Development Scenario Area (RFDS Area). While the terms Tract and RFDS Area define slightly different footprints, they are often used interchangeably in this Report.

This technical report describes groundwater and surface water resources in the Flat Canyon Coal Lease Tract and the adjacent fee lands (Figure 1.2). Together the tract and the private lands are described as the 'RFDS area' in this report. The study area for this investigation extends beyond the RFDS as shown in Figure 1.2. This investigation relies on data, information, and experience from the existing Skyline Mine permit area (Figure 1.2), which is east of and contiguous with the RFDS area. This area is referred to throughout this report as the Skyline Mine area.

The EIS Summary is attached as Appendix A. The Table of Resource Element Evaluation is attached as Appendix B.



LEGEND

- RAILROAD
- HIGHWAY
- ROAD
- LAKE/RIVER
- CITY

DETAIL AREA

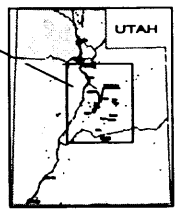


FIGURE 1.1

PROJECT LOCATION MAP

DATE: 10/18/2000

FILE: 2439LOCATION

NorWest

2.0 SURFACE WATER

All surface waters in the study area, with a single exception, drain into Upper Huntington Creek, which is a tributary of the San Rafael River. The San Rafael River flows into the Green River approximately 80 miles southeast of the study area. A small portion (< 6%) of the study area is in the Upper Gooseberry Creek drainage. Upper Gooseberry Creek flows into Fish Creek above the Scofield Reservoir on the Price River. The Price River flows into the Green River approximately 60 miles southeast of the study area. The region of investigation for this analysis is an area of approximately 12.7 square miles.

Perennial stream reaches have been identified in Boulger, Flat, Swens, Little Swens, and Cunningham Canyons. Upper Huntington Creek, which defines the northern and eastern boundaries of the study area, is also a perennial stream. In order to simplify the characterization and analysis of surface water systems in the study area, the surface water drainages have been divided into sub-basins. These sub-basins are shown on Figure 2.1. Also shown on Figure 2.1 are the reaches of the individual streams that have been classified as perennial for this analysis.

Several drainages that have not previously been classified as perennial were determined to possibly be perennial as a part of this study. These reaches are indicated on Figure 1.2. Determinations of possibly perennial were based on field observations of streamflow and vegetation types and through inspection of aerial photographs.

The specific characteristics of each sub-basin in the study area are described below.

2.1 FLAT CANYON SUB-BASIN

The Flat Canyon sub-basin includes an area of 1.76 square miles, which is approximately 13.8% of the study area. The gradient in Flat Canyon, approximately 0.93%, is the lowest of any of the sub-basins in the RFDS area. Flat Canyon is so called because of the broad, flat-bottomed valley floor through which Flat Canyon Creek flows. The broad riparian corridor in Flat Canyon is up to 1,000 feet wide. Flat Canyon Creek, in its upper reaches, where it meanders through the broad alluvial valley, is a Rosgen (1996) E5 type stream. This reach is dominated by run features. The channel substrate underlying the creek in Flat Canyon consists primarily of thick, saturated

Table 1.2 Flat Canyon Area Average Water Quality Data

Site	n	pH	Cond. µS/cm	HCO3 mg/L	CO3 mg/L	T Alk. mg/L	As (D) mg/L	B (D) mg/L	Cd (D) mg/L	Ca (D) mg/L	Cl mg/L	Hard. mg/L	Fe (D) mg/L	Fe (T) mg/L	Pb (D) mg/L	Mg (D) mg/L	Mn (D) mg/L	Mn (T) mg/L	Hg (D) mg/L	NO3 mg/L	NO2 mg/L	O&G mg/L	D.O. mg/L	PO4 mg/L	K mg/L	Se mg/L	Na (D) mg/L	TDS mg/L	TSS mg/L	SO4 mg/L	Turb NTU
Springs																															
2-413	5	7.7	339	245	0	201	0	0.16	0	62.2	4.2	192	0	1.54	0	9	0	0	0.04	1.8	0			0.006	0	0	2.2	231		4.4	
3-290	5	7.4	270	199	0	163	0	0.12	0	50.0	1.6	159	0	0.54	0	7.8	0	0	0	0.4	0			0.022	0	0	2.4	188		4	
4-173	5	7.2	243	195	0	160	0	0.14	0	48.0	1.6	158	0	0.14	0	9.2	0	0	0	1.0	0			0.016	0	0	2	185		5.2	
5-231	5	7.1	194	142	0	117	0	0.16	0	38.2	1	113	0	0.72	0	4.2	0	0	0	0.4	0			0.046	0	0	1.8	142		7.8	
5-238	1	7.2	459	267	0	219	0	0.2	0	71.0	10	210	0	0	0	8	0	0	0	0.6	0			0.02	0	0	4	230		0	
5-253	5	6.8	122	92	0	75	0	0.1	0	23.8	0.4	69	0	0.02	0	2.4	0	0	0	1.0	0			0.004	0	0	1	88		5.6	
21-222	5	7.4	286	203	0	166	0	0.1	0	48.6	0.8	168	0	0.32	0	11.2	0	0	0	1.1	0			0.006	0	0	1.6	190		6.6	
28-110	5	7.5	312	225	0	184	0	0.16	0	55.6	1.6	179	0	0.44	0	9.8	0	0.04	0	0.5	0			0.006	0	0	2.2	207		7	
29-133	5	7.4	278	211	0	173	0	0.16	0	59.4	1.2	168	0	0	0	4.8	0	0	0	0.6	0			0.01	0	0	2	194		5.4	
29-138	5	7.2	417	300	0	246	0	0.14	0	82.2	3.6	219	0	0.1	0	8.2	0	0	0	0.4	0			0.006	0	0	2.4	271		4	
31-181	1	7.4	484	309	0	254	0	0.2	0	86.0	2	248	0	0	0	8	0	0	0	0.0	0			0.02	0	0	1	280		5	
32-183	5	7.0	159	120	0	98	0	0.14	0	28.4	0.8	92	0	0.02	0	5.2	0	0	0	0.4	0			0.004	0	0	1.6	123		5.2	
32-277	5	7.2	207	163	0	134	0	0.175	0	40.3	1	129	0	1.175	0	6.75	0	0.05	0	0.9	0			0.01	0.25	0	1.5	169		7.75	
32-279	5	7.3	310	239	0	196	0	0.14	0	54.2	1	197	0	0	0	15	0	0	0	1.0	0			0.002	0	0	1.8	224		8.4	
33-268	2	7.4	87	46	0	42	0	0.1	0	13.5	2	42	0	3.45	0	2	0	0	0	0.9	0			0.06	0	0	1.5	72		7	
33-271	1	6.5	98	47	0	39	0	0.1	0	13.0	2	45	0	0	0	3	0	0	0	0.6	0			0.08	0	0	0	60		0	
33-273	1	7.3	295	160	0	131	0	0.2	0	48.0	3	145	0	0	0	6	0	0	0	0.3	0			0.13	0	0	1	140		17	
MSS-1	1	7.7	370	236	0	193	0	0	0	59.0	2	180	0	0.9	0	8	0	0	0	0.4	0			0.03	0	0	2	240		10	
Spring-Supplied Water Tanks																															
4-429	2	7.3	141	84	0	69	0	0.1	0	21.5	1	70	0	0	0	4	0	0	0	0.7	0			0.065	0	0	1.5	78		1.5	
33-276	1	7.2	5	260	0	213	0	0.2	0	58.0	2	202	0	0	0	14	0	0	0	1.0	0			0.02	0	0	3	220		7	
MST-1	1	7.8	369	237	0	194	0	0	0	62.0	1	188	0	0	0	8	0	0	0	0.3	0			0.03	0	0	1	200		0	
MST-2	1	8.2	195	112	0	92	0	0	0	30.0	2	83	0	0	0	2	0	0	0	0.3	0			0.03	0	0	2	140		0	
MST-3	2	8.0	327	270	0	221	0	0	0	57.0	2	208	0	0	0	16	0	0	0	0.2	0			0.02	0	0	2	250		6	
Creeks																															
C-1	5	8.0	213	130	0	107	0	0.16	0	38.4	3	114	0.08	0.64	0	4.4	0	0	0	0.3	0	0	4.7	0.006	0.2	0	2.4	150	3	15.2	
C-2	5	8.3	242	175	3	154	0	0.125	0	49.3	1.75	147	0	0.125	0	6.25	0	0	0	0.7	0	0	4.6	0.005	0.25	0	1.75	181	5.25	7.5	
C-3	5	8.4	259	192	4	176	0	0.16	0	52.2	1	156	0	0.3	0	6.4	0	0	0	0.3	0.028	0.6	4.9	0.006	0.2	0	1.6	190	4.2	6.2	
C-4	5	8.3	251	160	3	137	0	0.1	0	42.2	3.6	133	0	0.18	0	6.6	0	0	0	0.6	0	0	4.65	0.004	0	0	2.4	161	2.2	5.4	
C-5	5	7.8	212	148	0	121	0	0.06	0	36.8	1.4	116	0	0.2	0	5.8	0	0.02	0	0.4	0	0	4.5	0.006	0	0	2.4	146	5.6	4.6	
C-6	1	8.2	268	169	0	139	0	0.2	0	46.0	5	144	0	0.2	0	7	0	0	0	0.7	0	0	5.1	0	0	0	4	169	6	7	
C-7	1	8.4	236	172	0	141	0	0.1	0	41.0	0	131	0	0.2	0	7	0	0	0	0.3	0	0	5.3	0	0	0	2	151	9	3	
C-8	1	8.4	252	164	0	134	0	0.1	0	44.0	1	135	0	0.1	0	6	0	0	0	0.8	0	0	5.5	0	0	0	2	156	0	4	
CS-10	70	7.5	237	133	1	112	0	0.0282	0	38.6	3.13	120	0.17	0.74	0.0006	4.58	0.016	0.032		0.1	0	0.2111	8.5	0.01	0.51	0	4.25	139	4.88	17.27	10.92
CS-7	62	7.9	375	226	2	193	0	0.0373	0	61.1	3.42	198	0.01	0.16	0.0007	11.49	0	0.0077		0.5	0	0.3	7.9	0.01	0.44	0	4.95	208	7.07	13.31	3.78
CS-8	71	7.6	300	188	3	162	0	0.0405	0	50.0	8.02	181	0.02	0.37	0	8.51	0	0.0128		0.3		0.15	8.5	0.02	0.45	0	6.21	191	6.84	16.80	6.59
UPL-10	69	7.9	295	183	2	154	0	0.0282	0	53.0	6.30	158	0.05	0.36	0.0003	9.91	0.002	0.0183		0.1	0	3.225	8.4	0.02	0.54	0	3.67	182	4.78	14.28	8.71

Table 1.3 Unstable Isotopic Compositions

Site	Date	^{14}C (pmC)	^{3}H (TU)
2-413	10/8/97	95.71	14.9
2-413	7/22/98	91.68	15
7-242	10/9/97	73.52	10.5
8-253	10/9/97	84.39	29.7
8-253	7/21/98	79.06	30
29-138	10/8/97	88.58	12.9
29-138	7/21/98	90.96	14
32-279	10/9/97	68.62	14.0
32-279	7/21/98	71.67	15
MST-3	9/11/97		13.1
MST-3	7/21/98	71.35	10.3

Table 1.1 Flat Canyon Tract Baseline Hydrologic Data (continued)

Site	Date	pH	Flow gpm	Cond. µS/cm	Temp. °C	HCO3 mg/L	CO3 mg/L	T Alk. mg/L	As (D) mg/L	B (D) mg/L	Cd (D) mg/L	Ca (D) mg/L	Cl mg/L	Hard. mg/L	Fe (D) mg/L	Fe (T) mg/L	Pb (D) mg/L	Mg (D) mg/L	Mn (D) mg/L	Mn (T) mg/L	Hg (D) mg/L	NO3 mg/L	NO2 mg/L	O&G mg/L	D.O. mg/L	PO4 mg/L	K mg/L	Se mg/L	Na (D) mg/L	TDS mg/L	TSS mg/L	SO4 mg/L	Turb NTU
29-133	10/8/97	7.2	20	278	8.5	205	0	168	0	0.3	0	60	2	170	0	0	0	5	0	0	0	0	0			0.03	0	0	2	180		6	
29-133	7/21/98	6.9	60	230	3.4	205	<5	168	<0.01	0.1	<0.01	60	1	166	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	0.3	<0.03			0.02	<1	<0.01	1	212		6	
29-133	10/13/98	7.8	15	270	3.4	224	<5	184	<0.01	0.1	<0.01	61	2	169	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	0.4	<0.03			<0.05	<1	<0.01	2	203		5	
29-133	7/8/99	7.47	60	290	2.5	205	<5	168	<0.01	0.1	<0.01	56	<1	156	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	1.23	<0.03			<0.05	<1	<0.01	3	181		4	
29-133	10/19/99	7.5	25	322	2.9	215	<5	176	<0.01	0.2	<0.01	60	1	179	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.2	0.91	<0.03			<0.05	<1	<0.01	2	195		6	
29-138	10/8/97	7.0	15	478	6.4	300	0	246	0	0.2	0	79	2	226	0	0.5	0	7	0	0	0	0	0			0.03	0	0	2	280		5	
29-138	7/21/98	7	30	350	4.8	299	<5	245	<0.01	0.1	<0.01	85	13	241	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.2	0.2	<0.03			<0.01	<1	<0.01	2	293		3	
29-138	10/13/98	7.6	1.7	390	5.9	307	<5	252	<0.01	0.1	<0.01	85	2	145	<0.1	<0.1	<0.1	8	<0.1	<0.1	<0.2	0.3	<0.03			<0.05	<1	<0.01	2	270		4	
29-138	7/8/99	7.34	28	420	3.9	295	<5	242	<0.01	0.2	<0.01	78	<1	224	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.2	0.65	<0.03			<0.05	<1	<0.01	3	251		3	
29-138	10/19/99	7.28	3.1	448	5.1	300	<5	246	<0.01	0.1	<0.01	84	1	259	<0.1	<0.1	<0.1	12	<0.1	<0.1	<0.2	0.71	<0.03			<0.05	<1	<0.01	3	262		5	
31-181	10/8/97	7.4		484	4.4	309	0	254	0	0.2	0	86	2	248	0	0	0	8	0	0	0	0	0			0.02	0	0	1	280		5	
32-183	10/9/97	6.9	4	230	4.2	136	0	111	0	0.2	0	32	2	100	0	0	0	5	0	0	0	0.4	0			0.02	0	0	2	140		6	
32-183	7/21/98	5.9	17	80	3.6	95	<5	78	<0.01	<0.1	<0.01	23	1	74	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	0.3	<0.03			<0.01	<1	<0.01	1	131		4	
32-183	10/13/98	7.5	4	160	3.8	133	<5	109	<0.01	0.2	<0.01	32	1	105	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.2	0.4	<0.03			<0.05	<1	<0.01	2	134		6	
32-183	7/7/99	7.03	20	134	2.5	95	<5	78	<0.01	0.2	<0.01	22	<1	71	<0.1	0.1	<0.1	4	<0.1	<0.1	<0.2	0.4	<0.03			<0.05	<1	<0.01	1	91		4	
32-183	10/19/99	7.88	3.2	193	1.9	140	<5	114	<0.01	0.1	<0.01	33	<1	111	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.2	0.64	<0.03			<0.05	<1	<0.01	2	117		6	
32-277	10/13/97	7.5	1.5	208	6.1	163	0	134	0	0.2	0	41	2	131	0	2	0	7	0	0.2	0	0.9	0			0.04	0	0	1	180		10	
32-277	7/21/98	6.1	2.1	150	5.2	154	<5	126	<0.01	0.1	<0.01	40	1	125	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.2	0.9	<0.03			<0.01	<1	<0.01	2	176		7	
32-277	10/13/98	7.9	0.75	240	5.9	189	<5	155	<0.01	0.2	<0.01	44	1	143	<0.1	0.9	<0.1	8	<0.1	<0.1	<0.2	0.4	<0.03			<0.05	1	<0.01	2	181		8	
32-277	7/7/99	7.33	3	228	4.2	147	<5	121	<0.01	0.2	<0.01	36	<1	115	<0.1	1.8	<0.1	6	<0.1	<0.1	<0.2	1.2	<0.03			<0.05	<1	<0.01	1	137		6	
32-277	10/19/99		Damp																														
32-279	10/9/97	7.3	2.8	360	7.2	247	0	202	0	0.1	0	57	2	204	0	0	0	15	0	0	0	1	0			0.01	0	0	2	230		11	
32-279	7/21/98	7.2	2.8	210	5.6	224	<5	184	<0.01	0.1	<0.01	52	1	187	<0.1	<0.1	<0.1	14	<0.1	<0.1	<0.2	0.7	<0.03			<0.01	<1	<0.01	1	234		5	
32-279	10/13/98	7.4	0.9	310	5.9	259	<5	212	<0.01	0.1	<0.01	57	2	212	<0.1	<0.1	<0.1	17	<0.1	<0.1	<0.2	0.9	<0.03			<0.05	<1	<0.01	2	240		10	
32-279	7/7/99	7.44	6	283	4.3	215	<5	176	<0.01	0.2	<0.01	47	<1	167	<0.1	<0.1	<0.1	12	<0.1	<0.1	<0.2	1.49	<0.03			<0.05	<1	<0.01	1	190		6	
32-279	10/19/99	7.4	1.6	387	5.4	250	<5	205	<0.01	0.2	<0.01	58	<1	215	<0.1	<0.1	<0.1	17	<0.1	<0.1	<0.2	1.08	<0.03			<0.05	<1	<0.01	3	224		10	
33-268	10/13/97	6.6	1	114	3.4	46	0	37	0	0.1	0	14	2	47	0	0	0	3	0	0	0	0.9	0			0.12	0	0	1	70		9	
33-268	10/13/98	8.1	0	60	3.9	46	<5	47	<0.01	0.1	<0.01	13	2	37	<0.1	6.9	<0.1	1	<0.1	<0.1	<0.2	0.9	<0.03			<0.05	<1	<0.01	2	73		5	
33-271	10/13/97	6.5	0.25	98	3.8	47	0	39	0	0.1	0	13	2	45	0	0	0	3	0	0	0	0.6	0			0.08	0	0	0	60		0	
33-273	10/13/97	7.3	3	295	4.1	160	0	131	0	0.2	0	48	3	145	0	0	0	6	0	0	0	0.3	0			0.13	0	0	1	140		17	
MSS-1	9/11/97	7.7		370	6	236	0	193	0	0	0	59	2	180	0	0.9	0	8	0	0	0	0.4	0			0.03	0	0	2	240		10	
Spring-Supplied Water Tanks																																	
4-429	10/20/97	7.2	2	149	6	84	0	69	0	0.1	0	22	2	71	0	0	0	4	0	0	0	0	0			0.05	0	0	2	80		0	
4-429	10/19/99	7.3	1.4	133	5.8	83	<5	68	<0.01	0.1	<0.01	21	<1	69	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	1.38	<0.03			0.08	<1	<0.01	1	76		3	
32-276	10/13/97	7.2	1	4.6	6.9	260	0	213	0	0.2	0	58	2	202	0	0	0	14	0	0	0	1	0			0.02	0	0	3	220		7	

Baseline data are presented in Table 1.1. Table 1.2 reports average water quality for the period of record. Table 1.3 reports the unstable isotopic data for the RFDS area. Hydrologic monitoring sites in the RFDS area and in the Skyline Mine area are shown on Figure 1.2.

Hydrologic data has been collected at springs and creeks in the Skyline Mine area since 1981. These data were obtained in electronic format from the DOGM (2000) hydrologic database. Data from the Upper Huntington Creek drainage have been included in tabulations of average baseline hydrologic data for this report (Table 1.1).

The USGS (2000) collected daily streamflow discharge data for Boulger Creek from 1938 to 1949. No other continuous or quasi-continuous stream discharge data are known.

Information regarding water rights has been obtained from the Utah Division of Water Rights.

1.9.3 Field Visits

During early July 2000, perennial reaches of Boulger, Flat, Swens, and Little Swens Creeks were surveyed. The purpose of the survey was to evaluate and map stream morphology, bank stability, and stream ecology. As part of the survey, individual stream reaches were classified according to Rosgen's (1996) stream classification system. Also noted during the stream survey were the nature of the channel substrate (i.e., bedrock, gravel, or fines dominated), riparian vegetation types, and the general stability and vegetative cover of the canyon walls adjacent to the streams.

As part of this analysis, perennial stream reaches have been delineated based upon baseline stream discharge data, field observations of vegetation types, and through analysis of aerial photographs. As additional data are collected in the future, the delineation of perennial stream reaches may be refined.

1.10 METHODOLOGY

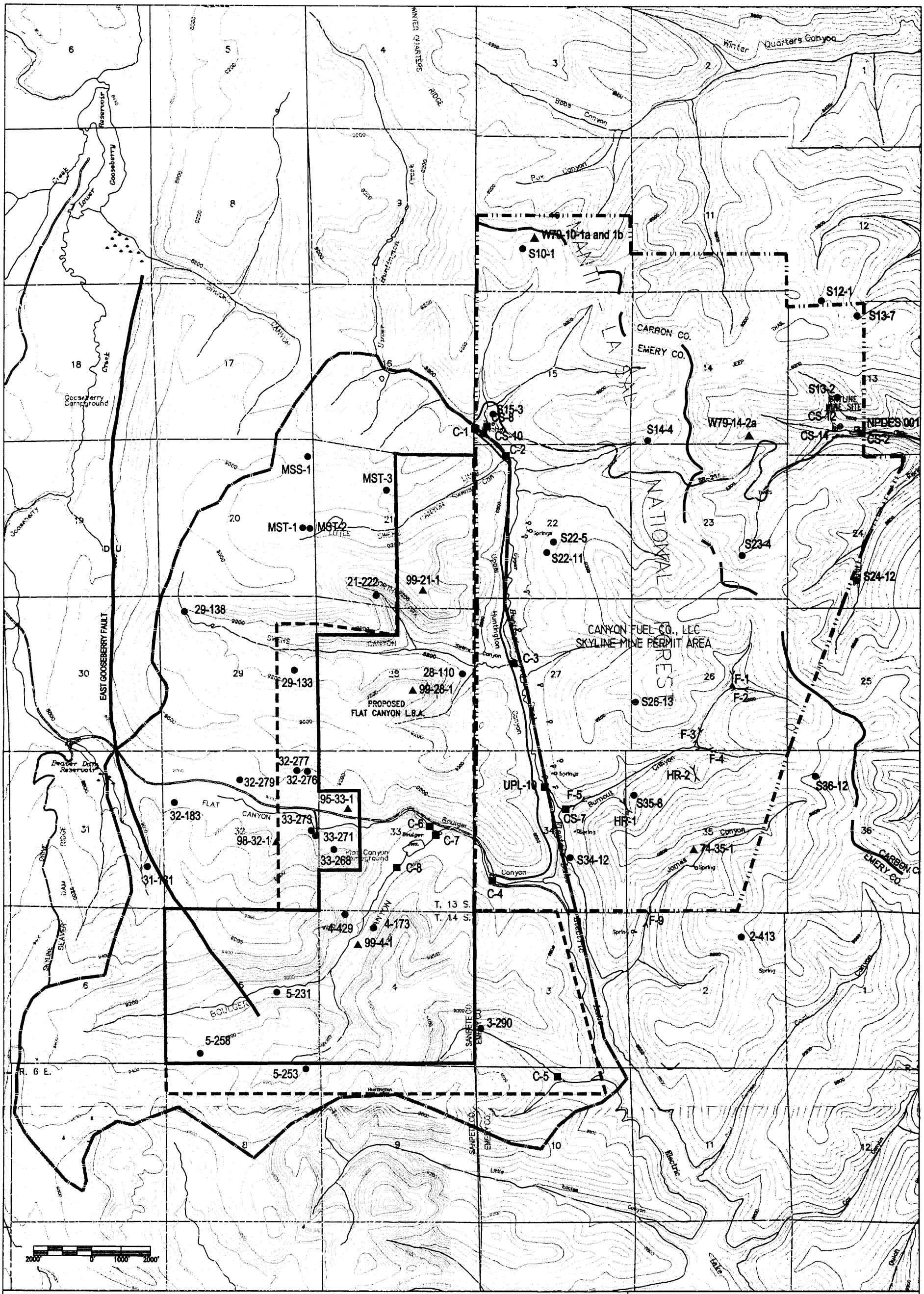
The description of hydrologic resources presented in this report is based on graphical and statistical analysis of hydrologic data collected within the study area, field observations, and hydrologic characterizations of the Skyline Mine area. Hydrologic characterizations of the Skyline Mine area are valuable for understanding surface water and groundwater conditions in the study area because the two areas have similar stratigraphy, geomorphology, climate, and vegetative cover.

Table 1.1 Flat Canyon Tract Baseline Hydrologic Data (continued)

Site	Date	pH	Flow gpm	Cond. µS/cm	Temp. °C	HCO3 mg/L	CO3 mg/L	T Alk. mg/L	As (D) mg/L	B (D) mg/L	Cd (D) mg/L	Ca (D) mg/L	Cl mg/L	Hard. mg/L	Fe (D) mg/L	Fe (T) mg/L	Pb (D) mg/L	Mg (D) mg/L	Mn (D) mg/L	Mn (T) mg/L	Hg (D) mg/L	NO3 mg/L	NO2 mg/L	O&G mg/L	D.O. mg/L	PO4 mg/L	K mg/L	Se mg/L	Na (D) mg/L	TDS mg/L	TSS mg/L	SO4 mg/L	Turb NTU
MST-1	9/11/97	7.8		369	9.6	237	0	194	0	0	0	62	1	188	0	0	0	8	0	0	0	0.3	0			0.03	0	0	1	200		0	
MST-2	9/11/97	8.2		195.2	8	112	0	92	0	0	0	30	2	83	0	0	0	2	0	0	0	0.3	0			0.03	0	0	2	140		0	
MST-3	9/11/97	7.8		423	7.9	270	0	221	0	0	0	57	2	208	0	0	0	16	0	0	0	0.2	0			0.02	0	0	2	250		6	
MST-3	7/21/98	8.2	15	230	20																												
Creeks																																	
C-1	10/20/97	7.7	0.88	239	3.2	119	0	98	0	0.1	0	34	4	101	0.2	0.7	0	4	0	0	0	0.1	0	0	4.2	0.02	0	0	4	140	0	17	
C-1	7/21/98	7.9	325	200	13.5	132	<5	108	<0.01	0.1	<0.01	38	2	107	<0.1	0.6	<0.1	3	<0.1	<0.1	<0.2	0.2	<0.01	<2		0.01	<1	<0.01	2	170	<5	10	
C-1	10/12/98	8.5	292	180	6.7	134	<5	109	<0.01	0.2	<0.01	39	4	122	0.1	0.7	<0.1	6	<0.1	<0.1	<0.2	0.2	<0.03	<2		<0.05	1	<0.01	3	151	7	18	
C-1	7/8/99	8.14	628	195	12.7	126	<5	104	<0.01	0.2	<0.01	37	2	109	0.1	0.6	<0.1	4	<0.1	<0.1	<0.2	0.34	<0.03	<2		<0.05	<1	<0.01	<1	137	<5	9	
C-1	10/19/99	7.95	140	252	-0.3	140	<5	114	<0.01	0.2	<0.01	44	3	130	<0.1	0.6	<0.1	5	<0.1	<0.1	<0.2	0.71	<0.03	<2	5.2	<0.05	<1	<0.01	3	154	8	22	
C-2	7/21/98	8.2	211	220	13.2	145	11	138	<0.01	<0.1	<0.01	46	2	135	<0.1	0.3	<0.1	5	<0.1	<0.1	<0.2	0.4	<0.03	<2		0.02	<1	<0.01	2	183	15	6	
C-2	10/12/98	8.5	16	180	3.4	181	<5	163	<0.01	0.2	<0.01	47	3	141	<0.1	0.1	<0.1	7	<0.1	<0.1	<0.2	0.4	<0.03	<2		<0.05	1	<0.01	2	176	<5	9	
C-2	7/7/99	8.4	115	244	13.4	158	<5	136	<0.01	0.1	<0.01	44	<1	130	<0.1	0.1	<0.1	5	<0.1	<0.1	<0.2	1.09	<0.03	<2		<0.05	<1	<0.01	<1	151	<5	4	
C-2	10/19/99	7.97	21	324	-0.6	216	<5	177	<0.01	0.2	<0.01	60	2	183	<0.1	<0.1	<0.1	8	<0.1	<0.1	<0.2	1	<0.03	<2	4.6	<0.05	<1	<0.01	3	214	6	11	
C-3	10/20/97	8.3	1.54	322	2.8	210	0	172	0	0.1	0	53	3	161	0	0.3	0	7	0	0	0	0.2	0	0	5.4	0.01	0	0	3	180	0	8	
C-3	7/21/98	8.5	300	230	13.1	172	12	162	<0.01	<0.1	<0.01	52	<1	150	<0.1	0.5	<0.1	5	<0.1	<0.1	<0.2	0.1	0.14	3		0.02	<1	<0.01	1	200	7	4	
C-3	10/12/98	8.3	32	220	6.7	180	<5	209	<0.01	0.4	<0.01	45	2	145	<0.1	0.2	<0.1	8	<0.1	<0.1	<0.2	0.2	<0.03	<2		<0.05	1	<0.01	2	178	<5	7	
C-3	7/7/99	8.5	300	218	13.4	182	7	161	<0.01	0.1	<0.01	52	<1	150	<0.1	0.3	<0.1	5	<0.1	<0.1	<0.2	0.4	<0.03	<2		<0.05	<1	<0.01	<1	177	9	4	
C-3	10/19/99	8.2	200	306	-0.5	215	<5	176	<0.01	0.2	<0.01	59	<1	176	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.54	<0.03	<2	4.4	<0.05	<1	<0.01	2	213	5	8	
C-4	10/20/97	8.3	4.5	279	5.7	161	0	136	0	0.1	0	39	6	122	0	0.2	0	6	0	0	0	0.9	0	0	5.1	0.02	0	0	4	140	0	7	
C-4	7/21/98	8.1	1828	250	14.8	148	14	144	<0.01	<0.1	<0.01	46	3	145	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.1	<0.03	<2		<0.01	<1	<0.01	2	190	<5	5	
C-4	10/12/98	8.3	964	200	10.1	158	<5	129	<0.01	0.2	<0.01	38	4	124	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.1	<0.03	<2		<0.05	<1	<0.01	2	144	5	5	
C-4	7/8/99	8.51	3120	270	14.4	171	<5	146	<0.01	0.1	<0.01	46	2	140	<0.1	0.2	<0.1	6	<0.1	<0.1	<0.2	1.28	<0.03	<2		<0.05	<1	<0.01	1	168	6	5	
C-4	10/19/99	8.25	450	255	5.2	160	<5	131	<0.01	0.1	<0.01	42	3	134	<0.1	0.1	<0.1	7	<0.1	<0.1	<0.2	0.41	<0.03	<2	4.2	<0.05	<1	<0.01	3	161	<5	5	
C-5	10/20/97	7.5	0.36	244	4.6	148	0	121	0	0.1	0	36	2	110	0	0.3	0	5	0	0	0	0.3	0	0	4.8	0.03	0	0	3	140	16	6	
C-5	7/23/98	8	44.6	170	8.8	138	<5	113	<0.01	<0.1	<0.01	33	1	103	<0.1	0.1	<0.1	5	<0.1	0.1	<0.2	0.3	<0.03	<2		<0.05	<1	<0.01	2	153	<5	4	
C-5	10/13/98	7.6	20	190	5.6	170	<5	140	<0.01	<0.1	<0.01	42	2	134	<0.1	0.3	<0.1	7	<0.1	<0.1	<0.2	0.2	<0.03	<2		<0.05	<1	<0.01	3	165	<5	5	
C-5	7/8/99	8.07	70	192	9	123	<5	100	<0.01	0.1	<0.01	31	1	98	<0.1	0.1	<0.1	5	<0.1	<0.1	<0.2	0.45	<0.03	<2		<0.05	<1	<0.01	2	118	5	4	
C-5	10/19/99	7.76	23	266	1.6	161	<5	132	<0.01	0.1	<0.01	42	1	134	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.61	<0.03	<2	4.2	<0.05	<1	<0.01	2	155	7	4	
C-6	10/19/99	8.23	91	268	1.2	169	<5	139	<0.01	0.2	<0.01	46	5	144	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.66	<0.03	<2	5.1	<0.05	<1	<0.01	4	169	6	7	
C-7	10/19/99	8.35	530	236	4.9	172	<5	141	<0.01	0.1	<0.01	41	<1	131	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.34	<0.03	<2	5.3	<0.05	<1	<0.01	2	151	9	3	
C-8	10/19/99	8.4	390	252	4.2	164	<5	134	<0.01	0.1	<0.01	44	1	135	<0.1	0.1	<0.1	6	<0.1	<0.1	<0.2	0.76	<0.03	<2	5.5	<0.05	<1	<0.01	2	156	<5	4	

Table 1.1 Flat Canyon Tract Baseline Hydrologic Data

Site	Date	pH	Flow gpm	Cond. µS/cm	Temp. °C	HCO3 mg/L	CO3 mg/L	T Alk. mg/L	As (D) mg/L	B (D) mg/L	Cd (D) mg/L	Ca (D) mg/L	Cl mg/L	Hard. mg/L	Fe (D) mg/L	Fe (T) mg/L	Pb (D) mg/L	Mg (D) mg/L	Mn (D) mg/L	Mn (T) mg/L	Hg (D) mg/L	NO3 mg/L	NO2 mg/L	O&G mg/L	D.O. mg/L	PO4 mg/L	K mg/L	Se mg/L	Na (D) mg/L	TDS mg/L	TSS mg/L	SO4 mg/L	Turb NTU
Springs																																	
2-413	10/8/97	6.9	5	304	6.8	241	0	198	0	0.2	0	60	5	187	0	0.4	0	9	0	0	0	0.3	0			0.03	0	0	2	240		6	
2-413	7/22/98	7.8	4	270	10.7	253	<5	207	<0.01	0.1	<0.01	62	4	192	<0.1	2.1	<0.1	9	<0.1	<0.1	0.2	1.6	<0.03			<0.05	<1	<0.01	2	245		4	
2-413	10/13/98	8.4	2.1	360	4.5	247	<5	203	<0.01	0.1	<0.01	62	4	188	<0.1	2.7	<0.1	8	<0.1	<0.1	<0.2	2.4	<0.03			<0.05	<1	<0.01	2	226		4	
2-413	7/7/99	7.54	6	382	5.8	244	<5	200	<0.01	0.2	<0.01	63	4	194	<0.1	<0.1	<0.1	9	<0.1	<0.1	<0.2	2.18	<0.03			<0.05	<1	<0.01	2	224		4	
2-413	10/19/99	7.8	2.3	377	4.9	240	<5	197	<0.01	0.2	<0.01	64	4	201	<0.1	2.5	<0.1	10	<0.1	<0.1	<0.2	2.75	<0.03			<0.05	<1	<0.01	3	220		4	
3-290	10/13/97	7.1	3	336	5.2	215	0	176	0	0.1	0	53	3	173	0	1.6	0	8	0	0	0	0.4	0			0.05	0	0	4	200		5	
3-290	7/23/98	7.2	4.6	230	5.1	205	<5	168	<0.01	0.1	<0.01	52	1	163	<0.1	0.3	<0.1	8	<0.1	<0.1	<0.2	0.4	<0.03			<0.05	<1	<0.01	2	210		4	
3-290	10/13/98	7.9	2.7	250	5.5	220	<5	180	<0.01	0.2	<0.01	57	2	175	<0.1	0.3	<0.1	8	<0.1	<0.1	<0.2	0.5	<0.03			<0.05	<1	<0.01	2	209		4	
3-290	7/8/99	7.13	6	265	4.1	180	<5	147	<0.01	0.1	<0.01	44	1	139	<0.1	0.3	<0.1	7	<0.1	<0.1	<0.2	0.63	<0.03			0.06	<1	<0.01	2	171		3	
3-290	10/19/99	7.83	7.6	267	3.1	176	<5	144	<0.01	0.1	<0.01	44	1	143	<0.1	0.2	<0.1	8	<0.1	<0.1	<0.2	0.27	<0.03			<0.05	<1	<0.01	2	151		4	
4-173	10/9/97	7.2	5	322	4.6	195	0	160	0	0.2	0	49	2	159	0	0.2	0	9	0	0	0	0.9	0			0.04	0	0	2	200		5	
4-173	7/21/98	6.2	2.5	160	4.3	191	<5	156	<0.01	0.1	<0.01	48	2	157	<0.1	0.2	<0.1	9	<0.1	<0.1	<02	0.9	<0.03			0.04	<1	<0.01	1	204		6	
4-173	10/13/98	7.6	2.1	230	4.5	200	<5	164	<0.01	0.1	<0.01	49	2	159	<0.1	<0.1	<0.1	9	<0.1	<0.1	<0.2	0.9	<0.03			<0.05	<1	<0.01	2	188		5	
4-173	7/7/99	7.33	1.5	199	2.9	192	<5	158	<0.01	0.1	<0.01	45	1	149	<0.1	<0.1	<0.1	9	<0.1	<0.1	<0.2	1.17	<0.03			<0.05	<1	<0.01	3	171		5	
4-173	10/19/99	7.8	1.2	303	3.3	196	<5	161	<0.01	0.2	<0.01	49	1	164	<0.1	0.3	<0.1	10	<0.1	<0.1	<0.2	1.18	<0.03			<0.05	<1	<0.01	2	163		5	
5-231	10/13/97	7.1	3	244	3.4	143	0	117	0	0.2	0	38	2	115	0	2.4	0	5	0	0	0	1.2	0			0.09	0	0	1	140		17	
5-231	7/21/98	6.2	3	120	2.8	137	<5	112	<0.01	0.1	<0.01	38	1	107	<0.1	1.2	<0.1	3	<0.1	<0.1	<0.2	<0.1	<0.03			<0.01	<1	<0.01	1	161		5	
5-231	10/13/98	7.8	2.4	170	3.5	152	<5	124	<0.01	0.2	<0.01	40	2	116	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	<0.1	<0.03			<0.05	<1	<0.01	2	148		6	
5-231	7/7/99	7.16	8	205	1.9	132	<5	113	<0.01	0.1	<0.01	35	<1	100	<0.1	<0.1	<0.1	3	<0.1	<0.1	<0.2	0.34	<0.03			0.07	<1	<0.01	3	133		5	
5-231	10/19/99	7.3	1.4	231	2.7	146	<5	120	<0.01	0.2	<0.01	40	<1	125	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.2	0.44	<0.03			0.07	<1	<0.01	2	130		6	
5-238	10/9/97	7.2	6	459	4.3	267	0	219	0	0.2	0	71	10	210	0	0	0	8	0	0	0	0.6	0			0.02	0	0	4	230		0	
5-253	10/9/97	6.6	20+	151	3.8	100	0	82	0	0.1	0	24	1	68	0	0	0	2	0	0	0	0.6	0			0.02	0	0	1	70		19	
5-253	7/21/98	5.97	1.4	80	3.3	86	<5	71	<0.01	<0.1	<0.01	24	<1	68	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.2	0.5	<0.03			<0.01	<1	<0.01	<1	118		2	
5-253	10/13/98	7.8	12	100	4.1	95	<5	78	<0.01	0.2	<0.01	24	1	72	<0.1	0.1	<0.1	3	<0.1	<0.1	<0.2	0.5	<0.03			<0.05	<1	<0.01	1	91		2	
5-253	7/7/99	6.76	12	140	2.3	87	<5	71	<0.01	0.1	<0.01	23	<1	66	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.2	2.43	<0.03			<0.05	<1	<0.01	2	80		2	
5-253	10/19/99	7	18	141	3.2	90	<5	74	<0.01	0.1	<0.01	24	<1	72	<0.1	<0.1	<0.1	3	<0.1	<0.1	<0.2	0.89	<0.03			<0.05	<1	<0.01	1	79		3	
21-222	10/9/97	7.2	10	350	4.4	208	0	171	0	0.1	0	51	2	177	0	0.8	0	12	0	0	0	1	0			0.02	0	0	2	190		9	
21-222	7/21/98	7.3	18	200	6.4	190	<5	155	<0.01	<0.1	<0.01	45	1	154	<0.1	0.2	<0.1	10	<0.1	<0.1	<0.2	1	<0.03			0.01	<1	<0.01	1	200		5	
21-222	10/13/98	7.7	6	280	4.1	218	<5	178	<0.01	0.1	<0.01	52	1	179	<0.1	0.5	<0.1	12	<0.1	<0.1	<0.2	1	<0.03			<0.05	<1	<0.01	2	196		7	
21-222	7/7/99	7.41	12	260	2.4	178	<5	146	<0.01	0.2	<0.01	40	<1	137	<0.1	<0.1	<0.1	9	<0.1	<0.1	<0.2	1.21	<0.03			<0.05	<1	<0.01	1	160		5	
21-222	10/19/99	7.5	5.5	339	3.5	221	<5	181	<0.01	0.1	<0.01	55	<1	191	<0.1	0.1	<0.1	13	<0.1	<0.1	<0.2	1.51	<0.03			<0.05	<1	<0.01	2	204		7	
28-110	10/8/97	7.2	2.1	310	6.5	219	0	179	0	0.2	0	56	2	181	0	0	0	10	0	0	0	0	0			0.03	0	0	2	200		7	
28-110	7/21/98	7.4	2	250	5.9	224	<5	184	<0.01	0.1	<0.01	56	2	177	<0.1	0.2	<0.1	9	<0.1	<0.1	<0.2	0.3	<0.03			<0.01	<1	<0.01	2	226		7	
28-110	10/13/98	7.8	1.8	330	5.8	238	<5	195	<0.01	0.1	<0.01	55	2	179	<0.1	<0.1	<0.1	10	<0.1	<0.1	<0.2	0.3	<0.03			<0.05	<1	<0.01	2	209		7	
28-110	7/7/99	7.48	1.3	327	4.8	219	<5	179	<0.01	0.2	<0.01	53	1	169	<0.1	1.8	<0.1	9	<0.1	0.2	<0.2	0.52	<0.03			<0.05	<1	<0.01	2	194		7	
28-110	10/19/99	7.42	1.9	343	5.5	225	<5	185	<0.01	0.2	<0.01	58	1	190	<0.1	0.2	<0.1	11	<0.1	<0.1	<0.2	1.21	<0.03			<0.05	<1	<0.01	3	204		7	



LEGEND

- FLAT CANYON COAL LEASE TRACT
- RFDS AREA
- SKYLINE MINE PERMIT AREA
- HYDROLOGY STUDY AREA
- STREAM
- SPRING
- WELL – MONITORING
- MINE DISCHARGE
- NPDES DISCHARGE POINTS
- STREAM FLOW MONITORING SITE (FLUME OR HALF–ROUND)

FIGURE 1.2

LOCATION MAP AND HYDROLOGIC MONITORING POINTS

FILE: HYDRO1–2.DWG	SCALE 1" = 3200'	NorWest
DATE: 10/13/2000		

1.1 AUTHORS

This technical report was prepared by NorWest Mine Services, Inc. (NorWest) and Mayo and Associates, LC (Mayo). Primary authors are:

- Kelly Payne (Groundwater), Hydrogeologist, NorWest
- Erik Petersen (Surface Water), Hydrologist, Mayo

Contributing authors and reviewers are:

- James (Jim) Alto, Co-Project Manager, NorWest
- Conrad (Con) Houser, Co-Project Manager, NorWest
- Patrick Mullen, Senior Biologist, Maxim Technologies, Inc.

1.2 PROPOSED ACTION

The FS and BLM propose to offer the Tract for competitive leasing based on CFC's application for lease as modified by the Interagency Tract Delineation Team. Only when or if it is determined that lease of this Tract, with special stipulations established by FS and BLM, can meet the primary objectives of all supervising agencies, will the Tract be offered.

1.3 PURPOSE AND NEED

The FS and BLM propose to offer the Tract for competitive leasing based on CFC's application for lease as modified by the Interagency Tract Delineation Team. The Tract would be accessed from the existing Skyline Mine. The TDT concluded, "no other independent access to the coal appears to be feasible." If a company other than CFC were to acquire the Tract, the most likely access to coal reserves would be through a 1200-foot shaft in the Boulger Canyon area between Boulger Reservoir and Electric Lake, as the coal does not outcrop. This is unlikely to be economically feasible (see the TDT's Reasonable Foreseeable Development Scenario discussed below).

Successful acquisition of the Tract by CFC would extend the life of the Skyline Mine by nine to twelve years, based on the reserves defined by the BLM Tract Delineation Report and an annual production rate from 3 to 4 million tons. However, if the BLM special stipulations are applied for resource protection then the reserves and mine life could be significantly reduced.

The Skyline Mine is a longwall operation. This technique for coal extraction would be extended into the Tract. Mine water discharge would be either from the existing permitted discharge point in Eccles Canyon or a proposed discharge into Electric Lake in the Huntington Creek drainage.

Surface disturbance associated with the development of facilities and exploration drilling on the Tract would be small: being limited to a number of exploratory drill holes and one or two passive ventilation shafts being the only newly constructed facilities. The locations of the exploratory holes are preliminary and subject to change depending on geologic and environmental considerations.

Each drill hole would require a pad with an area of about one-half acre, approximately 100 ft by 200 ft and a temporary access road about 1,000 ft in length. If 10 additional holes are drilled, the area disturbed would be about 7.4 acres including drill pads and roads.

Ventilation shafts would not be constructed until underground mining progressed to each location and additional ventilation was required for safe operations. The construction footprint for each ventilation shaft would be approximately one acre. Total disturbance for access roads to each ventilation shaft would be about 1,000 ft by 16 ft, or 0.36 acres for both shafts. The two shafts would be used for the life of the mine and would be abandoned and reclaimed thereafter. Disturbance and reclamation would be completed in accordance with permits issued by the FS and the State of Utah.

Total new surface disturbance for the Tract would be approximately 9.8 acres. This disturbance is related to predicted surface facilities only and does not include subsidence.

1.4 REASONABLE FORESEEABLE DEVELOPMENT SCENARIO (RFDS) - SUMMARY

The Tract covers an area of 2,692 acres and would be mined using longwall methods with multiple seam mining of two seams over the majority of the area and a total of 36 million tons of coal estimated to be recoverable. Continuous miners would be used for mine development. The reasonable range of longwall operational mining height would be from 7 to 12.5 ft and vary for each seam. Combined longwall extraction of two seams, based on reasonable operational constraints, could be as much as 22.5 ft of coal in some areas. These mining limits should not be

regarded as rigid, as it may be possible to extract coal with a thickness down to 6 feet, or greater than 12.5 feet in some cases. Additional coal resources, not amenable to longwall mining, may be recovered by room and pillar methods with partial or full extraction.

The Tract would be accessed from the existing Skyline Mine (Federal Leases U-044076 and U-0147570) adjacent to the Huntington Creek drainage. A development corridor, running parallel and under Huntington Creek, is the most likely mining scenario for main access to the Tract. This corridor is located mainly within the existing lease, but a small portion is within private land in the south. Development with full support

room and pillar mining under the existing lease would be used to preclude subsidence of this creek.

1.5 REVIEWING AGENCY OBJECTIVES

The primary objectives of the BLM are to ensure:

- maximum economic recovery (MER) of the coal is achieved;
- the environment is protected; and
- all potential impacts resulting from mining are addressed and resolved.

To meet these objectives, the EIS must evaluate the Tract based on the following assumptions:

- assume full extraction mining to determine all potential surface impacts;
- surface areas determined to be not conducive to full extraction mining must be re-evaluated for impacts from partial extraction, first mining, or development mining;
- protective non-subsidence buffer zones must be considered (with appropriate angle-of-draw) for protection of sensitive resources, where these resources are protected by applicable laws, regulations, and management direction if the need is indicated or effects are relatively uncertain;
- geologic conditions that could limit coal extraction (other than coal thickness, interburden and depth) have only been considered where the data is thought to be sufficiently reliable;
- drilling of about 10 additional exploration holes would be necessary to delineate the reserves; and
- development of two passive vent holes.

The Forest Service has a wide range of Forest Management goals including the following:

- manage geologic resources to meet resource needs and minimize adverse effects;
- maintain satisfactory watershed conditions while providing favorable conditions for water flow;
- provide for production of mineral resources consistent with applicable laws, regulations, and Forest Plan management direction; and
- provide for public safety.

Where there is conflict between MER and the other objectives, the EIS must consider the effects of a reasonable range of alternatives, including no action, to allow for informed scientifically based decisions to be made.

1.6 ALTERNATIVES

Four alternatives were developed to address the significant issues associated with this proposed lease action and to meet the requirements of NEPA. This Technical Report will address Alternatives 2 and 3 and make recommendations to help FS and BLM compile special lease stipulations needed for inclusion in Alternative 4.

1.6.1 No Action (Alternative 1)

This alternative provides a baseline for estimating the effects of the action alternatives. Under this alternative, the lease Tract would not be offered for leasing and there would be no mining.

1.6.2 Offer The Tract For Leasing As Delineated With Special Lease Stipulations (Alternative 2)

Under this alternative the Tract would be offered for competitive leasing, as delineated, with standard terms and conditions and special stipulations to protect non-mineral resources and uses. Subsidence of perennial drainages, Boulger Dam and Reservoir, Flat Canyon Campground, State Highway SR 264 and Mainline #41 gas transmission pipeline would not be allowed.

1.6.3 Offer The Tract For Leasing As Delineated Without Special Lease Stipulations (Alternative 3)

Under this alternative the Tract would be offered for competitive leasing, as delineated by the TDT with standard lease terms and conditions. No special stipulations would be included. Longwall (full-extraction) mining

would be allowed throughout the Tract resulting in subsidence of perennial drainages, Boulger Dam and Reservoir, and Flat Canyon Campground. It would be analyzed as the basis for comparison with other action alternatives that would include special stipulations needed to protect non-mineral resources and uses.

1.6.4 Offer The Tract With A Specific List Of Special Stipulations Needed To Protect Non-Mineral Resources (Alternative 4)

This alternative will be developed to address significant social, economic, or environmental issues or opportunities.

1.7 STATEMENT OF ISSUES AND EVALUATION CRITERIA

Hydrologic issues have been identified by the agencies and are analyzed in this technical report. Issues are listed below together with evaluation criteria.

- Subsidence could change the flow of springs and seeps, affecting spring discharge rates and groundwater contribution to streams. This could, in turn, affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Description of effects and duration, % probability.

- Subsidence of perennial streams and the Boulger Dam and Reservoir could intercept flowing/impounded water and divert it underground, changing the hydrologic balance. Changes in stream gradient could cause changes in stream morphology.

  Evaluation Criteria: Description of potential flow changes by quantity and duration of baseflow and % probability; description of bedload/sediment transport associated with change in stream gradient.

- Interception of ground water in underground mine workings and subsequent discharge to Eccles Creek (the existing mine water discharge point) or discharge Electric Lake could cause transbasin diversions of surface and ground water. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

Evaluation Criteria: Description of potential diversions, estimates of amount of water that may be encountered, amount and location of discharge to surface waters, % probability. Change in mine water discharge to each watershed, expected change in flow duration and base flows in Eccles and Upper Huntington Creeks (gpm, acre-feet, %), expected change to inflow and discharge (%, acre-feet) to/from Scofield Reservoir and Electric Lake.

- Discharge of mine water into Eccles Creek or Electric Lake could change quality of receiving waters. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Water quality of the discharge water vs. water quality standards associated with the most restrictive of the designated beneficial uses of the receiving waters (meets/does not meet), change in receiving stream water quality (parameters with and without limits specific to beneficial use standards including TDS, RCRA metals, oil and grease, TMDL, and drinking water standards) addressed in part by estimating volume of discharge water as percentage of resulting total flows and determining whether discharge water is being diluted or receiving waters are being "contaminated", change in lake chemistry, including water column and lake bed sediments.

- Equipment and materials spilled, used, and/or abandoned in underground mine workings could change ground water quality and any connected surface water sources. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Description of potential changes in quality by affected parameter and duration.

1.8 CONTACTS MADE

The CFC Environmental Manager, Chris Hansen, and the Skyline Mine Geologist, Mark Bunnell, provided information regarding environmental activities, data, and other relevant affairs at the Skyline Mine and the Tract.

Mr. Keith Zobell, former environmental was contacted regarding hydrologic monitoring questions.

FS and BLM personnel provided data and insights.

1.9 DESCRIPTION OF DATA

1.9.1 Previous Investigations

As part of the Mining and Reclamation Permit (MRP), CFC (1996) described groundwater and surface water hydrology in the current permit area. Included as part of the Skyline Mine MRP, is a report prepared by EarthFax Engineering (1992) describing the probable hydrologic consequences of mining in the Skyline Mine area.

CFC, the Manti-La Sal National Forest, and the USDA Forestry Sciences Laboratory (Logan, Utah) have jointly investigated the hydrologic impacts of undermining Burnout Creek (Figure 1.2), a perennial watercourse. This study included measurements of stream morphology characteristics, stream sediment grain size compositions, longitudinal and cross sectional profiles, and stream discharge. Results of this investigation have been reported by Forestry Sciences Laboratory (1998), Mattson et al. (1995), and Sidle et al. (2000).

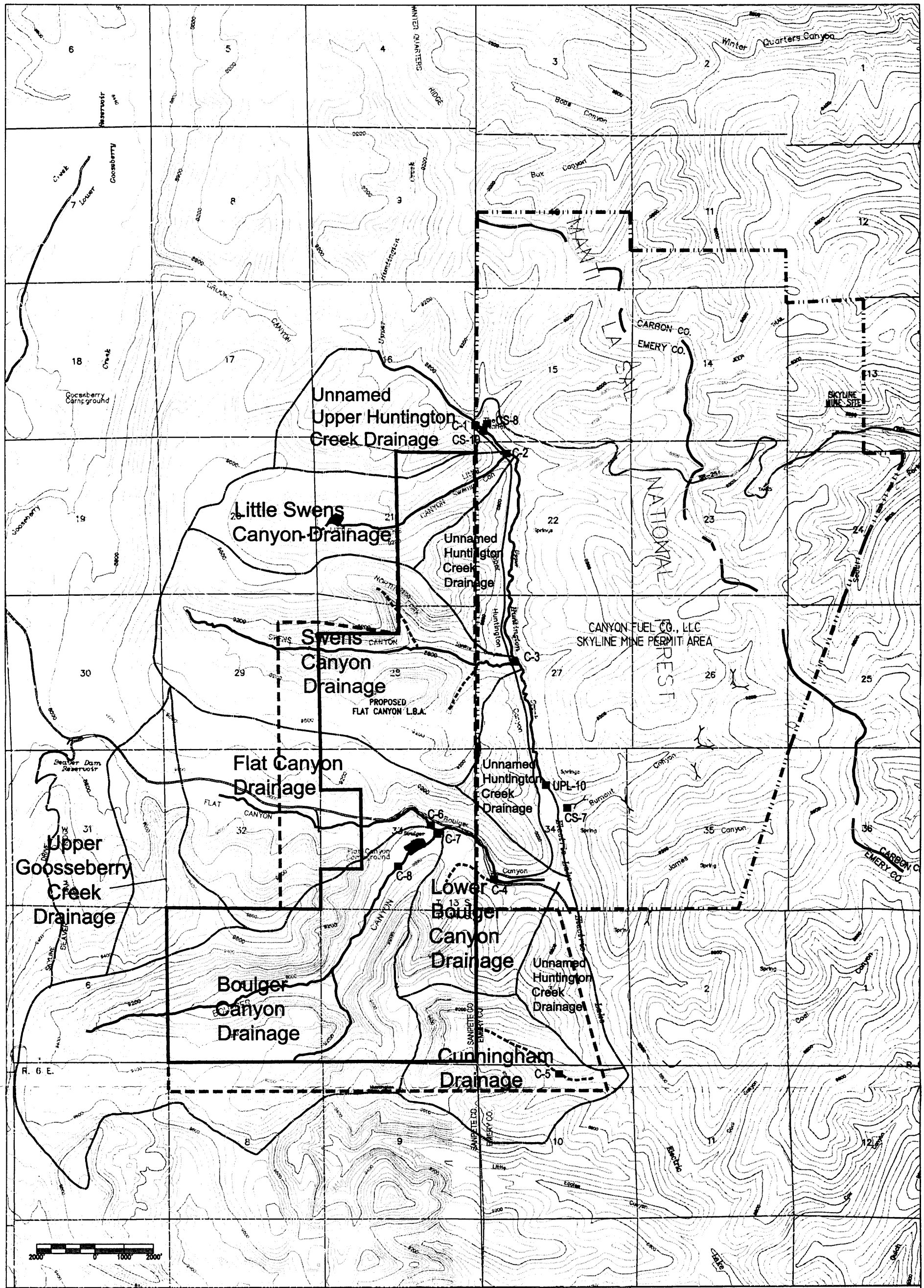
Mayo and Associates (1994) investigated the factors contributing to the solute composition and concentration of Skyline Mine's discharge water. Mayo and Associates (1996) characterized groundwater and surface water systems and mining-related impacts in the Skyline Mine area. Recent groundwater inflows have also been investigated by Mayo and Associates (1999a).

Two regional hydrogeologic investigations have been conducted by BYU graduate students. Peltier (1999) characterized the hydrogeology of the coal producing sequences in the Wasatch Plateau. Bills (2000) described groundwater flow systems in the Star Point Sandstone in the Wasatch Plateau.

1.9.2 Existing Data

CFC has collected baseline hydrologic information in the RFDS area since 1997. These data include:

- spring and seep location, discharge rate, and field parameter data from inventories conducted during Fall 1997 and Springtime 1998;
- high-flow and low-flow baseline water quality and discharge rate data for 24 springs and 8 creek sites beginning in Fall 1997; and
- unstable isotopic data collected from selected springs in the RFDS area in Fall 1997 and Springtime 1998.



LEGEND

- FLAT CANYON COAL LEASE TRACT
- RFDS AREA
- SKYLINE MINE PERMIT AREA
- HYDROLOGY STUDY AREA
- PERENNIAL STREAM
- POSSIBLY PERENNIAL STREAM
- STREAM MONITORING SITE

FIGURE 2.1

WATERSHED BOUNDARIES AND PERENNIAL STREAM REACHES

FILE: HYDRO1-2.DWG	SCALE 1" = 3200'	NorWest
DATE: 8/30/2000		

glacio-lacustrine sediments. The sediments along the margin of the canyon are approximately 80 feet thick, consisting mostly of sand.

In the lower reaches of Flat Canyon Creek, the channel is more deeply incised and the gradient is much steeper (3%). This reach is a Rosgen (1996) B3 type, which consists primarily of riffles with less than 5% pools. The banks in this reach are well vegetated and stable. The substrate in lower Flat Canyon Creek consists primarily of cobbles and boulders. It appears well armored and stable.

The north-facing canyon walls in Flat Canyon are vegetated with dense conifer forests. Portions of these conifer stands have recently undergone logging. The south facing canyon walls are vegetated primarily with scattered, dense stands of quaking aspen.

Flat Canyon creek is separated from the underlying coal seams by 1,000 to 1,800 feet of overburden.

Discharge and water quality at Flat Canyon Creek have were monitored in October 1999 and July 2000 (Table 1.1). The October discharge measurement was 91 gpm while the July measurement was 215 gpm. The water in Flat Canyon Creek during October was of the calcium-bicarbonate chemical type with a TDS concentration of 169 mg/l.

2.2 BOULGER CANYON SUB-BASIN

The Boulger Canyon sub-basin, which occupies approximately 3.92 square miles, or 30.8% of the study area, is the largest of the sub-basins. Included in this area are the upper drainage (above Boulger Reservoir), which is approximately 3.22 square miles in area, and the lower drainage, which occupies an area of approximately 0.70 square miles (Figure 2.1). Boulger Creek is a third order stream that flows to the northeast where it joins Flat Canyon Creek and then flows into Electric Lake. The gradients on Boulger Creek are steeper than are those of the adjacent Flat Canyon creek. The gradient on the main reach below the confluence of the two forks and above the reservoir averages 1.7%.

The reach of Boulger Creek extending from below the upper forks to Electric Lake contains reaches that are Rosgen (1996) types C3 and B3. The stream in this area, which meanders tightly, is 8-10 feet wide and is dominated by riffles and runs with a channel depth ranging from 6 inches to 2 feet. The substrate in areas of low gradient appears stable and well armored. It is composed of

approximately 50% cobbles, 15% gravel, and 35% sand/silt. The stream banks in this portion of the drainage are well vegetated and appear stable. The drainage in this area supports a moderately wide strip of riparian vegetation up to approximately 350 feet wide along the valley bottom. Much of the riparian vegetation along the margins of the valley bottom appears to be supported by inflows of alluvial and colluvial groundwater (Section 3.3) from the lower canyon walls. This groundwater also provides recharge to the creek.

Approximately 1,800 feet above the confluence with Electric Lake, a small unnamed tributary to Boulger Creek enters from the south side of the canyon (Figure 2.1). This stream appears to be perennial based on the narrow corridor of riparian vegetation that exists along and adjacent to the stream channel. Discharge and field parameters were measured in this drainage by Mayo and Associates during October 1999 and July 2000. On both occasions water was flowing in the stream. The stream was flowing at 32.8 gpm during July 2000. Inspection of aerial photographs suggests that the stream has the appearance of being perennial for a distance of approximately one-half mile above the confluence with Boulger Creek.

The right (north) fork of Boulger Creek has an average gradient of approximately 4.3%. There is a narrow strip of riparian vegetation associated with this reach of the creak. For the first approximately 1,800 feet of this drainage, the stream is a Rosgen (1996) type B3 stream. The channel substrate in this reach is made up of material ranging from 2-inch gravels to 12-inch and greater cobble/boulder material. Runs and riffles make up approximately 60% of the stream, with approximately 40% pools. Raleigh Consultants (1992) noted sedimentation in the right fork of Boulger Creek that was attributed potentially to inactive beaver dams. The next approximately 2,000 feet of the right fork consists of a meandering Rosgen (1996) C3 type stream. The channel in this reach is approximately 10 feet wide and 6 inches deep. The stream contains approximately 80% riffles and runs and 20% pools and the substrate in this reach is made up of approximately 50% cobbles, 20% sand and silt, and 35% gravel. The stream banks appear stable. The final approximately 5,000 feet in the uppermost portion of the drainage is a steep, Rosgen (1996) type A2 or B2 stream with riffles comprising about 90% and pools 10%. The width of the stream in this reach is approximately 5 feet, with depths ranging from 4 inches in the riffles to 1 foot in the pools. The substrate in this reach is dominated by large cobbles, boulders, and bedrock.

The left (south) fork of Boulger Creek is a steep drainage with an average gradient of approximately 7.5%. The channel in the lower reach of the left fork is a Rosgen (1996) type A3 channel, while the upper, headwaters area is a Rosgen (1996) C5 or E5 type. The channel substrate in the lower part of the south fork is comprised of large cobbles and boulders. In the headwaters region of the left fork a large meadow is present in a glacial cirque. The stream channel substrate in this region consists primarily of fine-grained alluvial material. Much of the baseflow of the left fork of Boulger Creek originates from springs along the margins of this meadow.

The depth of cover separating Boulger Creek from the coal seams that may be mined ranges from 700 feet in the lower reaches near Electric Lake to more than 2,200 feet in the headwaters areas.

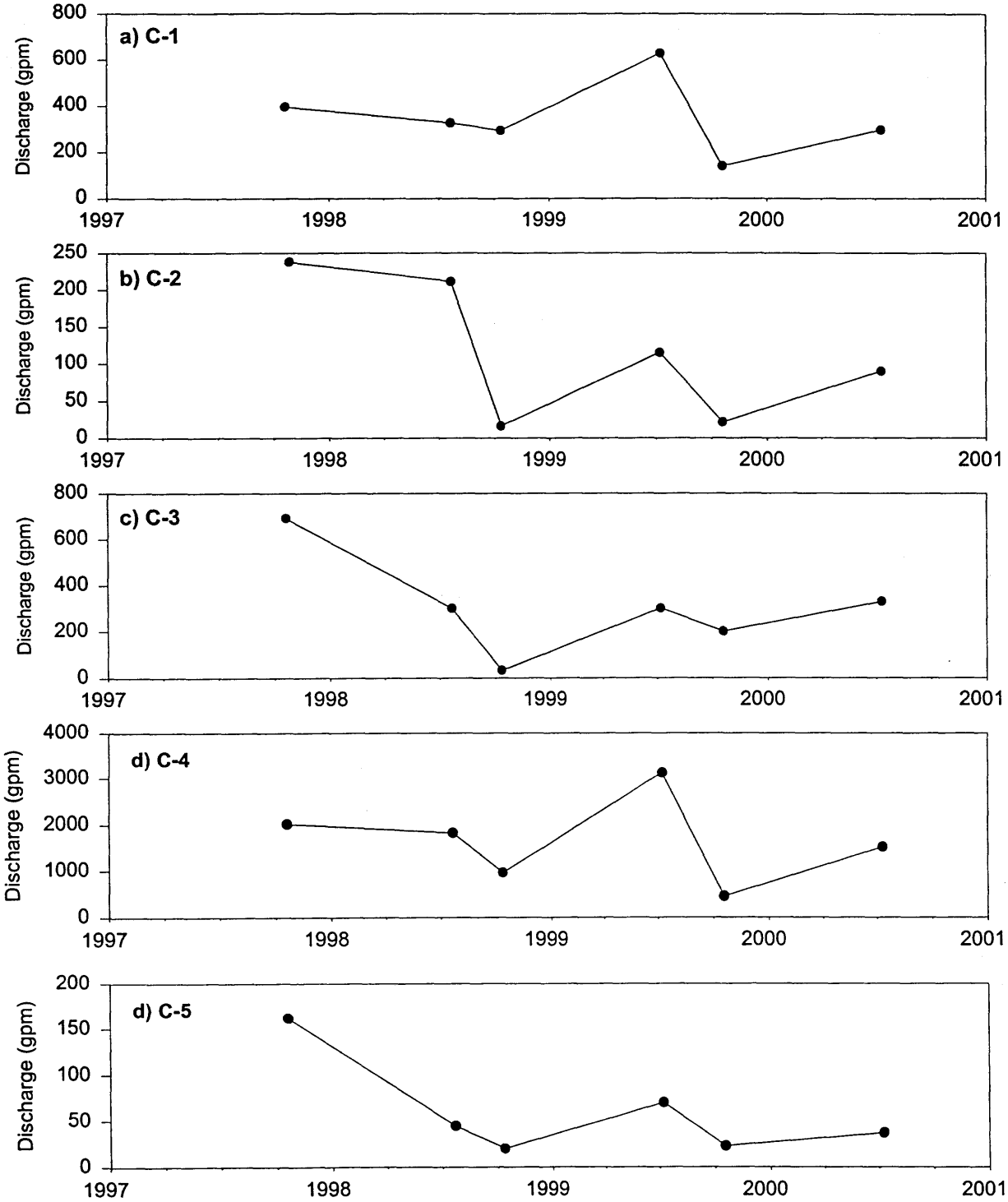
Discharge and water quality in Boulger Creek have been monitored at C-4, C-7, and C-8 (Table 1.1; Figure 2.2). Discharge has been measured at C-4 (below the confluence with Flat Canyon creek) since 1997 (Table 1.1). The maximum recorded discharge, 3,120 gpm, occurred during July 1999. A minimum flow of 450 gpm was measured during October 1999. Streamwater in Boulger Creek is of the calcium-bicarbonate chemical type. TDS concentrations at C-4 have remained relatively constant during the baseline monitoring period, ranging from 140 to 190 mg/l.

Boulger Reservoir is a man-made water body with a surface area of approximately 4.52 acres with a storage capacity of 45 acre-feet. The reservoir is a popular recreation site for fishing, swimming, and rafting. Boulger Reservoir is separated from the underlying coal seams by approximately 1,200 feet of cover. Comparison of discharge and water quality measurements from C-8 (immediately above the reservoir) and C-7 (immediately below the reservoir) suggests that the water quality of Boulger Creek is not degraded as a result of being in the reservoir (Table 1.1).

2.3 SWENS CANYON SUB-BASIN

The Swens Canyon sub-basin occupies 2.33 square miles or 18.4% of the study area. The stream drains westward into Upper Huntington Creek, with a gradient averaging 3.1%. Swens Canyon Creek is a third order stream that meanders tightly, particularly in the lower reaches of the drainage. The stream banks and adjacent areas are heavily vegetated with riparian vegetation and appear to be relatively stable. Swens Canyon Creek appears to be a gaining stream over its entire reach. It is apparent that much of the

Figure 2.2
Plots of Discharge Versus Time for Creeks in the Study Area



riparian vegetation along the margins of the valley bottom in Swens Canyon Creek is not sustained by direct recharge from the stream. Rather, these vegetated areas appear to be sustained by discharge from shallow, colluvial groundwater systems discharging low on the canyon walls.

Along the length of Swens Canyon Creek, there is evidence that the hillsides have periodically encroached into the stream channel resulting in impounding of the stream. These encroachments appear to be the result of mass movement (i.e. hillside slumping) of the Blackhawk Formation sediments that compose the hillsides. The fact that the lowermost canyon slopes are commonly wet from groundwater seepage may be a contributing factor to the frequency of mass movements. It is evident that the drainage has also been periodically dammed in many locations by beavers. As a result of these occurrences, thick sections of sediment have been emplaced by stream deposition in the backwater areas that existed when the stream was dammed, while adjacent areas have not experienced that degree of sedimentation. These conditions, in conjunction with changes in geologic formation or geologic structure underlying the stream bottom, have resulted in a somewhat stair-stepped topography in the canyon bottom.

The lower 5,000 feet of the stream channel in Swens Canyon is comprised of fine-grained material interspersed with gravel, cobbles, and occasional boulders. This reach is a Rosgen (1996) C3 type. This reach of the stream consists of approximately 80-90% runs and riffles, and 10-20% pools. In this reach the stream meanders tightly and the stream channel is well incised in its channel. Groundwater inflows are apparent along much of the extent of this reach of the drainage. These commonly consist of small springs or seepage fronts that emerge near the transition between the valley bottom and the canyon walls.

A small tributary to Swens Canyon Creek enters from the south approximately 1,000 feet above the confluence with Upper Huntington Creek. This tributary, which extends for approximately one-half mile, appears to possibly be perennial based upon the well-established riparian vegetation along the stream banks. No baseline discharge data are available for this tributary. However, it was noted by Mayo and Associates that there was appreciable flow in the drainage during October 1999 and again in July 2000.

The North Fork enters Swens Canyon Creek approximately 3,000 feet above the confluence with Upper Huntington Creek (Figure 2.1). This

tributary is approximately 2,500 feet in length and is very steep. The average channel gradient is approximately 13.8%. This stream reach appears to possibly be perennial based upon the well-established riparian vegetation along the stream banks. No baseline discharge data are available for this tributary. However, it was noted by Mayo and Associates that there was appreciable flow in the drainage during October 1999 and again in July 2000. Much of the baseflow discharge to the stream originates from a series of springs discharging from colluvial groundwater systems in its headwaters region.

In the reach of Swens Canyon Creek extending from the confluence with the North Fork and upstream for approximately 3,500 feet the stream channel narrows considerably. In this reach, the channel substrate is dominated by cobbles and boulders. In some locations, bedrock outcrops are visible in the channel bottom. The channel, which meanders slightly in this reach, contains many active and inactive beaver dams.

In the headwaters reaches of Swens Canyon Creek, the valley broadens into a region of wide meadows and grasslands. The stream channel in this reach is a narrow Rosgen (1996) A2 type. Much of the baseflow to Swens Canyon Creek appears to originate in this region. Many springs and groundwater seepages enter the stream channel from the lower hillsides adjacent to the stream.

Swens Canyon Creek is separated from the underlying coal seams by 800 feet of cover at the confluence with Upper Huntington Creek to approximately 2,400 feet of cover in its headwaters area.

Swens Canyon Creek has been monitored by CFC at C-3 since 1997 (Table 1.1; Figure 2.2). Discharge has ranged from 30 gpm during October 1998 to 300 gpm during both July 1998 and July 1999. The water in Swens Canyon Creek is of the calcium-bicarbonate chemical type. Baseline TDS concentrations in Swens Canyon Creek have ranged from 177 to 213 mg/l.

2.4 LITTLE SWENS SUB-BASIN

Little Swens Creek flows northeast from highland areas toward its confluence with Upper Huntington Creek. The basin encompasses an area of 0.98 square miles, which is 7.7% of the study area. The drainage is steep, with a stream gradient of approximately 5.9%. Little Swens

Canyon Creek is a tightly meandering stream with relatively stable, well-vegetated stream banks. Like the adjacent Swens Canyon drainage, there is evidence of a long history of encroachment of hillsides by mass movement onto valley floor. There is also evidence of a long history of beaver dam construction in the drainage. These conditions have resulted in accumulation of sediment in some areas with considerably less sediment in other areas resulting in a somewhat stair-stepped topography on along the canyon bottom.

The stream channel in the lower approximately one-half mile of the drainage is a Rosgen (1996) B3 type. The valley bottom in this reach is approximately 30 feet wide. The channel substrate in this reach consists of gravel, cobbles and boulders. Generally, the stream channel in Little Swens Canyon is more dominated by rocky material and appears to have less fine-grained material in the substrate than does the adjacent Swens Canyon. The stream banks in this reach are heavily vegetated and appear stable.

In the next 1,000 feet of the drainage, the channel narrows slightly and the channel substrate is dominated by boulders and bedrock. This reach appears to have been impacted considerably by beaver dams and encroachment of the lower canyon walls into the drainage by mass movement. This reach of the drainage is a Rosgen (1996) A2 type.

A small reservoir has been constructed in the upper reaches of this drainage. This pond has a surface area of approximately 3.15 acres and is used for recreation purposes by a privately owned girl's camp that surrounds the pond.

The Little Swens Canyon drainage is separated from the underlying coal seams by 1,100 feet of overburden near the confluence of the stream with Upper Huntington Creek. In the headwaters regions, the overburden is approximately 2,100 feet. The overburden between the reservoir at the girls camp and the coal seams ranges from about 1,900 to 2,000 feet

Baseline water quality and discharge measurements have been performed on Little Swens Canyon Creek at C-2 from 1998 to 2000 (Table 1.1; Figure 2.2). Discharge at C-2 has varied from 16 gpm during October 1998 to 211 gpm during July 1998. Discharge in the creek is of the calcium-bicarbonate chemical type. TDS concentrations have ranged from 151 to 214 mg/l.

2.5 CUNNINGHAM CANYON SUB-BASIN

The Cunningham Canyon sub-basin, with an area of 0.92 square miles, is a relatively small drainage located near the southern margin of the RFDS area. Cunningham Canyon Creek is an easterly flowing drainage that flows into Electric Lake in the Upper Huntington Creek drainage. The drainage has a steep gradient, averaging 8.0%. The channel substrate in the upper reaches is dominated by cobbles and boulders. In the lower reaches, near the confluence with Electric Lake, the channel substrate is dominated by fine-grained materials including silt and soil. The stream is entrenched below the land surface by approximately 1 to 2 feet in the lower reaches of the drainage. Riparian vegetation along the stream banks and adjacent flood plain in the lower reaches of the canyon is dense and the stream channel appears stable.

Water quality and discharge have been monitored by CFC at C-5 (Table 1.1; Figure 2.2) from 1997 to 2000. Discharge at C-5 has varied from 20 gpm in October 1998 to 162 gpm during October 1997. TDS concentrations at C-5 have varied from 118 to 165 mg/l.

The Cunningham Canyon drainage is separated from the coal seams by 700 feet in its lower reaches near Electric Lake to approximately 1,900 feet in the headwaters area.

2.6 UPPER HUNTINGTON CREEK SUB-BASIN

Within the RFDS area there are a series of unnamed small, east and northeast facing ephemeral drainages to Upper Huntington Creek (Figure 2.1). These drainages, which all exist on the steep, western slope of Upper Huntington Creek, range in size from 0.4 to 0.78 square miles. Gradients of the unnamed Upper Huntington Creek sub-basins are all very steep, ranging from approximately 17% to 32%.

None of these drainages are known to support perennial streams. One intermittent stream located immediately south of Little Swens Canyon (Figure 2.1) was monitored for discharge and field parameters by CFC in July 2000. Discharge from this stream was meager at 7 gpm.

The overburden separating the unnamed Upper Huntington Creek drainages from the coal seams ranges in thickness from approximately 700 feet near Electric Lake to more than 2,000 feet in the highland areas above Huntington Canyon

2.7 UPPER GOOSEBERRY CREEK SUB-BASIN

A small portion (0.73 square miles, less than 6%) of the RFDS area drains to the Upper Gooseberry Creek drainage. Gooseberry Creek drains to the north-northwest and flows into Fish Creek which discharges to Scofield Reservoir. While Upper Gooseberry Creek near the RFDS area may possibly be perennial, the stream itself is beyond the RFDS area and would not be undermined. For this reason, this stream has not been investigated.

All of the Upper Gooseberry Creek sub-basin within the RFDS area is separated from the coal seams by more than 1,500 feet of cover.

2.8 SUMMARY OF GENERAL CHARACTERISTICS OF SURFACE-WATER SYSTEM IN THE RFDS AREA

Both ephemeral and perennial drainages in the RFDS area are supported in the late winter and spring months by the annual snowmelt event. Because of the large quantities of snowmelt water relative to the amount of groundwater that can be stored and discharged from shallow groundwater systems in the area, perennial streams commonly have high-flow discharge rates that exceed their low-flow baseflow discharge rates by many times.

Perennial streams in the RFDS area exist where 1) there is adequate groundwater recharge and subsurface storage capacity in the drainage basins to sustain discharge from shallow groundwater systems throughout the year and 2) there is a low-permeability confining layer beneath the stream that prevents downward percolation of water in the stream channel (i.e. the stream is perched).

Field observations by the principal authors during 1997-2000 suggest that the perennial streams in the RFDS area are generally gaining streams. Observations of stream conditions in the springtime and late fall suggest that this condition persists throughout the year. The streams gain flow from discharge from shallow groundwater systems in the form of springs, seeps, and discharge directly to the stream channel. These are common along the lengths of the perennial drainages (Sections 3.3.1 and 3.3.2).

Figure 3.2 (continued)
Plots of Discharge Versus Time for Springs in the Study Area

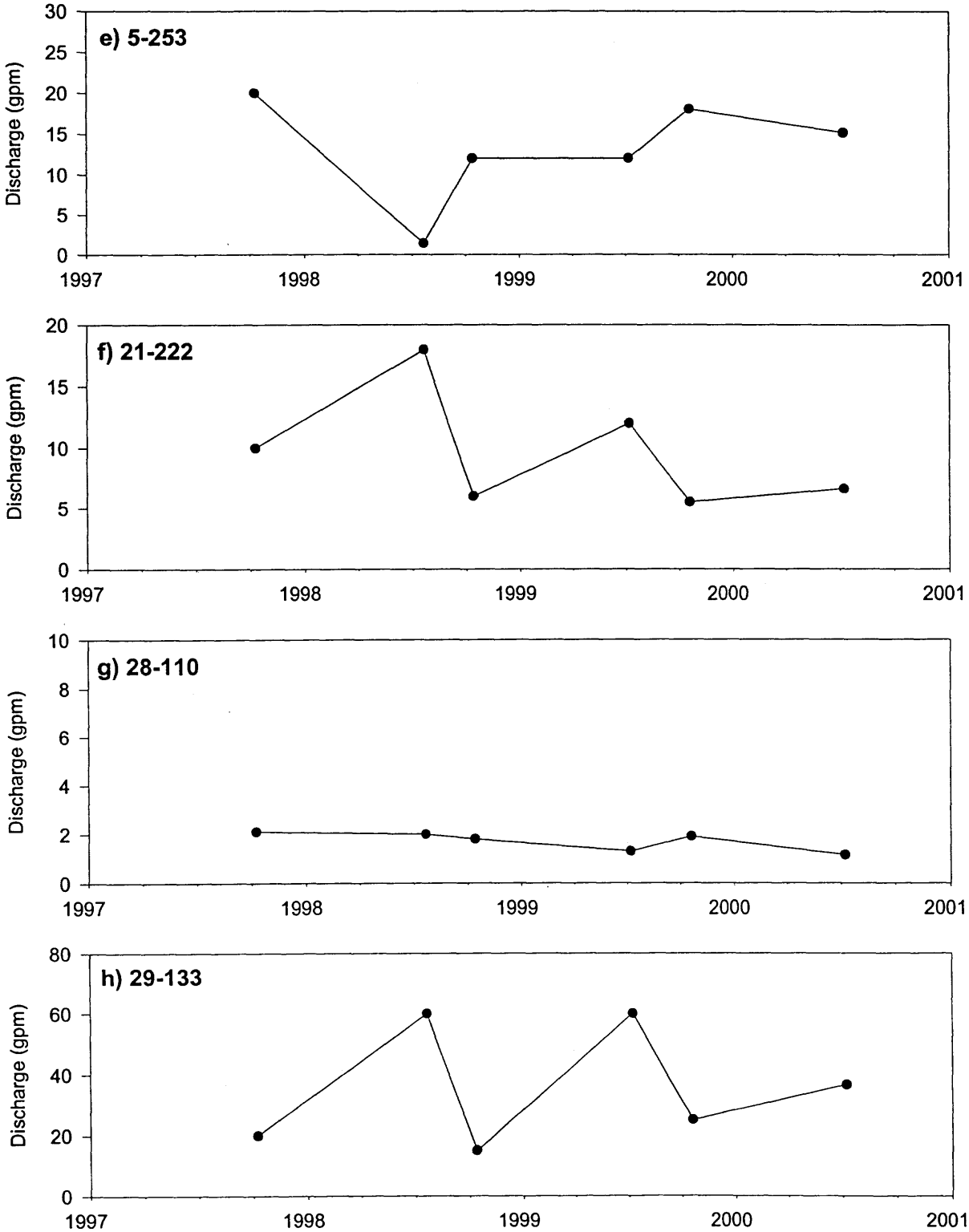
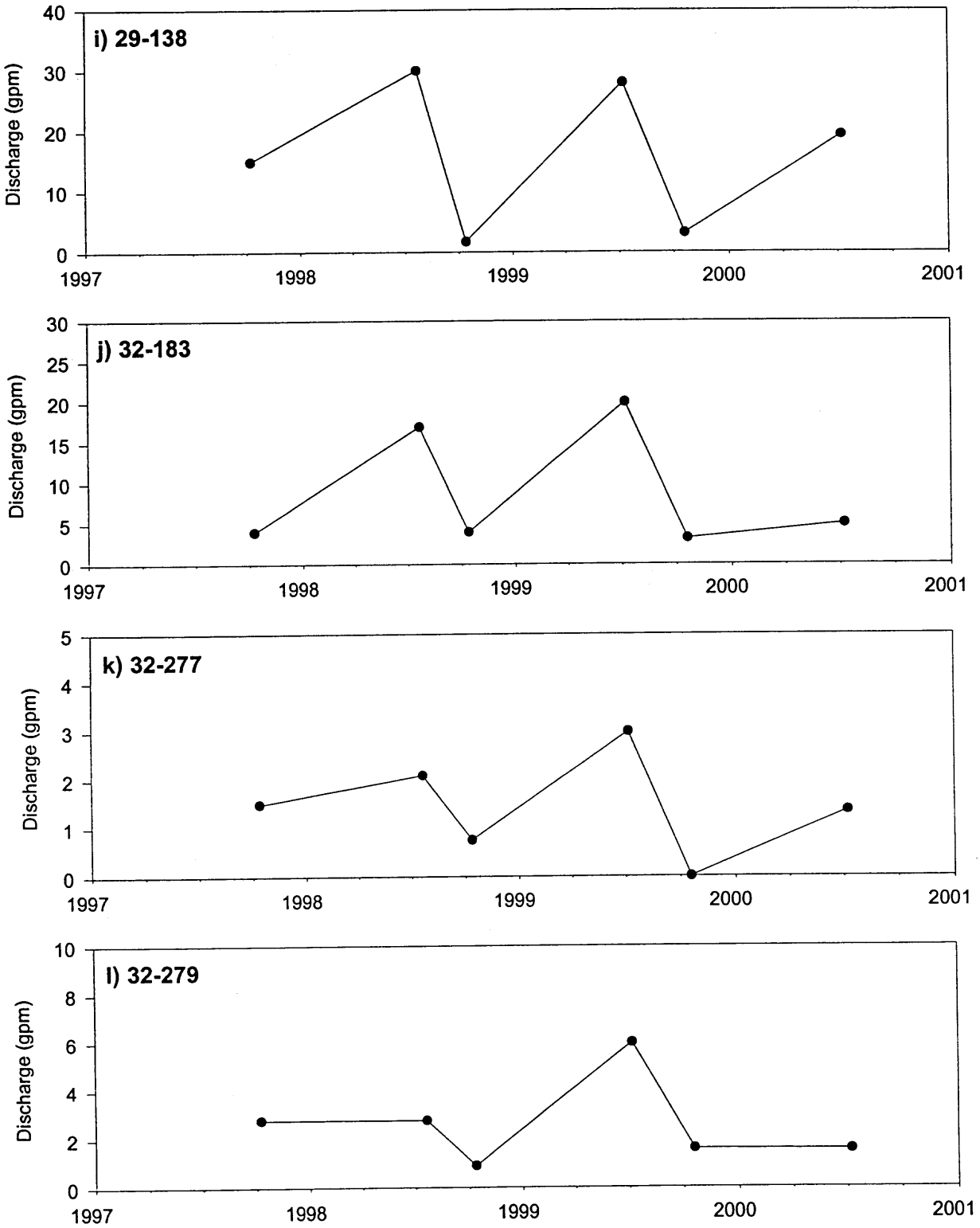


Figure 3.2 (continued)
Plots of Discharge Versus Time for Springs in the Study Area



location. Discharge from two other springs (3-290 and 5-253) does not follow the pattern of high springtime flows and low fall discharge. The discharge history of these springs is problematic and is perhaps attributable to how discharge measurements were made. A number of springs had lower discharges in springtime 2000 than during previous springtimes. This reflects sensitivity to climatic changes such as the drought conditions that the region has seen since the beginning of 2000 (Figure 3.1).

Spring and seep survey data also indicate the dependence on seasonal recharge. The total discharge from all of the springs located in the Fall 1997 survey was 1,073 gpm. During the following spring the total discharge was 2,895 gpm, a nearly three-fold increase. Although these data were not collected during the same snowmelt recharge cycle, both surveys were conducted during similar moderately wet climatic conditions (Figure 3.1).

That springs respond quickly to season and climate suggests that time between recharge and discharge in colluvial/shallow bedrock groundwater systems is less than one year. As noted, much of the baseline discharge data for these springs have been collected during a lengthy wet-spell (Table 1.1; Figure 3.1). Because of the heavy climatic dependence of these springs, it is expected that many of the springs in the study area would have much lower discharge rates or dry up in drought years.

CFC has collected unstable isotopic data from five springs in the study area. These data are shown in Table 1.3. All spring waters sampled in the study area contain anthropogenic carbon and abundant tritium. These compositions indicate that recharge to the groundwater systems supporting discharge from these springs occurred within the last approximately 50 years.

3.3.2 Boulger Canyon Alluvial Groundwater System

Alluvial sediments deposited in the relatively broad-bottomed portions of Boulger Canyon support groundwater. A distinct groundwater system has been designated for these sediments because of the comparatively larger depth and extent of these deposits relative to other, much steeper canyons in the RFDS area. The depth of this alluvium is known in one location where exploration drilling (drill hole 99-4-1; Figure 1.2) encountered 40 feet of alluvial sediments.

Groundwater in these sediments is recharged largely by interflow from colluvial/shallow bedrock groundwater systems. During dry times Boulger Creek could also provide recharge. However, visual observations of the creek by the principal authors suggest that Boulger Creek is a gaining creek year round, suggesting that discharge from the alluvial groundwater system is predominately to the creek.

3.3.3 Flat Canyon Groundwater System

Exploration drilling by CFC in the Flat Canyon area has revealed that there is a thick deposit of unconsolidated sediments in the canyon. Drill logs for wells 98-32-1 and 95-33-1 were provided for review by CFC. The locations of these two wells are indicated on Figure 1.2. The drill logs indicate that these sediments are 70 to 90 feet thick on the margins of Flat Canyon. These sediments consist primarily of sand and gravel with only minor fine-grained materials, and thus are expected to be fairly permeable. Inspection of geomorphology in air photos and in the field suggests that these alluvial sediments were likely deposited in an impoundment created by the glacier(s) in Boulger Canyon and the lateral and terminal moraine deposits of the Boulger Canyon glacier(s). Glacial moraine deposits typically have low hydraulic permeabilities (Freeze and Cherry, 1979). Consequently, water is largely impounded in glacio-lacustrine sediments behind the lateral and end moraines at the confluence of Flat and Boulger Canyons. Because of the thickness, lateral extent, and saturation of these deposits, the Flat Canyon glacio-lacustrine sediments have been designated as a distinct groundwater system.

Discharge from colluvial/shallow bedrock groundwater systems provides the bulk of recharge to the Flat Canyon glacio-lacustrine sediments.

A large portion of the discharge from the Flat Canyon groundwater system occurs directly to Flat Canyon Creek. Flat Canyon Creek does not appear to be fed by perennial creeks in any of the side drainages. Rather, Flat Canyon Creek appears to gradually gain flow throughout the year along its course due to discharge from springs and groundwater discharge directly to the creek.

A limited amount of water is also transmitted from the Flat Canyon alluvium through the glacial moraine deposits. This water supports several small wet areas on the hillslope west of Boulger Reservoir. Groundwater discharge from the Flat Canyon alluvium at this location has not been quantified or monitored. It is believed that this groundwater discharge is largely consumed by transpiration due to the presence of

phreatophytes on the hillside. It is expected that because of the large storage volume in the Flat Canyon glacio-lacustrine sediments, that discharge in this location will be essentially constant even during drier climatic cycles.

Discharge from the Flat Canyon groundwater system may also occur via underflow through the basal moraine deposits or bedrock underlying the moraine deposits. Any underflow would recharge the glacial/alluvial sediments below the moraine and would ultimately discharge to either Boulger Creek below the reservoir or via groundwater inflow to Electric Lake. A small amount of water may also migrate downward and recharge underlying bedrock. However, there is no evidence suggesting that discharge occurs via these two mechanisms.

3.3.4 Deep Blackhawk Formation Groundwater Systems

Deep Blackhawk Formation groundwater systems occur at depths greater than about 150 feet where the Blackhawk Formation is ~~the~~ exposed at the surface. Deep Blackhawk Formation groundwater systems have been encountered in underground workings at the Skyline Mine and have been encountered by exploration drilling in the RFDS area (CFC, 1999). These systems occur in paleochannel sandstones that are encased in three dimensions by relatively impermeable mudstones and shales. Consequently there is poor hydraulic communication between sandstones both laterally and vertically. Groundwater in these sandstone channels may occur under unconfined or confined conditions. Confined conditions in the underlying Star Point Sandstone attest to the ability of fine-grained units in the Blackhawk Formation to act as substantial barriers to vertical groundwater flow.

Experience at Skyline Mine and other mines in the Wasatch Plateau indicates that coal seams themselves do not bear water; in fact, water must be used to control dust as coal is cut by mining equipment.

The mechanics of deep Blackhawk Formation groundwater systems are not as well understood as the mechanics of near surface groundwater systems described above. Mining encounters groundwater in these systems at a point along the flow path but recharge and discharge locations are not obvious. Groundwater flow direction is estimated to be in the direction of bedrock dip (westward).

Mayo and Associates (1996) have determined that groundwaters in the deep Blackhawk Formation groundwater system have radiocarbon ages of

2,500 to 18,500 years and contain essentially no tritium. This suggests that these systems are hydraulically isolated from the surface and that groundwater flow is likely slow. The stable isotopic ratios (δ^2H and $\delta^{18}O$) of mine inflow waters are considerably more negative than shallow subsurface groundwaters, suggesting that these waters likely recharged anciently under cooler paleoclimatic conditions such as glacial periods.

Mayo and Associates (1996) cite several other lines of evidence to demonstrate that deep Blackhawk Formation groundwater systems are discontinuous and hydraulically isolated from the surface (and recharge sources). First, a 192-foot long upward well was constructed in the roof of the lower O'Connor A seam (Hydrometrics, 1987). The well only encountered groundwater at the 40-, 100-, and 120-foot intervals while all other horizons were dry. Similarly, a 128-foot deep well in the floor of the mine intercepted water at 98 feet. From the bottom of the mine to 98 feet the rock was not saturated. Second, discharge rates decline rapidly in newly exposed roof drips. Lastly, the total mine water discharge rate does not increase appreciably with time despite the fact that the total mined area continues to increase. The rate of discharge from mine workings is dependent on the rate of coal production and the timing of the encounter of large water-bearing features.

Faults do not appear to be important in the conveyance of water in the deep Blackhawk Formation groundwater system. CFC (1999) reports that of the 44 individual fault planes that were encountered prior to 1999, groundwater inflows occurred from only five. Four of the five appeared to intersect water-saturated sandstone paleochannels in the mine roof. Indeed, experience has indicated that most water-bearing faults encountered in Wasatch Plateau coal mines are associated with sandstone paleochannels. Thus, it is not anticipated that in the RFDS area, large volumes of water would be encountered in faults in the Blackhawk Formation. Recently large groundwater inflows have occurred in the Skyline Mine from two faults; however, these appear to be connected with the Star Point Sandstone and are discussed in the subsequent section.

water shown not correct

Potential discharge locations of deep Blackhawk Formation groundwater systems have not been identified. Due to the estimated low flow rates in this type of groundwater system, groundwater discharge at the natural discharge location is not expected to be large in magnitude and thus would be difficult to identify. Nevertheless, because of the westward dip of rocks in the Skyline Mine area and the RFDS area, groundwater in deep perched bedrock groundwater systems likely discharges, under natural

conditions, west of the RFDS area. However, there are no outcrops of the lower Blackhawk Formation west of the RFDS area. Instead, the lower Blackhawk Formation is dissected by the East Gooseberry Fault west of the study area (Figure 1.2), which likely hinders further westward groundwater flow.

Experience in the Wasatch Plateau suggests that large-offset faults are generally barriers to lateral flow across a fault due to the presence of low-permeability fault gouge. If the East Gooseberry Fault is indeed a barrier to horizontal flow across the fault, then groundwater flow is diverted at the fault in some direction along the fault. The damage zone (rock on either side of the fault that is fractured due to faulting) likely facilitates and supports groundwater flow along the fault. It is doubtful that groundwater from deep Blackhawk Formation groundwater systems discharges to the surface along the surface trace of the East Gooseberry Fault because deep perched systems would not have sufficient hydraulic head.

3.3.5 Star Point Sandstone Groundwater Systems

As described in the Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000), the Star Point Sandstone is comprised of two sandstone members, the upper Storrs Tongue and the lower Panther Tongue. Mining at the Skyline Mine has encountered water associated with both the Storrs Tongue and the Panther Tongue. Because of the westward dip of the bedrock, there is a high probability that mining in the RFDS area would encounter additional inflows of water from the Star Point Sandstone.

As indicated on Figure 3.3, the Storrs Tongue interfingers with the Blackhawk Formation and divides the Lower O'Connnor A Seam from the Flat Canyon Seam. However, in the western portion of the RFDS area, the Storrs Tongue pinches out and the Lower O'Connor A Seam and the Flat Canyon Seam merge. The Panther Tongue underlies the Flat Canyon Seam, the lower-most seam where mining would occur in the RFDS area. The Flat Canyon Seam is separated from the Panther Sandstone by 15-30 feet of shale, mudstone, and thin coals.

The tongues of the Star Point Sandstone are laterally more extensive than individual sandstones in the overlying Blackhawk Formation. It is anticipated that over larger areas, such as the Skyline Mine and RFDS areas, each tongue operates as a single groundwater system. However, it is not believed that the Star Point Sandstone is a regional aquifer in the sense that there is hydraulic continuity throughout the Wasatch Plateau.

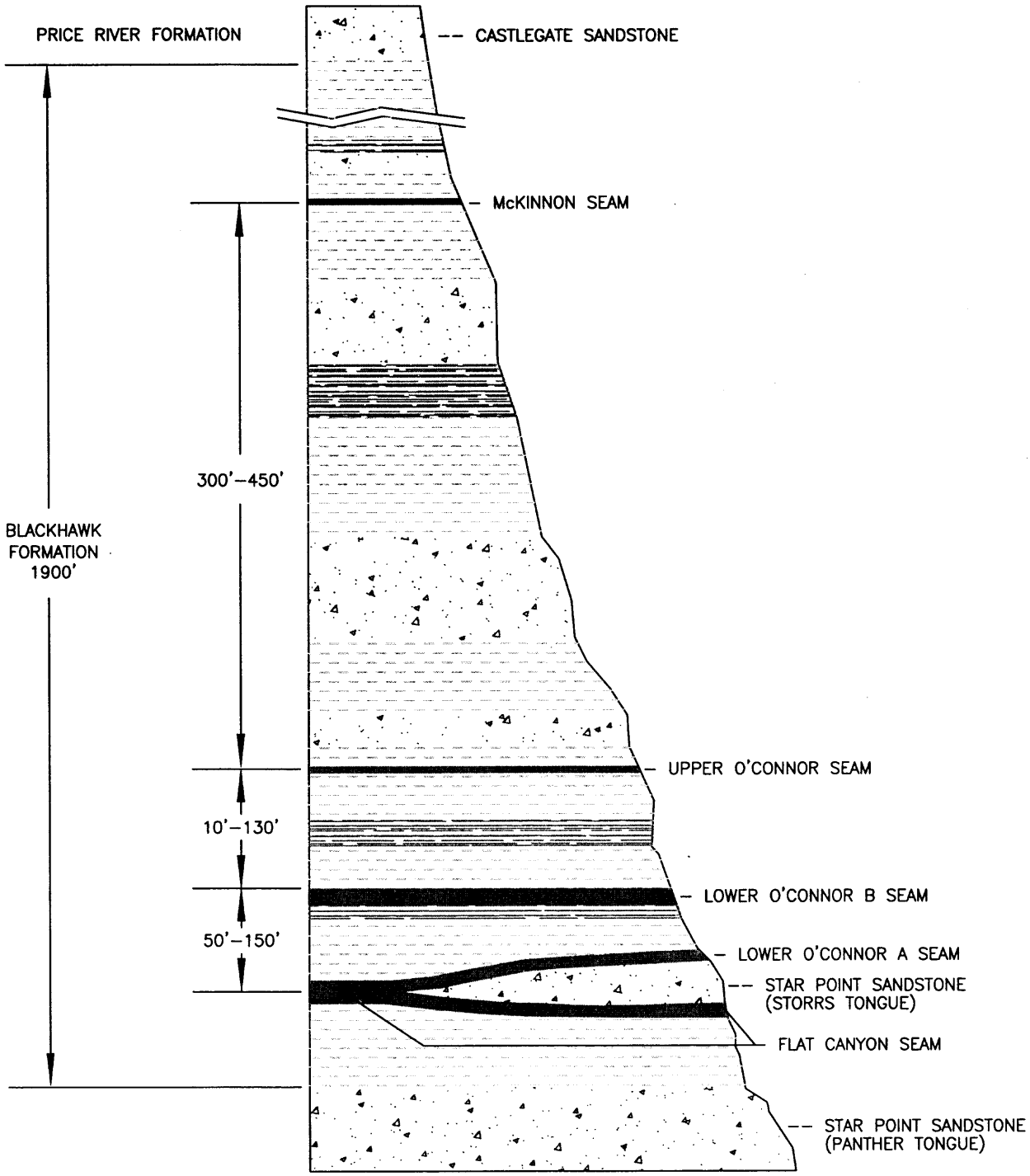


FIGURE 3.3

GENERALIZED COLUMNAR SECTION

FLAT CANYON TRACT AREA

DATE: 10/20/2000

DWG: HYDRO3–4.DWG

NorWest

The mechanics of Star Point Sandstone groundwater systems are not well understood. The Star Point Sandstone is exposed in Pleasant Valley east of the Skyline Mine area and the RFDS area and dips westward. This suggests that recharge occurs in the east and groundwater flow is to the west. Because of the inclination of the formation and the low hydraulic conductivity of Blackhawk Formation shales and mudstones overlying the Star Point Sandstone members, confined groundwater conditions are created. Similar confined conditions in the Star Point Sandstone have been observed at other coal mines in the Wasatch Plateau such as the Trail Mountain Mine.

Large groundwater inflows from faults have recently been encountered in the workings of the Flat Canyon Seam in the Skyline Mine. CFC (1999) reports that a fault with approximately 8 feet of offset was encountered during development of the 14L Headgate. The fault initially produced water from the roof and the floor at a rate of 1,200 to 1,400 gpm. Discharge from the roof ceased after a short period but water still continues to be produced from the floor. A second fault along the same trend was encountered in the 16L Headgate. This fault produces 300 gpm of water from the floor. It is believed that this water discharges from the Panther Tongue of the Star Point Sandstone.

Mayo and Associates (1999a) report that groundwater inflows to the Skyline Mine from the Star Point Sandstone have radiocarbon ages greater than 13,000 years and contain no tritium. This suggests that groundwater flow through the Star Point Sandstone is slow and that there is limited hydraulic communication with the surface. Slow flow rates in the Star Point Sandstone are substantiated by the measurement of hydraulic conductivity in other areas of the Wasatch Plateau. At the Crandall Canyon Mine in the Huntington Canyon area, slug testing revealed a hydraulic conductivity of 4.8×10^{-8} to 7.4×10^{-8} ft/s (Mayo and Associates, 1997a). Bills (2000) determined a hydraulic conductivity of 4.06×10^{-6} ft/s for the Star Point Sandstone in the Straight Canyon area. This latter result is higher than the first because of fracturing associated with the Straight Canyon syncline.

The Star Point Sandstone does not crop out west of Pleasant Valley. Consequently discharge locations for Star Point Sandstone groundwater systems have not been observed in the study area. The Storrs Tongue pinches out in the RFDS area indicating that groundwater is not transmitted westward beyond the study area by the Storrs Tongue. As noted in the previous section, the East Gooseberry Fault truncates the

bedrock formations west of the RFDS area. This fault is presumed to be a barrier to lateral flow across the fault. This being the case, groundwater flow is diverted at the fault in some direction along the fault and flow is accommodated in the damage zone of the fault. Potentiometric levels in two monitoring wells, 99-21-1, and 99-28-1 (Figure 1.2), in the RFDS area that are completed in the first sandstone below the Flat Canyon Seam (which may be the Panther Tongue) suggest that the hydraulic head in the Panther Sandstone (elevation 8,419 and 8,515 feet, respectively) may not be sufficient to cause water to discharge at the surface trace of the East Gooseberry Fault (elevation greater than about 8,800 feet, directly west of the RFDS area).

Although it is not known where groundwater in the Star Point Sandstone in the study area ultimately discharges, it can be surmised with some certainty that groundwater in the Star Point Sandstone in the study area is not in hydraulic communication with the Star Point Sandstone groundwater systems that supply water to the large-discharge culinary water supply springs in Huntington Canyon (Big Bear, Little Bear, or Birch springs). First, as noted above, the radiocarbon ages of Panther tongue water encountered at the Skyline Mine is 13,000 years. The radiocarbon ages of groundwater that discharges from the Huntington Canyon Springs (Mayo and Associates, 1997b; Mayo and Associates, 1999b) are summarized below.

Spring	Radiocarbon Age
Birch Spring	1,700-3,600 years
Big Bear Spring	Mixed; 3,500-4,500 years
Little Bear Spring	Modern

Because water in the Star Point Sandstone in the study area has appreciably greater radiocarbon ages, it is unlikely that this water is hydraulically connected to the Star Point Sandstone in the Huntington Canyon. Second, the East Gooseberry Fault, the surmised location for groundwater discharge from the Panther Tongue, is not structurally connected to fault systems in the vicinity of the Huntington Canyon springs. The Huntington Canyon springs discharge in and near the Pleasant Valley Graben and associated faults whereas the Gooseberry Graben is on the same trend as the Joes Valley Graben.

3.4 WATER QUALITY

Groundwater discharge from springs in the study area is low-TDS, calcium-bicarbonate water. For springs that have been monitored for baseline water quality, the average TDS ranges from 60 to 280 mg/l and the average TDS is 180 mg/l (Table 1.2). Concentrations of sodium ion and sulfate are very low (Table 1.2). Groundwater quality meets State of Utah drinking water standards for the parameters that have been analyzed. Untreated spring water is used throughout the study area at cabins and campgrounds for culinary uses. Additionally, groundwater discharge supports baseflow to creeks that have been classified as "High Quality Waters – Category 1" by the State of Utah (UAC R317-2).

3.0 GROUNDWATER

3.1 CLIMATIC SETTING

The study area is located in an area of subalpine climate. Precipitation is measured at the Skyline Mine surface facility in Eccles Canyon west of the study area. Between 1985 and 1995 the average annual (calendar year) precipitation ranged from 17.2 to 29.4 and averaged 23.9 inches (Mayo and Associates, 1996). Monthly average temperatures at the mine range from 8.0 to 74.4 °F (CFC, 1999).

The National Resource Conservation Service (NRCS) maintains two high elevation precipitation stations east of the study area. During the period 1961-1990 (NRCS, 1995) the average annual precipitation was 29 inches at the Mammoth-Cottonwood Station (elevation 8,800 feet), and 33 inches at the Red Pine Ridge Station (elevation 9,200).

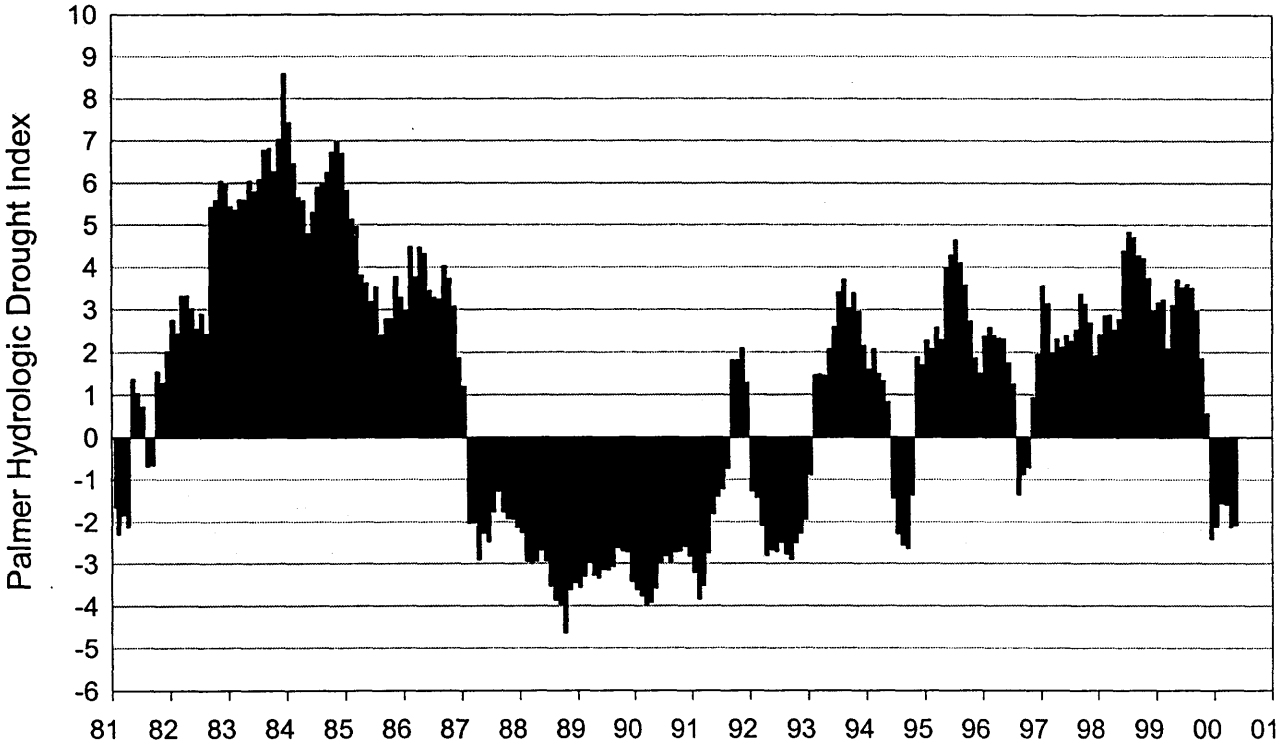
A tool that has been useful in understanding the relationship between surface water and groundwater discharge in the Wasatch Plateau is the Palmer Hydrologic Drought Index (PHDI; NCDC, 2000; Karl, 1986; Guttman, 1991). The PHDI is a monthly value generated by the National Climatic Data Center (NCDC) that indicates the severity of a wet or dry spell and is useful for identifying longer-term climatic trends. The PHDI is computed from climatic and hydrologic parameters such as temperature, precipitation, evapotranspiration, soil water recharge, soil water loss, and runoff. Because the PHDI takes into account parameters that affect the balance between moisture supply and moisture demand, the index is a useful tool for evaluating the long-term relationship between climate and groundwater recharge and discharge.

Figure 3.1 is a plot of the PHDI for Utah Division 5. On this graph, positive numbers indicate wet conditions and negative numbers indicate dry conditions. The magnitude of the value indicates the severity of the wet or dry spell.

This graph indicates several extremely wet years during the early and mid 1980s, followed by an extended drought from 1987 to 1993. Since 1993 the region has enjoyed mostly wet conditions. However, beginning in January 2000 the region entered a drought period. It is important to note

that most baseline hydrologic collection by CFC occurred during the moderately wet period in the late 1990s.

Figure 3.1
Palmer Hydrologic Drought Index (PHDI) for Utah Division 5



3.2 GEOLOGIC SETTING

The geology of the study area has been described in the Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000) prepared concurrently with this report. Five bedrock formations of concern to coal mining activities in the study area are, in descending stratigraphic order, the North Horn Formation, Price River Formation, Castlegate Sandstone, Blackhawk Formation, and Star Point Sandstone. These rocks are composed of interbedded shale, mudstone, siltstone, and sandstone layers that are laterally discontinuous. The heterogeneity and lateral discontinuity of these rocks have a profound effect on water-bearing and water-transmitting properties. Water is not generally transmitted great

distances either vertically or horizontally, and the many low-permeability units create perched conditions. Unconsolidated alluvial, colluvial, and glacial deposits as well as soil are important hydrogeologic units in the study area.

3.3 GROUNDWATER SYSTEMS

The concept of a groundwater system refers to 1) where and how recharge occurs, 2) how flow is accommodated, and 3) where and how groundwater discharges. Five types of groundwater systems are defined in the study area. These systems are:

- colluvial/shallow bedrock groundwater systems;
- Boulger Canyon alluvial groundwater system;
- Flat Canyon groundwater system;
- deep Blackhawk Formation groundwater systems; and
- Star Point Sandstone groundwater systems

These five systems have been defined because stratigraphic, lithologic, and structural constraints cause each type of system to operate differently. The concept of a groundwater system is limited to how a system operates and does not indicate or preclude hydraulic communication among the systems of a given type. This concept is useful in places such as the study area where groundwater commonly occurs in localized areas, and where aquifers, in which there is hydraulic communication over a greater expanse, do not exist.

Each type of groundwater system is described below.

3.3.1 Colluvial/Shallow Bedrock Groundwater Systems

Colluvial/shallow bedrock groundwater systems occur throughout the study area. This type of system occurs in the thick soil mantle, slope wash colluvial deposits, and shallow bedrock in which the porosity has been enhanced by weathering or fracturing. Groundwater in shallow alluvial deposits is also included in this type of system. The abundance of relatively low-permeability horizons in bedrock formations of the study area hinders appreciable migration of groundwater to deeper stratigraphic horizons and creates perched groundwater conditions in colluvium and shallow bedrock.

The depth of colluvial/shallow bedrock groundwater systems has not been investigated but is estimated to range from several tens of feet to perhaps over 100 feet in some areas. Data from the Skyline Mine area indicate that a water monitoring well (W79-14-2a; Section 4.1.2) completed in the Blackhawk Formation at a depth of 102 to 122 feet exhibits seasonal water level responses (Mayo and Associates, 1996), which, as discussed below, is a characteristic of colluvial/shallow bedrock groundwater systems. However, two wells completed at depths ranging from 150 to 200 feet do not show seasonal water level responses.

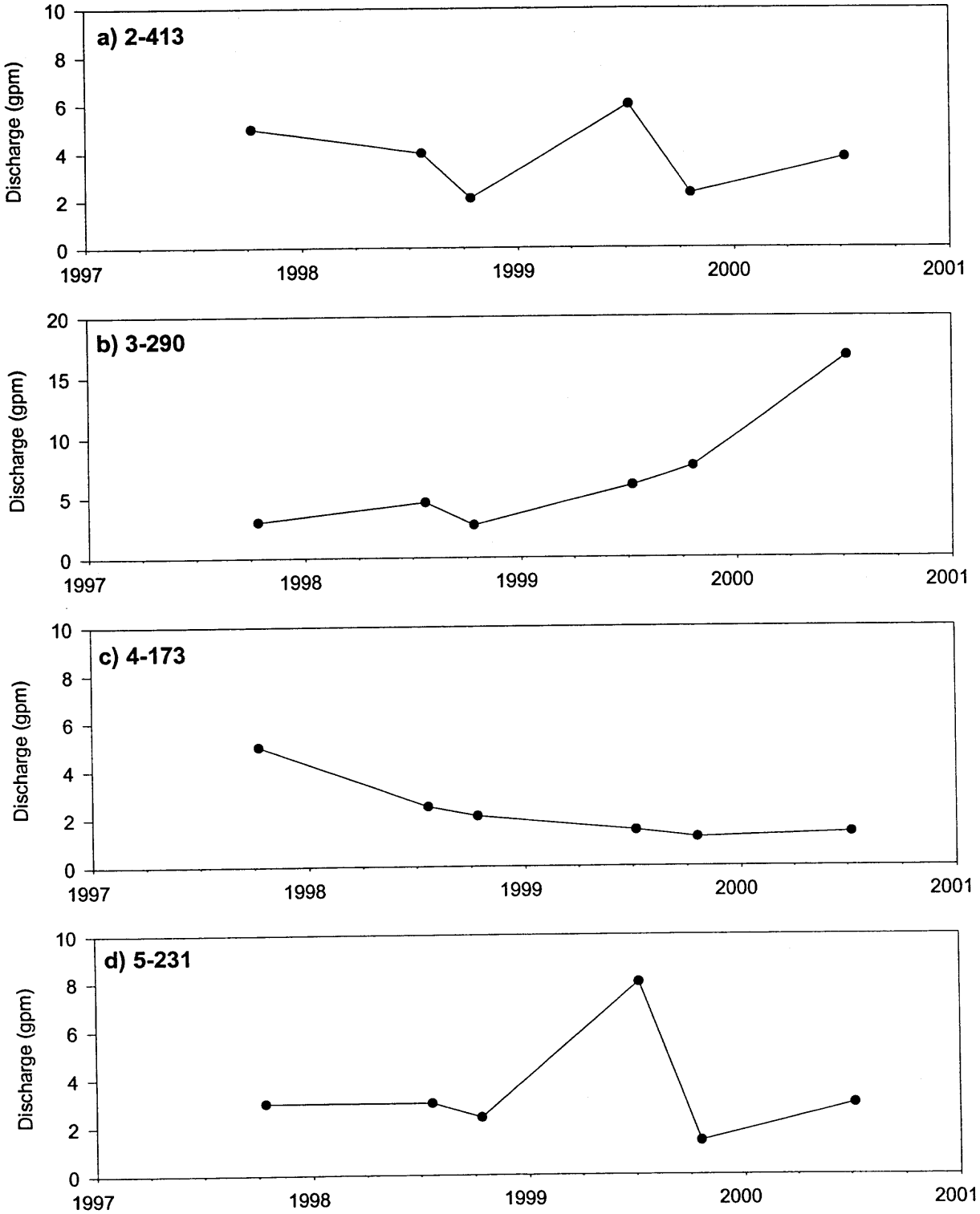
Colluvial/shallow bedrock groundwater systems are directly recharged by snowmelt, especially snow that melts relatively slowly in dense wooded stands common in the study area. Groundwater flow follows topographic gradient and flow path lengths are relatively short: no more than from the top of a ridge to a canyon bottom.

Groundwater in colluvial/shallow bedrock systems supports discharge from nearly all of the springs in the study area. Discharge from this type of system directly to creeks is indicated by gaining stream flows (Section 2.8). Groundwater discharge from this type of system occurs primarily along the bottoms of canyons. Some groundwater discharge occurs higher on a number of hillsides because of 1) local breaks in slope such as in the head of Swens Canyon where glacial moraine materials create a less steep slope, or 2) groundwater in permeable shallow bedrock, such as a sandstone paleochannel or the Castlegate Sandstone, encounters a less permeable bedrock horizon.

Storage in colluvial/shallow bedrock groundwater systems is small because of the generally limited depth of colluvial and shallow bedrock materials, short flow path lengths, relatively large hydraulic conductivities, and relatively steep hydraulic gradients. Consequently, this type of groundwater system is acutely sensitive to seasonal and climatic variations in precipitation.

Seasonal and climatic dependence is demonstrated by variations in spring discharge rates. Discharge plots for springs in the study area are shown on Figure 3.2. These plots indicate that discharge from springs is typically greatest in the springtime and declines appreciably during the summer and fall months. Discharge from several springs monitored in the RFDS area (4-173 and 28-110) does not appear to vary greatly. This is attributed to the fact that the peak discharge likely occurred earlier in the season than when springtime discharge measurements were made at the spring

Figure 3.2
Plots of Discharge Versus Time for Springs in the Study Area



4.0 HYDROLOGIC IMPACTS FROM COAL MINING AT THE SKYLINE MINE

Analysis of the hydrologic consequences of mining in the Skyline Mine area is useful for predicting the probable hydrologic consequences of mining in the RFDS area. In the Skyline Mine area several springs, stretches of perennial creeks, and several water monitoring wells have been undermined and subsided. Appreciable groundwater has been intercepted in mine workings. This section describes the impacts of mining in the Skyline Mine area to water quantity, water quality, and stream morphology.

4.1 WATER QUANTITY

4.1.1 Spring Discharge Rates

Two springs, S10-1 and S23-4, which are part of the CFC hydrologic monitoring program have been undermined and subsided at the Skyline Mine. The locations of these springs are shown on Figure 1.2. Three additional springs, S13-2, S13-7, S14-4, have been undermined by full support mining and have not been subsided. Nine other springs are monitored by CFC that are located above unmined portions of the Skyline permit area or just outside the permit area. Discharge data for all of these springs are plotted on Figure 4.1 and discussed below. Data are included in tabular format in Appendix D.

Spring S10-1 is located near the top of a ridge and does not have a large potential recharge area. Consequently the spring is extremely sensitive to climatic variations (Figure 4.1a). Large flows in the springtime are attributed to snowmelt in the immediate vicinity of the spring. The magnitude of the peak is dictated by the depth of snowpack and springtime temperatures.

Spring S10-1 was undermined in September 1993 as indicated on Figure 4.1a. The spring is located above the end of a longwall panel where the strata have been placed in permanent tension. The overburden in this area is over 1,800 feet. Since the spring was undermined, the annual high-flow peaks have been muted relative to annual peaks prior to undermining. However, the baseflow (late season) discharge has not been appreciably impacted. The period since 1993 when the spring was undermined has been moderately wet as indicted by the PHDI (Figure 3.1). Baseflow discharge should be more sensitive to mining-related effects because baseflow is derived from storage in the groundwater system. Thus, because baseflow discharge has not been appreciably impacted, it

Figure 4.1
Plots of Discharge Versus Time for Springs in the Skyline Mine area

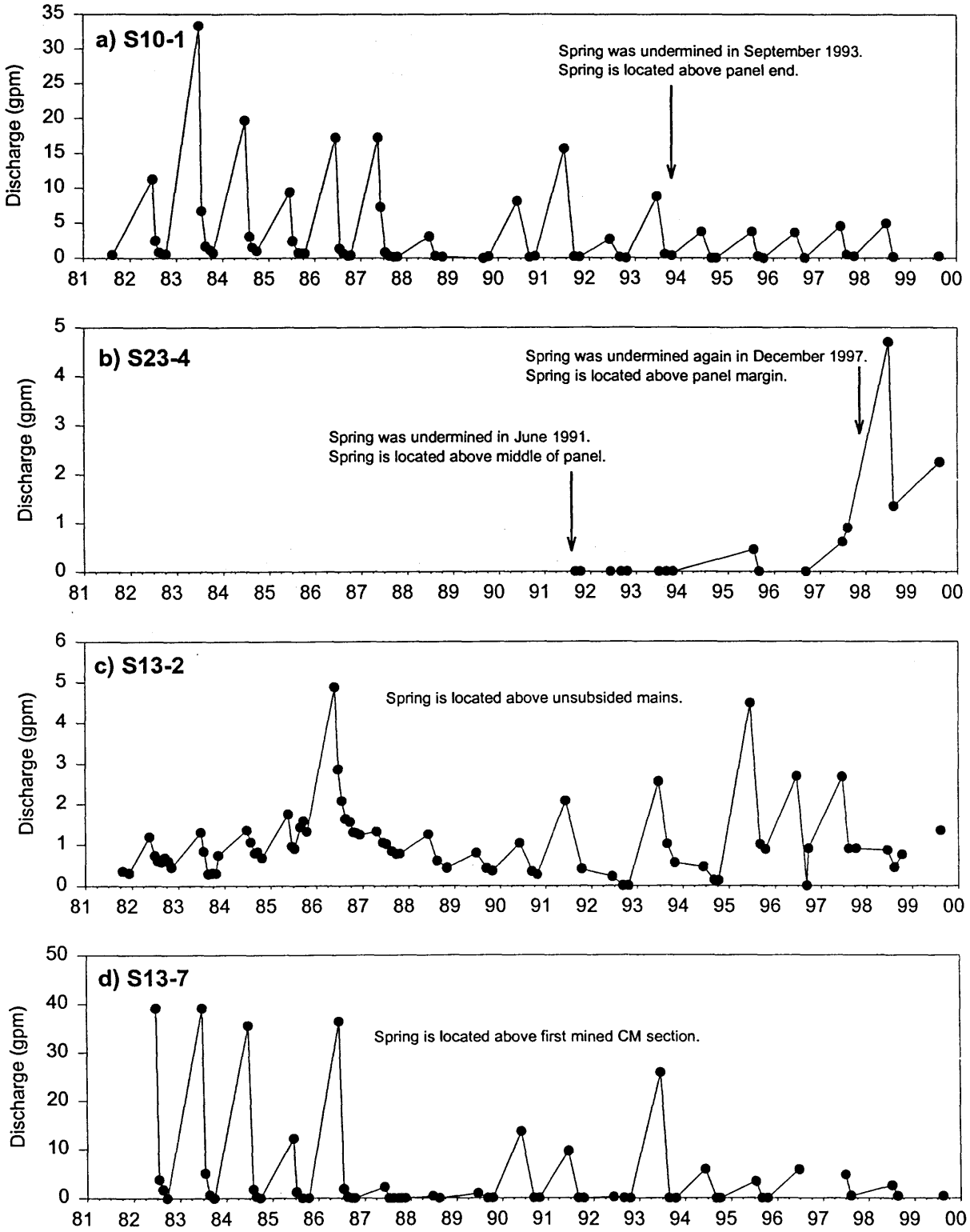


Figure 4.1 (continued)
Plots of Discharge Versus Time for Springs in the Skyline Mine area

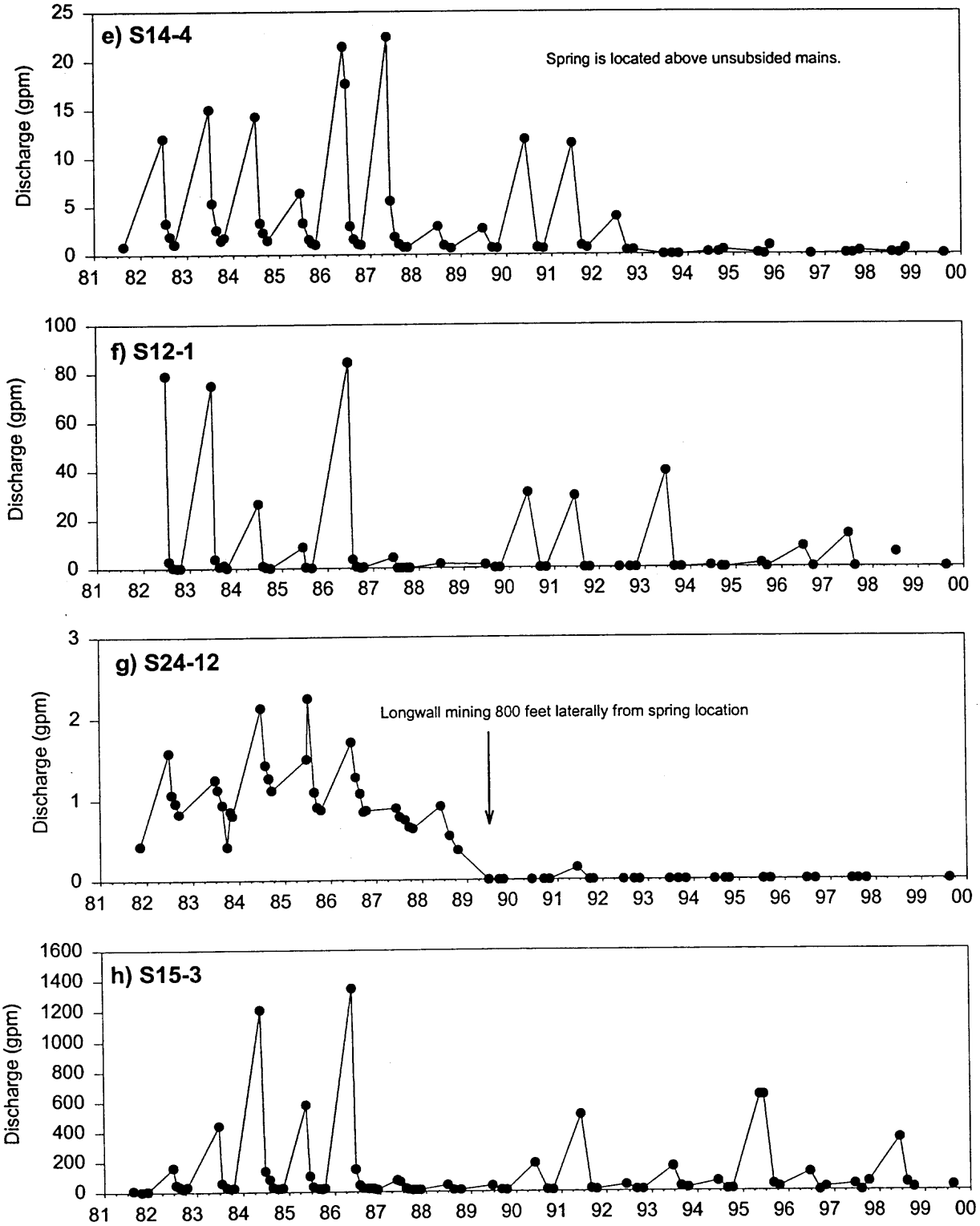


Figure 4.1 (continued)
Plots of Discharge Versus Time for Springs in the Skyline Mine area

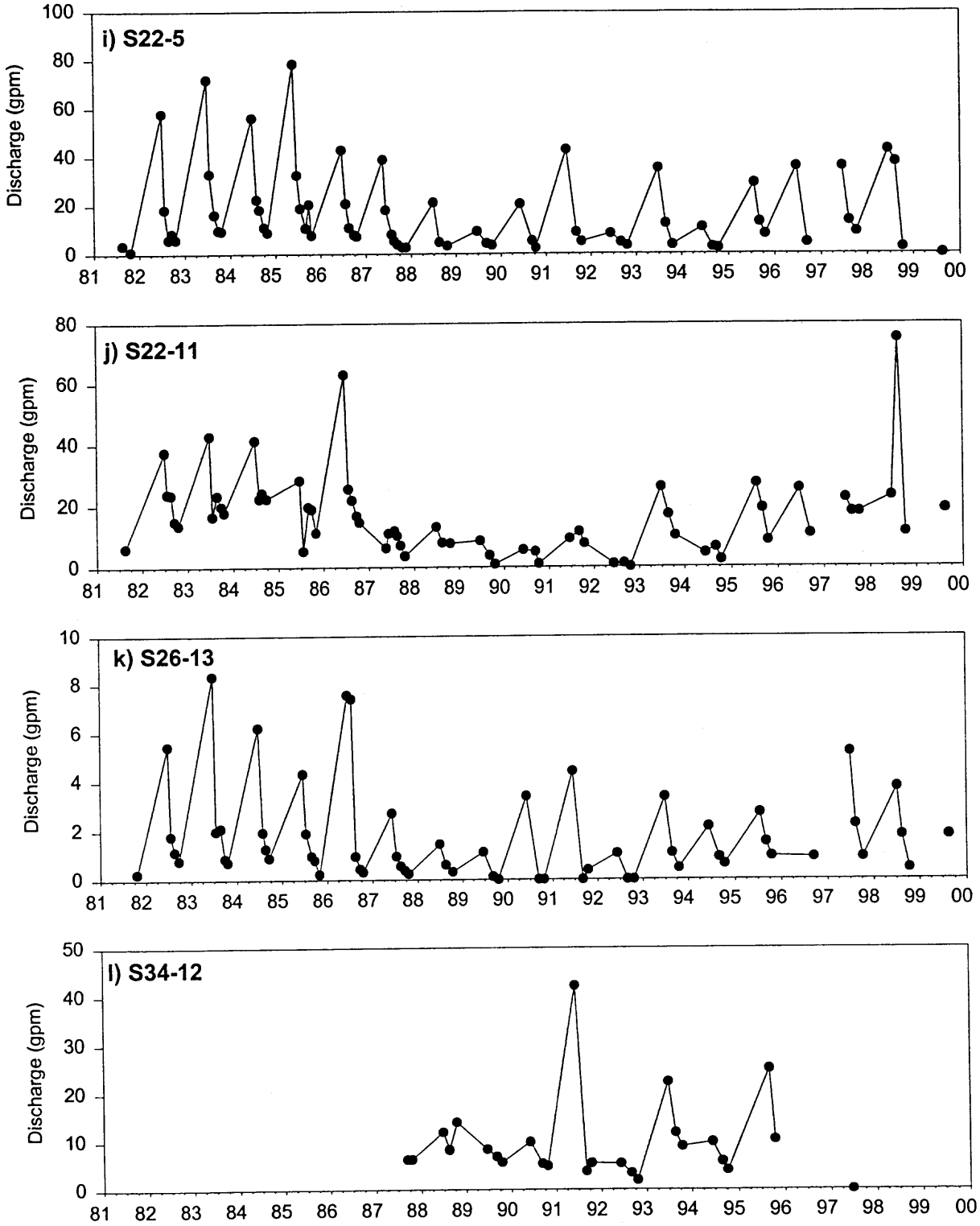
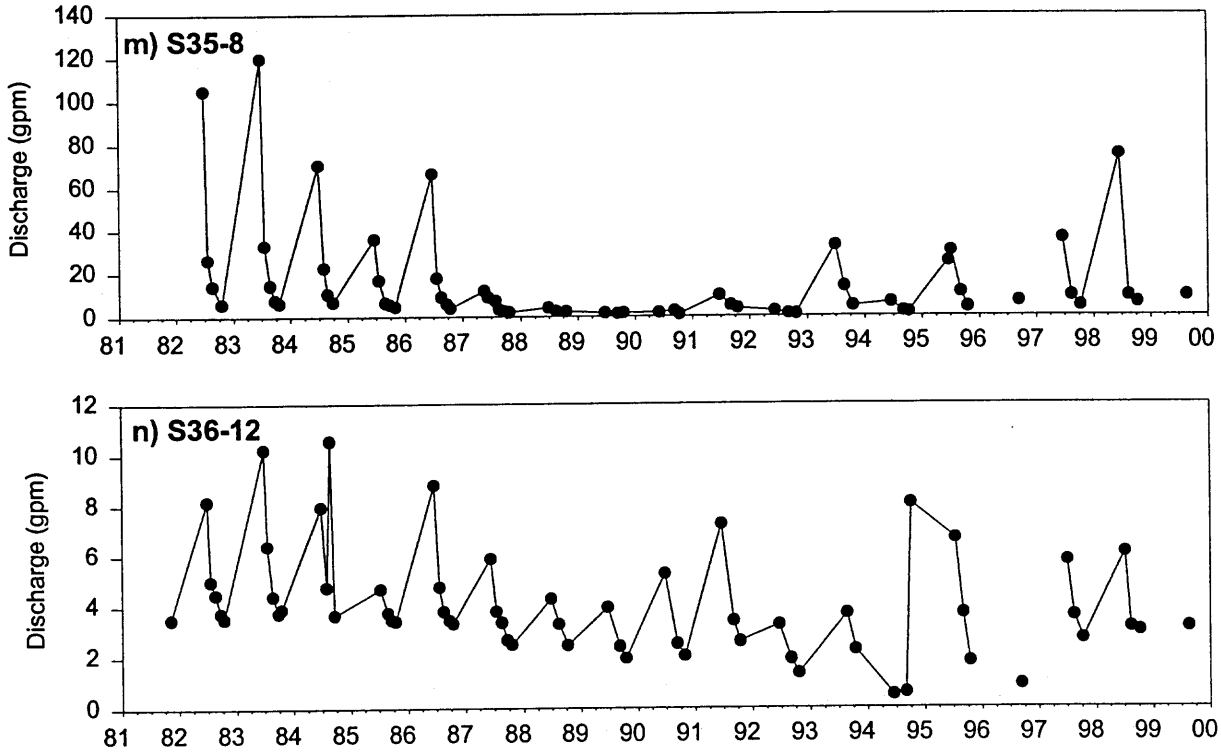


Figure 4.1 (continued)
Plots of Discharge Versus Time for Springs in the Skyline Mine area



is unlikely that the muted peak flows are attributable to mining. Instead it is postulated that the muted peak flows are attributable to local climatic factors, such as timing of the snowmelt. Two springs, S12-1 and S13-7 (discussed below), are located on nearby ridgetops and had similar muted peak flows since 1994, substantiating the idea of a local climatic factor affecting discharge of these springs.

Additionally, as discussed in Section 4.1.2, water levels in a nearby monitoring well, W79-10-1b, registered a response to undermining but indicated that the saturated horizon that the well is completed in (790-810 feet bgs) was not dewatered. If the horizon monitored by 79-10-1b was not dewatered, it is unlikely that overlying horizons were dewatered. Also, experience in the Wasatch Plateau suggests that single seam extraction under 1,800 feet of cover should not have a deleterious impact to near-surface groundwater systems.

Spring S23-4 is a seep that has supported a small puddle about 16 inches in diameter. This puddle has not had measurable outflow since monitoring was initiated and only water quality samples have been collected from this spring. Spring S23-4 was undermined in June 1991 and is located above the middle of a panel in the upper coal seam. After S23-4 was undermined in June 1991, the puddle dried up. (Keith Zobell, Personal Communication, 2000). Beginning in 1997, an adjacent spring located 50-100 feet away from S23-4 has been monitored and in 1998 was designated as S23-4. This new monitoring location was undermined in December 1997 and is located above a panel margin in the lower coal seam. Although the discharge history at this new location is short (Figure 4.1b), it appears that discharge from the new location has not been diminished by mining.

Spring S13-2 is located above fully supported main entries. Discharge from S13-2 (Figure 4.1c) does not show any unusual variations in peak-flow or baseflow discharge over the period of record.

Spring S13-7 is located above fully-supported gateroads of a pillar panel that was first mined only in the early 1980s and has not been subsided. Discharge from S13-7 (Figure 4.1d) is very responsive to climate such as the extremely wet years of the early 1980s. However, this spring has had muted peak flows since 1994 despite the region experiencing a wet period. The muted peak flows are not believed to be a consequence of mining as no subsidence has occurred within one-half mile of the spring. The muted peak discharge rates from S13-7 are attributed to either a natural phenomenon or, perhaps, a change in monitoring methods. There is copious evidence throughout the Wasatch Plateau of historic spring discharge (e.g. tufa deposits) where there is no longer a spring. This spring is

located near S12-1 and S10-1, which, as discussed above and below, have also shown muted peak flows since about 1994.
Spring S14-4 is a developed livestock watering spring. This spring is located above fully supported main entries above which there has been no subsidence. Like spring S13-7, this spring is acutely responsive to climate but has had appreciably lower discharge rates since 1993 (Figure 4.1e). Mining of the longwall panels adjacent to the mains above which S14-4 is located did not occur until late 1995 and late 1996, after the spring first demonstrated decreased discharge. According to personnel working for Skyline Mine at the time (Keith Zobell, Personal Communication, 2000), the decrease in discharge was reported to the Forest Service and repairs were made to the spring collection system. The repairs have not been successful in restoring spring flow to previous levels. Diminution of discharge from S14-4 is attributed to problems with the spring collection system. It is doubtful that mining has had any impact on the discharge from this spring.

Discharge from S12-1 has had muted annual peak discharges since 1994 (Figure 4.1f). This spring has not been undermined, but is located within 500 lateral feet of an area that has been first mined only and has not been subsided. This spring is located in the same area at S13-7 and S10-1, which, as discussed above, also have had muted peak flows since about 1994.

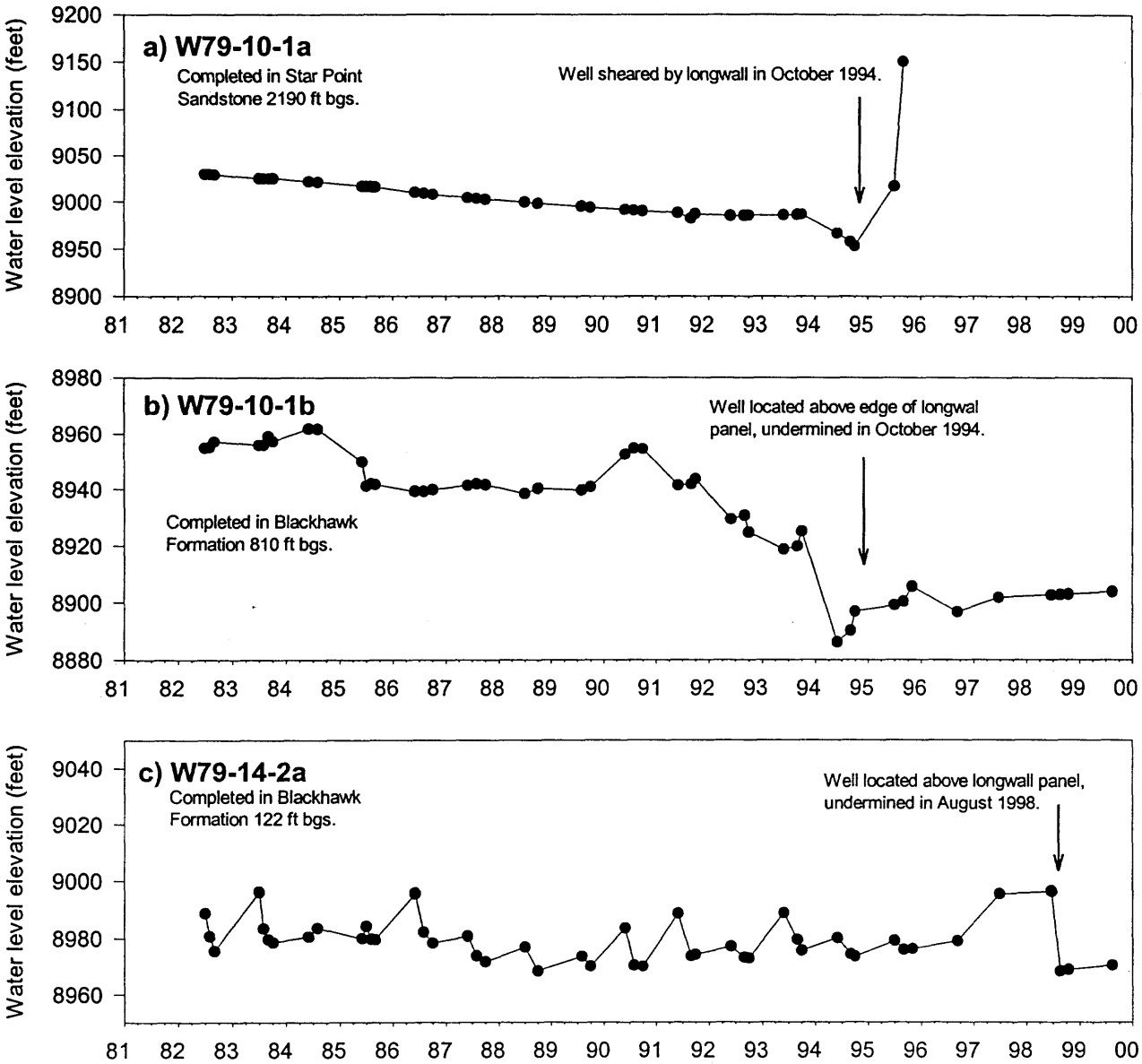
Discharge data from spring S24-12 (Figure 4.1g) indicate that the spring has been dry since late 1989. According to personnel working for Skyline Mine at the time (Keith Zobell, Personal Communication, 2000), S24-12 discharges from a landslide along the surface trace of a major fault. Movement occurred along this landslide in 1989 and discharge from the spring became diffuse whereas before the landslide the discharge was concentrated. Consequently water no longer discharged at the spot originally designated at S24-12, but discharged lower down the slope. In mid 1989, mining was initiated in a longwall panel located laterally about 800 feet from the spring. Although the spring area was not subsided, mining could have precipitated continued movement of the landslide. However, it does not appear that mining has dewatered the groundwater system supporting this spring.

Discharge hydrographs (Figure 4.1h through 4.1n) for other springs that have not been undermined show recent peak flows consistent with previous years.

4.1.2 Monitoring Well Water Levels

Monitoring wells in two locations (Figure 1.2) have been undermined and subsided. Water level hydrographs for these wells are shown on Figure 4.2.

Figure 4.2
Monitoring Well Water Level Hydrographs



The nested well pair W79-10-1a and W79-10-1b was undermined in October 1994. Well W79-10-1a is completed in the Star Point Sandstone, 2170 to 2190 feet below ground surface (bgs). When undermined, W79-10-1a was sheared at the elevation of the coal seams. Water remained in the well bore after the well was mined through (Figure 4.2a), the reason for which is not understood.

A response to undermining was seen in the shallower of these two wells, W79-10-1b, which is screened in the Blackhawk Formation 790 to 810 feet bgs and over 1,200 feet above the mined coal seams. This well is monitored quarterly by CFC (Figure 4.2b). Additionally, as part of a study by the U.S. Bureau of Mines (Mattson et al., 1995), this well was outfitted with a pressure transducer and data logger that monitored water levels daily for three months prior to undermining and for one year after undermining the well location.

CFC data (Figure 4.2b) indicate that the water level in 79-10-1b began a steady decline in 1990. However, longwall mining in the vicinity of the well did not begin until July 1992. At least several months prior to the well being undermined there was a precipitous water level drop, likely as a result of extracting the adjacent panel in the latter part of 1993. After the well was undermined, the water level rose slightly and restabilized at a level about 60 feet lower than the pre-mining level.

Mattson et al. (1995) report that the water level in the well began to rise in 79-10-1b as the longwall face approached the well. After the face passed the well, the water level initially dropped then increased dramatically. With time the water level gradually decreased but remained above the level measured when the data logger was installed prior to undermining. They state that the dramatic variations in water level indicate that the water-bearing zone was not damaged by subsidence (i.e. dewatered) but rather pressurized as a result of stresses building in the overburden after mining. This conclusion is consistent with the longer-term CFC data described above.

Well W79-14-2a is a shallow well completed in the Blackhawk Formation 102-122 feet bgs. The groundwater system that this well monitors appears to be in good hydraulic communication with the surface as indicated by seasonal water level responses. This well was undermined in August 1998. Approximately a year prior to undermining the water rose 16 feet. Immediately after the well was undermined there was a precipitous 28-foot water level decline. In the short time since undermining, data indicate that the water level has not continued to decrease but has stabilized at a level equivalent to the levels observed during the dry years 1987-1992. This type of response, a rise followed by a decline in water level, is attributed to pressure changes in the groundwater system as a response to

differential subsidence. It does not appear that the groundwater system that this well monitored was dewatered.

4.1.3 Stream Discharge Rates And Stream Morphology

As part of this investigation, discharge data from Burnout Creek, which is a perennial drainage in Skyline Mine area, were compiled and analyzed. Burnout Creek is located on the eastern slope of Huntington Canyon less than 1 mile from the RFDS area. The purpose of this analysis is to determine whether stream water has been or is being lost as a result of undermining and subsidence of the stream. The overburden thickness in the area, which consists of the sandstones, mudstones, and shales of the Blackhawk Formation, ranges from 600 to 850 feet above the uppermost seam to be mined. These conditions are essentially identical to those beneath the perennial streams that could be undermined in the RFDS area. For this reason, it is believed that the impacts that have occurred as a result of undermining Burnout Canyon are a good predictor of the impacts that would likely occur if perennial streams in the RFDS area were undermined.

Since 1991, as the Burnout Creek drainage has been experiencing on-going single-seam or multiple-seam longwall undermining, discharge data have been regularly collected at seven monitoring stations. These include six stations on the upper forks of the stream and one station at the mouth of Burnout Creek near its confluence with Upper Huntington Creek. Discharge data are collected at these sites at frequent intervals, commonly every week to 10 days between June and November when the region is accessible. Because discharge data were generally not collected before June, it is possible that the annual maximum springtime discharge peaks were not measured in Burnout Creek. Monitoring locations are indicated on Figure 1.2 and discharge hydrographs for each station are presented in Figure 4.3.

Five of the Burnout Creek monitoring sites (F-1 through F-5) are flumes located on the main perennial tributaries of the drainage system. Sites HR-1 and HR-2 are monitoring stations located in ephemeral or intermittent drainages that are tributary to the lower trunk of the drainage. A discussion of the discharge characteristics and discharge history of each of these portions of the Burnout Creek drainage is presented below.

F-1 (Upper North Flume)

F-1 is located at the base of the northernmost perennial tributary to Burnout Creek (Figure 1.2). This drainage was first longwall undermined during late 1991 and in late 1992. A second coal seam was longwall mined beneath the drainage in 1998 and 1999. In both seams, a fire barrier pillar was left under this drainage. These two fire barrier pillars are stacked. According to the Geology, Mining, Subsidence, and

Figure 4.3
Stream Hydrographs for Burnout and James Creeks

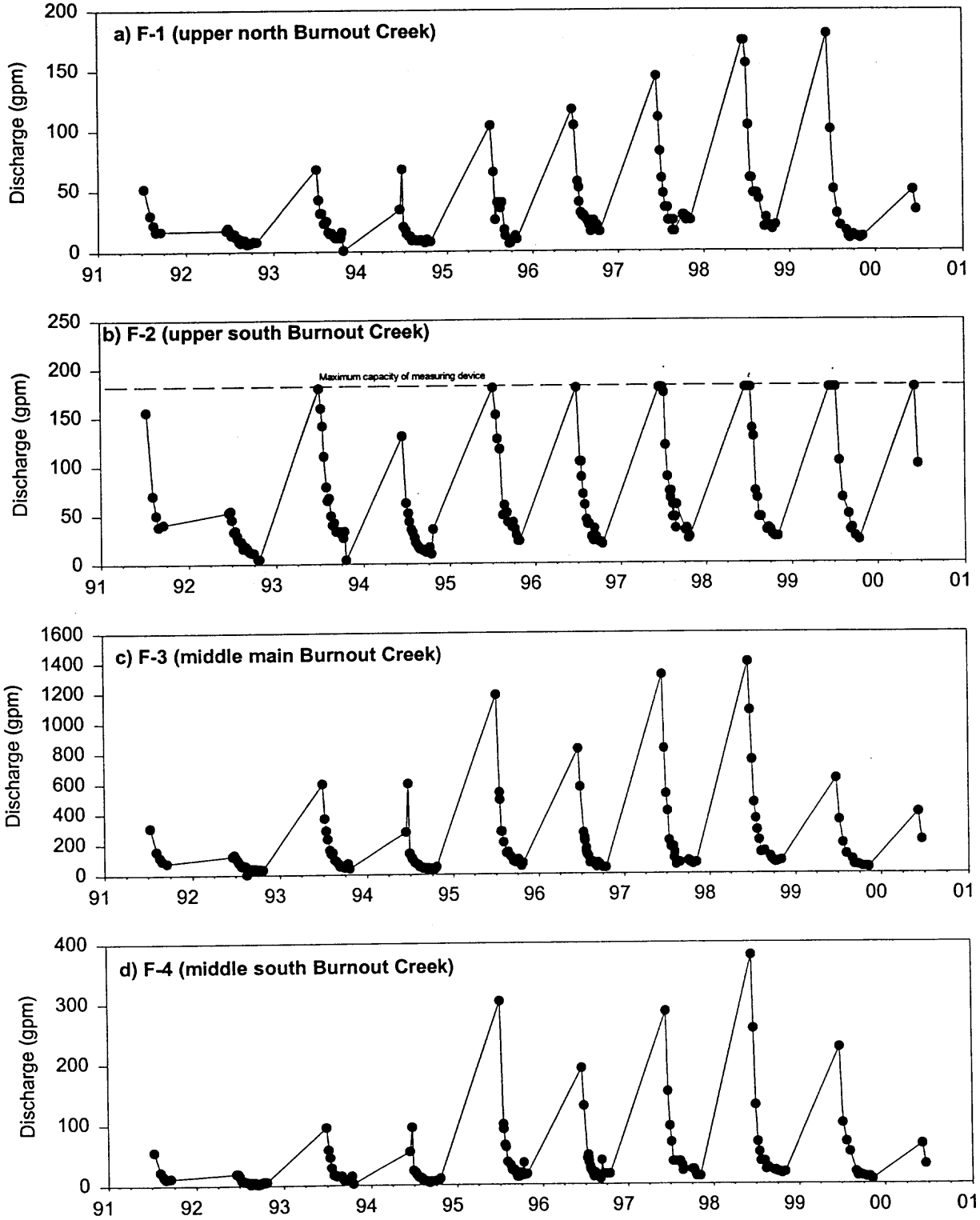
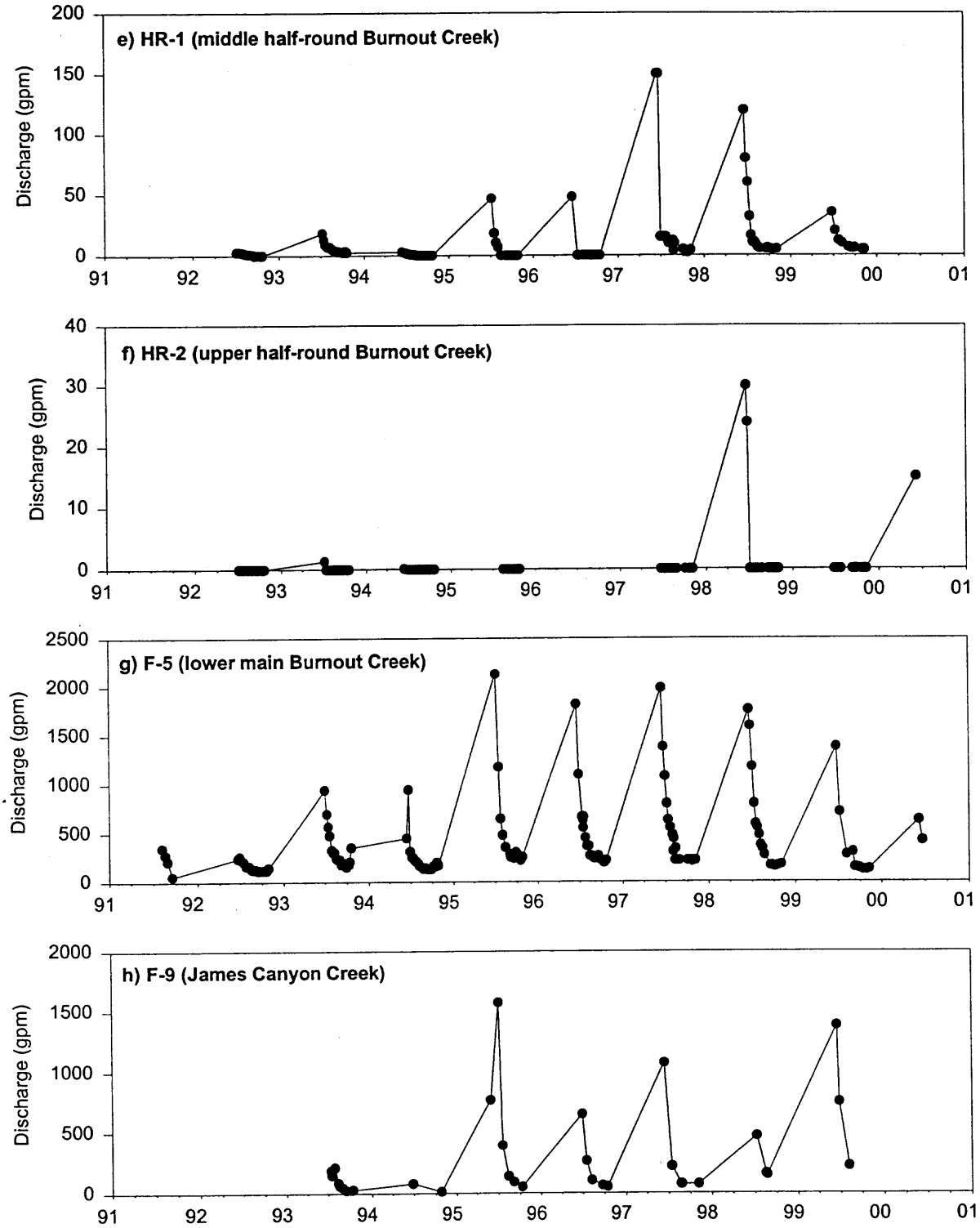


Figure 4.3 (continued)
Stream Hydrographs for Burnout and James Creeks



Seismicity technical report (NorWest, 2000) the strata overlying double stacked fire barrier pillars experience appreciable horizontal strain and have the greatest potential for cracking. However, the discharge hydrograph for F-1 indicates that during the period of undermining (1993-1999), the annual peak discharge rates correspond well with climatologic conditions as expressed by the PHDI (Figure 3.1). The relatively lower peak discharge measured at F-1 during the spring of 2000 is likely attributable the drought conditions the area experienced during this time (Figure 3.1). During the springtime of 2000, there was also an earlier than normal melting of the winter snowpack. As a result, the peak discharges in the Burnout Creek flumes may have occurred prior to the first monitoring event in early June 2000. Baseflow discharge rates during the period of record have remained relatively stable. This suggests that mining has not had a detrimental impact on discharge rates in the drainage.

F-2 (Upper South Flume)

F-2 is located at the base of the east-west trending perennial drainage immediately adjacent to site F-1. Small portions of this drainage were longwall undermined in August 1991 and October 1992. Very small portions of the drainage were again longwall undermined in April and December of 1998. Although only small portions of this drainage were longwall undermined, the undermined portions were located near the ends and lateral margins of the longwall panels, where the potential for the formation of subsidence fractures is usually greatest. The peak high-flow discharge at F-2 exceeded the measuring capacity of the flow measuring device (180 gpm) in 1993 and in each year from 1995 to 2000. Thus it is not possible to analyze the recent peak flow characteristics of this drainage. The discharge hydrograph of F-2 shows that the baseflow discharge from the drainage has increased steadily since 1993 and 1994. It is possible that the low baseflow discharge rates measured during 1992 and 1993 were mining-related impacts. However, it seems more likely that the low discharge rates were the result of the protracted, nearly continuous drought that the area experienced from 1987 to mid-1993. This hypothesis is supported by data from James Canyon, which was not undermined prior to early 1995. Since 1995, ~~the~~ only minimal portions of the drainage have been undermined. Although discharge data from James Canyon are not available for 1992, low baseflow discharge rates were measured during 1993 and 1994. After that time, the baseflow discharge rates in James Canyon increased in response to wetter climatic conditions (Section 3.1). In either case, the data indicate that there were no long-lasting detrimental effects to the drainage resulting from the multiple-seam longwall mining that occurred beneath the drainage.

F-3 (Middle Main Flume)
F-3 is located on the main trunk of Burnout Creek about ½ mile below sites F-1 and F-2. This portion of the drainage was first longwall undermined during 1992, 1994, and 1995. A second coal seam was longwall mined beneath the drainage in 1999. The annual peak discharge rates at F-3 have generally followed climatic trends and baseflow discharge rates at F-3 have remained relatively constant since 1991. The high-flow peak discharge rates measured at F-3 during 1999 and 2000 (after the area underwent second seam mining) are lower than those measured during the previous 4 years. However, as is apparent in the plot of the PHDI (Figure 3.1), the climate gradually become drier during 1999 and 2000, moving from a protracted period of moderate to extreme wetness to a period of moderate drought. It is important to note that, because the PHDI takes into account several hydrologic factors other than precipitation (among other things reservoir storage and soil moisture; Guttman, 1991) there may be a delay between a lack of precipitation and its reflection in the PHDI value. For this reason, a lack of precipitation that contributes to the overall drought severity may result in a gradual lowering of the PHDI value but may not be immediately reflected in the monthly PHDI value. Rather, there would be a declining trend in the PHDI. Thus, a decline in high-flow peak discharge rates at F-3 during 1999 and 2000 would be predicted by the climatic conditions that occurred during this period. Additionally, as discussed above, the early melting of the winter snowpack in 2000 may have resulted in the peak discharge rates at F-3 occurring prior to the first monitoring event in early June 2000. Thus, although it is possible that mining-related impacts to the drainage could have occurred, it seems much more likely that the diminished peak flow discharge rates measured at F-3 during 1999 and 2000 are a result of climatic conditions.

This suggests that there have been no measurable mining-related impacts in this section of Burnout Creek.

F-4 (Middle South Flume)
F-4 is located on the southernmost perennial tributary to Burnout Creek immediately adjacent to F-3. This drainage was first longwall undermined in 1992, late 1993, and mid-1995. The second seam was extracted beneath a portion of the drainage in mid-1999. The discharge hydrograph for F-4 shows that the annual peak discharge rates generally correlate with climate. Baseflow discharge rates also are a general reflection of climatic conditions.

The annual peak discharge rates at F-4 have followed trends essentially identical to those at F-3. As discussed for F-3 above, it is believed that the lower high-flow peak discharges measured at F-4 are the result of the general drying out of the climate during 1999 and 2000, and possibly to the early melting of the winter

snowpack in 2000. Thus, although it is possible that mining-related impacts to the drainage could have occurred, it seems much more likely that the diminished peak flow discharge rates measured at F-4 during 1999 and 2000 are a result of climatic conditions.

This suggests that there have been no measurable mining-related impacts in this section of Burnout Creek.

HR-1 (Upper Half Round)
HR-1 is located in an ephemeral drainage that flows into the main trunk of Burnout Creek below F-3 and F-4. This drainage flows only in direct response to snowmelt or precipitation events. Since 1992, when monitoring at HR-1 began, water was measured in the drainage on only five occasions. Thus, it is not possible to determine whether mining has had any detrimental impacts on this drainage.

HR-2 (Middle Half Round)
HR-2 is located in an intermittent drainage that flows into the main trunk of Burnout Creek. The discharge in this drainage has varied with climate. Discharge during the drought years from 1992 through 1994 was meager, while discharge in the generally wet years from 1995 through 1999 has been much greater. There is no evidence that measurable mining-related impacts to discharge in this drainage have occurred.

F-5 (Lower Main Flume)
F-5 is located near the confluence of Burnout Creek with Upper Huntington Creek. The discharge measured at F-5 represents the combined discharge from all of the other monitoring stations. The cumulative effects of any mining-related diminution of flow in the Burnout Canyon drainage would be detected at F-5. The annual peak discharge flow rates measured at F-5 generally reflect climatic conditions in the area. As anticipated, the annual peak discharge rates at F-5 have followed trends that are very similar to those at F-3 and F-4. As discussed above, it is believed that the lower high-flow peak discharges measured at these locations are the result of the general drying out of the climate during 1999 and 2000, and possibly to the early melting of the winter snowpack in 2000. Thus, although it is possible that mining-related impacts to the drainage could have occurred, it seems much more likely that the diminished peak flow discharge rates measured at F-5 during 1999 and 2000 are a result of climatic conditions.

Baseflow discharge rates have remained relatively constant from 1992 to the present. There is no indication that mining activities have had any measurable or lasting impacts to discharge rates in Burnout Canyon. Rather, the baseflow

discharge rates measured at each of the seven monitoring station during October 1999 were greater than those measured in October 1992. It is important to note that during late 1992 the region was in a period of moderate drought. During October 1999 the region was entering period of drought of similar severity to that in 1992. Thus, the baseflows measured during these periods are somewhat lower than those measured during the years intervening between 1992 and 1999.

Summary

In summary, it is apparent from the Burnout Creek discharge hydrographs (Figure 4.3) that 1) baseflow discharge rates in the creek over the past several years (Figure 4.4) are not considerably different from those measured in the early 1990s when mining in the area first began, and 2) the magnitude of the annual discharge from the creek correlates well with the PHDI for Utah Region 5 (Figure 3.1), suggesting that the source of variability in the yearly discharge peaks is a function of climatic conditions. There is no indication that measurable quantities of water have been lost from the Burnout Creek drainage as a result of the longwall undermining of the creek.

Similar findings are reported by Sidle et al. (2000), who compared baseflow discharge rates at the mouth of Burnout Creek from 1981 to 1991 with discharge measured during 1992-94, a period of direct undermining of the perennial stream. They found that the baseflow discharge during 1981-91 (193 gpm) was essentially the same as that measured during 1992-94 (179 gpm). They also found that there was no statistically significant difference between pre-mining and post-mining baseflows based on t-test comparisons (α=0.05).

Sidle et al. (2000) also evaluated changes in channel characteristics, including sediment sources and distribution, which occurred after the Burnout Creek drainage was subsided by as much as to 5 feet during 1993 and 1994. They found that 1) there was an increase in the lengths of cascades and, to a lesser extent, glides, 2) there were increases in pool length, numbers, and volumes, 3) there were increases in median particle diameter of bed sediment in pools, and 4) there was some constriction in channel geometry. They found that most of these changes appeared to be short-lived, and that the channel had recovered to near pre-mining conditions by 1994. However, they also found similar near-channel sedimentation and loss of pool volume during this same time period in the adjacent James Creek drainage, which had not at that time experienced any longwall mining. It is possible that some of the observed temporary stream morphology changes in both Burnout and James Canyons may have been related to the intense livestock grazing that occurred in both canyons during the dry summer of 1994. Thus, it is difficult to determine the degree (if any) to which the

mining activities contributed to the changes in stream morphology in Burnout Canyon.

4.2 WATER QUALITY

The quality of spring discharge water in the Skyline Mine area has not been measurably impacted by mining (Mayo and Associates, 1996). However, discharge of mine water to Eccles Creek has had a water quality impact.

It is anticipated that the chemical quality of groundwater intercepted by mining in the RFDS area would be of the same general character as that encountered in the Skyline Mine area because of similar lithologic, mineralogic, and hydrogeologic conditions. A brief characterization of the water quality of discharge waters from the Skyline Mine is presented below.

Mine discharge water quality data from the Skyline Mine are available for both Mine 1 and Mine 3 (DOGM, 2000). Average TDS concentrations are approximately 1,100 mg/l for Mine 1 and 800 mg/l for Mine 3. Both Mine 1 and Mine 3 discharge waters are of are of the calcium-magnesium-bicarbonate-sulfate chemical type. Concentrations of total and dissolved iron and manganese are consistently below the specified discharge limits (Mayo and Associates, 1996).

Mayo and Associates (1994) report that TDS concentrations in Skyline Mine discharge water measured at NPDES-001 (combined discharge from Mine 1 and Mine 3) rose steadily between 1984 and 1992. During this period, TDS concentrations of mine discharge water increased from approximately 300 to more than 1,500 mg/l. Most of this increase in TDS was attributable to a substantial increase in the concentrations of sulfate and, to a lesser extent, bicarbonate. Mayo and Associates (1994) attributed these increases to 1) the long-term use of gypsum rock-dust in the mine, and 2) the oxidation of fugitive longwall emulsion. Thus, the increases in TDS are believed to be the result of human induced factors and are not a result of natural spatial variations in groundwater quality in the groundwater system. This suggests that when new mining areas are accessed in the RFDS area, elevated TDS mine discharges may be avoided by not using gypsum rock dust and exercising care when using longwall emulsion fluid.

5.0 POTENTIAL ENVIRONMENTAL CONSEQUENCES—SURFACE WATER

5.1 ALTERNATIVE 2: LEASE WITH BLM STANDARD LEASE TERMS AND CONDITIONS AND FOREST SERVICE SPECIAL COAL LEASE STIPULATIONS

5.1.1 Potential Decreases In Baseflow Discharge Of Creeks

Under this alternative, the application of SCLS #9, perennial streams would not be undermined and thus the potential for direct impacts to perennial creeks is avoided.

However, creek discharge could be indirectly impacted if there were a diminution of discharge from groundwater systems that supply baseflow to perennial streams. As discussed in Section 6.1.1, the potential for diminution of discharge from shallow groundwater systems is considered negligible. This is largely because of the existence of low-permeability rocks that create perched conditions in the groundwater systems that provide baseflow to creeks. Therefore, the probability of decreased baseflow in creeks in the RFDS area under Alternative 2 is negligible.

If, in the unlikely event, there were a perceptible or quantifiable decrease in streamflow as an indirect result of subsidence, SCLS #17 would require that the operator replace, at his expense, any surface water identified for protection that may be lost or adversely affected with water from an alternate source in sufficient quality and quantity to maintain existing riparian habitat, fishery habitat, livestock and wildlife use, or other land uses.

5.1.2 Increased Sediment Loading Resulting From Subsidence

Because perennial streams would not be subsided under Alternative 2, the potential for a direct increase sediment loading under this alternative would only occur in ephemeral or intermittent drainages. However, when there is sufficient water in these drainages, the sediment in the ephemeral or intermittent streams may be transported into perennial streams, lakes, or reservoirs.

Differential subsidence of surface water drainages has the potential to increase the sediment load of streams. Differential subsidence of the land surface can locally cause increased stream gradients, which increases stream velocity and erosion potential. This increased erosion potential may result in increased sediment

loading of the stream. Differential subsidence of surface-water drainages can also locally result in decreases in sediment loading. If there is an overall increase in the frequency of pools in a watercourse, bed-load sediment carried by the stream may be deposited in these low-energy reaches, resulting in a decrease in sediment loading downstream of the pools.

Both of these impacts, if they were to occur, are likely to be short-lived. This is because the erosion of steep-gradient regions and the deposition of material in low-gradient regions result in a gradual bringing of the stream into equilibrium with its channel. Sediment loading may result from either 1) erosion and deepening of the streambed, or 2) a widening of the stream channel as a result of bank erosion. As the stream reaches equilibrium with the channel, the sediment loading in the stream would likely return to near pre-mining conditions. The rate at which this would occur is a function of the type and resistance to erosion of the subsided sediments. If the sediments are soft and easily eroded (i.e. soil horizons or soft, weathered sedimentary rocks common in the RFDS area) the stream would rapidly come into equilibrium and the increased sediment loading in the stream would rapidly cease. If the channel substrate consists of resistant bedrock, then the stream would take much longer to achieve equilibrium with its channel, but because the rock is not easily eroded, there would be minimal or no increases in sediment loading of the stream.

It should be noted that the north facing slopes of Flat, Cunningham, and Swens Canyons have recently experienced considerable logging activities including the associated road construction and soil and vegetation disturbances. Because of these disturbances, there is a likelihood of increased sediment yield from the logged areas in the near future whether or not mining occurs.

5.1.3 Impacts To Water Quantity And Water Quality Of Eccles Creek And Downstream Watercourses Resulting From The Discharge Of Intercepted Groundwater

Skyline Mine currently discharges about 500 gpm. CFC estimates that mine discharge could be as high as 3,000 gpm if mining were to occur in the RFDS area. This rate would not be sustained continuously but represents a maximum occasional discharge. The actual discharge rate of water from mine workings would be dependant on the amount of water encountered, the amount of water that would be impounded underground, and cycles of the water handling system. The impact of additional discharge to Eccles Creek is discussed in this section.

As discussed in Section 4.2, it is anticipated that the chemical quality of groundwater encountered during mining in the RFDS area would be similar to that encountered in the Skyline Mine area. Therefore, if mine water discharge

rates were to remain at current levels (approximately 500 gpm), and mine water were to continue to be discharged into Eccles Creek, there would be no new impacts to water quality or quantity beyond those currently occurring. Assuming that future discharge rates from the mine increased from current levels to 3,000 gpm (an approximate six-fold increase) then greater impacts to water quantity and quality in Eccles Creek and downstream watercourses would be anticipated.

The overall quality of Skyline Mine discharge water has been appreciably lower than of Eccles Creek (Mayo and Associates, 1996). Therefore there is a direct relationship between the percentage contribution of mine water to the creek and the overall quality of creek water below the mine discharge point. The greater the relative contribution of mine water to the creek, the greater would be the degradation of water quality in the creek.

Because the average solute concentrations of major ions in mine discharge water and Eccles Creek water are known, it is possible to use a flow-weighted linear mixing model to estimate the anticipated water quality at CS-2 (Eccles Creek below the mine discharge point) if additional mine discharge water enters the creek. Results of these calculations for a projected mine water discharge rate of 3,000 gpm are shown in Table 5.1. Because the Skyline Mine is currently discharging approximately 500 gpm into the creek, a total mine discharge of 3,000 gpm would represent an increase of 2,500 gpm above current levels. The linear mixing model suggests that TDS concentrations at CS-2 on Eccles Creek would average approximately 877 mg/l. Currently, with a 500-gpm mine discharge, TDS concentrations average approximately 554 mg/l (Table 5.1). A substantial portion of the TDS increase would result from increases in sulfate concentrations, which would average approximately 400 mg/l. Currently, with a 500-gpm discharge, sulfate concentrations at CS-2 average 193 mg/l. Most other solute species would have smaller increases because the concentrations of these species in mine water are nearer those of the receiving water. It should be noted that these estimates are based on a continuous mine discharge of 3,000 gpm. It is likely that pumping of mine water would occur intermittently and the long-term average pumping rate would be considerably less than 3,000 gpm. Thus, these estimates should be considered as worst-case estimates. The magnitude of the potential water quality impacts may be considerably less than those estimated above.

The results of the flow-weighted mixing calculations are acceptable for estimating the general order of impacts to Eccles Creek because of the relatively low concentrations of solute species in both mine water and receiving water. However, it should be noted that, because this technique does not consider

mg/L

Table 5.1 Flow-weighted linear mixing model results

	Flow	TDS	Ca	Mg	Na	K	HCO_3	SO_4	Cl
Historic mean values for Skyline Mine discharge water									
CS-12 (Mine 3 discharge)	242	797	74.9	49.7	52.5	7.5	280	361	11
CS-14 (Mine 1 discharge)	153	1104	141	85.3	62.9	13.1	310	525	14.8
Weighted average mine discharge water		916	100	63	57	10	292	424	12
Historic mean values for receiving waters									
CS-4 (Eccles Creek above mine discharge)	190	269	74	14	6	1	266	15	12
CS-2 (Eccles Creek below mine discharge)	1015	554	88	35	52	6.1	321	193	14
UPL-10 (Upper Huntington Creek at Electric Lake)	3857	182	53	9.9	3.7	1	183	15.2	6.5
Estimated CS-2 assuming mine discharge of 3,000 gpm	**3190**	**877**	**99**	**61**	**54**	**9**	**290**	**400**	**12**
Estimated UPL-10 assuming mine discharge of 3,000 gpm	**6857**	**503**	**74**	**33**	**27**	**5**	**231**	**194**	**9**

thermodynamic factors, there is the potential for error in the calculations, particularly in non-dilute solutions.

Currently, Skyline Mine is permitted to discharge 7.1 tons per day of dissolved solids. Assuming that discharge increases to 3,000 gpm total mine discharge (6.68 cfs) and the average mine discharge TDS concentration of 916 mg/l remains the same, there would be a salt loading of 16.5 tons per day, an increase of 9.4 tons per day.

Scofield Reservoir and the Price River and its tributaries have been designated as protected by the Utah Division of Drinking Water (UAC R317-2) for 1) domestic purposes with prior treatment by treatment processes, 2) secondary contact recreation such as boating, wading, or similar uses, 3) cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain, and 4) agricultural uses including irrigation of crops and stock watering.

Before any mine water could be discharged into these waters, the current UPDES discharge permit may need to be modified. In order to receive a new or modify an existing UPDES permit, it must be demonstrated that beneficial use standards would not be exceeded in the receiving water. When a UPDES discharge permit is issued or modified, the water quality of the proposed discharge water is evaluated by the Utah Division of Water Quality (Personal Communication, Mike Herkimer, 2000). WET testing is performed to ensure that the water is not toxic (either chronic or acute) to aquatic organisms. If harmful constituents are identified in the proposed discharge water, then an approved water treatment plan must be implemented before any water may be discharged. If constituents are found in the water that are regulated under TMDL or which may cause the receiving water to not meet the quality standards for the designated beneficial uses, then specific discharge limits are placed on these constituents. Routine water quality monitoring of the discharge water is required for all parameters requested by the Division of Water Quality to demonstrate compliance with the UPDES permit.

As demonstrated by many years of continuous water quality monitoring, the quality of raw mine discharge water from the Skyline Mine, in terms of TDS, sulfate and pH, is acceptable for all of the protected beneficial uses and is within the drinking water standards set fourth by the Utah Division of Drinking Water (UAC 317-2). Limited chemical data are available for most other chemical parameters controlled by the designated beneficial use standards. These data are summarized in Appendix D. Also included in Appendix D is a listing of the regulated chemical parameters for which no data have been located.

With a few exceptions discussed below, the quality of the mine discharge water has generally been acceptable for all of the designated beneficial uses of the receiving water (in terms of the chemical constituents for which water quality data are available). Concentrations of total boron, cyanide, dissolved lead, total phosphorous, and TDS have on at least one occasion exceeded the concentration limits specified by one or more of its beneficial use standards. Concentrations of cyanide from CS-12 on one occasion exceeded the beneficial use standard for aquatic wildlife. On each of the other 12 monitoring events, no cyanide was detected. During the single cyanide-monitoring event from the UPDES outfall, the concentration of cyanide also slightly exceeded the standard. The concentration of total phosphorous has occasionally been exceeded in discharge from CS-12 and CS-14, and was exceeded in the single phosphorous-monitoring event from the UPDES outfall. The average concentration of total phosphorous from CS-12 discharge is within the beneficial use standards, while those standards are somewhat exceeded in the average CS-14 discharge. The concentration of total mercury also exceeded the beneficial use standards during the single mercury-monitoring event from the UPDES outfall. Concentrations of phenol, an organic compound, have exceeded the beneficial use standards on a few occasions at both CS-12 and CS-14, while on all other occasions, there was no phenol detected in the discharge water. The causes of the occasional elevated phenol concentrations in the mine discharge water are not known.

It is important to note that for each of the chemical parameters discussed above, (with the exception of phenol and possibly total phosphorous) although certain beneficial use standards have occasionally been exceeded in the discharge water from either CS-12 or CS-14, the average concentration of mine discharge water, which is a combination of water from these two sources, is generally suitable for each of the beneficial uses. As discussed above, important chemical parameters of potential mine discharge water would be strictly controlled through the UPDES permitting process and would be monitored by several Utah State regulatory agencies. Additionally, continuous, automated monitoring equipment has been installed in the Skyline Mine discharge system that ensures that water that is excessively elevated in TDS, ph, turbidity, or oil and grease concentrations would not be discharged. If poor quality mine discharge water is detected by this system, it is automatically rerouted to underground storage areas within the Skyline Mine and is not discharged.

The addition of approximately 2,500 gpm (5.57 cfs) of mine discharge water to Eccles Creek above current levels (about 500 gpm) would constitute a considerable increase to the natural discharge in the creek. During low-flow periods, discharge in Eccles Creek measured at CS-2 is commonly between about

0.1 and 2 cfs. Thus, an addition of 5.57 cfs would result in a discharge between 2.8 and 56 times current levels. The addition of this amount of sediment-free water during low-flow periods would cause increased sediment transport. The magnitude of this impact has not been quantified. The data necessary to perform a rigorous and meaningful analysis have not been collected. However, the erosion potential would be mitigated in part because of the well-armored nature of the stream channel. The stream channel in Eccles Creek is dominated by cobbles and boulders and appears to be relatively stable. During periods of high flow in the creek, when current discharges commonly exceed 10 to 50 cfs, the addition of 5.57 cfs of mine discharge water would constitute a relatively smaller impact.

Eccles Creek is a tributary of Mud Creek, which is a tributary of Scofield Reservoir. Therefore an increase in the mine water discharge rate to Eccles Creek would also impact downstream watercourses including Mud Creek and Scofield Reservoir. Unlike Eccles Creek, the channel substrate in Mud Creek, particularly in its lower reaches, appears less armored than Eccles Creek and contains reaches dominated by fine-grained material. Therefore, the potential for increased erosion rates in Mud Creek would likely be greater than for Eccles Creek. However, because Mud Creek is a larger watercourse than is Eccles Creek, the addition of 5.57 cfs to the discharge represents a smaller percentage increase to the total stream flow. Thus, this additional water would be more readily accommodated in the channel. Likewise, because of the larger volume of discharge in Mud Creek relative to Eccles Creek, the degradation of water quality in this watercourse would be less.

During dry years, the addition of 5.57 cfs to Scofield Reservoir from Mud Creek would likely not result in any major impacts in terms of the ability of the reservoir to accommodate the additional water. Rather, the increased recharge to the reservoir would likely be considered a positive impact by those who use the water. This would be particularly true during dry years, because as discussed in Section 3.2.3, the inflow of deep, perched groundwater into the mine workings is not related to climate. During extremely wet years, when water is spilling from the reservoir, the addition of this amount of water would be a meager amount relative to the 6,200 cfs capacity of the spillway. During extremely wet years, when there is no available storage capacity in the reservoir, the mine discharge water would increase the high-flow discharge rate in the Price River below the dam by 5.57 cfs. This would constitute a small percentage of the high-flow discharge of the Price River below the reservoir.

If the mine discharge water were redirected to the Upper Huntington Creek drainage, the discharge to Eccles Creek could cease. Under this scenario, the water quality in Eccles Creek would revert to its pre-mining condition, with an

average TDS concentration of approximately 269 mg/l. Water quality in Mud Creek would also improve to pre-mining levels. As discussed above, there would be a net decrease of approximately 2.8 tons per day of salt loading to Scofield Reservoir. Discharge rates in Eccles Creek would decrease dramatically to pre-mining conditions. This would be particularly noticeable during baseflow conditions, when stream discharge rates would decrease from the current levels in dry years to perhaps less than 100 gpm. The loss of approximately 500 gpm of mine discharge water would represent a loss of approximately 800 acre-feet of water per year in Scofield Reservoir.

5.1.4 Impacts To Water Quantity And Water Quality Of Electric Lake And Downstream Watercourses Resulting From The Discharge Of Intercepted Groundwater

It is proposed in the RFDS that mine water might be discharged to Electric Lake at or below the high water line in Upper Huntington Canyon. The possibility of discharging water some distance out into the lake has also been discussed by USFS personnel and CFC. This section discusses the possible impacts to chemical and physical water quality as a result of discharging mine water to Electric Lake. The chemical water quality impacts are expected to be the same regardless of weather water is discharged near the high water line or father out into the lake. The physical quality of the lake could be impacted if discharge near the high water line results in appreciable entrainment and transport of lake bottom sediments during low stand periods.

As discussed in Section 4.2, it is anticipated that the chemical quality of groundwater encountered during mining in the RFDS area would be similar to that encountered in the Skyline Mine area. Because the anticipated quality of mine discharge water is poorer than that in Upper Huntington Creek, the water quality of Upper Huntington Creek would be degraded by the addition of any mine water. The magnitude of this impact is directly related to the volume of mine water discharged into the receiving water. In the following discussion, water quality impacts to Electric Lake have been analyzed by comparing the water quality of Upper Huntington Creek at UPL-10 to the average quality of Skyline Mine discharge water. However, the water quality impacts to Electric Lake resulting from proposed mining activities in the RFDS area would be less than those occurring in Upper Huntington Creek due to dilution in the lake.

Because the average solute concentrations of major ions in mine discharge water and Upper Huntington Creek water are known, it is possible to use a flow-weighted linear mixing model to estimate the anticipated water quality at UPL-10 (Upper Huntington Creek just above Electric Lake) at different mine water discharge rates. The results of these calculations for an anticipated mine water

discharge rate of 3,000 gpm are shown in Table 5.1. Because there is currently no mine discharge into Upper Huntington Creek, the entire 3,000 gpm would constitute a new impact to the stream. The linear mixing model suggests that TDS concentrations at UPL-10 could increase from approximately 182 mg/l to 502 mg/l (Table 5.1). Much of this increase would be caused by increases in the sulfate concentration in the stream, which could increase from 15 to 194 mg/l. Smaller increases in other solute species would also occur (Table 5.1). As discussed above, these estimates are based on a continuous discharge of 3,000 gpm into the stream. It is more likely that mine water would only be pumped intermittently, and thus, the average pumping rate would be considerably less. Therefore, these estimates should be considered as worst-case estimates. The actual water quality impacts may be considerably smaller than those described above. The results of the flow-weighted mixing calculations are of value in estimating the general magnitude of impacts to Upper Huntington Creek, but as described in Section 5.1.3, it should be noted that there is the potential for error using this technique. Assuming an average TDS concentration of mine discharge water of 916 mg/l, there would be an additional 16.5 tons per day of salt loading to the reservoir.

Huntington Creek and Electric Lake are protected for secondary contact recreation such as boating, wading, or similar uses. These waters are also protected for cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain. The waters are also protected for agricultural uses including irrigation of crops and stock watering. Huntington Creek has been designated as protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water.

Before any mine water could be discharged into these waters, a UPDES discharge permit would be required. In order to receive this permit, it would need to be demonstrated that the beneficial use standards for these waters would not be exceeded. Water quality analyses for the Skyline Mine discharge for important parameters regulated under the beneficial use standards are included in Appendix D. As discussed in Section 5.1.3, the quality of mine discharge water for all parameters regulated under beneficial use standards (with the exception of phenol and possibly total phosphorous) for which data are available is generally acceptable for the designated beneficial uses. As discussed above, all important water quality parameters would be controlled through the UPDES permitting process and are regulated by several Utah State regulatory agencies. Additionally, continuous, automated monitoring equipment has been installed in the Skyline Mine discharge system that ensures that water that is excessively elevated in TDS, pH, turbidity, or oil and grease concentrations would not be

discharged. If poor quality mine discharge water is detected by this system, it is automatically rerouted to underground storage areas within the Skyline Mine and is not discharged.

Because the mine discharge water is generally of sufficient quality to meet drinking water standards and all of the designated beneficial uses of the receiving waters (for the chemical parameters for which data are available and with the exception of phenol and possibly total phosphorous), it is unlikely that there would be adverse impacts to ecosystems in downstream water courses or that there would be adverse water quality impacts to downstream water users.

The temperature of groundwater from the Skyline Mine has averaged between about 11 and 16°C (Mayo and Associates, 1994). If this water is discharged directly into Electric Lake during the winter months when temperatures of the lake water are near 0°C, there would be an alteration of the thermal regime of the lake. This may locally result in the melting or thinning of the surface ice in the vicinity of the discharge point and may also impact ecosystems in the immediate vicinity of the discharge point.

In the event that mine water is discharged near the high water line of Electric Lake, there is potential for appreciable erosion of lake bed sediments during times of the year when Electric Lake is not at high water. When the lake is not at high water, mine water discharge would first mix with Upper Huntington Creek discharge before flowing in the lake. When the lake is not at high water, Huntington Creek flows in a channel carved into unvegetated lake bed sediments. The addition of approximately 3,000 gpm (6.68 cfs) of mine discharge water to Upper Huntington Creek would constitute a considerable increase in the discharge in the creek. During low-flow periods, discharge from Upper Huntington Creek to Electric Lake is commonly between about 1 and 3 cfs (Mayo and Associates, 1996). Thus, an addition of 6.68 cfs would result in a baseflow discharge that is between about 2.2 and 6.7 times current levels.

The potential for disturbance of lake-bottom sediments would be greatly diminished if discharge water were conveyed via pipeline to a point further out into the lake. Because the mine water discharged into the lake would be essentially sediment free, there would likely not be any perceptible deposition of sediment at the mine discharge point.

During dry years and during the late summer months, the addition of 6.68 cfs of water to Electric Lake may be seen as a beneficial impact. This would be particularly true during drought years, because as discussed in Section 3.2.3, the inflow of deep, perched groundwater into the mine workings is not related to

climate. During extremely wet years, when water is spilling from the reservoir, the addition of this amount of water would be a meager amount relative to the 2,300 cfs capacity of the spillway. During extremely wet years, when there is no available storage capacity in the reservoir, the mine discharge water would increase the high-flow discharge rate in Huntington Creek below the dam by 6.68 cfs. This would constitute a small percentage of the high-flow discharge of Huntington Creek below the reservoir.

5.1.5 Impairment Of Water Rights Resulting From Decreased Stream Flows

Numerous water rights for creeks are held in the RFDS area by both private land owners and government agencies. As described in Section 5.1.1, perceptible or quantifiable impacts to creek discharge rates are not anticipated. If there are no impacts to creek discharge rates then there should be no impairment of water rights. In the event that there is a mining-related flow diminution of an appropriated surface water source, Utah Code 40-10-18 requires the mine operator to "promptly replace any state appropriated water in existence prior to the application for a surface coal mining and reclamation permit."

5.2 ALTERNATIVE 3: LEASE WITH BLM STANDARD LEASE TERMS AND CONDITIONS ONLY

Under Alternative 3, the SCLS are not applied to the lease. The potential environmental impacts under this alternative include the impacts described under Alternative 2 and the potential impacts described below.

5.2.1 Diversion Of Surface Water From Perennial Creeks And Boulger Reservoir Into The Subsurface As A Result Of Undermining And Subsidence

Perennial streamflow may be impacted if subsidence-related tension fractures caused diversion of surface water into the subsurface. As discussed in Section 2.8, it is believed that low-permeability confining or perching layers exist beneath all of the perennial streams in the RFDS area. This is expected to be the case regardless of the geomorphology. For instance, although Boulger Canyon is wide with a low stream gradient whereas Swens Canyon is narrow and steep, the same bedrock formation underlies the unconsolidated sediments in each canyon. Canyon geomorphology in the study area is a function of erosional process (fluvial and glacial) not the underlying bedrock. It is for this reason that the results of undermining Burnout Canyon with respect to stream dewatering can be extrapolated to all of the perennial drainages in the study area.

Therefore, in order for surface waters to be diverted from a creek, the integrity of the perching layer(s) would need to be compromised such that downward migration of surface waters into deeper unsaturated rock horizons could occur. The subsidence fractures must be sufficiently extensive and interconnected so as to facilitate the conveyance of stream water out of the drainage. As discussed in Section 6.1.1, it is expected that the integrity of the low-permeability bedrock horizons that support both streams and shallow groundwater systems in the RFDS area would not be compromised. For these reasons, the potential for the direct interception and translocation of surface waters by subsidence fractures is considered remote. The existence of low-permeability layers creates shallow, perched groundwater systems beneath the stream. Were this not the case, the streams in the RFDS area would be losing streams because the groundwater derived baseflow component would flow downward into the unsaturated horizons that exist deeper beneath the surface.

If subsidence fractures were to occur above the impermeable perching layer, these would be of relatively little consequence to the hydrologic regime. Because sediments above the perching layer are believed to be fully saturated, there could be no loss of water to these fractures. As discussed in Section 6.1.1, subsidence fractures that could develop in the Blackhawk Formation would heal rapidly as a fracture plane is wetted due to swelling clays in the Blackhawk Formation. Thus, if subsidence fractures were to damage the perching layer beneath the stream, these fractures would likely remain open for only a short period of time.

The experience of CFC performing longwall extraction beneath Burnout Creek provides support for the idea that perceptible or quantifiable detrimental impacts to perennial streams would not likely occur if these drainages were undermined. As discussed in Section 4.1.3, there have been no quantifiable impacts to baseflow discharge in Burnout Creek after it was undermined that could be attributed to mining activities. It is believed that the geologic conditions in the RFDS area (geologic formation, overburden thickness, and degree of fracturing and faulting) are sufficiently similar to those at Burnout Canyon (less than 1 mile from the RFDS area) to give scientific validity to extrapolating the observed effects of undermining Burnout Creek to those that may occur if perennial surface water drainages in the RFDS area are undermined with longwall mining techniques. Thus, it is probable that no perceptible or quantifiable losses of surface water would occur if surface water drainages in the RFDS area are undermined.

As discussed in Section 6.1.1, there is a potential for localized shifting of groundwater discharge locations as a result of mining-related subsidence. This can result from minor alterations in the attitude of bedrock horizons (i.e. a change

in the groundwater flow direction) or changes to fracture networks that may support groundwater discharge. However, because the drainages that support surface water in the RFDS area are all well entrenched and the surface gradients are relatively steep, the possibility that minor shifting of groundwater discharge locations could remove perceptible or quantifiable amounts of surface water from the drainage is remote. Rather, it is likely that groundwater entering the stream channel would simply enter slightly higher or lower in the drainage. Under this scenario, there would be no net loss of water from the watercourse.

For the reasons discussed above, it is believed that the potential for diminished baseflow discharge in creeks in the RFDS area under Alternative 3 is negligible. However, if perceptible or quantifiable detrimental impacts to groundwater systems that provide baseflow to streams in the RFDS area do occur, then these impacts would be reflected in decreased baseflow in streams. These potential impacts to perennial streams, were they to occur, would likely be of relatively short duration, likely on the order of one or two seasons. As discussed in Section 6.1.1, tension fractures in the Blackhawk Formation tend to heal rapidly because of the existence of hydrophilic swelling clays in the rocks of the formation. If subsidence fractures were to intercept groundwater, the fractures would rapidly heal as the clays along the fracture planes became wetted and subsequently swelled. If subsidence fractures appear in a stream channel that has a bare bedrock substrate (that may not contain swelling clays) the subsidence fractures would likely fill with sediment transported by the stream. It was evident in the July 2000 stream survey that each of the streams surveyed was actively transporting quantities of sediment that would be sufficient to fill even a relatively large subsidence fracture in a short period of time. Assuming a typical fracture width of 1 inch, a depth of 30 feet, and a length of 50 feet, a fracture volume of 125 cubic feet is calculated. Although no direct measurements of sediment transport in streams in the area are available, it is believed that the quantities of sediment transported annually in perennial streams in the RFDS area greatly exceed this amount. Thus, even if several subsidence fractures occurred in the drainage, the duration of a potential stream-water loss resulting from subsidence fractures physically intersecting a bedrock channel would be relatively short, perhaps on the order of one or two seasons.

In the event that there were a perceptible or quantifiable mining-related diminution of discharge in a creek that has been designated for protection, the application of SCLS #17 would require the lessee to replace any water lost from or adversely affected by mining operations with water from an alternate source in sufficient quality to maintain existing riparian habitat, fishery habitat, or livestock and wildlife use.

5.2.2 Changes In Stream Morphology Due To Subsidence Of Creeks

Longwall mining commonly results in differential subsidence of the land surface. If longwall mining occurs under a stream drainage, there would be localized changes in channel gradient near the margins of a subsided area. These changes may result in a deepening or a widening of the stream channel. In the interior of a subsided area, the land subsidence is more uniform and changes in stream gradient should theoretically be small. Therefore, the greatest potential for major alterations in stream morphology occurs above panel ends or above longwall gateroads. Although the potential for major changes in stream morphology does exist, the experience of CFC in mining Burnout Canyon suggests that the changes that may occur would not be large enough to cause major detrimental impacts to the streams in the RFDS area.

It was observed by the authors that the subsidence-induced changes in channel gradient at Burnout Canyon, even in the areas of maximum differential subsidence, were not great enough to cause barriers to fish movement in the stream. Rather, as has been observed in other subsided areas in the Wasatch Plateau, the subsidence around the margins of longwall panels occurs in a more distributed, gradual fashion. Thus, it is believed to be unlikely that fish barriers would form as a result of potential longwall mining in the RFDS area.

Sidel et al. (2000) report that changes to the stream morphology in Burnout Creek during the period it underwent longwall mining were minor and consisted primarily in an increase in the percentage of pools along the drainage. However, similar morphological changes occurred in the adjacent James Canyon, which was a mostly non-undermined control for their study. Thus, it is difficult to determine to what extent, if any, the mining activity had on the stream morphology in the drainage. The morphological changes that did occur in both drainages were short-lived. Within a year the drainage had returned to near-pre-mining conditions (Sidel et al., 2000). However, it is possible that there will be an increase in pooling in portions of streams that are undermined using longwall mining techniques.

Thus it is believed that although differential subsidence of perennial drainages above longwall-mined areas would occur under to Alternative 3, these changes would generally be minor. If a major impact to stream morphology were to occur, the impacts would likely be short-lived.

It has been determined in the Geology, Mining, Subsidence, and Seismicity technical report (NorWest, 2000) that in portions of some perennial stream drainages in the RFDS area, there could be moderate changes in the channel gradients. In most sections of the perennial streams in the RFDS area, the stream gradients are steep enough for the stream to adjust to subsidence-induced slope

changes without any major changes to stream morphology. However, in some perennial drainages, including portions of the Flat Canyon and Boulger Canyon, and the lower reaches of Swens Canyon, there are reaches with relatively low stream gradients that may experience moderate subsidence-induced gradient changes. In these areas, there is the potential for low or possibly even negative stream gradient to occur if the slope changes are sufficiently large. The precise locations where these effects could occur are entirely contingent upon the specific locations, geometries, and orientations of longwall panels. Thus, in the absence of a detailed mine plan, it is difficult to be more specific in predicting locations where these effects may occur. If negative gradients occur in these areas, pooling of water in the subsidence troughs near gradient inflection points may result. This could result in the creation of new ponds or wetland areas in the drainages. If ponding occurs in areas containing thick alluvial deposits (such as those found in the Flat Canyon and lower Boulger Canyon drainages) these ponds or wetlands may persist for a relatively short period of time. This is because the stream has a tendency to actively erode soft sediments in highland areas and deposit the abundant, easily eroded sediment in lowland areas. Thus, the stream would have the tendency to quickly come into equilibrium with its channel in terms of channel gradient. In areas of maximum differential subsidence, there is the potential for head cutting in stream channels that would result in increased sediment loading and temporary changes to stream morphology. Changes in channel width resulting from erosion of stream banks may also occur. In areas directly underlain by bedrock formations, where relatively less sediment is transported and the substrate is less easily eroded, the effects would persist for a longer period.

In areas where subsidence-induced changes to stream gradients could result in local reversals of stream gradient and potential ponding of water or the creation of wetland areas (most notably in Flat Canyon and possibly also in portions of Boulger Canyon and Swens Canyon) there is the potential for flooding of structures that are located near the streambank. The authors have not observed structures in these areas that appear to have the potential to be flooded. Thus, this impact is not anticipated in the RFDS area.

According to the RFDS, Upper Huntington Creek would not be subsided by longwall undermining. However, there is a possibility that Upper Huntington Creek and portions of Electric Lake would be directly undermined for the development of mains. As discussed in the Geology, Mining, Subsidence, and Seismicity technical report (NorWest, 2000), subsidence above regions mined using room and pillar techniques is expected to proceed gradually at a very slow rate, possibly requiring several centuries or even millennia to complete. For these reasons, it is believed that any subsidence fractures that may develop beneath

Upper Huntington Creek would likely develop slowly and gradually. Because of the presence of thick, soft alluvial sediments in the drainage, any subsidence fractures that develop would likely be filled with sediment at a fast enough rate to keep the fractures continuously and completely filled with sediment as the region subsides. As these sediments are compacted over the centuries, their ability to transmit water would continuously be diminished. The amount of water potentially transmitted in these fractures would be very small relative to the amount of water in the drainage. Therefore, no measurable or perceptible impacts to water quantity in Upper Huntington Creek or Electric Lake are anticipated as a result of room and pillar extraction beneath these areas.

5.2.3 Increased Sediment Loading Resulting From Subsidence Of Creeks

As discussed in Section 5.1.2, differential subsidence of surface water drainages has the potential to increase the sediment load of streams.

Under Alternative 3, the potential for increased sediment loading resulting from subsidence would be the same as those under Alternative 2, with the exception that sediment load increases could occur in perennial drainages. Whereas sediment loading in ephemeral or intermittent drainages is only of consequence for part of the year when these watercourses are transporting water and sediment, if perennial drainages are affected, this impact could occur throughout the year.

6.0 POTENTIAL ENVIRONMENTAL CONSEQUENCES — GROUNDWATER

6.1 ALTERNATIVE 2: LEASE WITH BLM STANDARD LEASE TERMS AND CONDITIONS AND FOREST SERVICE SPECIAL COAL LEASE STIPULATIONS

6.1.1 Potential Impacts to Groundwater Systems

There are two mechanisms through which underground coal mining has the potential to impact groundwater resources. The first mechanism is the direct interception of groundwater by mine workings. The second mechanism is by interruption or deformation of strata overlying subsided areas. Each of these mechanisms is discussed below.

Direct Interception of Groundwater

Direct interception of groundwater results in the local dewatering of deep groundwater systems. As described in Section 3.3, groundwater that is encountered in underground workings at the Skyline Mine and groundwater that may be encountered in the RFDS area issues from either deep Blackhawk Formation groundwater systems or Star Point Sandstone groundwater systems.

Deep Blackhawk Formation groundwater systems do not have good hydraulic communication with the surface as indicated by radiocarbon ages that are many thousands of years, the lack of tritium, and the rapid decline of inflow rates after a water-bearing feature is encountered. What this suggests is that the dewatering of these horizons should not induce renewed recharge to these systems and therefore there should be no impact to the hydrologic balance in the recharge areas. Because deep Blackhawk Formation groundwater systems drain quickly when encountered, it is doubtful that these systems support perceptible or quantifiable discharge to the surface.

Star Point Sandstone groundwater systems also discharge water to mine workings that is many thousands of years old. Because of the lateral continuity of the Star Point Sandstone, it is possible that there may be hydraulic continuity from the recharge zone to where water is encountered in mine workings. However, pump test analysis (Mayo and Associates, 1997a; Bills, 2000) indicates that the hydraulic conductivity of unfractured Star Point Sandstone is low, and thus recharge to the Star Point Sandstone is largely constrained by the low permeability of the unit. Thus it is unlikely that dewatering of the sandstone would perceptibly or quantifiably impact the hydrologic balance in the recharge

area. Due to the antiquity of water in the Star Point Sandstone, it is unlikely that discharge from the Star Point Sandstone, wherever that may occur, is important to the hydrologic balance of that area.

Subsidence-Related Impacts to Groundwater

Subsidence-induced interruption and deformation of strata has the potential to impact groundwater systems by 1) enhancing existing or creating new flow pathways for vertical groundwater migration and thereby partially or wholly dewatering a saturated horizon, and/or by 2) locally altering natural groundwater flow directions. In the study area, subsidence has the potential to impact near surface groundwater systems and deep bedrock groundwater systems that exist above the mined horizon.

The potential impacts of mining-related subsidence to dewater near surface groundwater systems are, for the most part, analogous to the potential impacts to perennial creeks (Section 5.2.1). As with perennial creeks, the operation of near surface groundwater systems is fundamentally dependent on the presence of low-permeability bedrock horizons that create perched groundwater conditions. The critical question that must be evaluated, then, is how would subsidence and subsidence-related fracturing affect the bedrock immediately below where these systems operate.

The Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000) describes the reaction of rock strata above longwall mined areas as a function of overburden thickness. There are four zones of movement above subsided areas. These include the cave zone, fracture zone, flexure zone, and soil zone. In the RFDS area the fracture zone is estimated to extend above the Lower O'Connor B seam up to 375 feet for single seam extraction and up to 675 feet above the Flat Canyon Seam for double seam extraction. The minimum overburden thickness in the RFDS area where longwall mining could occur is about 900 feet for the Lower O'Connor B seam. Most of the surface is more than 1,200 above the Lower O'Connor B seam. Thus, both colluvial/shallow bedrock groundwater systems operate entirely with the flexure zone and soil zone.

The expected response in the flexure zone is that there would be movement along existing joints and bedding planes, which can open up in zones of tension. Vertical movement along fractures typically remains within individual beds and is not vertically extensive unless massive strong beds are in the zone. Weaker rocks in the upper part of the zone may flex without causing failure along joints or tension cracks to form. In the soil zone materials are weak and generally do not fail due to the ability to flex. Tension crack formation does occur in the active tension zone but cracks close again when the compression zone reaches that point.

Based on the previous discussion, it is expected that the integrity of the low permeability bedrock horizons that are fundamental to the operation of colluvial/shallow bedrock groundwater systems generally would not be compromised. The exception would be the creation of tension cracks in high-strain zones as discussed below.

In zones of permanent tension that form above such features as panel ends, fire barrier pillars, and the outer edge of a block of panels, tension cracks are possible in shallow subsurface strata and may persist for a time. The degree to which these tension cracks impact shallow groundwater systems would be dependant on the degree of interconnectedness of fractures with other fractures or permeable horizons that are capable of receiving water. However, it is anticipated that because of lithologic heterogeneity and the abundance of swelling clays in the Blackhawk Formation, that tension fractures which do form would heal quickly.

Experience in the Skyline Mine area also suggests that shallow bedrock horizons are not compromised to the degree that there is perceptible or quantifiable dewatering of a stream or spring. The experience at Burnout Creek is especially important (Section 4.1.3). The strata underneath Burnout Creek have been subjected, in various locations, to tensile stresses caused by panel ends, stacked double seam fire barrier pillars, and the outer margin of a block of panels. Nevertheless, there has not been a decrease in stream discharge. Second, the response of springs and wells (Section 4.1.1) to undermining and subsidence suggests that subsidence does not result in dewatering of groundwater systems. Lastly, exploration drill holes in the Blackhawk are very unstable, and when left open for a few days, slough badly (Vaughn Hansen Associates, 1982) suggesting that any subsurface openings created by subsidence would heal quickly.

Subsidence also has the potential to locally alter groundwater flow directions. This is caused by slightly altering the attitude of shallow bedrock or by subtle disturbances in unconsolidated material. While this could affect the discharge rate from an individual spring, the total discharge from the groundwater system would remain the same as groundwater is diverted to other nearby existing discharge locations or new discharge locations.

The probability of impacting deep bedrock groundwater systems that exist above the mined horizon decreases with increasing overburden thickness. As noted in Section 4.1.2, subsidence causes water level perturbations in deeper groundwater systems but there is no indication that the groundwater systems monitored by wells have been dewatered. If a saturated horizon in the deeper bedrock were dewatered, it is unlikely that there would be a perceptible or quantifiable impact

to the hydrologic balance because of the limited recharge and discharge of these systems.

Summary

Although mine workings encounter a large amount of groundwater, sometimes more than 1,000 gpm, this water is derived from storage in the groundwater system. Where groundwater naturally discharges from deep bedrock groundwater systems, it is surmised that the discharge rate is several orders of magnitude less than the rate that water inflows to mine workings. It is estimated that there is a remote probability that direct interception of groundwater by mine workings would cause perceptible or quantifiable impacts to the hydrologic balance at either the recharge or discharge areas of deep groundwater systems.

It is estimated that there is a negligible probability of perceptibly or quantifiably dewatering near surface groundwater systems as a result of mining-related subsidence and fracturing. There is a possibility that there may be some local alterations in groundwater flow direction, which might affect the discharge from an individual spring but not diminish the total discharge from the groundwater system supporting that spring.

In the event that there were a perceptible or quantifiable mining-related diminution of groundwater discharge at a developed spring location in the area, the application of SCLS #17 would require the lessee to replace any water lost from developed groundwater sources with water of similar quality.

6.1.2 Trans-Basin Diversion of Intercepted Groundwater

The potential for transbasin diversions arises if water that is encountered underground is discharged to another drainage other than the one where the water would naturally discharge. The Skyline Mine area and mine workings straddle the surface water divide between two major river basins of the region, the Price River and the San Rafael River basins. Most of the surface area in the RFDS area is within the San Rafael River Basin. The southwest corner of the RFDS area is within the Gooseberry Creek drainage (Figure 2.1), which is tributary to the Price River Basin. It is important to note that the Upper Huntington Creek drainage is a peninsula-like extension of the San Rafael River Basin into the Price River Basin.

At the Skyline Mine, groundwater is encountered underground on both sides of the surface water drainage. However, all water encountered in the mine is currently discharged to Eccles Creek, a tributary to the Price River. It is anticipated that CFC would discharge groundwater encountered by mining in the RFDS area to Eccles Creek, unless a discharge point could be permitted in the Upper Huntington Creek drainage. It presently would not be possible to

discharge mine water to the Upper Huntington Creek drainage because watercourses within the outer boundary of the National Forest are designated by the State of Utah to be "High Quality Waters – Category 1" and new point source discharges into these waters are prohibited (UAC R317-2-3).

It is important in the analysis of potential transbasin diversion to identify the source of water intercepted by mine workings and the natural discharge locations of intercepted water. As described in the previous section, mining at the Skyline Mine does not appear to have created pathways for the downward migration of water from the surface or near surface to the mine. Thus, water that is intercepted in mine workings is likely groundwater that is naturally resident in the horizons immediately above or below the mined coal seam. It is anticipated that mining in the RFDS area would only encounter water that naturally occurs in the strata immediately above or below the mined coal seams.

As described in Section 3.2.3 and 3.2.4, groundwater in deep Blackhawk Formation groundwater systems and in the Star Point Sandstone groundwater systems does not appear to naturally discharge to the surface within the study area. It is surmised that the East Gooseberry Fault may intercept groundwater flowing westward in the deep bedrock. Where groundwater is conveyed by the East Gooseberry Fault is not known.

Because the natural discharge locations of groundwater potentially encountered by mining in the RFDS area are only speculative, the nature of any transbasin impact cannot be stated with certainty. However, the magnitude of this impact, regardless of where it occurs, can be estimated by considering the mean residence times of groundwater encountered by mining. Mayo and Associates (1996, 1999a) report that the radiocarbon ages of groundwater inflows to the Skyline Mine are many thousands of years. What this means is that the rate of flow through these systems is slow and thus the magnitude of discharge from these systems is likely meager. Thus it would not be correct to assume that the rate of discharge from mine workings in the RFDS area is equivalent to the possible decrease in natural groundwater flow rates at the discharge location. Mining accelerates the rate of groundwater discharge from deep bedrock inactive flow groundwater systems.

A helpful analogy would be a livestock watering trough that is fed by a small trickle. Once the trough is full, water spills from the trough at the same rate that water enters the trough—at a trickle. If the bottom of the trough were punctured, the magnitude of discharge from the trough would be large compared to the trickle that once discharged from the system. What is lost from the pre-punctured

system is the small trickle, not the large outflow resulting from the trough being breached.

It is highly probable that if water intercepted by mining in the RFDS area is discharged to a basin other than that which the water was naturally tributary, there would be not be a perceptible or quantifiable impact to the hydrologic balance of the basin from which water was diverted.

6.1.3 Impacts to Water Rights Resulting From The Diminution Of Spring Flows

Numerous water rights for springs are held in the RFDS area by both private land owners and the U.S. Forest Service. As described in Section 6.1.1, perceptible or quantifiable impacts to spring discharge rates are not anticipated. If there are no impacts to spring discharge rates then there should be no impairment of water rights. In the event that there was a mining-related flow diminution of an appropriated spring, Utah Code 40-10-18 requires the mine operator to "promptly replace any state appropriated water in existence prior to the application for a surface coal mining and reclamation permit."

A water right has a specified point of diversion. It is possible that if a spring discharge location shifted as a result of subsidence, this impact a water right because water could no longer be diverted at the specified point. If such a situation were to occur, the State Engineer would need to make a finding.

6.1.4 Potential Degradation of Water Quality in the Mine Environment

The quality of water that passes through the mine environment may be degraded by chemical interactions with naturally occurring minerals or materials and equipment introduced into the mine. Potential environmental impacts can occur if degraded water discharges from the mine workings either during active mining or after mining activities cease. These potential impacts are discussed below.

Acid mine drainage is caused by the oxidation and dissolution of naturally occurring sulfide minerals (principally pyrite and marcasite) when these minerals are exposed to the atmosphere in mine openings. Under natural (non-mined) conditions, the lack of available oxygen in the vicinity of the coal seams prohibits this reaction. The oxidation of sulfide minerals results in the release of hydrogen ions (acid), and increased iron and sulfate concentrations. However, acid mine drainage is rarely a problem in western coal mines because free hydrogen ions readily dissolve carbonate minerals (calcite and dolomite), which are abundant in the mine environment, and the sulfur content of coal is low. The dissolution of carbonate minerals results in increased concentrations of bicarbonate, calcium ion, and magnesium ion. Both of these reactions increase the total dissolved solids (TDS) concentration of mine water. Ion exchange of calcium ion and

magnesium ion for sodium ion is common due to the presence of clay and zeolite minerals (Mayo and Associates, 1994). Ion exchange reactions do not appreciably change the TDS concentration of mine water. The end result of these interrelated and secondary mineral reactions is that after water has passed through the mine environment, it is elevated in sodium ion, bicarbonate, and sulfate relative to groundwater that flows into the mine. Mine discharge water of this type is common from coal mines in the Wasatch Plateau.

Increased iron concentrations resulting from the oxidation of sulfide minerals does not typically result in negative water quality impacts in the Wasatch Plateau. Because most mine discharge waters and receiving waters are basic, dissolved iron is rapidly precipitated as iron hydroxides as the water comes in contact with the atmosphere and microbes at the surface. Water flowing in a surface stream that is fully aerated should not contain more than a few micrograms per liter of uncomplexed iron at equilibrium in the pH range of about 6.5 to 8.5 (Hem, 1985). Fine-grained iron precipitates are sometimes noted at mine water discharge points. These precipitates are generally not prolific enough to cause notable suspended sediment water quality impacts.

The dissolution of gypsum, halite, or other highly soluble minerals, which occur naturally in small quantities in the rocks adjacent to mine openings, may degrade the quality of the water discharging from the mine. The dissolution of gypsum increases the calcium ion, sulfate, and TDS concentrations of mine water. The dissolution of halite increases sodium ion, chloride, and TDS concentrations. These dissolution reactions affect water quality if these minerals are present in abundant quantities along groundwater flowpaths newly created by mining. This impact is generally not observed in Wasatch Plateau coal mines.

Some materials used in mining operations, when brought into contact with groundwater, have the potential to adversely impact the quality of water discharged from the mine. Mayo and Associates (1994) report that in the late 1980s gypsum rock dust was used in the Skyline Mine. This practice resulted in exceedence of TDS limits for mine discharge water because of the high solubility of gypsum. In March 1991, Skyline Mine began using carbonate rock dust, which is considerably less soluble in water. As a result of this change water quality of mine discharge water eventually improved. Mayo and Associates (1994) also note that part of the increase in TDS of mine discharge waters relative to mine inflow waters is a result of the oxidation of longwall emulsion fluid. When fugitive longwall emulsion fluid comes in contact with mine waters, the organic molecules in the fluid are readily oxidized by bacterial action resulting in the production of carbon dioxide gas. Carbon dioxide gas reacts with water to form carbonic acid (H_2CO_3), which dissociates into hydrogen ions and bicarbonate.

The liberated hydrogen ions are rapidly consumed in reactions with naturally occurring carbonate minerals, resulting in increased calcium ion, magnesium ion, and bicarbonate concentrations in mine water.

During the course of mining operations, many tons of ferrous metals are utilized. Some of the metal objects are removed after mining ceases and, as a necessity, others are left in place. The largest permanent use of metal in mining operations is in roof-support. Thousands of metal roof-bolts are installed at regular spacings in the mine roof to prevent roof collapse. In some locations, wire mesh is also installed. For safety reasons, it is not possible to remove the roof-bolts or wire mesh after mining in an area has ceased. Additionally, metal is used in stoppings and man-doors, overcasts, cribbing, well casings, pipes, and miscellaneous items such as hangers and signs. There is the potential for the metal in these objects to oxidize (rust) as it comes in contact with water in the mine environment.

Oxidation of ferrous materials results in the release of iron into the water. The magnitude and rate of the potential oxidation is constrained by a complex variety of factors, including the temperature, Eh, and pH of the water, the pressure on the system, the presence or absence of bacteria, and the solute chemistry of the mine water. As a result, this potential impact is difficult to quantify. However, discharge water from Wasatch Plateau coal mines has not been degraded by elevated iron concentrations. To what extent the iron concentration in mine discharge water may change after mining operations cease is difficult to determine. However, the concentration would likely remain low because dissolved iron is rapidly precipitated as iron hydroxides as noted previously.

Mining equipment may be abandoned underground as dictated by safety or economic considerations. However, it is Forest Service policy to not allow any new solid waste disposal facilities on National Forest System lands and to not add to existing facilities. Equipment left underground would be considered a solid waste and it would not be consistent with Forest Policy to allow the abandonment of equipment underground. Further, Section 7 of the BLM lease form requires lessees to remove equipment and materials "as required by the authorized officer." In the event that it were necessary to leave equipment underground for safety reasons, it is unlikely that corrosion of abandoned equipment would degrade the quality of water in the mine environment. Mining equipment, such as longwall mining machines, roof bolters, and continuous miners, is made of high quality steel alloy containing chromium. The metal is highly resistant to corrosion. Calculations of the corrosion potential of the steel used in longwall mining machines have been performed by the University of Utah Metallurgy Department (BLM, 1998). They determined that it would take thousands of years for the metal to corrode away, and that the metal would need to be ground to a fine

particulate for chromium to be dissolved. The University of Utah (BLM, 1998) report indicates that the general conditions required to hasten the corrosion of this metal do not exist in the Utah coal mining environment.

Petroleum, oils, and lubricants are regularly used in mining operations. These materials may degrade discharge water quality if they are mishandled or abandoned underground and exposed to water passing through the mine. Any toxic or hazardous materials which are used underground would have to be removed from the mine prior to closure.

Although the impacts to water quality are expected to minimal, the application of SCLS #19 would require that the operator remove mine equipment and materials that are not needed for continued operations, roof support, and mine safety from underground workings prior to abandonment of mine sections.

6.2 ALTERNATIVE 3: LEASE WITH BLM STANDARD LEASE TERMS AND CONDITIONS ONLY

The potential impacts to groundwater resources under this alternative are the same as under Alternative 2, except that the area of potential impact increases as a result of not applying stipulations that preclude the subsidence of perennial creeks, paved roads, and structures.

By not applying the SCLS under this alternative, impact mitigation dictated by SCLS #17 and SCLS #19 would not be required.

Under this alternative, the operator would not be specifically required to remove equipment that is not incorporated into the mine. However, as noted, it is Forest Service policy to not allow any new solid waste disposal facilities on National Forest System lands and to not add to existing facilities. Equipment left underground would be considered a solid waste and it would not be consistent with Forest Policy to allow the abandonment of equipment underground. Further, Section 7 of the BLM lease form requires lessees to remove equipment and materials "as required by the authorized officer."

Nevertheless, if mine equipment were left underground, it is unlikely that ferrous equipment such as longwall shields, longwall shears, or continuous miners would perceptibly or quantifiably impact water quality even if these pieces of equipment were abandoned in areas that subsequently flooded. As noted in the previous section, the general conditions facilitating oxidation of metals do not exist in Utah coal mines. Minor water quality impacts could occur if lubricants were not

drained from the equipment prior to abandonment. The magnitude of this impact would depend on the amount of organic materials, the volume of water in a flooded section, and the rate of intrinsic bioremediation. Computerized controls on equipment may contain lead, cadmium, mercury, and chromium and could cause water quality impacts if located in a flooded section. However, the magnitude of this impact is estimated to be minimal because of the small amount of controls relative the volume of water likely to be impounded and the slow oxidation rates of these materials in the mine environment.

7.0 RECOMMENDATIONS FOR MONITORING AND MITIGATION

7.1 SURFACE WATER

CFC has monitored stream discharges and water quality at eight sites in the RFDS area. For the SMCRA mining permit, an operational monitoring program that would need to be approved by UDOGM would be developed that builds on the baseline monitoring. It is recommended that, where possible, long-term discharge measurement devices be installed at locations selected for operational monitoring. This would facilitate greater accuracy and consistency in the flow measurements, which greatly increases the usefulness of these data. It is recommended that continuous recording devices be installed at surface-water monitoring stations on critical drainages.

Additionally, it is recommended that those stream reaches that have been classified as likely being perennial be monitored periodically in the future to refine the delineation of perennial reaches in the RFDS area.

Perceptible or quantifiable impacts to surface water discharge rates are not expected as a result of mining in the RFDS area. Therefore, no measures are recommended to decrease the likelihood of a perceptible or quantifiable impact. If surface water discharge rates were to be impacted, mitigation would be required by SMCRA for culinary drinking water sources and Utah State Code 40-10-18 for state appropriated waters. If SCLS #17 is applied to the lease, the lessee would be required to replace any water lost from creeks designated for protection with water of similar quality.

It is recommended that if mine water is discharged directly into Electric Lake that consideration be given to the placement of the discharge point. If the water is allowed to flow rapidly over the shoreline of the lake, appreciable erosion and sediment redistribution may occur. It may be advantageous to install an energy dissipating system that would decrease the discharge velocity and erosion potential of the discharging water.

Site-specific pre-mining investigations and planning should be carried out before mining proceeds in those areas where it is determined that there is high potential for subsidence-induced stream gradient reversal and pond or wetland formation. The precise locations of areas of potential stream gradient change would be a function of the implemented mining plan. Therefore, where possible, mining plans should be designed to minimize the potential for this occurrence.

7.2 GROUNDWATER

CFC has monitored 24 springs in the RFDS area for baseline water quality and discharge. It is expected that an operational monitoring program that builds on this baseline monitoring would be required under the SMCRA permit administered by UDOGM. The most critical data that can be collected are spring discharge measurements and emphasis should be placed on collection of flow data over water quality data. No additional monitoring of groundwater resources is recommended.

Perceptible or quantifiable impacts to groundwater resources are not expected as a result of mining in the RFDS area. No measures are recommended to decrease the likelihood of a perceptible or quantifiable impact. If groundwater resources were to be impacted, mitigation would be required by SMCRA for culinary drinking water sources and Utah State Code 40-10-18 for state appropriated waters. If SCLS #17 is applied to the lease, the lessee would be required to replace any water lost from developed groundwater sources with water of similar quality.

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APPENDIX A

EIS SUMMARY

EIS SUMMARY
SURFACE-WATER AND GROUNDWATER RESOURCES

AFFECTED ENVIRONMENT

This summary describes groundwater and surface water resources in the Flat Canyon Coal Lease Tract and the adjacent fee lands. Together the tract and the private lands are described as the 'RFDS area' in this summary. The study area for this investigation extends beyond the RFDS as shown in Figure 1. This investigation relies on data, information, and experience from the existing Skyline Mine permit area (Figure 1), which is east of and contiguous with the RFDS area. This area is referred to throughout this report as the Skyline Mine area.

SURFACE WATER

All surface waters in the study area, with a single exception, drain into Upper Huntington Creek, which is a tributary of the San Rafael River. The San Rafael River flows into the Green River approximately 80 miles southeast of the study area. A small portion (< 6%) of the study area is in the Upper Gooseberry Creek drainage. Upper Gooseberry Creek flows into Fish Creek above the Scofield Reservoir on the Price River. The Price River flows into the Green River approximately 60 miles southeast of the study area. The region of investigation for this analysis is an area of approximately 12.7 square miles. Perennial stream reaches have been identified in Boulger, Flat, Swens, Little Swens, and Cunningham Canyons. Upper Huntington Creek, which defines the northern and eastern boundaries of the study area, is also a perennial stream. In order to simplify the characterization and analysis of surface water systems in the study area, the surface water drainages have been divided into sub-basins. These sub-basins are shown on Figure 2. Also shown on Figure 2 are the reaches of the individual streams that have been classified as perennial for this analysis.

Several drainages that have not previously been classified as perennial were determined to possibly be perennial as a part of this study. These reaches are indicated on Figure 1.2. Determinations of possibly perennial reaches were based on field observations of streamflow and vegetation types and through inspection of aerial photographs.

The specific characteristics of each sub-basin in the study area are described below.

Flat Canyon Sub-Basin

The Flat Canyon sub-basin includes an area of 1.76 square miles, which is approximately 13.8% of the study area. The gradient in Flat Canyon, approximately 0.93%, is the lowest of any of the sub-basins in the RFDS area. Flat Canyon is so called because of the broad, flat-bottomed valley floor through which Flat Canyon Creek flows. The broad riparian corridor in Flat Canyon is up to 1,000 feet wide. Flat Canyon Creek in its upper reaches, where it meanders through the broad alluvial valley, is a Rosgen (1996) E5 type stream. This reach is dominated by run features. The channel substrate underlying the creek in Flat Canyon consists primarily of thick, saturated

glacio-lacustrine sediments. The sediments along the margin of the canyon are approximately 80 feet thick, consisting mostly of sand.

In the lower reaches of Flat Canyon Creek, the channel is more deeply incised and the gradient is much steeper (3%). This reach is a Rosgen (1996) B3 type, which consists primarily of riffles with less than 5% pools. The banks in this reach are well vegetated and stable. The substrate in lower Flat Canyon Creek consists primarily of cobbles and boulders. It appears well armored and stable.

The north-facing canyon walls in Flat Canyon are vegetated with dense conifer forests. Portions of these conifer stands have recently undergone logging. The south facing canyon walls are vegetated primarily with scattered, dense stands of quaking aspen. Flat Canyon creek is separated from the underlying coal seams by 1,000 to 1,800 feet of overburden.

Discharge and water quality at Flat Canyon Creek have were monitored in October 1999 and July 2000 (NorWest, 2000a). The October discharge measurement was 91 gpm while the July measurement was 215 gpm. The water in Flat Canyon Creek during October was of the calcium-bicarbonate chemical type with a TDS concentration of 169 mg/l.

Boulger Canyon Sub-Basin

The Boulger Canyon sub-basin, which occupies approximately 3.92 square miles, or 30.8% of the study area, is the largest of the sub-basins. Included in this area are the upper drainage (above Boulger Reservoir), which is approximately 3.22 square miles in area, and the lower drainage, which occupies an area of approximately 0.70 square miles (Figure 2). Boulger Creek is a third order stream that flows to the northeast where it joins Flat Canyon Creek and then flows into Electric Lake. The gradients on Boulger Creek are steeper than are those of the adjacent Flat Canyon creek. The gradient on the main reach below the confluence of the two forks and above the reservoir averages 1.7%.

The reach of Boulger Creek extending from below the upper forks to Electric Lake contains reaches that are Rosgen (1996) type C3 and B3. The stream in this area, which meanders tightly, is 8-10 feet wide and is dominated by riffles and runs with a channel depth ranging from 6 inches to 2 feet. The substrate in areas of low gradient appears stable and well armored. It is composed of approximately 50% cobbles, 15% gravel, and 35% sand/silt. The stream banks in this portion of the drainage are well vegetated and appear stable. The drainage in this area supports a moderately wide strip of riparian vegetation up to approximately 350 feet wide along the valley bottom. Much of the riparian vegetation along the margins of the valley bottom appears to be supported by inflows of alluvial and colluvial groundwater from the lower canyon walls. This groundwater also provides recharge to the creek.

Approximately 1,800 feet above the confluence with Electric Lake, a small unnamed tributary to Boulger Creek enters from the south side of the canyon (Figure 2). This stream appears to be perennial based on the narrow corridor of riparian vegetation that exists along and adjacent to the stream channel. Discharge and field parameters were measured in this drainage by Mayo and Associates during October 1999 and July 2000. On both occasions water was flowing in the

stream. The stream was flowing at 32.8 gpm during July 2000. Inspection of aerial photographs suggests that the stream has the appearance of being perennial for a distance of approximately one-half mile above the confluence with Boulger Creek.

The right (north) fork of Boulger Creek has an average gradient of approximately 4.3%. There is a narrow strip of riparian vegetation associated with this reach of the creak. For the first approximately 1,800 feet of this drainage, the stream is a Rosgen (1996) type B3 stream. The channel substrate in this reach is made up of material ranging from 2-inch gravels to 12-inch and greater cobble/boulder material. Runs and riffles make up approximately 60% of the stream, with approximately 40% pools. Raleigh Consultants (1992) noted sedimentation in the right fork of Boulger Creek that was attributed potentially to inactive beaver dams. The next approximately 2,000 feet of the right fork consists of a meandering Rosgen (1996) C3 type stream. The channel in this reach is approximately 10 feet wide and 6 inches deep. The stream contains approximately 80% riffles and runs and 20% pools and the substrate in this reach is made up of approximately 50% cobbles, 20% sand and silt, and 35% gravel. The stream banks appear stable. The final approximately 5,000 feet in the uppermost portion of the drainage is a steep, Rosgen (1996) type A2 or B2 stream with riffles comprising about 90% and pools 10%. The width of the stream in this reach is approximately 5 feet, with depths ranging from 4 inches in the riffles to 1 foot in the pools. The substrate in this reach is dominated by large cobbles, boulders, and bedrock.

The left (south) fork of Boulger Creek is a steep drainage with an average gradient of approximately 7.5%. The channel in the lower reach of the left fork is a Rosgen (1996) type A3 channel, while the upper, headwaters area is a Rosgen (1996) C5 or E5 type. The channel substrate in the lower part of the south fork is comprised of large cobbles and boulders. In the headwaters region of the left fork a large meadow is present in a glacial cirque. The stream channel substrate in this region consists primarily of fine-grained alluvial material. Much of the baseflow of the left fork of Boulger Creek originates from springs along the margins of this meadow.

The depth of cover separating Boulger Creek from the coal seams that may be mined ranges from 700 feet in the lower reaches near Electric Lake to more than 2,200 feet in the headwaters areas.

Discharge and water quality in Boulger Creek have been monitored at C-4, C-7, and C-8 (Figure 2; NorWest, 2000a). Discharge has been measured at C-4 (below the confluence with Flat Canyon creek) since 1997. The maximum recorded discharge, 3,120 gpm, occurred during July 1999. A minimum flow of 450 gpm was measured during October 1999. Streamwater in Boulger Creek is of the calcium-bicarbonate chemical type. TDS concentrations at C-4 have remained relatively constant during the baseline monitoring period, ranging from 140 to 190 mg/l.

Boulger Reservoir is a man-made water body with a surface area of approximately 4.52 acres with a storage capacity of 45 acre-feet. The reservoir is a popular recreation site for fishing, swimming, and rafting. Boulger Reservoir is separated from the underlying coal seams by approximately 1,200 feet of cover. Comparison of discharge and water quality measurements

from C-8 (immediately above the reservoir) and C-7 (immediately below the reservoir) suggests that the water quality of Boulger Creek is not degraded as a result of being in the reservoir.

Swens Canyon Sub-Basin

The Swens Canyon sub-basin occupies 2.33 square miles or 18.4% of the study area. The stream drains westward into Upper Huntington Creek, with a gradient averaging 3.1%. Swens Canyon Creek is a third order stream that meanders tightly, particularly in the lower reaches of the drainage. The stream banks and adjacent areas are heavily vegetated with riparian vegetation and appear to be relatively stable. Swens Canyon Creek appears to be a gaining stream over its entire reach. It is apparent that much of the riparian vegetation along the margins of the valley bottom in Swens Canyon Creek is not sustained by direct recharge from the stream. Rather, these vegetated areas appear to be sustained by discharge from shallow, colluvial groundwater systems discharging low on the canyon walls.

Along the length of Swens Canyon Creek, there is evidence that the hillsides have periodically encroached into the stream channel resulting in impounding of the stream. These encroachments appear to be the result of mass movement (i.e. hillside slumping) of the Blackhawk Formation sediments that compose the hillsides. The fact that the lowermost canyon slopes are commonly wet from groundwater seepage may be a contributing factor to the frequency of mass movements. It is evident that the drainage has also been periodically dammed in many locations by beavers. As a result of these occurrences, thick sections of sediment have been emplaced by stream deposition in the backwater areas that existed when the stream was dammed, while adjacent areas have not experienced that degree of sedimentation. These conditions, in conjunction with changes in geologic formation or geologic structure underlying the stream bottom, have resulted in a somewhat stair-stepped topography in the canyon bottom.

The lower 5,000 feet of the stream channel in Swens Canyon is comprised of fine-grained material interspersed with gravel, cobbles, and occasional boulders. This reach is a Rosgen (1996) C3 type. This reach of the stream consists of approximately 80-90% runs and riffles, and 10-20% pools. In this reach the stream meanders tightly and the stream channel is well incised in its channel. Groundwater inflows are apparent along much of the extent of this reach of the drainage. These commonly consist of small springs or seepage fronts that emerge near the transition between the valley bottom and the canyon walls.

A small tributary to Swens Canyon Creek enters from the south approximately 1,000 feet above the confluence with Upper Huntington Creek. This tributary, which extends for approximately one-half mile, appears to possibly be perennial based upon the well-established riparian vegetation along the stream banks. No baseline discharge data are available for this tributary. However, it was noted by Mayo and Associates that there was appreciable flow in the drainage during October 1999 and again in July 2000.

The North Fork enters Swens Canyon Creek approximately 3,000 feet above the confluence with Upper Huntington Creek (Figure 2.1). This tributary is approximately 2,500 feet in length and is very steep. The average channel gradient is approximately 13.8%. This stream reach appears to possibly be perennial based upon the well-established riparian vegetation along the stream banks.

No baseline discharge data are available for this tributary. However, it was noted by Mayo and Associates that there was appreciable flow in the drainage during October 1999 and again in July 2000. Much of the baseflow discharge to the stream originates from a series of springs discharging from colluvial groundwater systems in its headwaters region.

In the reach of Swens Canyon Creek extending from the confluence with the North Fork and upstream for approximately 3,500 feet the stream channel narrows considerably. In this reach, the channel substrate is dominated by cobbles and boulders. In some locations, bedrock outcrops are visible in the channel bottom. The channel, which meanders slightly in this reach, contains many active and inactive beaver dams.

In the headwaters reaches of Swens Canyon Creek, the valley broadens into a region of wide meadows and grasslands. The stream channel in this reach is a narrow Rosgen (1996) A2 type. Much of the baseflow to Swens Canyon Creek appears to originate in this region. Many springs and groundwater seepages enter the stream channel from the lower hillsides adjacent to the stream.

Swens Canyon Creek is separated from the underlying coal seams by 800 feet of cover at the confluence with Upper Huntington Creek to approximately 2,400 feet of cover in its headwaters area.

Swens Canyon Creek has been monitored by CFC at C-3 since 1997 (Figure 2; NorWest, 2000a). Discharge has ranged from 30 gpm during October 1998 to 300 gpm during both July 1998 and July 1999. The water in Swens Canyon Creek is of the calcium-bicarbonate chemical type. Baseline TDS concentrations in Swens Canyon Creek have ranged from 177 to 213 mg/l.

Little Swens Sub-Basin

Little Swens Creek flows northeast from highland areas toward its confluence with Upper Huntington Creek. The basin encompasses an area of 0.98 square miles, which is 7.7% of the study area. The drainage is steep, with a stream gradient of approximately 5.9%. Little Swens Canyon Creek is a tightly meandering stream with relatively stable, well-vegetated stream banks. Like the adjacent Swens Canyon drainage, there is evidence of a long history of encroachment of hillsides by mass movement onto valley floor. There is also evidence of a long history of beaver dam construction in the drainage. These conditions have resulted in accumulation of sediment in some areas with considerably less sediment in other areas resulting in a somewhat stair-stepped topography on along the canyon bottom.

The stream channel in the lower approximately one-half mile of the drainage is a Rosgen (1996) B3 type. The valley bottom in this reach is approximately 30 feet wide. The channel substrate in this reach consists of gravel, cobbles and boulders. Generally, the stream channel in Little Swens Canyon is more dominated by rocky material and appears to have less fine-grained material in the substrate than does the adjacent Swens Canyon. The stream banks in this reach are heavily vegetated and appear stable.

In the next 1,000 feet of the drainage, the channel narrows slightly and the channel substrate is dominated by boulders and bedrock. This reach appears to have been impacted considerably by beaver dams and encroachment of the lower canyon walls into the drainage by mass movement. This reach of the drainage is a Rosgen (1996) A2 type.

A small reservoir has been constructed in the upper reaches of this drainage. This pond has a surface area of approximately 3.15 acres and is used for recreation purposes by a privately owned girl's camp that surrounds the pond.

The Little Swens Canyon drainage is separated from the underlying coal seams by 1,100 feet of overburden near the confluence of the stream with Upper Huntington Creek. In the headwaters regions, the overburden is approximately 2,100 feet. The overburden between the reservoir at the girls camp and the coal seams ranges from about 1,900 to 2,000 feet

Baseline water quality and discharge measurements have been performed on Little Swens Canyon Creek at C-2 from 1998 to 2000 (Figure 2; NorWest, 2000a). Discharge at C-2 has varied from 16 gpm during October 1998 to 211 gpm during July 1998. Discharge in the creek is of the calcium-bicarbonate chemical type. TDS concentrations have ranged from 151 to 214 mg/l.

Cunningham Canyon Sub-Basin

The Cunningham Canyon sub-basin, with an area of 0.92 square miles, is a relatively small drainage located near the southern margin of the RFDS area. Cunningham Canyon Creek is an easterly flowing drainage that flows into Electric Lake in the Upper Huntington Creek drainage. The drainage has a steep gradient, averaging 8.0%. The channel substrate in the upper reaches is dominated by cobbles and boulders. In the lower reaches, near the confluence with electric lake, the channel substrate is dominated by fine-grained materials including silt and soil. The stream is entrenched below the land surface by approximately 1 to 2 feet in the lower reaches of the drainage. Riparian vegetation along the stream banks and adjacent flood plain in the lower reaches of the canyon is dense and the stream channel appears stable.

Water quality and discharge have been monitored by CFC at C-5 (Figure 2; NorWest, 2000a) from 1997 to 2000. Discharge at C-5 has varied from 20 gpm in October 1998 to 162 gpm during October 1997. TDS concentrations at C-5 have varied from 118 to 165 mg/l.

The Cunningham Canyon drainage is separated from the coal seams by 700 feet in its lower reaches near Electric Lake to approximately 1,900 feet in the headwaters area.

Upper Huntington Creek Sub-Basin

Within the RFDS area there are a series of unnamed small, east and northeast facing ephemeral drainages to Upper Huntington Creek (Figure 2). These drainages, which all exist on the steep, western slope of Upper Huntington Creek, range in size from 0.4 to 0.78 square miles. Gradients of the unnamed Upper Huntington Creek sub-basins are all very steep, ranging from approximately 17% to 32%.

None of these drainages are known to support perennial streams. One intermittent stream located immediately south of Little Swens Canyon (Figure 2) was monitored for discharge and field parameters by CFC in July 2000. Discharge from this stream was meager at 7 gpm.

The overburden separating the unnamed Upper Huntington Creek drainages from the coal seams ranges in thickness from approximately 700 feet near Electric Lake to more than 2,000 feet in the highland areas above Huntington Canyon

Upper Gooseberry Creek Sub-Basin
A small portion (0.73 square miles, less than 6%) of the RFDS area drains to the Upper Gooseberry Creek drainage. Gooseberry Creek drains to the north-northwest and flows into Fish Creek which discharges to Scofield Reservoir. While Upper Gooseberry Creek near the RFDS area may possibly be perennial, the stream itself is beyond the RFDS area and would not be undermined. For this reason, this stream has not been investigated.

All of the Upper Gooseberry Creek sub-basin within the RFDS area is separated from the coal seams by more than 1,500 feet of cover.

Summary of General Characteristics of Surface-Water Systems in the RFDS Area
Both ephemeral and perennial drainages in the RFDS area are supported in the late winter and spring months by the annual snowmelt event. Because of the large quantities of snowmelt water relative to the amount of groundwater that can be stored and discharged from shallow groundwater systems in the area, perennial streams commonly have high-flow discharge rates that exceed their low-flow baseflow discharge rates by many times.

Perennial streams in the RFDS area exist where 1) there is adequate groundwater recharge and subsurface storage capacity in the drainage basins to sustain discharge from shallow groundwater systems throughout the year and 2) there is a low-permeability confining layer beneath the stream that prevents downward percolation of water in the stream channel (i.e. the stream is perched).

Field observations by the principal authors during 1997-2000 suggest that the perennial streams in the RFDS area are generally gaining streams. Observations of stream conditions in the springtime and late fall suggest that this condition persists throughout the year. The streams gain flow from discharge from shallow groundwater systems in the form of springs, seeps, and discharge directly to the stream channel. These are common along the lengths of the perennial drainages.

GROUNDWATER

Climatic Setting

The study area is located in an area of subalpine climate. Precipitation is measured at the Skyline Mine surface facility in Eccles Canyon west of the study area. Between 1985 and 1995 the average annual (calendar year) precipitation ranged from 17.2 to 29.4 and averaged 23.9 inches (Mayo and Associates, 1996). Monthly average temperatures at the mine range from 8.0 to 74.4 °F (CFC, 1999).

The National Resource Conservation Service (NRCS) maintains two high elevation precipitation stations east of the study area. During the period 1961-1990 (NRCS, 1995) the average annual precipitation was 29 inches at the Mammoth-Cottonwood Station (elevation 8,800 feet), and 33 inches at the Red Pine Ridge Station (elevation 9,200).

The study area is in a region that has experienced several extremely wet years during the early and mid 1980s, followed by an extended drought from 1987 to 1993. Since 1993 the region has enjoyed mostly wet conditions. However, beginning in January 2000 the region entered a drought period. It is important to note that most baseline hydrologic collection by CFC occurred during the moderately wet period in the late 1990s.

Geologic Setting

The geology of the study area has been described in the Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000b) prepared concurrently with this report. Five bedrock formations of concern to coal mining activities in the study area are, in descending stratigraphic order, the North Horn Formation, Price River Formation, Castlegate Sandstone, Blackhawk Formation, and Star Point Sandstone. These rocks are composed of interbedded shale, mudstone, siltstone, and sandstone layers that are laterally discontinuous. The heterogeneity and lateral discontinuity of these rocks have a profound effect on water-bearing and water-transmitting properties. Water is not generally transmitted great distances either vertically or horizontally, and the many low-permeability units create perched conditions. Unconsolidated alluvial, colluvial, and glacial deposits as well as soil are important hydrogeologic units in the study area.

Groundwater Systems

The concept of a groundwater system refers to 1) where and how recharge occurs, 2) how flow is accommodated, and 3) where and how groundwater discharges. Five types of groundwater systems are defined in the study area. These systems are:

- colluvial/shallow bedrock groundwater systems;
- Boulger Canyon alluvial groundwater system;

- Flat Canyon groundwater system;
- deep Blackhawk Formation groundwater systems; and
- Star Point Sandstone groundwater systems

These five systems have been defined because stratigraphic, lithologic, and structural constraints cause each type of system to operate differently. The concept of a groundwater system is limited to how a system operates and does not indicate or preclude hydraulic communication among the systems of a given type. This concept is useful in places such as the study area where groundwater commonly occurs in localized areas, and where aquifers, in which there is hydraulic communication over a greater expanse, do not exist.

Each type of groundwater system is described below.

Colluvial/Shallow Bedrock Groundwater Systems

Colluvial/shallow bedrock groundwater systems occur throughout the study area. This type of system occurs in the thick soil mantle, slope wash colluvial deposits, and shallow bedrock in which the porosity has been enhanced by weathering or fracturing. Groundwater in shallow alluvial deposits is alsoincluded in this type of system. The abundance of relatively low-permeability horizons in bedrock formations of the study area hinders appreciable migration of groundwater to deeper stratigraphic horizons and creates perched groundwater conditions in colluvium and shallow bedrock.

The depth of colluvial/shallow bedrock groundwater systems has not been investigated but is estimated to range from several tens of feet to perhaps over 100 feet in some areas. Data from the Skyline Mine area indicate that a water monitoring well (W79-14-2a) completed in the Blackhawk Formation at a depth of 102 to 122 feet exhibits seasonal water level responses (Mayo and Associates, 1996), which, as discussed below, is a characteristic of colluvial/shallow bedrock groundwater systems. However, two wells completed at depths ranging from 150 to 200 feet do not show seasonal water level responses.

Colluvial/shallow bedrock groundwater systems are directly recharged by snowmelt, especially snow that melts relatively slowly in dense wooded stands common in the study area. Groundwater flow follows topographic gradient and flow path lengths are relatively short: no more than from the top of a ridge to a canyon bottom.

Groundwater in colluvial/shallow bedrock systems supports discharge from nearly all of the springs in the study area. Discharge from this type of system directly to creeks is indicated by gaining stream flows. Groundwater discharge from this type of system occurs primarily along the bottoms of canyons. Some groundwater discharge occurs higher on a number of hillsides because of 1) local breaks in slope such as in the head of Swens Canyon where glacial moraine materials create a less steep slope, or 2) groundwater in permeable shallow bedrock, such as a sandstone paleochannel or the Castlegate Sandstone, encounters a less permeable bedrock horizon.

Storage in colluvial/shallow bedrock groundwater systems is small because of the generally limited depth of colluvial and shallow bedrock materials, short flow path lengths, relatively large hydraulic conductivities, and relatively steep hydraulic gradients. Consequently, this type of groundwater system is acutely sensitive to seasonal and climatic variations in precipitation. Seasonal and climatic dependence is demonstrated by variations in spring discharge rates. Discharge from springs is typically greatest in the springtime and declines appreciably during the summer and fall months. A number of springs had lower discharges in springtime 2000 than during previous springtimes. This reflects sensitivity to climatic changes such as the drought conditions that the region has seen since the beginning of 2000.

Spring and seep survey data also indicate the dependence on seasonal recharge. The total discharge from all of the springs located in the Fall 1997 survey was 1,073 gpm. During the following spring the total discharge was 2,895 gpm, a nearly three-fold increase. Although these data were not collected during the same snowmelt recharge cycle, both surveys were conducted during similar moderately wet climatic conditions.

That springs respond quickly to season and climate suggests that time between recharge and discharge in colluvial/shallow bedrock groundwater systems is less than one year. As noted, much of the baseline discharge data for these springs have been collected during a lengthy wet-spell. Because of the heavy climatic dependence of these springs, it is expected that many of the springs in the study area would have much lower discharge rates or dry up in drought years.

CFC has collected unstable isotopic data from five springs in the study area (NorWest 2000a). All spring waters sampled in the study area contain anthropogenic carbon and abundant tritium. These compositions indicate that recharge to the groundwater systems supporting discharge from these springs occurred within the last approximately 50 years.

Boulger Canyon Alluvial Groundwater System

Alluvial sediments deposited in the relatively broad-bottomed portions of Boulger Canyon support groundwater. A distinct groundwater system has been designated for these sediments because of the comparatively larger depth and extent of these deposits relative to other, much steeper canyons in the RFDS area. The depth of this alluvium is known in one location where exploration drilling (drill hole 99-4-1; Figure 1.2) encountered 40 feet of alluvial sediments.

Groundwater in these sediments is recharged largely by interflow from colluvial/shallow bedrock groundwater systems. During dry times Boulger Creek could also provide recharge. However, visual observations of the creek by the principal authors suggest that Boulger Creek is a gaining creek year round, suggesting that discharge from the alluvial groundwater system is predominately to the creek.

Flat Canyon Groundwater System

Exploration drilling by CFC in the Flat Canyon area has revealed that there is a thick deposit of unconsolidated sediments in the canyon. Drill logs for wells 98-32-1 and 95-33-1 were provided for review by CFC. The locations of these two wells are indicated on Figure 1.2. The drill logs indicate that these sediments are 70 to 90 feet thick on the margins of Flat Canyon. These sediments consist primarily of sand and gravel with only minor fine-grained materials, and thus

are expected to be fairly permeable. Inspection of geomorphology in air photos and in the field suggests that these alluvial sediments were likely deposited in an impoundment created by the glacier(s) in Boulger Canyon and the lateral and terminal moraine deposits of the Boulger Canyon glacier(s). Glacial moraine deposits typically have low hydraulic permeabilities (Freeze and Cherry, 1979). Consequently, water is largely impounded in glacio-lacustrine sediments behind the lateral and end moraines at the confluence of Flat and Boulger Canyons. Because of the thickness, lateral extent, and saturation of these deposits, the Flat Canyon glacio-lacustrine sediments have been designated as a distinct groundwater system.

Discharge from colluvial/shallow bedrock groundwater systems provides the bulk of recharge to the Flat Canyon glacio-lacustrine sediments.

A large portion of the discharge from the Flat Canyon groundwater system occurs directly to Flat Canyon Creek. Flat Canyon Creek does not appear to be fed by perennial creeks in any of the side drainages. Rather, Flat Canyon Creek appears to gradually gain flow throughout the year along its course due to discharge from springs and groundwater discharge directly to the creek.

A limited amount of water is also transmitted from the Flat Canyon alluvium through the glacial moraine deposits. This water supports several small wet areas on the hillslope west of Boulger Reservoir. Groundwater discharge from the Flat Canyon alluvium at this location has not been quantified or monitored. It is believed that this groundwater discharge is largely consumed by transpiration due to the presence of phreatophytes on the hillside. It is expected that because of the large storage volume in the Flat Canyon glacio-lacustrine sediments, that discharge in this location will be essentially constant even during drier climatic cycles.

Discharge from the Flat Canyon groundwater system may also occur via underflow through the basal moraine deposits or bedrock underlying the moraine deposits. Any underflow would recharge the glacial/alluvial sediments below the moraine and would ultimately discharge to either Boulger Creek below the reservoir or via groundwater inflow to Electric Lake. A small amount of water may also migrate downward and recharge underlying bedrock. However, there is no evidence suggesting that discharge occurs via these two mechanisms.

Deep Blackhawk Formation Groundwater Systems

Deep Blackhawk Formation groundwater systems occur at depths greater than about 150 feet where the Blackhawk Formation is the exposed at the surface. Deep Blackhawk Formation groundwater systems have been encountered in underground workings at the Skyline Mine and have been encountered by exploration drilling in the RFDS area (CFC, 1999). These systems occur in paleochannel sandstones that are encased in three dimensions by relatively impermeable mudstones and shales. Consequently there is poor hydraulic communication between sandstones both laterally and vertically. Groundwater in these sandstone channels may occur under unconfined or confined conditions. Confined conditions in the underlying Star Point Sandstone attest to the ability of fine-grained units in the Blackhawk Formation to act as substantial barriers to vertical groundwater flow.

Experience at Skyline Mine and other mines in the Wasatch Plateau indicates that coal seams themselves do not bear water; in fact, water must be used to control dust as coal is cut by mining equipment.

The mechanics of deep Blackhawk Formation groundwater systems are not as well understood as the mechanics of near surface groundwater systems described above. Mining encounters groundwater in these systems at a point along the flow path but recharge and discharge locations are not obvious. Groundwater flow direction is estimated to be in the direction of bedrock dip(westward).

Mayo and Associates (1996) have determined that groundwaters in the deep Blackhawk Formation groundwater system have radiocarbon ages of 2,500 to 18,500 years and contain essentially no tritium. This suggests that these systems are hydraulically isolated from the surface and that groundwater flow is likely slow. The stable isotopic ratios of mine inflow waters are considerably more negative than shallow subsurface groundwaters, suggesting that these waters likely recharged anciently under cooler paleoclimatic conditions such as glacial periods.

Mayo and Associates (1996) cite several other lines of evidence to demonstrate that deep Blackhawk Formation groundwater systems are discontinuous and hydraulically isolated from the surface (and recharge sources). First, a 192-foot long upward well was constructed in the roof of the Lower O'Connor A Seam (Hydrometrics, 1987). The well only encountered groundwater at the 40-, 100-, and 120-foot intervals while all other horizons were dry. Similarly, a 128-foot deep well in the floor of the mine intercepted water at 98 feet. From the bottom of the mine to 98 feet the rock was not saturated. Second, discharge rates decline rapidly in newly exposed roof drips. Lastly, the total mine water discharge rate does not increase appreciably with time despite the fact that the total mined area continues to increase. The rate of discharge from mine workings is dependent on the rate of coal production and the timing of the encounter of large water-bearing features.

Faults do not appear to be important in the conveyance of water in the deep Blackhawk Formation groundwater system. CFC (1999) reports that of the 44 individual fault planes that were encountered prior to 1999, groundwater inflows occurred from only five. Four of the five appeared to intersect water-saturated sandstone paleochannels in the mine roof. Indeed, experience has indicated that most water-bearing faults encountered in Wasatch Plateau coal mines are associated with sandstone paleochannels. Thus, it is not anticipated that in the RFDS area, large volumes of water would be encountered in faults in the Blackhawk Formation. Recently large groundwater inflows have occurred in the Skyline Mine from two faults; however, these appear to be connected with the Star Point Sandstone and are discussed in the next section.

Potential discharge locations of deep Blackhawk Formation groundwater systems have not been identified. Due to the estimated low flow rates in this type of groundwater system, groundwater discharge at the natural discharge location is not expected to be large in magnitude and thus would be difficult to identify. Nevertheless, because of the westward dip of rocks in the Skyline Mine area and the RFDS area, groundwater in deep perched bedrock groundwater systems likely

discharges, under natural conditions, west of the RFDS area. However, there are no outcrops of the lower Blackhawk Formation west of the RFDS area. Instead, the lower Blackhawk Formation is dissected by the East Gooseberry Fault west of the study area (Figure 1), which likely hinders further westward groundwater flow.

Experience in the Wasatch Plateau suggests that large-offset faults are generally barriers to lateral flow across a fault due to the presence of low-permeability fault gouge. If the East Gooseberry Fault is indeed a barrier to horizontal flow across the fault, then groundwater flow is diverted at the fault in some direction along the fault. The damage zone (rock on either side of the fault that is fractured due to faulting) likely facilitates and supports groundwater flow along the fault. It is doubtful that groundwater from deep Blackhawk Formation groundwater systems discharges to the surface along the surface trace of the East Gooseberry Fault because deep perched systems would not have sufficient hydraulic head.

Star Point Sandstone Groundwater Systems

As described in the Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000b), the Star Point Sandstone is comprised of two sandstone members, the upper Storrs Tongue and the lower Panther Tongue. Mining at the Skyline Mine has encountered water associated with both the Storrs Tongue and the Panther Tongue. Because of the westward dip of the bedrock, there is a high probability that mining in the RFDS area would encounter additional inflows of water from the Star Point Sandstone.

The Storrs Tongue interfingers with the Blackhawk Formation and divides the Lower O'Connnor A Seam from the Flat Canyon Seam. However, in the western portion of the RFDS area, the Storrs Tongue pinches out and the Lower O'Connor A Seam and the Flat Canyon Seam merge. The Panther Tongue underlies the Flat Canyon Seam, the lower-most seam where mining would occur in the RFDS area. The Flat Canyon Seam is separated from the Panther Sandstone by 15-30 feet of shale, mudstone, and thin coals.

The tongues of the Star Point Sandstone are laterally more extensive than individual sandstones in the overlying Blackhawk Formation. It is anticipated that over larger areas, such as the Skyline Mine and RFDS areas, each tongue operates as a single groundwater system. However, it is not believed that the Star Point Sandstone is a regional aquifer in the sense that there is hydraulic continuity throughout the Wasatch Plateau.

The mechanics of Star Point Sandstone groundwater systems are not well understood. The Star Point Sandstone is exposed in Pleasant Valley east of the Skyline Mine area and the RFDS area and dips westward. This suggests that recharge occurs in the east and groundwater flow is to the west. Because of the inclination of the formation and the low hydraulic conductivity of Blackhawk Formation shales and mudstones overlying the Star Point Sandstone members, confined groundwater conditions are created. Similar confined conditions in the Star Point Sandstone have been observed at other coal mines in the Wasatch Plateau such as the Trail Mountain Mine.

Large groundwater inflows from faults have recently been encountered in the workings of the Flat Canyon Seam in the Skyline Mine. CFC (1999) reports that a fault with approximately 8 feet of offset was encountered during development of the 14L Headgate. The fault initially produced water from the roof and the floor at a rate of 1,200 to 1,400 gpm. Discharge from the roof ceased after a short period but water still continues to be produced from the floor. A second fault along the same trend was encountered in the 16L Headgate. This fault produces 300 gpm of water from the floor. It is believed that this water discharges from the Panther Tongue of the Star Point Sandstone.

Mayo and Associates (1999a) report that groundwater inflows to the Skyline Mine from the Star Point Sandstone have radiocarbon ages greater than 13,000 years and contain no tritium. This suggests that groundwater flow through the Star Point Sandstone is slow and that there is limited hydraulic communication with the surface. Slow flow rates in the Star Point Sandstone are substantiated by the measurement of hydraulic conductivity in other areas of the Wasatch Plateau. At the Crandall Canyon Mine in the Huntington Canyon area, slug testing revealed a hydraulic conductivity of 4.8×10^{-8} to 7.4×10^{-8} ft/s (Mayo and Associates, 1997a). Bills (2000) determined a hydraulic conductivity of 4.06×10^{-6} ft/s for the Star Point Sandstone in the Straight Canyon area. This latter result is higher than the first because of fracturing associated with the Straight Canyon syncline.

The Star Point Sandstone does not crop out west of Pleasant Valley. Consequently discharge locations for Star Point Sandstone groundwater systems have not been observed in the study area. The Storrs Tongue pinches out in the RFDS area indicating that groundwater is not transmitted westward beyond the study area by the Storrs Tongue. As noted in the previous section, the East Gooseberry Fault truncates the bedrock formations west of the RFDS area. This fault is presumed to be a barrier to lateral flow across the fault. This being the case, groundwater flow is diverted at the fault in some direction along the fault and flow is accommodated in the damage zone of the fault. Potentiometric levels in two monitoring wells, 99-21-1, and 99-28-1 (Figure 1), in the RFDS area that are completed in the first sandstone below the Flat Canyon Seam (which may be the Panther Tongue) suggest that the hydraulic head in the Panther Sandstone (elevation 8,419 and 8,515 feet, respectively) is not sufficient to cause water to discharge at the surface trace of the East Gooseberry Fault (elevation greater than about 8,800 feet, directly west of the RFDS area).

Although it is not known where groundwater in the Star Point Sandstone in the study area ultimately discharges, it can be surmised with some certainty that groundwater in the Star Point Sandstone in the study area is not in hydraulic communication with the Star Point Sandstone groundwater systems that supply water to the large-discharge culinary water supply springs in Huntington Canyon (Big Bear, Little Bear, or Birch springs). First, as noted above, the radiocarbon ages of Panther tongue water encountered at the Skyline Mine is 13,000 years. The radiocarbon ages of groundwater that discharges from the Huntington Canyon Springs (Mayo and Associates, 1997b; Mayo and Associates, 1999b) are summarized below.

Spring	Radiocarbon Age
Birch Spring	1,700-3,600 years
Big Bear Spring	Mixed; 3,500-4,500 years
Little Bear Spring	Modern

Because water in the Star Point Sandstone in the study area has appreciably greater radiocarbon ages, it is unlikely that this water is hydraulically connected to the Star Point Sandstone in the Huntington Canyon. Second, the East Gooseberry Fault, the surmised location for groundwater discharge from the Panther Tongue, is not structurally connected to fault systems in the vicinity of the Huntington Canyon springs. The Huntington Canyon springs discharge in and near the Pleasant Valley Graben and associated faults whereas the Gooseberry Graben is on the same trend as the Joes Valley Graben.

Water Quality

Groundwater discharge from springs in the study area is low-TDS, calcium-bicarbonate water. For springs that have been monitored for baseline water quality, the average TDS ranges from 60 to 280 mg/l and the average TDS is 180 mg/l (NorWest, 2000a). Concentrations of sodium ion and sulfate are very low. Groundwater quality meets State of Utah drinking water standards for the parameters that have been analyzed. Untreated spring water is used throughout the study area at cabins and campgrounds for culinary uses. Additionally, groundwater discharge supports baseflow to creeks that have been classified as "High Quality Waters – Category 1" by the State of Utah (UAC R317-2).

POTENTIAL ENVIRONMENTAL CONSEQUENCES

ISSUES AND EVALUATION CRITERIA

Hydrologic issues have been identified by the agencies and are analyzed in this technical report. Issues are listed below together with evaluation criteria.

- Subsidence could change the flow of springs and seeps, affecting spring discharge rates and groundwater contribution to streams. This could, in turn, affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Description of effects and duration, % probability.

- Subsidence of perennial streams and the Boulger Dam and Reservoir could intercept flowing/impounded water and divert it underground, changing the hydrologic balance. Changes in stream gradient could cause changes in stream morphology.

  Evaluation Criteria: Description of potential flow changes by quantity and duration of baseflow and % probability; description of bedload/sediment transport associated with change in stream gradient.

- Interception of ground water in underground mine workings and subsequent discharge to Eccles Creek (the existing mine water discharge point) or discharge Electric Lake could cause transbasin diversions of surface and ground water. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Description of potential diversions, estimates of amount of water that may be encountered, amount and location of discharge to surface waters, % probability. Change in mine water discharge to each watershed, expected change in flow duration and base flows in Eccles and Upper Huntington Creeks (gpm, acre-feet, %), expected change to inflow and discharge (%, acre-feet) to/from Scofield Reservoir and Electric Lake.

- Discharge of mine water into Eccles Creek or Electric Lake could change quality of receiving waters. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Water quality of the discharge water vs. water quality standards associated with the most restrictive of the designated beneficial uses of the receiving waters (meets/does not meet), change in receiving stream water quality (parameters with and without limits specific to beneficial use standards including TDS, RCRA metals, oil and grease, TMDL, and drinking water standards) addressed in part by estimating volume of discharge water as percentage of resulting total flows and determining whether discharge water is being diluted or receiving waters are being "contaminated", change in lake chemistry, including water column and lake bed sediments.

- Equipment and materials spilled, used, and/or abandoned in underground mine workings could change ground water quality and any connected surface water sources. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Description of potential changes in quality by affected parameter and duration.

SURFACE WATER

Alternative 2: Lease with BLM Standard Lease Terms and Conditions and Forest Service Special Coal Lease Stipulations

Potential Decreases In Baseflow Discharge Of Creeks
Under this alternative, the application of SCLS #9, perennial streams would not be undermined and thus the potential for direct impacts to perennial creeks is avoided.

However, creek discharge could be indirectly impacted if there were a diminution of discharge from groundwater systems that supply baseflow to perennial streams. As discussed below in the groundwater section, the potential for diminution of discharge from shallow groundwater systems is considered negligible. This is largely because of the existence of low-permeability rocks that create perched conditions in the groundwater systems that provide baseflow to creeks. Therefore, the probability of decreased baseflow in creeks in the RFDS area under Alternative 2 is negligible.

If, in the unlikely event, there were a perceptible or quantifiable decrease in streamflow as an indirect result of subsidence, SCLS #17 would require that the operator replace, at his expense, any surface water identified for protection that may be lost or adversely affected with water from an alternate source in sufficient quality and quantity to maintain existing riparian habitat, fishery habitat, livestock and wildlife use, or other land uses.

Increased Sediment Loading Resulting From Subsidence
Because perennial streams would not be subsided under Alternative 2, the potential for a direct increase sediment loading under this alternative would only occur in ephemeral or intermittent drainages. However, when there is sufficient water in these drainages, the sediment in the ephemeral or intermittent streams may be transported into perennial streams, lakes, or reservoirs.

Differential subsidence of surface water drainages has the potential to increase the sediment load of streams. Differential subsidence of the land surface can locally cause increased stream gradients, which increases stream velocity and erosion potential. This increased erosion potential may result in increased sediment loading of the stream. Differential subsidence of surface-water drainages can also locally result in decreases in sediment loading. If there is an overall increase in the frequency of pools in a watercourse, bed-load sediment carried by the stream may be deposited in these low-energy reaches, resulting in a decrease in sediment loading downstream of the pools.

Both of these impacts, if they were to occur, are likely to be short-lived. This is because the erosion of steep-gradient regions and the deposition of material in low-gradient regions result in a gradual bringing of the stream into equilibrium with its channel. Sediment loading may result from either 1) erosion anddeepening of the streambed, or 2) a widening of the stream channel as a result of bank erosion. As the stream reaches equilibrium with the channel, the sediment loading in the stream would likely return to near pre-mining conditions. The rate at which this would occur is a function of the type and resistance to erosion of the subsided sediments. If the sediments are soft and easily eroded (i.e. soil horizons or soft, weathered sedimentary rocks common in the RFDS area) the stream would rapidly come into equilibrium and the increased sediment loading in the stream would rapidly cease. If the channel substrate consists of resistant bedrock, then the stream would take much longer to achieve equilibrium with its channel, but because the rock is not easily eroded, there would be minimal or no increases in sediment loading of the stream.

It should be noted that the north facing slopes of Flat, Cunningham, and Swens Canyons have recently experienced considerable logging activities including the associated road construction and soil and vegetation disturbances. Because of these disturbances, there is a likelihood of increased sediment yield from the logged areas in the near future whether or not mining occurs.

Impacts To Water Quantity And Water Quality Of Eccles Creek And Downstream Watercourses Resulting From The Discharge Of Intercepted Groundwater

Skyline Mine currently discharges about 500 gpm. CFC estimates that mine discharge could be as high as 3,000 gpm if mining were to occur in the RFDS area. This rate would not be sustained continuously but represents a maximum occasional discharge. The actual discharge rate of water from mine workings would be dependant on the amount of water encountered, the amount of water that would be impounded underground, and cycles of the water handling system. The impact of additional discharge to Eccles Creek is discussed in this section.

It is anticipated that the chemical quality of groundwater encountered during mining in the RFDS area would be similar to that encountered in the Skyline Mine area (NorWest, 2000a). Therefore, if mine water discharge rates were to remain at current levels (approximately 500 gpm), and mine water were to continue to be discharged into Eccles Creek, there would be no new impacts to water quality or quantity beyond those currently occurring. Assuming that future discharge rates from the mine increased from current levels to 3,000 gpm (an approximate six-fold increase) then greater impacts to water quantity and quality in Eccles Creek and downstream watercourses would be anticipated.

The overall quality of Skyline Mine discharge water has been appreciably lower than of Eccles Creek (Mayo and Associates, 1996). Therefore there is a direct relationship between the percentage contribution of mine water to the creek and the overall quality of creek water below the mine discharge point. The greater the relative contribution of mine water to the creek, the greater would be the degradation of water quality in the creek.

Because the average solute concentrations of mine discharge water and Eccles Creek water are known, it is possible to use a flow-weighted linear mixing model to estimate the anticipated water quality at CS-2 (Eccles Creek below the mine discharge point) if additional mine discharge

water enters the creek. Because the Skyline Mine is currently discharging approximately 500 gpm into the creek, a total mine discharge of 3,000 gpm would represent an increase of 2,500 gpm above current levels. The linear mixing model suggests that TDS concentrations at CS-2 on Eccles Creek would average approximately 877 mg/l. Currently, with a 500-gpm mine discharge, TDS concentrations average approximately 554 mg/l. A substantial portion of the TDS increase would result from increases in sulfate concentrations, which would average approximately 400 mg/l. Currently, with a 500-gpm discharge, sulfate concentrations at CS-2 average 193 mg/l. Most other solute species would have smaller increases because the concentrations of these species in mine water are nearer those of the receiving water. It should be noted that these estimates are based on a continuous mine discharge of 3,000 gpm. It is likely that pumping of mine water would occur intermittently and the long-term average pumping rate would be considerably less than 3,000 gpm. Thus, these estimates should be considered as worst-case estimates. The magnitude of the potential water quality impacts may be considerably less than those estimated above.

The results of the flow-weighted mixing calculations are acceptable for estimating the general order of impacts to Eccles Creek because of the relatively low concentrations of solute species in both mine water and receiving water. However, it should be noted that, because this technique does not consider thermodynamic factors, there is the potential for error in the calculations, particularly in non-dilute solutions.

Currently, Skyline Mine is permitted to discharge 7.1 tons per day of dissolved solids. Assuming that discharge increases to 3,000 gpm total mine discharge (6.68 cfs) and the average mine discharge TDS concentration of 916 mg/l remains the same, there would be a salt loading of 16.5 tons per day, an increase of 9.4 tons per day.

Scofield Reservoir and the Price River and its tributaries have been designated as protected by the Utah Division of Drinking Water (UAC R317-2) for 1) domestic purposes with prior treatment by treatment processes, 2) secondary contact recreation such as boating, wading, or similar uses, 3) cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain, and 4) agricultural uses including irrigation of crops and stock watering.

Before any mine water could be discharged into these waters, the current UPDES discharge permit may need to be modified. In order to receive a new or modify an existing UPDES permit, it must be demonstrated that beneficial use standards would not be exceeded in the receiving water. When a UPDES discharge permit is issued or modified, the water quality of the proposed discharge water is evaluated by the Utah Division of Water Quality (Personal Communication, Mike Herkimer, 2000). WET testing is performed to ensure that the water is not toxic (either chronic or acute) to aquatic organisms. If harmful constituents are identified in the proposed discharge water, then an approved water treatment plan must be implemented before any water may be discharged. If constituents are found in the water that are regulated under TMDL or which may cause the receiving water to not meet the quality standards for the designated beneficial uses, then specific discharge limits are placed on these constituents. Routine water quality monitoring of the discharge water is required for all parameters requested by the Division of Water Quality to demonstrate compliance with the UPDES permit.

As demonstrated by many years of continuous water quality monitoring, the quality of raw mine discharge water from the Skyline Mine, in terms of TDS, sulfate and pH, is acceptable for all of the protected beneficial uses and is within the drinking water standards set fourth by the Utah Division of Drinking Water (UAC 317-2). Limited chemical data are available for most other chemical parameters controlled by the designated beneficial use standards.

With a few exceptions discussed below, the quality of the mine discharge water has generally been acceptable for all of the designated beneficial uses of the receiving water (in terms of the chemical constituents for which water quality data are available). Concentrations of total boron, cyanide, dissolved lead, total phosphorous, and TDS have on at least one occasion exceeded the concentration limits specified by one or more of its beneficial use standards. Concentrations of cyanide from CS-12 on one occasion exceeded the beneficial use standard for aquatic wildlife. On each of the other 12 monitoring events, no cyanide was detected. During the single cyanide-monitoring event from the UPDES outfall, the concentration of cyanide also slightly exceeded the standard. The concentration of total phosphorous has occasionally been exceeded in discharge from CS-12 and CS-14, and was exceeded in the single phosphorous-monitoring event from the UPDES outfall. The average concentration of total phosphorous from CS-12 discharge is within the beneficial use standards, while those standards are somewhat exceeded in the average CS-14 discharge. The concentration of total mercury also exceeded the beneficial use standards during the single mercury-monitoring event from the UPDES outfall. Concentrations of phenol, an organic compound, have exceeded the beneficial use standards on a few occasions at both CS-12 and CS-14, while on all other occasions, there was no phenol detected in the discharge water. The causes of the occasional elevated phenol concentrations in the mine discharge water are not known.

It is important to note that for each of the chemical parameters discussed above, (with the exception of phenol and possibly total phosphorous) although certain beneficial use standards have occasionally been exceeded in the discharge water from either CS-12 or CS-14, the average concentration of mine discharge water, which is a combination of water from these two sources, is generally suitable for each of the beneficial uses. As discussed above, important chemical parameters of potential mine discharge water would be strictly controlled through the UPDES permitting process and would be monitored by several Utah State regulatory agencies. Additionally, continuous, automated monitoring equipment has been installed in the Skyline Mine discharge system that ensures that water that is excessively elevated in TDS, ph, turbidity, or oil and grease concentrations would not be discharged. If poor quality mine discharge water is detected by this system, it is automatically rerouted to underground storage areas within the Skyline Mine and is not discharged.

The addition of approximately 2,500 gpm (5.57 cfs) of mine discharge water to Eccles Creek above current levels (about 500 gpm) would constitute a considerable increase to the natural discharge in the creek. During low-flow periods, discharge in Eccles Creek measured at CS-2 is commonly between about 0.1 and 2 cfs. Thus, an addition of 5.57 cfs would result in a discharge between 2.8 and 56 times current levels. The addition of this amount of sediment-free water during low-flow periods would cause increased sediment transport. The magnitude of this impact has not been quantified. The data necessary to perform a rigorous and meaningful analysis have not been collected. However, the erosion potential would be mitigated in part

because of the well-armored nature of the stream channel. The stream channel in Eccles Creek is dominated by cobbles and boulders and appears to be relatively stable. During periods of high flow in the creek, when current discharges commonly exceed 10 to 50 cfs, the addition of 5.57 cfs of mine discharge water would constitute a relatively smaller impact.

Eccles Creek is a tributary of Mud Creek, which is a tributary of Scofield Reservoir. Therefore an increase in the mine water discharge rate to Eccles Creek would also impact downstream watercourses including Mud Creek and Scofield Reservoir. Unlike Eccles Creek, the channel substrate in Mud Creek, particularly in its lower reaches, appears less armored than Eccles Creek and contains reaches dominated by fine-grained material. Therefore, the potential for increased erosion rates in Mud Creek would likely be greater than for Eccles Creek. However, because Mud Creek is a larger watercourse than is Eccles Creek, the addition of 5.57 cfs to the discharge represents a smaller percentage increase to the total stream flow. Thus, this additional water would be more readily accommodated in the channel. Likewise, because of the larger volume of discharge in Mud Creek relative to Eccles Creek, the degradation of water quality in this watercourse would be less.

During dry years, the addition of 5.57 cfs to Scofield Reservoir from Mud Creek would likely not result in any major impacts in terms of the ability of the reservoir to accommodate the additional water. Rather, the increased recharge to the reservoir would likely be considered a positive impact by those who use the water. This would be particularly true during dry years because the inflow of deep, perched groundwater into the mine workings is not related to climate. During extremely wet years, when water is spilling from the reservoir, the addition of this amount of water would be a meager amount relative to the 6,200 cfs capacity of the spillway. During extremely wet years, when there is no available storage capacity in the reservoir, the mine discharge water would increase the high-flow discharge rate in the Price River below the dam by 5.57 cfs. This would constitute a small percentage of the high-flow discharge of the Price River below the reservoir.

If the mine discharge water were redirected to the Upper Huntington Creek drainage, the discharge to Eccles Creek could cease. Under this scenario, the water quality in Eccles Creek would revert to its pre-mining condition, with an average TDS concentration of approximately 269 mg/l. Water quality in Mud Creek would also improve to pre-mining levels. As discussed above, there would be a net decrease of approximately 2.8 tons per day of salt loading to Scofield Reservoir. Discharge rates in Eccles Creek would decrease dramatically to pre-mining conditions. This would be particularly noticeable during baseflow conditions, when stream discharge rates would decrease from the current levels in dry years to perhaps less than 100 gpm. The loss of approximately 500 gpm of mine discharge water would represent a loss of approximately 800 acre-feet of water per year in Scofield Reservoir.

Impacts to Water Quantity and Water Quality of Electric Lake and Downstream Watercourses Resulting from the Discharge of Intercepted Groundwater

It is proposed in the RFDS that mine water might be discharged to Electric Lake at or below the high water line in Upper Huntington Canyon. The possibility of discharging water some distance out into the lake has also been discussed by USFS personnel and CFC. This section

discusses the possible impacts to chemical and physical water quality as a result of discharging mine water to Electric Lake. The chemical water quality impacts are expected to be the same regardless of weather water is discharged near the high water line or father out into the lake. The physical quality of the lake could be impacted if discharge near the high water line results in appreciable entrainment and transport of lake bottom sediments during low stand periods.

It is anticipated that the chemical quality of groundwater encountered during mining in the RFDS area would be similar to that encountered in the Skyline Mine area. Because the anticipated quality of mine discharge water is poorer than that in Upper Huntington Creek, the water quality of Upper Huntington Creek would be degraded by the addition of any mine water. The magnitude of this impact is directly related to the volume of mine water discharged into the receiving water. In the following discussion, water quality impacts to Electric Lake have been analyzed by comparing the water quality of Upper Huntington Creek at UPL-10 to the average quality of Skyline Mine discharge water. However, the water quality impacts to Electric Lake resulting from proposed mining activities in the RFDS area would be less than those occurring in Upper Huntington Creek due to dilution in the lake.

Because the average solute concentrations of mine discharge water and Upper Huntington Creek water are known, it is possible to use a flow-weighted linear mixing model to estimate the anticipated water quality at UPL-10 (Upper Huntington Creek just above Electric Lake) at different mine water discharge rates. The results of these calculations for an anticipated mine water discharge rate of 3,000 gpm are shown in Table 5.1. Because there is currently no mine discharge into Upper Huntington Creek, the entire 3,000 gpm would constitute a new impact to the stream. The linear mixing model suggests that TDS concentrations at UPL-10 could increase from approximately 182 mg/l to 502 mg/l. Much of this increase would be caused by increases in the sulfate concentration in the stream, which could increase from 15 to 194 mg/l. Smaller increases in other solute species would also occur. As discussed above, these estimates are based on a continuous discharge of 3,000 gpm into the stream. It is more likely that mine water would only be pumped intermittently, and thus, the average pumping rate would be considerably less. Therefore, these estimates should be considered as worst-case estimates. The actual water quality impacts may be considerably smaller than those described above. The results of the flow-weighted mixing calculations are of value in estimating the general magnitude of impacts to Upper Huntington Creek, but as described in Section 5.1.3, it should be noted that there is the potential for error using this technique. Assuming an average TDS concentration of mine discharge water of 916 mg/l, there would be an additional 16.5 tons per day of salt loading to the reservoir.

Huntington Creek and Electric Lake are protected for secondary contact recreation such as boating, wading, or similar uses. These waters are also protected for cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain. The waters are also protected for agricultural uses including irrigation of crops and stock watering. Huntington Creek has been designated as protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water.

Before any mine water could be discharged into these waters, a UPDES discharge permit would be required. In order to receive this permit, it would need to be demonstrated that the beneficial

use standards for these waters would not be exceeded. Water quality analyses for the Skyline Mine discharge for important parameters regulated under the beneficial use standards are included in Appendix D. As discussed above, the quality of mine discharge water for all parameters regulated under beneficial use standards (with the exception of phenol and possibly total phosphorous) for which data are available is generally acceptable for the designated beneficial uses. As discussed above, all important water quality parameters would be controlled through the UPDES permitting process and are regulated by several Utah State regulatory agencies. Additionally, continuous, automated monitoring equipment has been installed in the Skyline Mine discharge system that ensures that water that is excessively elevated in TDS, pH, turbidity, or oil and grease concentrations would not be discharged. If poor quality mine discharge water is detected by this system, it is automatically rerouted to underground storage areas within the Skyline Mine and is not discharged.

Because the mine discharge water is generally of sufficient quality to meet drinking water standards and all of the designated beneficial uses of the receiving waters (for the chemical parameters for which data are available and with the exception of phenol and possibly total phosphorous), it is unlikely that there would be adverse impacts to ecosystems in downstream water courses or that there would be adverse water quality impacts to downstream water users.

The temperature of groundwater from the Skyline Mine has averaged between about 11 and 16°C (Mayo and Associates, 1994). If this water is discharged directly into Electric Lake during the winter months when temperatures of the lake water are near 0°C, there would be an alteration of the thermal regime of the lake. This may locally result in the melting or thinning of the surface ice in the vicinity of the discharge point and may also impact ecosystems in the immediate vicinity of the discharge point.

In the event that mine water is discharged near the high water line of Electric Lake, there is potential for appreciable erosion of lake bed sediments during times of the year when Electric Lake is not at high water. When the lake is not at high water, mine water discharge would first mix with Upper Huntington Creek discharge before flowing in the lake. When the lake is not at high water, Huntington Creek flows in a channel carved into unvegetated lake bed sediments. The addition of approximately 3,000 gpm (6.68 cfs) of mine discharge water to Upper Huntington Creek would constitute a considerable increase in the discharge in the creek. During low-flow periods, discharge from Upper Huntington Creek to Electric Lake is commonly between about 1 and 3 cfs (Mayo and Associates, 1996). Thus, an addition of 6.68 cfs would result in a baseflow discharge that is between about 2.2 and 6.7 times current levels.

The potential for disturbance of lake-bottom sediments would be greatly diminished if discharge water were conveyed via pipeline to a point further out into the lake. Because the mine water discharged into the lake would be essentially sediment free, there would likely not be any perceptible deposition of sediment at the mine discharge point.

During dry years and during the late summer months, the addition of 6.68 cfs of water to Electric Lake may be seen as a beneficial impact. This would be particularly true during drought years, because as discussed in Section 3.2.3, the inflow of deep, perched groundwater into the mine workings is not related to climate. During extremely wet years, when water is spilling from the

reservoir, the addition of this amount of water would be a meager amount relative to the 2,300 cfs capacity of the spillway. During extremely wet years, when there is no available storage capacity in the reservoir, the mine discharge water would increase the high-flow discharge rate in Huntington Creek below the dam by 6.68 cfs. This would constitute a small percentage of the high-flow discharge of Huntington Creek below the reservoir.

Impairment Of Water Rights Resulting From Decreased Stream Flows
Numerous water rights for creeks are heldexist in the RFDS area by both private land owners and government agencies. As described in Section 5.1.1, perceptible or quantifiable impacts to creek discharge rates are not anticipated. If there are no impacts to creek discharge rates then there should be no impairment of water rights. In the event that there is a mining-related flow diminution of an appropriated surface water source, Utah Code 40-10-18 requires the mine operator to "promptly replace any state appropriated water in existence prior to the application for a surface coal mining and reclamation permit."

Alternative 3: Lease with BLM Standard Lease Terms and Conditions Only

Under Alternative 3, the SCLS are not applied to the lease. The potential environmental impacts under this alternative include the impacts described under Alternative 2 and the potential impacts described below.

Diversion of Surface Water from Perennial Creeks and Boulger Reservoir into the Subsurface as a Result of Undermining and Subsidence
Perennial streamflow may be impacted if subsidence-related tension fractures caused diversion of surface water into the subsurface. It is believed that low-permeability confining or perching layers exist beneath all of the perennial streams in the RFDS area. This is expected to be the case regardless of the geomorphology. For instance, although Boulger Canyon is wide with a low stream gradient whereas Swens Canyon is narrow and steep, the same bedrock formation underlies the unconsolidated sediments in each canyon. Canyon geomorphology in the study area is a function of erosional process (fluvial and glacial) not the underlying bedrock. It is for this reason that the results of undermining Burnout Canyon with respect to stream dewatering can be extrapolated to all of the perennial drainages in the study area.

Therefore, in order for surface waters to be diverted from a creek, the integrity of the perching layer(s) would need to be compromised such that downward migration of surface waters into deeper unsaturated rock horizons could occur. The subsidence fractures must be sufficiently extensive and interconnected so as to facilitate the conveyance of stream water out of the drainage. It is expected that the integrity of the low-permeability bedrock horizons that support both streams and shallow groundwater systems in the RFDS area would not be compromised (NorWest, 2000a). For these reasons, the potential for the direct interception and translocation of surface waters by subsidence fractures is considered remote. The existence of low-permeability layers creates shallow, perched groundwater systems beneath the stream. Were this not the case, the streams in the RFDS area would be losing streams because the groundwater derived baseflow component would flow downward into the unsaturated horizons that exist deeper beneath the surface.

If subsidence fractures were to occur above the impermeable perching layer, these would be of relatively little consequence to the hydrologic regime. Because sediments above the perching layer are believed to be fully saturated, there could be no loss of water to these fractures. Subsidence fractures that could develop in the Blackhawk Formation would heal rapidly as a fracture plane is wetted due to swelling clays in the Blackhawk Formation. Thus, if subsidence fractures were to damage the perching layer beneath the stream, these fractures would likely remain open for only a short period of time.

The experience of CFC performing longwall extraction beneath Burnout Creek (NorWest, 2000a) provides support for the idea that perceptible or quantifiable detrimental impacts to perennial streams would not likely occur if these drainages were undermined. As reported by NorWest (2000a), there have been no quantifiable impacts to baseflow discharge in Burnout Creek after it was undermined that could be attributed to mining activities. It is believed that the geologic conditions in the RFDS area (geologic formation, overburden thickness, and degree of fracturing and faulting) are sufficiently similar to those at Burnout Canyon (less than 1 mile from the RFDS area) to give scientific validity to extrapolating the observed effects of undermining Burnout Creek to those that may occur if perennial surface water drainages in the RFDS area are undermined with longwall mining techniques. Thus, it is probable that no perceptible or quantifiable losses of surface water would occur if surface water drainages in the RFDS area are undermined.

There is a potential for localized shifting of groundwater discharge locations as a result of mining-related subsidence. This can result from minor alterations in the attitude of bedrock horizons (i.e. a change in the groundwater flow direction) or changes to fracture networks that may support groundwater discharge. However, because the drainages that support surface water in the RFDS area are all well entrenched and the surface gradients are relatively steep, the possibility that minor shifting of groundwater discharge locations could remove perceptible or quantifiable amounts of surface water from the drainage is remote. Rather, it is likely that groundwater entering the stream channel would simply enter slightly higher or lower in the drainage. Under this scenario, there would be no net loss of water from the watercourse.

For the reasons discussed above, it is believed that the potential for diminished baseflow discharge in creeks in the RFDS area under Alternative 3 is negligible. However, if perceptible or quantifiable detrimental impacts to groundwater systems that provide baseflow to streams in the RFDS area do occur, then these impacts would be reflected in decreased baseflow in streams. These potential impacts to perennial streams, were they to occur, would likely be of relatively short duration, likely on the order of one or two seasons. As discussed in Section 6.1.1, tension fractures in the Blackhawk Formation tend to heal rapidly because of the existence of hydrophilic swelling clays in the rocks of the formation. If subsidence fractures were to intercept groundwater, the fractures would rapidly heal as the clays along the fracture planes became wetted and subsequently swelled. If subsidence fractures appear in a stream channel that has a bare bedrock substrate (that may not contain swelling clays) the subsidence fractures would likely fill with sediment transported by the stream. It was evident in the July 2000 stream survey that each of the streams surveyed was actively transporting quantities of sediment that would be sufficient to fill even a relatively large subsidence fracture in a short period of time. Assuming a typical fracture width of 1 inch, a depth of 30 feet, and a length of 50 feet, a fracture volume of

125 cubic feet is calculated. Although no direct measurements of sediment transport in streams in the area are available, it is believed that the quantities of sediment transported annually in perennial streams in the RFDS area greatly exceed this amount. Thus, even if several subsidence fractures occurred in the drainage, the duration of a potential stream-water loss resulting from subsidence fractures physically intersecting a bedrock channel would be relatively short, perhaps on the order of one or two seasons.

In the event that there were a perceptible or quantifiable mining-related diminution of discharge in a creek that has been designated for protection, the application of SCLS #17 would require the lessee to replace any water lost from or adversely affected by mining operations with water from an alternate source in sufficient quality to maintain existing riparian habitat, fishery habitat, or livestock and wildlife use.

Changes In Stream Morphology Due To Subsidence Of Creeks

Longwall mining commonly results in differential subsidence of the land surface. If longwall mining occurs under a stream drainage, there would be localized changes in channel gradient near the margins of a subsided area. **These changes may result in a deepening or a widening of the stream channel.** In the interior of a subsided area, the land subsidence is more uniform and changes in stream gradient should theoretically be small. Therefore, the greatest potential for major alterations in stream morphology occurs above panel ends or above longwall gateroads. Although the potential for major changes in stream morphology does exist, the experience of CFC in mining Burnout Canyon suggests that the changes that may occur would not be large enough to cause major detrimental impacts to the streams in the RFDS area.

It was observed by the authors that the subsidence-induced changes in channel gradient at Burnout Canyon, even in the areas of maximum differential subsidence, were not great enough to cause barriers to fish movement in the stream. Rather, as has been observed in other subsided areas in the Wasatch Plateau, the subsidence around the margins of longwall panels occurs in a more distributed, gradual fashion. Thus, it is believed to be unlikely that fish barriers would form as a result of potential longwall mining in the RFDS area.

Sidel et al. (2000) report that changes to the stream morphology in Burnout Creek during the period it underwent longwall mining were minor and consisted primarily in an increase in the percentage of pools along the drainage. However, similar morphological changes occurred in the adjacent James Canyon, which was a mostly non-undermined control for their study. Thus, it is difficult to determine to what extent, if any, the mining activity had on the stream morphology in the drainage. The morphological changes that did occur in these drainages were short-lived. Within a year the drainage had returned to near-pre-mining conditions (Sidel et al., 2000). However, it is possible that there will be an increase in pooling in portions of streams that are undermined using longwall mining techniques.

Thus it is believed that although differential subsidence of perennial drainages above longwall-mined areas would occur under to Alternative 3, these changes would generally be minor. If a major impact to stream morphology were to occur, the impacts would likely be short-lived.

It has been determined in the Geology, Mining, Subsidence, and Seismicity technical report (NorWest, 2000b) that in portions of some perennial stream drainages in the RFDS area, there could be moderate changes in the channel gradients. In most sections of the perennial streams in the RFDS area, the stream gradients are steep enough for the stream to adjust to subsidence-induced slope changes without any major changes to stream morphology. However, in some perennial drainages, including portions of the Flat Canyon and Boulger Canyon, and the lower reaches of Swens Canyon, there are reaches with relatively low stream gradients that may experience moderate subsidence-induced gradient changes. In these areas, there is the potential for low or possibly even negative stream gradient to occur if the slope changes are sufficiently large. The precise locations where these effects could occur are entirely contingent upon thespecific locations, geometries, and orientations of longwall panels. Thus, in the absence of a detailed mine plan, it is difficult to be more specific in predicting locations where these effects may occur. If negative gradients occur in these areas, pooling of water in the subsidence troughs near gradient inflectionpoints may result. This could result in the creation of new ponds or wetland areas in the drainages. If ponding occurs in areas containing thick alluvial deposits (such as those found in the Flat Canyon and lower Boulger Canyon drainages) these ponds or wetlands may persist for a relatively short period of time. This is because the stream has a tendency to actively erode soft sediments in highland areas and deposit the abundant, easily eroded sediment in lowland areas. Thus, the stream would have the tendency to quickly come into equilibrium with its channel in terms of channel gradient. In areas of maximum differential subsidence, there is the potential for head cutting in stream channels that would result in increased sediment loading and temporary changes to stream morphology. Changes in channel width resulting from erosion of stream banks may also occur. In areas directly underlain by bedrock formations, where relatively less sediment is transported and the substrate less easily eroded, the effects would persist for a longer period.

In areas where subsidence-induced changes to stream gradients could result in local reversals of stream gradient and potential ponding of water or the creation of wetland areas (most notably in Flat Canyon and possibly also in portions of Boulger Canyon and Swens Canyon) there is the potential for flooding of structures that are located near the streambank. The authors have not observed structures in these areas that appear to have the potential to be flooded. Thus, this impact is not anticipated in the RFDS area.

According to the RFDS, Upper Huntington Creek would not be subsided by longwall undermining. However, there is a possibility that Upper Huntington Creek and portions of Electric Lake would be directly undermined for the development of mains. As discussed in the Geology, Mining, Subsidence, and Seismicity technical report (NorWest, 2000b), subsidence above regions mined using room and pillar techniques is expected to proceed gradually at a very slow rate, possibly requiring several centuries or even millennia to complete. For these reasons, it is believed that any subsidence fractures that may develop beneath Upper Huntington Creek would likely develop slowly and gradually. Because of the presence of thick, soft alluvial sediments in the drainage, any subsidence fractures that develop would likely be filled with sediment at a fast enough rate to keep the fractures continuously and completely filled with sediment as the region subsides. As these sediments are compacted over the centuries, their ability to transmit water would continuously be diminished. The amount of water potentially transmitted in these fractures would be very small relative to the amount of water in the drainage.

Therefore, no measurable or perceptible impacts to water quantity in Upper Huntington Creek or Electric Lake are anticipated as a result of room and pillar extraction beneath these areas.

Increased Sediment Loading Resulting From Subsidence Of Creeks

Under Alternative 3, the potential for increased sediment loading resulting from subsidence would be the same as those under Alternative 2, with the exception that sediment load increases could occur in perennial drainages. Whereas sediment loading in ephemeral or intermittent drainages is only of consequence for part of the year when these watercourses are transporting water and sediment, if perennial drainages are affected, this impact could occur throughout the year.

GROUNDWATER

Alternative 2: Lease with BLM Standard Lease Terms and Conditions and Forest Service Special Coal Lease Stipulations

Potential Impacts to Groundwater Systems
There are two mechanisms through which underground coal mining has the potential to impact groundwater resources. The first mechanism is the direct interception of groundwater by mine workings. The second mechanism is by interruption or deformation of strata overlying subsided areas. Each of these mechanisms is discussed below.

Direct interception of groundwater results in the local dewatering of deep groundwater systems. Groundwater that is encountered in underground workings at the Skyline Mine and groundwater that may be encountered in the RFDS area issues from either deep Blackhawk Formation groundwater systems or Star Point Sandstone groundwater systems (NorWest, 2000a).

Deep Blackhawk Formation groundwater systems do not have good hydraulic communication with the surface as indicated by radiocarbon ages that are many thousands of years, the lack of tritium, and the rapid decline of inflow rates after a water-bearing feature is encountered. What this suggests is that the dewatering of these horizons should not induce renewed recharge to these systems and therefore there should be no impact to the hydrologic balance in the recharge areas. Because deep Blackhawk Formation groundwater systems drain quickly when encountered, it is doubtful that these systems support perceptible or quantifiable discharge to the surface.

Star Point Sandstone groundwater systems also discharge water to mine workings that is many thousands of years old. Because of the lateral continuity of the Star Point Sandstone, it is possible that there may be hydraulic continuity from the recharge zone to where water is encountered in mine workings. However, pump test analysis (Mayo and Associates, 1997a; Bills, 2000) indicates that the hydraulic conductivity of unfractured Star Point Sandstone is low, and thus recharge to the Star Point Sandstone is largely constrained by the low permeability of the unit. Thus it is unlikely that dewatering of the sandstone would perceptibly or quantifiably

impact the hydrologic balance in the recharge area. Due to the antiquity of water in the Star Point Sandstone, it is unlikely that discharge from the Star Point Sandstone, wherever that may occur, is important to the hydrologic balance of that area.

Subsidence-induced interruption and deformation of strata has the potential to impact groundwater systems by 1) enhancing existing or creating new flow pathways for vertical groundwater migration and thereby partially or wholly dewatering a saturated horizon, and/or by 2) locally altering natural groundwater flow directions. In the study area, subsidence has the potential to impact near surface groundwater systems and deep bedrock groundwater systems that exist above the mined horizon.

The potential impacts of mining-related subsidence to dewater near surface groundwater systems are, for the most part, analogous to the potential impacts to perennial creeks. As with perennial creeks, the operation of near surface groundwater systems is fundamentally dependent on the presence of low-permeability bedrock horizons that create perched groundwater conditions. The critical question that must be evaluated, then, is how would subsidence and subsidence-related fracturing affect the bedrock immediately below where these systems operate.

The Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000b) describes the reaction of rock strata above longwall mined areas as a function of overburden thickness. There are four zones of movement above subsided areas. These include the cave zone, fracture zone, flexure zone, and soil zone. In the RFDS area the fracture zone is estimated to extend above the Lower O'Connor B seam up to 375 feet for single seam extraction and up to 675 feet above the Flat Canyon Seam for double seam extraction. The minimum overburden thickness in the RFDS area where longwall mining could occur is about 900 feet for the Lower O'Connor B seam. Most of the surface is more than 1,200 above the Lower O'Connor B seam. Thus, both colluvial/shallow bedrock groundwater systems operate entirely with the flexure zone and soil zone.

The expected response in the flexure zone is that there would be movement along existing joints and bedding planes, which can open up in zones of tension. Vertical movement along fractures typically remains within individual beds and is not vertically extensive unless massive strong beds are in the zone. Weaker rocks in the upper part of the zone may flex without causing failure along joints or tension cracks to form. In the soil zone materials are weak and generally do not fail due to the ability to flex. Tension crack formation does occur in the active tension zone but cracks close again when the compression zone reaches that point.

Based on the previous discussion, it is expected that the integrity of the low permeability bedrock horizons that are fundamental to the operation of colluvial/shallow bedrock groundwater systems generally would not be compromised. The exception would be the creation of tension cracks in high-strain zones as discussed below.

In zones of permanent tension that form above such features as panel ends, fire barrier pillars, and the outer edge of a block of panels, tension cracks are possible in shallow subsurface strata and may persist for a time. The degree to which these tension cracks impact shallow groundwater systems would be dependant on the degree of interconnectedness of fractures with

other fractures or permeable horizons that are capable of receiving water. However, it is anticipated that because of lithologic heterogeneity and the abundance of swelling clays in the Blackhawk Formation, that tension fractures which do form would heal quickly.

Experience in the Skyline Mine area also suggests that shallow bedrock horizons are not compromised to the degree that there is perceptible or quantifiable dewatering of a stream or spring. The experience at Burnout Creek is especially important (NorWest, 2000a). The strata underneath Burnout Creek have been subjected, in various locations, to tensile stresses caused by panel ends, stacked double seam fire barrier pillars, and the outer margin of a block of panels. Nevertheless, there has not been a decrease in stream discharge. Second, the response of springs and wells (NorWest, 2000a) to undermining and subsidence suggests that subsidence does not result in dewatering of groundwater systems. Lastly, exploration drill holes in the Blackhawk are very unstable, and when left open for a few days, slough badly (Vaughn Hansen Associates, 1982) suggesting that any subsurface openings created by subsidence would heal quickly.

Subsidence also has the potential to locally alter groundwater flow directions. This is caused by slightly altering the attitude of shallow bedrock or by subtle disturbances in unconsolidated material. While this could affect the discharge rate from an individual spring, the total discharge from the groundwater system would remain the same as groundwater is diverted to other nearby existing discharge locations or new discharge locations.

The probability of impacting deep bedrock groundwater systems that exist above the mined horizon decreases with increasing overburden thickness. As noted by NorWest (2000a), subsidence causes water level perturbations in deeper groundwater systems but there is no indication that the groundwater systems monitored by wells have been dewatered. If a saturated horizon in the deeper bedrock were dewatered, it is unlikely that there would be a perceptible or quantifiable impact to the hydrologic balance because of the limited recharge and discharge of these systems.

In summary, although mine workings encounter a large amount of groundwater, more than 1,000 gpm, this water is derived from storage in the groundwater system. Where groundwater naturally discharges from deep bedrock groundwater systems, it is surmised that the discharge rate is several orders of magnitude less than the rate that water inflows to mine workings. It is estimated that there is a remote probability that direct interception of groundwater by mine workings would cause perceptible or quantifiable impacts to the hydrologic balance at either the recharge or discharge areas of deep groundwater systems.

It is estimated that there is a negligible probability of perceptibly or quantifiably dewatering near surface groundwater systems as a result of mining-related subsidence and fracturing. There is a possibility that there may be some local alterations in groundwater flow direction, which might affect the discharge from an individual spring but not diminish the total discharge from a groundwater system.

In the event that there were a perceptible or quantifiable mining-related diminution of groundwater discharge at a developed spring location in the area, the application of SCLS #17

flow data over water quality data. No additional monitoring of groundwater resources is recommended.

Perceptible or quantifiable impacts to groundwater resources are not expected as a result of mining in the RFDS area. No measures are recommended to decrease the likelihood of a perceptible or quantifiable impact. If groundwater resources were to be impacted, mitigation would be required by SMCRA for culinary drinking water sources and Utah State Code 40-10-18 for state appropriated waters. If SCLS #17 is applied to the lease, the lessee would be required to replace any water lost from developed groundwater sources with water of similar quality.

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would require the lessee to replace any water lost from developed groundwater sources with water of similar quality.

Transbasin Diversion of Intercepted Groundwater

The potential for transbasin diversions arises if water that is encountered underground is discharged to another drainage other than the one where the water would naturally discharge. The Skyline Mine area and mine workings straddle the surface water divide between two major river basins of the region, the Price River and the San Rafael River basins. Most of the surface area in the RFDS area is within the San Rafael River Basin. The southwest corner of the RFDS area is within the Gooseberry Creek drainage, which is tributary to the Price River Basin. It is important to note that the Upper Huntington Creek drainage is a peninsula-like extension of the San Rafael River Basin into the Price River Basin.

At the Skyline Mine, groundwater is encountered underground on both sides of the surface water drainage. However, all water encountered in the mine is currently discharged to Eccles Creek, a tributary to the Price River. It is anticipated that CFC would discharge groundwater encountered by mining in the RFDS area to Eccles Creek, unless a discharge point could be permitted in the Upper Huntington Creek drainage. It presently would not be possible to discharge mine water to the Upper Huntington Creek drainage because watercourses within the outer boundary of the National Forest are designated by the State of Utah to be "High Quality Waters – Category 1" and new point source discharges into these waters are prohibited (UAC R317-2-3).

It is important in the analysis of potential transbasin diversion to identify the source of water intercepted by mine workings and the natural discharge locations of intercepted water. As described in the previous section, mining at the Skyline Mine does not appear to have created pathways for the downward migration of water from the surface or near surface to the mine. Thus, water that is intercepted in mine workings is likely groundwater that is naturally resident in the horizons immediately above or below the mined coal seam. It is anticipated that mining in the RFDS area would only encounter water that naturally occurs in the strata immediately above or below the mined coal seams.

As described in the Affected Environment section, groundwater in deep Blackhawk Formation groundwater systems and in the Star Point Sandstone groundwater systems does not appear to naturally discharge to the surface within the study area. It is surmised that the East Gooseberry Fault may intercept groundwater flowing westward in the deep bedrock. Where groundwater is conveyed by the East Gooseberry Fault is not known.

Because the natural discharge locations of groundwater potentially encountered by mining in the RFDS area are only speculative, the nature of any transbasin impact cannot be stated with certainty. However, the magnitude of this impact, regardless of where it occurs, can be estimated by considering the mean residence times of groundwater encountered by mining. Mayo and Associates (1996, 1999a) report that the radiocarbon ages of groundwater inflows to the Skyline Mine are many thousands of years. What this means is that the rate of flow through these systems is slow and thus the magnitude of discharge from these systems is likely meager. Thus it would not be correct to assume that the rate of discharge from mine workings in the

RFDS area is equivalent to the possible decrease in natural groundwater flow rates at the discharge location. Mining accelerates the rate of groundwater discharge from deep bedrock inactive flow groundwater systems.

A helpful analogy would be a livestock watering trough that is fed by a small trickle. Once the trough is full, water spills from the trough at the same rate that water enters the trough—at a trickle. If the bottom of the trough were punctured, the magnitude of discharge from the trough would be large compared to the trickle that once discharged from the system. What is lost from the pre-punctured system is the small trickle, not the large outflow resulting from the trough being breached.

It is highly probable that if water intercepted by mining in the RFDS area is discharged to a basin other than that which the water was naturally tributary, there would be not be a perceptible or quantifiable impact to the hydrologic balance of the basin from which water was diverted.

Impacts to Water Rights Resulting From The Diminution Of Spring Flows
Numerous water rights for springs are held in the RFDS area by both private land owners and the U.S. Forest Service. As described in Section 6.1.1, perceptible or quantifiable impacts to spring discharge rates are not anticipated. If there are no impacts to spring discharge rates then there should be no impairment of water rights. In the event that there was a mining-related flow diminution of an appropriated spring, Utah Code 40-10-18 requires the mine operator to "promptly replace any state appropriated water in existence prior to the application for a surface coal mining and reclamation permit."

A water right has a specified point of diversion. It is possible that if a spring discharge location shifted as a result of subsidence, this impact a water right because water could no longer be diverted at the specified point. If such a situation were to occur, the State Engineer would need to make a finding.

Potential Degradation of Water Quality in the Mine Environment
The quality of water that passes through the mine environment may be degraded by chemical interactions with naturally occurring minerals or materials and equipment introduced into the mine. Potential environmental impacts can occur if degraded water discharges from the mine workings either during active mining or after mining activities cease. These potential impacts are discussed below.

Acid mine drainage is caused by the oxidation and dissolution of naturally occurring sulfide minerals (principally pyrite and marcasite) when these minerals are exposed to the atmosphere in mine openings. Under natural (non-mined) conditions, the lack of available oxygen in the vicinity of the coal seams prohibits this reaction. The oxidation of sulfide minerals results in the release of hydrogen ions (acid), and increased iron and sulfate concentrations. However, acid mine drainage is rarely a problem in western coal mines because free hydrogen ions readily dissolve carbonate minerals (calcite and dolomite), which are abundant in the mine environment, and the sulfur content of coal is low. The dissolution of carbonate minerals results in increased concentrations of bicarbonate, calcium ion, and magnesium ion. Both of these reactions increase

the total dissolved solids (TDS) concentration of mine water. Ion exchange of calcium ion and magnesium ion for sodium ion is common due to the presence of clay and zeolite minerals (Mayo and Associates, 1994). Ion exchange reactions do not appreciably change the TDS concentration of mine water. The end result of these interrelated and secondary mineral reactions is that after water has passed through the mine environment, it is elevated in sodium ion, bicarbonate, and sulfate relative to groundwater that flows into the mine. Mine discharge water of this type is common from coal mines in the Wasatch Plateau.

Increased iron concentrations resulting from the oxidation of sulfide minerals does not typically result in negative water quality impacts in the Wasatch Plateau. Because most mine discharge waters and receiving waters are basic, dissolved iron is rapidly precipitated as iron hydroxides as the water comes in contact with the atmosphere and microbes at the surface. Water flowing in a surface stream that is fully aerated should not contain more than a few micrograms per liter of uncomplexed iron at equilibrium in the pH range of about 6.5 to 8.5 (Hem, 1985). Fine-grained iron precipitates are sometimes noted at mine water discharge points. These precipitates are generally not prolific enough to cause notable suspended sediment water quality impacts.

The dissolution of gypsum, halite, or other highly soluble minerals, which occur naturally in small quantities in the rocks adjacent to mine openings, may degrade the quality of the water discharging from the mine. The dissolution of gypsum increases the calcium ion, sulfate, and TDS concentrations of mine water. The dissolution of halite increases sodium ion, chloride, and TDS concentrations. These dissolution reactions affect water quality if these minerals are present in abundant quantities along groundwater flowpaths newly created by mining. This impact is generally not noted in Wasatch Plateau coal mines.

Some materials used in mining operations, when brought into contact with groundwater, have the potential to adversely impact the quality of water discharged from the mine. Mayo and Associates (1994) report that in the late 1980s gypsum rock dust was used in the Skyline Mine. This practice resulted in exceedence of TDS limits for mine discharge water because of the high solubility of gypsum. In March 1991, Skyline Mine began using carbonate rock dust, which is considerably less soluble in water. As a result of this change water quality of mine discharge water eventually improved. Mayo and Associates (1994) also note that part of the increase in TDS of mine discharge waters relative to mine inflow waters is a result of the oxidation of longwall emulsion fluid. When fugitive longwall emulsion fluid comes in contact with mine waters, the organic molecules in the fluid are readily oxidized by bacterial action resulting in the production of carbon dioxide gas. Carbon dioxide gas reacts with water to form carbonic acid (H_2CO_3), which dissociates into hydrogen ions and bicarbonate. The liberated hydrogen ions are rapidly consumed in reactions with naturally occurring carbonate minerals, resulting in increased calcium ion, magnesium ion, and bicarbonate concentrations in mine water.

During the course of mining operations, many tons of ferrous metals are utilized. Some of the metal objects are removed after mining ceases and, as a necessity, others are left in place. The largest permanent use of metal in mining operations is in roof-support. Thousands of metal roof-bolts are installed at regular spacings in the mine roof to prevent roof collapse. In some locations, wire mesh is also installed. For safety reasons, it is not possible to remove the roof-bolts or wire mesh after mining in an area has ceased. Additionally, metal is used in stoppings

APPENDIX B

TECHNICAL REPORT SUMMARY TABLE

RESOURCE/ISSUE	EFFECTS BY ALTERNATIVE		
Alternative	**Alternative 1** No Action	**Alternative 2** Std. Terms and Conditions with Special Stipulations to Protect Resources. No Subsidence of Sensitive Resource Areas or Facilities	**Alternative 3** Standard Terms and Conditions Only
Surface Water			
Diminution of creek flows due to impacts to groundwater discharge that provides baseflow	No Effect	The probability of a perceptible or quantifiable diminution of discharge from springs that provide baseflow to streams in the RFDS area is remote.	Same as Alternative 2
Diversion of water from perennial creeks into subsurface	No Effect	No Effect	Negligible effect. It is very unlikely that water would be diverted. Any pathways potentially created into the subsurface would rapidly be healed when wetted.
Increased sediment loading resulting from subsidence	No Effect	Minor, temporary effect. Increases or decreases in sediment loading of ephemeral drainages may result from differential subsidence. These would be short lived because drainages naturally have the tendency to return to equilibrium with substrate.	Same as Alternative 2, except the temporary increases or decreases in sediment loading would occur in perennial drainages. The effect could therefore occur throughout the year.
Impacts to morphology of perennial streams due to subsidence	No Effect	No Effect	Minor effect. There could be localized changes in stream gradients where differential subsidence occurs. In areas with naturally low stream gradients, there is the possibility of the creation of small ponds or wetland areas.
Impacts to water quality and quantity in Eccles Creek and downstream watercourses	No Effect	Addition of 4,840 ac-ft/yr to watercourse. Minor increase in downstream flooding potential. Average TDS in	Same as Alternative 2

		Eccles Creek increases from about 550 mg/l to 880 mg/l. Total mine water salt loading to Scofield Reservoir of 16.5 tons per day, or an increase of 9.4 tons per day above current permitted discharge levels.	
Impacts to water quality and water quantity in Electric Lake and downstream watercourses	No Effect	Addition of 4,840 acft/yr to watercourse. Minor increase in downstream flooding potential. Average TDS in uppermost Electric Lake increases from about 180 mg/l to 500 mg/l. Because of dilution, average TDS increase in all of Electric Lake would be lower. Total mine water salt loading to Electric Lake of 16.5 tons per day.	Same as Alternative 2

Groundwater			
Dewatering of deep bedrock groundwater systems due to direct interception	No Effect	Deep bedrock groundwater systems would be locally dewatered. Remote possibility of impacting the hydrologic balance in either the recharge area or the discharge area.	Same as Alternative 2
Dewatering of groundwater in shallow horizons that support spring discharges in the RFDS area	No Effect	The probability of a perceptible or quantifiable diminution of discharge from spring in the RFDS area is remote.	Same as Alternative 2.
Potential for transbasin diversion of groundwater	No Effect	The specific nature of potential transbasin diversions cannot be ascertained. However, the magnitude of the impact is expected to not be perceptible or quantifiable.	Same as Alternative 2.
Water quality impacts associated with interactions of groundwater materials in the mine environment.	No Effect	Water quality is not expected to be impaired by interactions with either naturally occurring minerals or introduced materials. All equipment would be required to be removed prior to mine closure.	Same as Alternative 2 except that equipment might be allowed to be abandoned underground. However, no impairment of water quality expected

and man-doors, overcasts, cribbing, well casings, pipes, and miscellaneous items such as hangers and signs. There is the potential for the metal in these objects to oxidize (rust) as it comes in contact with water in the mine environment.

Oxidation of ferrous materials results in the release of iron into the water. The magnitude and rate of the potential oxidation is constrained by a complex variety of factors, including the temperature, Eh, and pH of the water, the pressure on the system, the presence or absence of bacteria, and the solute chemistry of the mine water. As a result, this potential impact is difficult to quantify. However, discharge water from Wasatch Plateau coal mines has not been degraded by elevated iron concentrations. To what extent the iron concentration in mine discharge water may change after mining operations cease is difficult to determine. However, the concentration would likely remain low because dissolved iron is rapidly precipitated as iron hydroxides as noted previously.

Mining equipment may be abandoned underground as dictated by safety or economic considerations. However, it is Forest Service policy to not allow any new solid waste disposal facilities on National Forest System lands and to not add to existing facilities. Equipment left underground would be considered a solid waste and it would not be consistent with Forest Policy to allow the abandonment of equipment underground. Further, Section 7 of the BLM lease form requires lessees to remove equipment and materials "as required by the authorized officer." In the event that it were necessary to leave equipment underground for safety reasons, it is unlikely that corrosion of abandoned equipment would degrade the quality of water in the mine environment. Mining equipment, such as longwall mining machines, roof bolters, and continuous miners, is made of high quality steel alloy containing chromium. The metal is highly resistant to corrosion. Calculations of the corrosion potential of the steel used in longwall mining machines have been performed by the University of Utah Metallurgy Department (BLM, 1998). They determined that it would take thousands of years for the metal to corrode away, and that the metal would need to be ground to a fine particulate for chromium to be dissolved. The University of Utah (BLM, 1998) report indicates that the general conditions required to hasten the corrosion of this metal do not exist in the Utah coal mining environment.

Petroleum, oils, and lubricants are regularly used in mining operations. These materials may degrade discharge water quality if they are mishandled or abandoned underground and exposed to water passing through the mine. Any toxic or hazardous materials which are used underground would have to be removed from the mine prior to closure.

Although the impacts to water quality are expected to minimal, the application of SCLS #19 would require that the operator remove mine equipment and materials that are not needed for continued operations, roof support, and mine safety from underground workings prior to abandonment of mine sections.

Alternative 3: Lease with BLM Standard Lease Terms and Conditions Only

The potential impacts to groundwater resources under this alternative are the same as under Alternative 2, except that the area of potential impact increases as a result of not applying stipulations that preclude the subsidence of perennial creeks, paved roads, and structures.

By not applying the SCLS under this alternative, impact mitigation dictated by SCLS #17 and SCLS #19 would not be required.

Under this alternative, the operator would not be specifically required to remove equipment that is not incorporated into the mine. However, as noted, it is Forest Service policy to not allow any new solid waste disposal facilities on National Forest System lands and to not add to existing facilities. Equipment left underground would be considered a solid waste and it would not be consistent with Forest Policy to allow the abandonment of equipment underground. Further, Section 7 of the BLM lease form requires lessees to remove equipment and materials "as required by the authorized officer."

Nevertheless, if mine equipment were left underground, it is unlikely that ferrous equipment such as longwall shields, longwall shears, or continuous miners would perceptibly or quantifiably impact water quality even if these pieces of equipment were abandoned in areas that subsequently flooded. As noted in the previous section, the general conditions facilitating oxidation of metals do not exist in Utah coal mines. Minor water quality impacts could occur if lubricants were not drained from the equipment prior to abandonment. The magnitude of this impact would depend on the amount of organic materials, the volume of water in a flooded section, and the rate of intrinsic bioremediation. Computerized controls on equipment may contain lead, cadmium, mercury, and chromium and could cause water quality impacts if located in a flooded section. However, the magnitude of this impact is estimated to be minimal because of the small amount of controls relative the volume of water likely to be impounded and the slow oxidation rates of these materials in the mine environment.

RECOMMENDATIONS FOR MONITORING AND MITIGATION

SURFACE WATER

CFC has monitored stream discharges and water quality at eight sites in the RFDS area. For the SMCRA mining permit, an operational monitoring program that would need to be approved by UDOGM would be developed that builds on the baseline monitoring. It is recommended that, where possible, long-term discharge measurement devices be installed at locations selected for operational monitoring. This would facilitate greater accuracy and consistency in the flow measurements, which greatly increases the usefulness of these data. It is recommended that continuous recording devices be installed at surface-water monitoring stations on critical drainages.

Additionally, it is recommended that those stream reaches that have been classified as likely being perennial be monitored periodically in the future to refine the delineation of perennial reaches in the RFDS area.

Perceptible or quantifiable impacts to surface water discharge rates are not expected as a result of mining in the RFDS area. Therefore, no measures are recommended to decrease the likelihood of a perceptible or quantifiable impact. If surface water discharge rates were to be impacted, mitigation would be required by SMCRA for culinary drinking water sources and Utah State Code 40-10-18 for state appropriated waters. If SCLS #17 were applied to the lease, the lessee would be required to replace any water lost from creeks designated for protection with water of similar quality.

It is recommended that if mine water is discharged directly into Electric Lake that consideration be given to the placement of the discharge point. If the water is allowed to flow rapidly over the shoreline of the lake, appreciable erosion and sediment redistribution may occur. It may be advantageous to install an energy dissipating system that would decrease the discharge velocity and erosion potential of the discharging water.

Site-specific pre-mining investigations and planning should be carried out before mining proceeds in those areas where it is determined that there is high potential for subsidence-induced stream gradient reversal and pond or wetland formation. The precise locations of areas of potential stream gradient change would be a function of the implemented mining plan. Therefore, where possible, mining plans should be designed to minimize the potential for this occurrence.

GROUNDWATER

CFC has monitored 24 springs in the RFDS area for baseline water quality and discharge. It is expected that an operational monitoring program that builds on this baseline monitoring would be required under the SMCRA permit administered by UDOGM. The most critical data that can be collected are spring discharge measurements and emphasis should be placed on collection of

Table D-1 Discharge Data for Springs Monitored in the Skyline Mine Area

Discharge in GPM

S10-1		S23-4		S13-2		S13-7		S14-4		S12-1		S24-12	
8/18/81	0.48	9/3/91	0	10/23/81	0.36	6/29/82	39.13	8/18/81	0.85	6/29/82	78.95	11/12/81	0.43
6/29/82	11.3	10/15/91	0	12/9/81	0.31	7/20/82	3.75	6/29/82	12	7/20/82	2.86	6/30/82	1.58
7/20/82	2.5	6/9/92	0	5/20/82	1.19	8/18/82	1.76	7/20/82	3.26	8/18/82	0.32	7/22/82	1.07
8/18/82	0.86	9/1/92	0	6/30/82	0.73	9/15/82	98.74	8/18/82	1.88	9/22/82	0	8/20/82	0.97
9/22/82	0.52	10/20/92	0	7/21/82	0.61	9/22/82	0	9/22/82	1.09	10/16/82	0.16	9/14/82	0.83
10/12/82	0.58	6/29/93	0	8/19/82	0.58	6/29/83	39.13	6/29/83	15	6/29/83	75	6/30/83	1.25
6/29/83	33.33	8/25/93	0	9/15/82	0.68	7/19/83	5.1	7/19/83	5.34	7/19/83	3.86	7/20/83	1.13
7/19/83	6.7	10/18/93	0	10/14/82	0.59	8/22/83	0.71	8/22/83	2.56	8/22/83	0.63	8/25/83	0.94
8/22/83	1.67	7/24/95	0.45	11/9/82	0.45	9/27/83	0	9/27/83	1.48	9/27/83	1.3	9/29/83	0.42
9/27/83	1.13	9/4/95	0	6/30/83	1.3	6/26/84	35.53	10/19/83	1.75	10/19/83	0.17	10/27/83	0.86
10/19/83	0.75	9/12/96	0	7/20/83	0.83	7/31/84	1.79	6/26/84	14.29	6/26/84	26.47	11/11/83	0.81
6/26/84	19.67	7/3/97	0.609	8/25/83	0.29	8/22/84	0.34	7/30/84	3.26	7/31/84	1.01	6/28/84	2.13
7/30/84	3.04	8/13/97	0.8976	9/28/83	0.31	9/26/84	0	8/22/84	2.29	8/22/84	0.34	7/30/84	1.43
8/22/84	1.54	7/6/98	4.7	10/26/83	0.3	6/18/85	12.21	9/26/84	1.49	9/26/84	<0.1	8/27/84	1.27
9/26/84	1.06	8/13/98	1.35	11/11/83	0.74	7/10/85	1.25	6/18/85	6.36	6/18/85	8.7	9/18/84	1.12
6/18/85	9.38	8/17/99	2.244	6/27/84	1.36	8/27/85	0	7/10/85	3.26	7/10/85	0.45	6/27/85	1.5
7/10/85	2.39			7/26/84	1.06	10/16/85	0	8/27/85	1.56	8/27/85	0	7/9/85	2.25
8/27/85	0.74			8/28/84	0.79	6/18/86	36.36	9/18/85	1.2	6/18/86	84.38	8/26/85	1.1
9/18/85	0.71			9/17/84	0.82	7/21/86	1.81	10/16/85	1.04	7/21/86	3.63	9/18/85	0.91
10/15/85	0.68			10/23/84	0.67	8/19/86	0.24	5/27/86	21.43	8/19/86	0.58	10/17/85	0.88
6/18/86	17.21			5/22/85	1.75	9/23/86	0	6/18/86	17.65	9/23/86	0.05	6/19/86	1.71
7/21/86	1.32			6/20/85	0.95	10/15/86	0	7/21/86	2.94	10/15/86	0.4	7/22/86	1.28
8/19/86	0.63			7/9/85	0.9	6/9/87	2.25	8/19/86	1.59	6/9/87	4.35	8/26/86	1.08
9/23/86	0.32			8/26/85	1.43	7/14/87	0	9/23/86	1.09	7/14/87	0	9/23/86	0.85
10/15/86	0.4			9/19/85	1.58	8/17/87	0	10/15/86	1.01	8/17/87	0	10/15/86	0.87
5/18/87	17.2			10/16/85	1.32	9/24/87	0	5/18/87	22.44	9/24/87	0	6/11/87	10.64
6/9/87	7.28			5/28/86	4.88	10/19/87	0	6/9/87	5.56	10/19/87	0	7/8/87	0.79
7/14/87	0.84			6/24/86	2.86	11/19/87	0	7/14/87	1.83	6/27/88	1.66	8/20/87	0.75
8/17/87	0.31			7/22/86	2.08	6/27/88	0.42	8/17/87	1.09	6/21/89	1.33	9/23/87	0.66
9/21/87	0.15			8/20/86	1.63	8/17/88	0	9/21/87	0.76	9/6/89	0	10/21/87	0.64
10/20/87	0.19			9/25/86	1.56	6/21/89	0.97	10/20/87	0.76	10/16/89	0	6/6/88	0.92
6/27/88	3.06			10/21/86	1.3	9/6/89	0	6/27/88	2.91	6/4/90	30.77	8/16/88	0.55
8/17/88	0.31			11/11/86	1.28	10/16/89	0	8/17/88	0.93	9/10/90	0	10/20/88	0.37
10/11/88	0.17			12/10/86	1.24	6/4/90	13.6	10/11/88	0.64	10/24/90	0	6/22/89	<0.1
9/5/89	<0.1			4/22/87	1.32	9/10/90	0	6/21/89	2.65	6/18/91	29.41	9/12/89	0
10/16/89	0.23			6/11/87	1.04	10/24/90	0	9/5/89	0.7	9/3/91	0	10/19/89	0
6/4/90	8.11			7/8/87	1.01	6/18/91	9.52	10/16/89	0.63	10/15/91	0	6/6/90	0
9/10/90	0.114			8/19/87	0.83	9/3/91	0	6/4/90	11.9	6/9/92	0	9/12/90	0
10/24/90	0.27			9/23/87	0.766	10/15/91	0	9/10/90	0.71	9/1/92	0	10/25/90	0
6/18/91	15.67			10/21/87	0.77	6/9/92	0.19	10/25/90	0.61	10/20/92	0	6/10/91	0.15
9/3/91	0.19			6/6/88	1.25	9/1/92	0	6/18/91	11.47	6/23/93	39.56	9/18/91	0
10/15/91	0.16			8/15/88	0.6	10/20/92	0	9/3/91	0.91	8/25/93	0	10/17/91	0
6/10/92	2.65			11/2/88	0.43	6/23/93	25.78	10/15/91	0.7	10/18/93	0	6/16/92	0
9/1/92	0.11			6/22/89	0.79	8/25/93	0	6/9/92	3.9	7/24/95	1.57	9/9/92	0
10/20/92	<0.1			9/13/89	0.42	10/18/93	0	9/1/92	0.39	9/4/95	0	10/22/92	0
6/23/93	8.82			10/31/89	0.36	7/17/95	3.35	10/20/92	0.47	6/24/96	8.53	6/23/93	0
8/25/93	0.54			6/6/90	1.03	9/4/95	0	6/23/93	0	9/11/96	0	8/30/93	0
10/18/93	0.33			9/13/90	0.34	10/17/95	0	8/25/93	0	6/23/97	13.464	10/28/93	0
7/17/95	3.7			10/25/90	0.27	6/27/96	5.8	10/18/93	0	8/13/97	0	6/16/94	0
9/4/95	0.22			6/11/91	2.08	7/3/97	4.76	7/17/95	0.12	7/6/98	5.9	9/8/94	0
6/24/96	3.59			10/17/91	0.4	8/13/97	0.4488	9/4/95	<0.1	8/17/99	0	10/10/94	0
9/11/96	0			6/15/92	0.22	7/6/98	2.56	10/17/95	0.88			7/11/95	0
6/23/97	4.488			9/8/92	<0.1	8/19/98	0.404	6/24/96	<44.88			9/6/95	0
8/13/97	0.4488			10/22/92	<0.1	8/17/99	0.40392	9/12/96	0			6/26/96	0
10/9/97	0.26928			6/22/93	2.56			6/23/97	0.097			9/1/96	0
6/22/98	4.9			8/26/93	1.01			8/13/97	0.08976				
8/19/98	0.18			10/27/93	0.55			10/9/97	0.31416			6/23/97	0
8/17/99	0.26928			6/20/95	4.48			6/22/98	0.13			8/13/97	0
				9/6/95	1			8/19/98	0.0898			10/15/97	0
				10/17/95	0.88			10/10/98	0.55				
				6/25/96	2.69			8/17/99	0.04039				
				9/11/96	0								
				9/24/96	0.8976								
				6/24/97	2.68							8/18/99	0
				8/13/97	0.8976								
				10/9/97	0.8976								
				6/16/98	0.86								
				8/11/98	0.4488								
				10/11/98	0.75								
				8/16/99	1.3464								

Table D-1 Discharge Data for Springs Monitored in the Skyline Mine Area (continued)

Discharge in GPM

S15-3		S22-5		S22-11		S26-13		S34-12		S35-8		S36-12	
8/18/81	9.38	8/18/81	3.5	8/18/81	6.14	10/22/81	0.25	9/15/87	6.3	6/28/82	105	11/10/81	3.5
10/22/81	4	10/22/81	1	6/29/82	37.5	6/29/82	5.45	10/19/87	6.36	7/20/82	26.25	6/29/82	8.18
12/8/81	5.5	6/29/82	58	7/20/82	24	7/20/82	1.8	6/28/88	12	8/17/82	14.12	7/20/82	5
6/28/82	161.54	7/20/82	18.37	8/18/82	23.68	8/18/82	1.15	8/17/88	8.33	10/15/82	6	8/18/82	4.49
7/21/82	48.65	8/18/82	6	9/15/82	15	9/22/82	0.79	10/19/88	14.06	6/28/83	120	9/22/82	3.75
8/18/82	37.5	9/15/82	8.42	10/15/82	13.64	6/29/83	8.33	6/22/89	8.45	7/19/83	32.93	10/12/82	3.53
9/15/82	22.44	10/15/82	6	6/28/83	42.86	7/19/83	2	9/7/89	6.87	8/24/83	14.52	6/29/83	10.23
10/15/82	35.29	6/28/83	72	7/19/83	16.67	8/24/83	2.11	10/17/89	5.7	9/23/83	7.69	7/19/83	6.41
6/28/83	439.82	7/19/83	32.93	8/24/83	23.33	9/28/83	0.87	6/4/90	9.9	10/20/83	6.38	8/24/83	4.41
7/19/83	57.14	8/24/83	16.27	9/28/83	19.9	10/19/83	0.72	9/10/90	5.39	6/28/84	70.59	9/28/83	3.75
8/24/83	30	9/27/83	9.74	10/20/83	1920	6/26/84	6.21	10/24/90	4.93	7/31/84	22.44	10/19/83	3.9
9/27/83	23.68	10/20/83	9.46	6/27/84	41.38	7/30/84	1.95	6/12/91	42.19	8/22/84	10.56	6/26/84	7.96
10/20/83	27.27	6/26/84	56.25	7/31/84	22.44	8/22/84	1.28	9/3/91	3.8	9/26/84	6.82	7/30/84	4.76
5/24/84	1206.4	7/31/84	22.44	8/23/84	24.32	9/18/84	0.9	10/15/91	5.5	6/19/85	36	8/23/84	10.56
6/26/84	138.46	8/23/84	18.27	9/26/84	22.44	6/18/85	4.33	6/9/92	5.39	7/18/85	16.67	9/18/84	3.66
7/31/84	85.27	9/27/84	11.07	6/19/85	28.38	7/10/85	1.91	9/2/92	3.35	8/29/85	6.41	7/10/85	4.69
8/24/84	30.36	10/25/84	8.82	7/17/85	5.23	8/26/85	0.98	10/21/92	1.9	9/25/85	5.68	8/27/85	3.75
9/27/84	23.94	5/21/85	78.57	8/28/85	19.74	9/18/85	0.81	6/28/93	22.34	10/30/85	4.58	9/18/85	3.49
10/25/84	24.49	6/19/85	32.43	9/24/85	19.05	10/30/85	0.22	8/25/93	11.76	6/24/86	66.67	10/15/85	3.41
11/13/84	26.67	7/17/85	18.75	10/30/85	11.25	6/19/86	7.56	10/18/93	8.96	7/22/86	17.65	6/19/86	8.82
5/21/85	578.95	8/28/85	10.71	6/19/86	63.16	7/21/86	7.41	6/14/94	9.8736	8/20/86	8.9	7/21/86	4.76
6/19/85	105.88	9/24/85	20.45	7/21/86	25.61	8/18/86	0.95	8/31/94	5.8344	9/24/86	5.91	8/18/86	3.8
7/17/85	36.36	10/15/85	7.69	8/19/86	21.88	9/23/86	0.43	10/10/94	4.0392	10/16/86	3.95	9/23/86	3.45
8/28/85	20.33	6/19/86	42.86	9/24/86	16.81	10/15/86	0.31	9/5/95	25	5/19/87	11.7	10/15/86	3.33
9/24/85	19.44	7/21/86	20.69	10/16/86	14.71	6/10/87	2.73	10/18/95	10.4	6/10/87	8.93	6/10/87	5.88
10/15/85	25	8/18/86	10.82	5/19/87	6.25	7/14/87	0.96			7/27/87	7.26	7/14/87	3.8
5/27/86	1346.4	9/24/86	7.89	6/10/87	11	8/18/87	0.56	6/23/97	0	8/18/87	3.46	8/18/87	3.37
6/19/86	150	10/16/86	7.22	7/29/87	11.8	9/21/87	0.38			9/15/87	2.78	9/21/87	2.68
7/22/86	44.44	5/19/87	38.9	8/18/87	10.27	10/20/87	0.24			10/19/87	2.03	10/20/87	2.5
8/18/86	25	6/10/87	18.06	9/15/87	7.08	6/28/88	1.46			6/28/88	4.11	6/28/88	4.29
9/24/86	21.43	7/29/87	8.04	10/20/87	3.61	8/17/88	0.6			8/17/88	2.55	8/17/88	3.3
10/16/86	22.34	8/18/87	5.42	6/28/88	13.16	10/12/88	0.31			10/19/88	2.37	10/12/88	2.48
11/13/86	19.23	9/15/87	3.87	8/17/88	7.89	6/21/89	1.13			6/21/89	1.61	6/21/89	3.95
12/10/86	16.25	10/20/87	2.67	10/20/88	7.66	9/6/89	0.11			9/7/89	1.4	9/6/89	2.42
5/18/87	76.296	11/19/87	2.6928	6/22/89	8.52	10/16/89	0			10/17/89	1.62	10/16/89	1.95
6/10/87	66.67	6/28/88	21.2	9/6/89	3.75	6/4/90	3.4			6/5/90	1.9	6/25/90	5.27
7/28/87	22.34	8/17/88	4.81	10/17/89	0.93	9/10/90	0			9/11/90	2.54	9/10/90	2.52
8/17/87	16.07	10/20/88	3.37	6/5/90	5.5	10/24/90	0			10/10/90	1	10/26/90	2.05
9/22/87	9.62	6/22/89	9.28	9/11/90	4.92	6/19/91	4.41			6/24/91	9.55	6/19/91	7.26
10/19/87	13.64	9/6/89	4.34	10/10/90	1	9/3/91	0			9/5/91	4.92	9/3/91	3.41
11/20/87	13.464	10/17/89	3.57	6/19/91	9.23	10/15/91	0.38			10/16/91	3.75	10/15/91	2.61
6/28/88	42.86	6/5/90	20.5	9/5/91	11.54	6/9/92	1.06			6/9/92	2.46	6/19/92	3.26
8/18/88	11.61	9/11/90	5.25	10/16/91	7.59	9/1/92	0			9/2/92	1.22	9/1/92	1.91
10/12/88	11.39	10/10/90	2.38	6/10/92	0.88	10/20/92	0			10/21/92	1.01	10/20/92	1.35
6/21/89	38.71	6/19/91	42.86	9/1/92	1.09	6/29/93	3.37			6/29/93	32.61	8/25/93	3.7
9/6/89	11.54	9/5/91	8.91	10/20/92	0	8/25/93	1.08			8/24/93	13.5	10/18/93	2.27
10/17/89	8.82	10/16/91	5.03	6/28/93	26.09	10/18/93	0.44			10/19/93	4.57	6/13/94	0.49368
6/4/90	185.26	6/10/92	8.26	8/25/93	17.14	6/13/94	2.15424			6/19/95	25.13	9/1/94	0.58344
9/11/90	10.17	9/1/92	4.69	10/18/93	10.17	9/1/94	0.8976			7/6/95	29.96	10/5/94	8.0784
10/25/90	8.45	10/20/92	3.26	6/13/94	4.488	10/13/94	0.62832			9/5/95	10.7	7/17/95	6.67
6/12/91	510.12	6/28/93	35.29	9/1/94	6.2832	7/19/95	2.73			10/18/95	3.99	9/4/95	3.7
9/3/91	16.67	8/25/93	12.35	10/13/94	2.244	9/4/95	1.53			9/11/96	6.732	10/17/95	1.8
10/16/91	13.95	10/18/93	3.51	7/19/95	27.27	10/17/95	0.94			6/19/97	35.904		
6/10/92	40.38	7/24/95	29.03	9/4/95	19.15	9/12/96	0.8976			8/13/97	8.976	9/11/96	0.8976
9/2/92	11.3	9/4/95	12.9	10/18/95	8.5					10/9/97	4.488		
10/21/92	11.54	10/18/95	7.91	6/20/96	25.58					6/15/98	75	7/3/97	5.77
6/23/93	162.38	6/20/96	35.9	9/12/96	10.7712	7/3/97	5.2			8/13/98	8.98	8/13/97	3.5904
8/26/93	30.47	9/11/96	4.488			8/13/97	2.244			10/8/98	6	10/9/97	2.6928
10/19/93	22.06	6/19/97	35.904	6/23/97	22.44	10/9/97	0.8976			8/19/99	8.976	7/6/98	6.1
5/19/95	637.296	8/12/97	13.464	8/12/97	17.952	7/6/98	3.75					8/13/98	3.14
6/19/95	637.296	10/9/97	8.976	10/9/97	17.952	8/13/98	1.8					10/10/98	3
9/4/95	42.86	6/15/98	42.8	6/21/98	23.1	10/10/98	0.43						
10/18/95	28.13	8/11/98	37.7	8/11/98	74.95							8/19/99	3.1416
6/24/96	122.07	10/8/98	2.5	10/8/98	11.25	8/17/99	1.7952						
9/11/96	4.488	8/18/99	0.02										
10/28/96	24.2352			8/18/99	18.8								
6/19/97	40.392												
8/12/97	3.5904												
10/9/97	58.344												
6/15/98	350.064												
8/11/98	53.86												
10/7/98	18												
8/19/99	31.416												

Table D-2 Comparison of Skyline Mine Discharge Water Quality to State of Utah Beneficial Use Standards (UAC R317-2)

		Beneficial Use Standards				CS-12				CS-14				UPDES Outfall			
Parameter	Unit	1C Domestic	2A, 2B Recreation	3A 4-Day Aquatic Wildlife	4 Agriculture	n	Max	Min	Average	n	Max	Min	Average	n	Max	Min	Average
226 Radium	pc/l	5				0	---	---		0	---	---		1	0	0	
Alpha gros	pc/l	15			15	0	---	---		0	---	---		1	0	0	
Ammonia N	mg/l			About 2		42	1.8	0	0.34	30	1.5	0	0.33	1	0.17	0.17	0.17
Arsenic-T*	mg/l	0.05		0.19	0.1	0	---	---		0	---	---		1	0	0	
B.O.D. 5	mg/l		5	5	5	1	7	7		0	---	---		1	9.3	9.3	9.30
Barium-D	mg/l	1				7	0.061	0	0.03	9	0.089	0	0.03	0	---	---	
Beta gross	pc/l	50		50	50	0	---	---		0	---	---		1	0	0	
Boron-T	mg/l				0.75	13	0.8	0.109	0.38	10	0.7	0.16	0.42	1	0.04	0.04	0.04
Cadmium-T*	mg/l	0.01		0.0011	0.01	0	---	---		0	---	---		1	0	0	
Chromium-T*	ug/l	0.05		0.011	0.1	0	---	---		0	---	---		1	0	0	
Copper-D	mg/l			0.012	0.2	7	0.01	0	0.00	9	0.01	0	0.00	0	---	---	
Cyanide	mg/l			0.0052		13	0.01	0	0.00077	10	0	0	0.00	1	0.014	0.014	0.0140
Fluoride	mg/l	2.4				17	2.07	0.1	0.65	10	1.52	0	0.45	1	0.33	0.33	0.33
Iron-D	mg/l			1 (Max)		7	0.23	0	0.07	8	0.23	0	0.03	0	---	---	
Lead-D	mg/l	0.05		0.0032	0.1	7	0.008	0	0.00114	9	0.008	0	0.00133	0	---	---	
Mercury-T*	ug/l	0.002		0.012		0	---	---		0	---	---		1	0.2	0.2	0.20
Nickel-T*	ug/l			0.16		0	---	---		0	---	---		1	0	0	0.00
Nitrate N	mg/l			4		29	2.7	0	0.80	20	12.32	0	2.47	1	0.84	0.84	0.84
NO2+NO3 N	mg/l	10				5	0.8	0.4	0.56	11	2.4	0	1.20	0	---	---	
Phenol	ug/l			0.01		18	1330	0	87.22	18	230	0	33.06	0	---	---	
Phos.-T	mg/l		0.05	0.05		38	0.21	0	0.04	19	0.99	0	0.13	1	0.62	0.62	0.62
TDS @ 180C	mg/l				1200	140	2084	288	797.08	67	2570	405	1104.12	28	718	120	311.21
Missing																	
Selenium		X		X	X												
Silver		X		X													
Zinc				X													
Residual Chlorine				X													
H2S				X													
TSS			X	X													
Strontium-90		X															
Tritium		X															

*Total used in lieu of dissolved because dissolved data not availble

APPENDIX D

SKYLINE MINE DATA

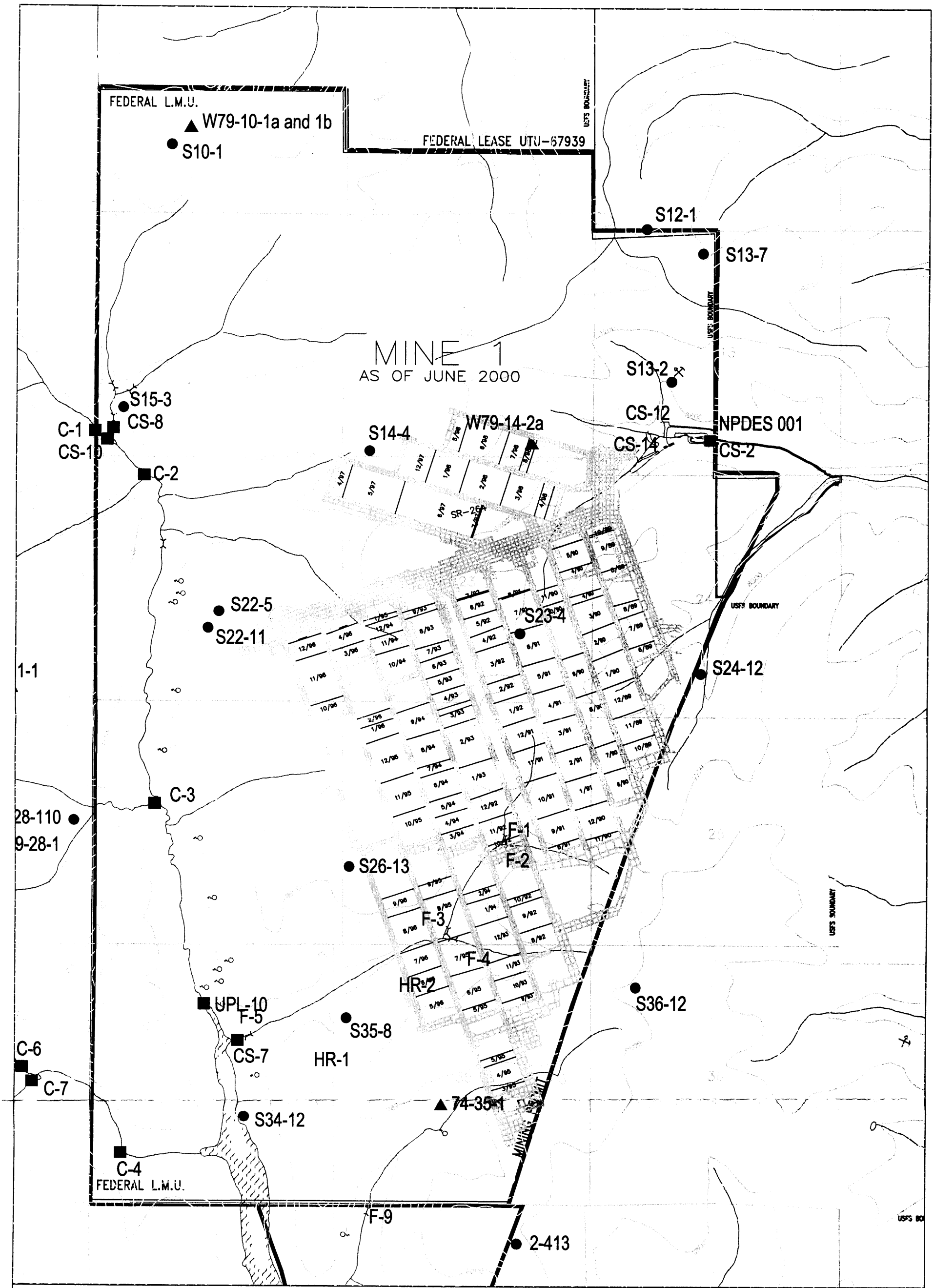

FIGURE D.1
MINE 1 WORKINGS AND
HYDROLOGIC MONITORING POINTS

FILE: DFIG.DWG	SCALE 1" = 2000'	NorWest
DATE: 10/20/2000		

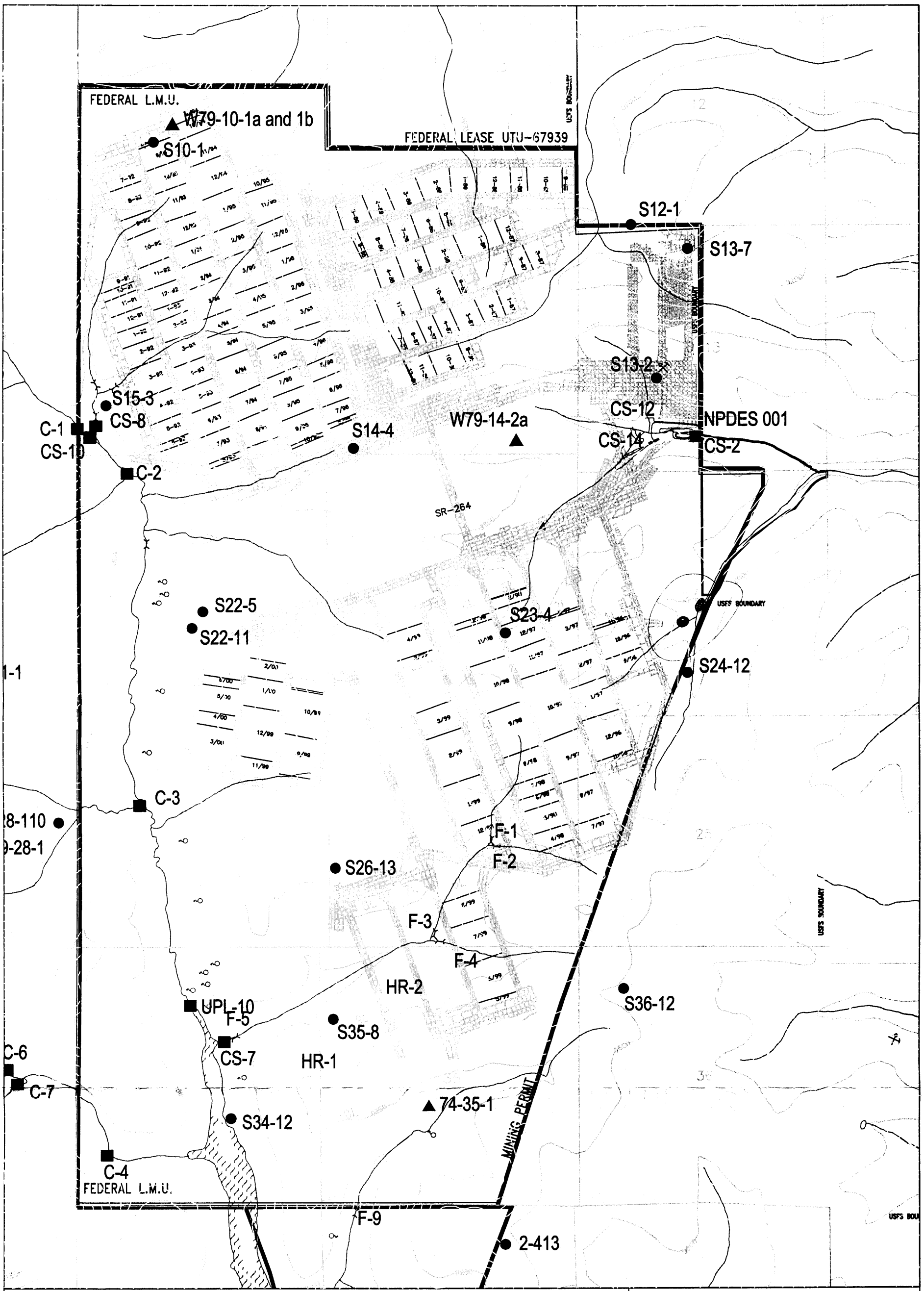

FIGURE D.2
MINE 2 AND MINE 3 WORKINGS AND
HYDROLOGIC MONITORING POINTS

FILE: DFIG.DWG	SCALE 1" = 2000'	NorWest
DATE: 10/20/2000		

NAME	T.W.P. (Tim) Peterson
TITLE	Senior Geotechnical Engineer
SUMMARY OF EXPERIENCE	Tim Peterson has over 25 years of engineering experience in geotechnical and civil engineering. He has been responsible for numerous geotechnical site investigations for thermal and hydroelectric power plants, dams, open cast mines, light to heavy industrial complexes, gas plants, low and high rise residential, hospital, educational, and commercial buildings, roads, bridges, port facilities, off-shore platforms, small and large diameter water, sulphur and gas pipelines and transmission lines. His experience includes the design of pad, raft and most types of piled foundations including foundation analyses for offshore platforms in the North Sea and Indian Ocean; the design of earth, tailings and water retaining structures; detailed settlement analyses; seismic analyses; and stability analyses of open pit mines, road and rail cuttings and embankments, earth and rockfill dams, and excavated marine slopes. He has specialized experience in the field of geotechnical engineering in permafrost regions, and has been responsible for conducting numerous geotechnical failure investigations for insurers. He has worked on several projects worldwide including major hydroelectric studies in Pakistan and Bolivia; open pit mines in Indonesia, Thailand, the Philippines, Colombia and Australia; industrial and commercial projects in the Middle East and the U.K. and spent most of 1994 managing field investigations for four high head hydroelectric schemes in Bolivia. He provides ongoing mining assistance to a major Canadian Utility, including design and monitoring of highwalls, waste dumps and tailings impoundments and geotechnical input to mine planning.
ACADEMIC AND PROFESSIONAL QUALIFICATIONS	B.Sc., (Civil Eng.), Portsmouth, U.K., 1973 H.N.D., (Civil Eng.), North East London Polytechnic, U.K., 1971 Member, Association of Professional Engineers, Geologists and Geophysicists of Alberta (P.Eng.) Chartered Engineer, U.K. (C.Eng.). Member, Institution of Civil Engineers (M.I.C.E.). Fellow, Geological Society of London, U.K. (F.G.S.). Member, British Geotechnical Society. Member, International Society for Soil Mechanics and Foundation Engineering.
PROFESSIONAL HISTORY	**1996 - Present** **NorWest Mine Services Ltd., Calgary, Alberta** SENIOR GEOTECHNICAL ENGINEER: Consulting services to a major

Canadian utility for civil and mining related work. Dam safety evaluations of ash lagoons and cooling ponds and design of incremental construction of ash tailings impoundments. Ongoing pit stability monitoring and input to mine planning. Remediation work associated with mine subsidence.

1980 - 1996
Monenco Agra, Calgary, Alberta

SENIOR SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department (1995 - October 1996). Responsible for mining, hydroelectric and process related projects. Specific projects include the design of the Snare Cascades Hydroelectric Project, Northwest Territories; design and reconstruction of Whiteman's Dam, Canmore, Alberta; Plant 4 Emergency Tailings at Suncor; design of a new sewage lagoon at Sundance Thermal Plant, Alberta; design of headpond impoundments, Miguillas Valley, Bolivia; upgrading power canal dykes, Brazeau, Alberta; seismic analysis of high head hydro developments, Zongo Valley, Bolivia, settlement monitoring and remediation of Highvale Mine Services Building, Alberta; geotechnical assessment of Highvale Mine long range plan area; dam safety assessment of the Wabamun Ash Lagoon, Alberta; and ongoing pit slope stability monitoring at Highvale and Whitewood Coal Mines.

MANAGER OF OPERATIONS: Miguillas Valley Hydroelectric Feasibility Study, Bolivia (1994 - 1995). Responsible for management and supervision of a nine month program of field investigations for four high head hydro schemes in the high Andes, including core drilling, geological mapping, hydrology, topographic, hydrographic and geophysical surveys, environmental and archaeological studies.

SENIOR SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department, Calgary (1989 - 1993). Responsible for mining, hydroelectric, and industrial projects. Geotechnical project coordination for open pit mine stability monitoring, groundwater monitoring and dewatering, mine design and planning at Highvale and Whitewood Mines, Alberta. Coordination, management and supervision of field investigations for Pasir Coal Project, Kalimantan, Indonesia; site selection and supervision of site investigations associated with Himalian and Panian Mine Feasibility Studies on Semirara Island, Philippines; geotechnical audits of a proposed coal mine in Colombia; and geotechnical assessment and coordination of investigations and review of geotechnical criteria for LP-2 coal project, Thailand. Designs for Three Sisters Dam, Spray Canal, Glenmore Causeway and Ghost Dam, Alberta. Geotechnical Project Engineer involved with design of the Husky Bi-Provincial Upgrader at Lloydminster, the LNS pilot project at Cold lake and road upgrading at CFB Suffield.

SENIOR SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department, Calgary (1987-1989). Responsible for project coordination and geotechnical input to hydroelectric, mining and industrial projects including North Fork, Bearspaw, Bighorn, Ghost, Glenmore and Three Sisters Dam safety assessments and upgrading; Highvale and Whitewood Mine geotechnical assessments and stability monitoring, and foundation analysis for the LRT Crowchild Bridge, Calgary.

SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department, Calgary (1984 - 1987). Responsible for mining, hydroelectric and industrial projects. These include dam safety evaluations; the design of new spillway structures; slope stability analyses of mines in Alberta, Nova Scotia and Australia, including Leigh Creek and Lochiel in South Australia; foundation recommendations for industrial and gas plants in Alberta and Saskatchewan; settlement analysis of piled foundations for multi-storey structures in Alberta; substation site preparation and foundation design in upper New York state; bridge foundation and abutment design for county roads at Whitewood, Entwistle and Brazeau, Alberta.

DIRECTOR OF FIELD INVESTIGATIONS, Basha, Pakistan (1982 - 1984). CIDA funded feasibility study of a hydro site on the Indus river at Basha, Pakistan, where the construction of a 200 m high rockfill dam and 50 mile long reservoir was proposed. Responsible for managing the site office and all site activities including over 4000 metres of drilling in rock and overburden, topographical and hydrological surveys, geological mapping of outcrops, organization and supervision of the site soil testing laboratory, preparation of all site related data for input to the Feasibility Study Report and the general Hydroelectric Studies Report prepared by MCL in Lahore, Pakistan.

MANAGER SPECIAL DESIGN GROUP, Calgary (1981 - 1982). Seconded to the Yukon Pipeline Design Joint Venture, Calgary, for the design of the Yukon Section of the Alaska Highway Gas Pipeline for Foothills Pipelines. Responsibilities included the coordination of all geotechnical input to the pipeline design, together with supervising all special design aspects required for the 48 and 56 inch diameter warm and chilled sections of the line to be constructed in intermittent permafrost, including geotechnical, geothermal, hydrological, drainage and erosion control and insulation. Specific geotechnical concerns included detailed analyses of frost heave and thaw settlement, pipeline restraint criteria and the stability of frozen and unfrozen excavated and natural slopes. An appraisal of site investigation methods in cold regions was carried out, together with a review of terrain analysis techniques and data from over one thousand boreholes along the entire route in the Yukon.

SENIOR GEOTECHNICAL SPECIALIST: Civil Engineering Department, Calgary (1980 - 1981). Responsible for investigation works, stability analysis using the Slope II computer model of existing hydroelectric developments for TransAlta Utilities. Foundation studies and recommendations for the Keephills Thermal Plant, Alberta, and recommendations involved in the planning and operating of the Highvale and Whitewood Coal Mines, Alberta.

1969 - 1980

Pell Frischmann and Partners, London, U.K.

SENIOR GEOTECHNICAL ENGINEER (1977 - 1980). Responsible for the planning, management and interpretation of site investigations; the design of foundations, deep basements and earth retaining structures for projects in the U.K., U.S.A., Nigeria and the Middle East, including multi-storey offices, hotels and hospitals, housing, industrial and civil engineering developments and offshore structures; the design and site supervision of land reclamation for British Steel Corporation's new Ore Terminal and direct Reduction Plant at Hunterston, Scotland; investigation and design of land reclamation for a Water Pollution Control Centre at Tubli, Bahrain; analyses of foundation design and operational behaviour of the Production Platform Jacket in the North Sea Brent Field for Shell; foundation design checking for the Bombay High Field Platform; state of the art study report on Containership Berthing Facilities with DMJM of Los Angeles for the Los Angeles Harbor Department; failure investigation of the fourteen berth extensions to the Port of Bandar Shahpour, Iran; slope stability analysis associated with deep excavations, embankments and dredged marine slopes; the investigation of and reporting on geotechnical failures for Insurers, and the completion of numerous feasibility studies for office and industrial developments in the U.K. and overseas.

GEOTECHNICAL ENGINEER (1973 - 1977). Responsible for the interpretation of site investigations, stability and settlement analyses, and the design of foundations.

ASSISTANT ENGINEER (1969 - 1973). Involved with site supervision of various large contracts in the U.K. and the design of multi-storey office and hospital buildings.

PAPERS PUBLISHED

1996 *"Collapse settlement of wetted mine waste - two case histories"*, with N.H. Wade, to be presented at Tailings and Mine Waste '97, Fort Collins, Colorado, January 1997.

1996 *"Whiteman's Earthfill Dam Internal Erosion"*, with L. Courage, A. Rothbauer, B. Pelz, to be presented at ICOLD, Florence, Italy, May 1997.

NAME	Richard Wright, C. Eng.
TITLE	Senior Mining Engineer
SUMMARY OF EXPERIENCE	Mr. Wright has over 20 years of mining related experience in operations, engineering and consultancy associated with both underground and surface mines in the USA, Canada, South Africa, Mexico and the U.K. His last two years were spent as project manager assisting an underground longwall coal expansion program in Mexico. He has spent five years in the USA progressing coal prospects from the feasibility phase through to operations planning and engineering, including a mine that has recently been setting world longwall production records. In addition he has about 10 years of consultancy experience covering geotechnical, mining and ventilation engineering for a variety of projects and clients, including design, engineering and planning applications and associated public inquiries.
ACADEMIC AND PROFESSIONAL QUALIFICATIONS	M.Sc. (Mining/Geotechnical), University of Alberta, 1981. B.Sc. (Mining Engineering), Royal School of Mines, London, UK, 1977. B.Sc. (Engineering Science), University of Leicester, UK, 1974. European Engineer (Registration No: UK/IMM/EE/94/8852) Chartered Engineer (No.410430), Member of the Institution of Mining and Metallurgy
PROFESSIONAL HISTORY	**1998 - Present** **NorWest Mine Services Ltd., Calgary, Alberta, Canada** SENIOR MINING ENGINEER: Engineering and Management of underground mining and geotechnical projects. Providing operational and planning assistance with emphasis on underground coal mine design and planning, mine rehabilitation, stability of underground openings and blasting vibrations impact analysis **1989 - 1998** **Wright Technical Services, Redruth, Cornwall, England** MINING / GEOTECHNICAL CONSULTANT: Independent Mining and Geotechnical Engineering Consultant with emphasis on coal mining, underground construction and radioactive waste disposal. Projects included: • Project Manager for operations and engineering assistance for upgrading of existing and new underground coal mines for

MICARE, Coahuila, Mexico;

- design, data evaluation and shaft/tunnel surveying for the planned Sellafield underground radioactive waste repository in the UK;
- geotechnical site investigations and evaluation of the stability of foundations, slopes and underground openings for a number of clients;
- ventilation design and monitoring for construction of the UK side of the Channel Tunnel; and
- various coal and metal mine engineering and planning studies for a number of clients.

1987 - 1989
Jay Mineral Services Limited, Truro, Cornwall, England
MINING CONSULTANT: Responsible for a variety of mining engineering projects including;

- various economic evaluations of underground and surface coal and metal mines in the UK and overseas;
- prediction of blasting vibrations for surface coal mines and preparation of expert witness evidence for the Smotherfly planning inquiry in the UK;
- pillar design of coal and salt mines in the UK and Ireland;
- shaft winding and headframe design for underground coal mines and preparation of expert witness evidence for the Hawkhurst Moor public inquiry in the UK;
- market study for full face hard rock boring of tunnels and shafts; and
- electricity tariff study for gold mining in Ghana..

1986 - 1987
Battelle Project Management Division, Columbus, Ohio, USA
SENIOR GEOTECHNICAL ENGINEER: Assistant Project Manager of a $10 million contract for underground geotechnical testing as part of the site characterization for a proposed underground nuclear waste repository in salt strata. This included planning for major long term tests on the rock mass and engineered barriers in an exploratory shaft facility in Texas, USA. The tests were designed to assess the mechanical, thermal, chemical and hydraulic performance under nuclear safety requirement for containment over 10,000 years.

1983 - 1986
Twentymile Coal Company, Colorado, USA
CHIEF MINING ENGINEER: responsible for the mine planning and engineering department of an underground coal mine. This involved detailed planning for

a 3.2 Mtpa operation with both longwall and room and pillar operations. This included ventilation survey and design, geology, geotechnical, hydrology, coal quality, construction, equipment selection, environmental, permitting, financial evaluations, surveying, sequencing and subsidence prediction and monitoring.

1981 - 1983
Getty Mining Company, Salt Lake City, Utah, USA
PROJECT ENGINEER: responsible for underground coal mine planning, mine design, feasibility studies and exploration programmes for new projects and operating coal mines. Developed geotechnical programs for rock characterization and hazard analysis for mine design and strata control studies.

1977 - 1978
Anglo Power Collieries, Kriel, Transvaal, South Africa
MINE ENGINEER: responsible for an underground coal production section and surface mine planning and engineering of an opencast coal mine (pit design, sequencing, geology, coal quality, etc.).

1974 - 1975
Anglo American Corporation, Welkom, Orange Free State, South Africa
MINE OFFICIAL: Practical experience in production, preparation, ventilation, surveying, sampling and other service departments of deep underground gold mines.

PUBLICATIONS

1988 Blasting Vibes I and II, J.Stocks and R.Wright, Mineral Planning, UK.
1982 Technology Management for Risk Minimization, J.D.Spalding, E.N.Thurmond, J.M.Mercier and R.Wright, International Conference on Coal Research (ICCR), London.
1981 Stability Analysis in Room and Pillar Coal Mining, M.Sc. Thesis, University of Alberta, Canada.

NAME	Kelly L. Payne
TITLE	Hydrogeologist
EDUCATION	M.S. Hydrogeology, Expected Graduation Date December 2000 Brigham Young University, Provo, Utah, Usa Thesis Title: *Occurrence and Geochemical Evolution of Shallow Groundwater in the Northern Altiplano, Bolivia: Implications for Groundwater Resource Development* B.S. Geology, 1994 Brigham Young University, Provo, Utah, USA
WORK EXPERIENCE	NorWest Mine Services, Inc, Salt Lake City, Utah, June 2000 to present. Mayo and Associates, LC, Lindon, Utah, April 1994 to June 2000, hydrogeologist, project manager, office manager
PROJECT EXPERIENCE	**Coal Mine Permitting** Supervised the preparation of Chapter 6 (Geology) and Chapter 7 (Hydrology) of the Mining and Reclamation Plan (MRP) for the new West Ridge Mine. Work was performed for WEST RIDGE Resources, Price, Utah. Supervised the investigation of groundwater systems, preparation of a statement of Probable Hydrologic Consequences (PHC), and a surface water and groundwater monitoring plan for existing coal leases and new properties acquired by the C.W. Mining Company, Huntington, Utah. Made a presentation at an Informal Conference before the director of UDOGM when the permit was protested. Characterized groundwater systems and evaluated the impacts of underground coal mining on surface water and groundwater at a number of mines in the Wasatch Plateau and Book Cliffs Coal Fields. Prepared a statement of the Probable Hydrologic Consequences (PHC) and a surface water and groundwater monitoring program, as required for a Mining and Reclamation Permit (MRP) by the Utah Division of Oil, Gas and Mining. These mines include:

Soldier Canyon Mine, Soldier Creek Coal Company, Wellington, Utah.
Skyline Mines, Canyon Fuel Company, Scofield, Utah
SUFCO Mine, Canyon Fuel Company, Salina, Utah
PacifiCorp Mines (Deer Creek, Cottonwood, and Trail Mountains), Huntington, Utah
Crandall Canyon Mine, GENWAL Resources, Inc, Huntington, Utah
Willow Creek Mine, Plateau Mining Corp., Helper, Utah

Supervised the investigation of potential impacts of longwall mining at the SUFCO Mine to the hydrologic balance of Box Canyon Creek, a perennial stream. Prepared a report summarizing impacts to cultural resources, riparian ecosystems, and hydrologic balance. The purpose of the investigation was to gain U.S. Forest Service consent to use longwall extraction to undermine the perennial stream. Evaluation performed for Canyon Fuel Company, Salina, Utah.

Investigated the source of large volume groundwater in-flows from faults in the West Elk Mine in order to predict future encounters and assess the hydrologic impacts of intercepting fault waters. This investigation was undertaken for Mountain Coal Company, Somerset, Colorado.

NEPA

Managed the preparation of technical reports and groundwater resource sections of Environmental Impact Statements for both The Pines and the Cottonwood Coal Lease Tracts. Work was performed for the Manti-La Sal National Forest as a third-party NEPA contractor.

Water Supply, Water Resources, and Water Rights

Performed a preliminary evaluation of the shallow groundwater resources and assessed the potential for contamination of shallow water wells in the northern Altiplano, Bolivia for the Benson Institute, a non-governmental organization based in Provo, Utah.

Managed the evaluation of background water quality and infiltration potential for a new sewage treatment facility in Cedar Valley, Utah. The project included the installation and sampling of monitoring wells and soil borings and in situ permeability tests.
Prepared Delineation Reports for the Drinking Water Source Protection Plan, required by the State of Utah for all public culinary water supplies. Work was completed for Skyline Mines and SUFCO Mine.

Preparing the Delineation Report and Drinking Water Source Protection Plan for Alpine Cove Water Company's culinary wells.

Characterized groundwater conditions in the New Harmony, Utah Area in order to help defend water rights held by the LDS Church. Gave oral testimony in deposition and at trial.

Hazardous Materials Investigations

Conducted geophysical investigations at several UST sites in Provo, Utah. The research evaluated the response of electrical resistivity (ER), very low frequency electromagnetic (VLF), and ground-penetrating radar (GPR) geophysical methods to shallow gasoline contamination.

Performed a characterization of groundwater flow regimes and the fate of hydrocarbon contamination in the Big Piney Oil and Natural Gas Field, Wyoming for Mobil Exploration and Producing, U.S.

Characterized the hydrogeology and extent of natural gas condensate contamination and prepared a groundwater monitoring plan for a natural gas production well site near Big Piney, Wyoming. Work was completed for Mobil Exploration and Producing, U.S. and Williams Field Services.

Provided technical and logistical support to the investigation of heavy metal contamination caused by irrigation with raw sewage in the Mezquital Valley north of Mexico City. This investigation was conducted by Brigham Young University and the University of Hidalgo in Pachuca, Hidalgo, Mexico. Performed initial project reconnaissance and provided verbal translation for BYU faculty.

Prepared a site characterization and groundwater monitoring plan for a hydrocarbon contaminated site at a natural gas compressor station in Wyoming. The project included the installation of monitoring wells, water quality sampling, and the review and analysis of historical data.

Managed the hydrogeologic characterization and hydrocarbon contamination evaluation at the Foundation Creek Natural Gas Compressor Station, Rangely, Colorado. This project involved the installation of monitoring wells and soil borings, chemical sampling, and preparation of final report. Work was completed for Williams Field Services.

Forensic Hydrogeology and Litigation

Participated in the hydrogeologic characterization and evaluation of the extent of Cr^{6+} contamination of an alluvial aquifer at Hinkley, California. The work was performed in support of the lawsuit Anderson v. PG&E and Aguyo v. PG&E. Complied a database from more than 80,000 pages of documents produced by the defendant. Produced maps, graphs, and interpretations that were used in the presentation of expert testimony.

Currently participating in the hydrologeologic characterization of evaluation of the extent of TCE and perchlorate contamination of aquifers supplying domestic water to the City of Redlands, California. Work is being performed in support of a class-action and direct-action lawsuit brought against Lockheed-Martin Corporation.

PUBLICATIONS

Benson, A.K., Payne, K.L., and Stubben, M.A., 1995, Detecting organic groundwater contamination using electrical resistivity and VLF surveys *in* Hinchee, R.E., Douglas, G.S., and Ong, S.K., eds., Monitoring and verification of bioremediation: Battelle Press, Columbus, p. 105-113.

Benson, A.K., Payne, K.L., and Stubben, M.A., 1997, Mapping groundwater contamination using dc resistivity and VLF geophysical methods—A case study: Geophysics, v. 62, n. 1, p. 80-86.

Mayo, A.L., Morris, T.H., Petersen, E.C., and Payne, K.L., 1997, Groundwater flow systems in the Utah Coal District: Proceedings Rocky Mountain Ground Water Conference, Boise, Idaho.

David Alan Newman

Education:

Doctor of Philosophy - Mining Engineering
The Pennsylvania State University, 1985
Master of Science - Mining Engineering
The Pennsylvania State University, 1980
Bachelor of Arts - Geology
Vassar College, 1977

Employment Background:

Present- 1985	President, **Appalachian Mining and Engineering, Inc./Geolab** Lexington, Kentucky
Present- 1989	President, **Newman Engineering, PSC.** Lexington, Kentucky
1988- 1984	Assistant Professor of Mining Engineering, Director of Weekend/Evening Graduate Program **University of Kentucky** Lexington, Kentucky
1984- 1978	Graduate Research Assistant **The Pennsylvania State University** University Park, Pennsylvania
1978- 1977	Assistant Drill Manager, **American Testing and Engineering Company**, Indianapolis, Indiana

Professional Registration:

Commonwealth of Kentucky, Registered Professional Engineer, No. 14,891
Commonwealth of Kentucky, Registered Professional Geologist, No. 2,601
State of West Virginia, Registered Professional Engineer, No. 11,656
Commonwealth of Virginia, Licensed Professional Engineer, No. 023660
State of Indiana, Registered Professional Engineer, No. PE19300222

Professional Experience:

Present-1985 **Appalachian Mining and Engineering, Inc./Geolab,** *President*
Engineering consulting firm specializing in rock and soil mechanics investigations, geotechnical engineering, subsidence prediction and abatement, blast design and evaluation, mine design and ground control, slope stability, mine property valuation and reserve analysis, coal refuse impoundment design and stability assessment, rock and soil property testing through **Geolab** a state-of-the-art materials testing laboratory using a computer controlled 200,000 pound capacity SATEC load frame.

Present-1988 **Newman Engineering, PSC.,** *President*
Municipal engineering projects involving urban hydrologic analysis and design, storm sewer design and evaluation, detention pond design, review of subdivision construction plans, highway design, and blasting projects.

1988-1984 **University of Kentucky**, *Assistant Professor - Mining Engineering*
Dr. Newman directed five externally funded research projects, conducted internally funded research while overseeing M.S. theses. He developed and directed the weekend/evening graduate program with Friday evening/Saturday morning courses at the Southeast Community College campus in Cumberland, Ky. Teaching responsibilities included undergraduate and graduate courses in rock mechanics, slope stability, and mine valuation. Dr. Newman developed and taught, the "Elements of Coal Mining" and "SUBSIDE" short courses.

1984-1978 **The Pennsylvania State University**, *Graduate Research Assistant*
Dr. Newman carried out research on four major research grants involving; development of a rock mass classification system for assessing mine roof stability,

- yield pillar design,
- longwall gateroad stability,
- coal pillar design for room-and-pillar mining,
- in-situ stress measurements,
- in-mine seismic refraction, and
- numerical simulation of roof behavior

1978-1977 Assistant drill manager, **ATEC Drilling**
Responsibilities included scheduling drilling crews, the maintenance of repair shop inventory, and geotechnical core logging. Projects included geotechnical drilling and conducting a seismic surveys

Professional Societies:

Society for Mining, Metallurgy, and Exploration, Inc. (SMME)
- Rock Mechanics Award Committee
- Professional Engineering Examination Committee
- Student Activities Committee

Central Appalachian Section, SMME
American Society for Testing and Materials
Order of the Engineer
National Coal Association - Acid Mine Drainage Committee

Listings and Recognitions:

Who's Who in the South and Southwest
Phi Kappa Phi Honor Society
Mineral Research Institute Fellowship
U.S. Office of Education Mining, Mineral, Mineral Fuel Conservation Fellowship

Patents and Inventions:

"A Flexible Wire Rope Roof Bolt for Use in Thin Seam Coal Mines," Patent disclosure document No. 246721

"An In-situ Coal Face Sampling Device," Patent disclosure document No. 177846

"A Method of Increasing the Bulk Density of Coal in Underground Haulage Equipment," Patent disclosure document No. 180682

Grants and Contracts:

1988-1986 **U.S. Bureau of Mines**, Generic Research Program Mine Systems Design and Ground Control Virginia Polytechnic Institute, Blacksburg, Va. Principal Investigator "Field Investigation of the Post-Failure Behavior of Coal Pillars"

1988-1986 **Arch of Kentucky**, Lynch, Kentucky Principal Investigator "Rock and Coal Property Testing for Proposed Multiple Seam Mining Operation"

1986 **Arch of Kentucky**, Lynch, Kentucky Principal Investigator "In-situ Stress Measurements at Mine 37"

1986 **U.S. Bureau of Mines**, Mining and Mineral Resources Research Institute Seed Grant Program Principal Investigator "Laboratory Investigation of the Post-Failure Behavior of Coal"

Grants and Contracts (continued):

1984 **University of Kentucky** - Graduate School Major Research Equipment Fund
Strain extensometers for post-failure research

1984- **SOHIO Center For Scientific Excellence in Mining Technology**, Researcher
1982 "Longwall Pillar Design and Gateroad Stability Assessment"

1984- **U.S. Bureau of Mines**, Mining and Mineral Resources Institute Grant,
1982 Contract No. G5105083, Researcher
"Design Procedures for Coal Mine Tunnels"

1983 G.A.I. Consultants, Inc., Monroeville, Pennsylvania
U.S. Dept. of Energy, Contract No. DE-AC22-80PC30120 Contract Researcher
"Characterization of Subsidence Over Pillar Extraction Panels"

1983- **U.S. Dept. of Energy**, Contract No. ET-78-G-01-3427 Researcher
1981 "Improved Design of Room-and-Pillar Coal Mining"

1980- **U.S. Dept. of Energy**, Contract No. ET-77-C-01-9144 Researcher
1978 "Geotechnical Investigation of Roof Conditions in the Area Mined by the Automated Extraction System"

Publications:

Newman, D.A., "The Role of Engineering and Geology in Analyzing Ground Control Conditions," 18th Int. Conf. on Ground Control in Mining, 1999, pp. 64 - 71.

Newman, D.A., "Landslide Occurrence in Steep Slope Areas of Appalachia," 17th Int. Conf. on Ground Control in Mining, 1998, pp. 309-316.

Newman, D.A., "Surface Subsidence and Structural Damage," Chapter 5 in: An Investigation of High Extraction Mining and Related Valley Fill Practices in Southwestern Pennsylvania, Audubon Society of Western Pennsylvania, 1998, pp. B-85 - B-120.

Newman, D.A., "Subsidence Prediction Techniques," Chapter 6 in: An Investigation of High Extraction Mining and Related Valley Fill Practices in Southwestern Pennsylvania, Audubon Society of Western Pennsylvania, 1998, pp. B-121 - B-131.

Newman, D.A., "Integration of Geology and Engineering Design in Mining: Multiple Seam Mining in the Southern Appalachian Coal Field," Milestones in Rock Engineering: A Jubilee Collection, Bieniawski, ed. A.A. Balkema, 1996.

Newman, D.A., "Planning and Design for Barrier Pillar Recovery - Three Case Histories," 14th Int. Conf. on Ground Control in Mining, West Virginia Univ., 1995, pp. 72-79.

Publications (continued):

Newman, D.A. and Hoelle, J.L., "The Impact and Variability in Coal Strength on Mine Planning and Design - A Case History," West Virginia Univ., 12th Int. Conf. on Ground Control in Mining, 1993, pp. 237-243.

Artrip. P.S., Nelson, J.S., and Newman, D.A., "Modern Geotechnical Exploration and Mine Design,"West Virginia Univ., 12th Int. Conf. on Ground Control in Mining, 1993, pp. 249-260.

Newman, D.A. and Bennett, D.G., "The Effect of Specimen Size and Stress Rate for the Brazilian Test - A Statistical Analysis," Rock Mechanics and Rock Engineering, Vol. 23, 1990, pp. 123-134.

Newman, D.A., "In-Situ Yield Behavior of a Coal Pillar," International Journal of Mining and Geological Engineering, No. 2, Vol. 7, May, 1989, pp. 163-170.

Leonard, J.W. and Newman, D.A., "Volumetric Efficiency and the Potential for Increased Productivity in Underground Haulage Units" AIME-Society of Mining Engineers Annual Transactions, 1989, pp. 1202-1203.

Newman, D.A., "Yield Pillar Behavior in Deep Coal Mines," Proc. Sixth Annual Technical Workshop of the Generic Mineral Technology Center, Univ. of Alaska, 1988, pp. .

Newman, D.A., "Automated Data Acquisition System for Remote Monitoring of Pillar and Roof Deformation on a Longwall Panel," AIME-Society of Mining Engineers Annual Meeting, Preprint 88-64, Phoenix, Arizona, January, 1988.

Newman, D.A. and Bennett, D.B., "A Microcomputer Based System for the Prediction of Mining Costs and Mine Property Valuation," AIME-Society of Mining Engineers Annual Meeting, Preprint 88-63, Phoenix, Arizona, January, 1988.

Martin, J.S. and Newman, D.A., "The Characterization and Redesign of a Failing Highwall in Eastern Kentucky," AIME-Society of Mining Engineers Annual Meeting, Phoenix, Preprint 88-80, Arizona, January, 1988.

Newman, D.A., "Evaluation of Stability in Longwall Chain Pillars - A Technical Note," AIME-SME Transactions, Vol. 281, 1987.

Newman, D.A., "Automated Monitoring of the Stress-Strain Behavior of a Yield Pillar," Proc. Fifth Annual Technical Workshop of the Generic Mineral Technology Center, Univ. of Alabama, 1987, pp. 94-100.

Newman, D.A., "A Laboratory Investigation of the Post-Failure Behavior of Coal," IMMR Highlights, University of Kentucky Institute for Mining and Minerals Research, Vol. 6, No. 5, 1987, pp. 1-2.

Publications (continued):

Newman, D.A. and Bieniawski, Z.T., "A Modified Version of the Geomechanics Classification for Roofspan Design in Underground Coal Mines," AIME-SME Transactions, Vol. 280, 1986, pp. 2134-2138.

Newman, D.A. and Bieniawski, Z.T., "A Modified Version of the Geomechanics Classification for Roofspan Design in Underground Coal Mines," Preprint No. 85-313, AIME-SME Fall Meeting, Albuquerque, 1985.

Newman, D.A., "Mine Drainage and Pumping," in: **Kentucky Coal Mine Reference Book**, Cameron ed., Dept. of Mines and Minerals and Kentucky Mining Institute, 1985, pp. 89-99.

Snodgrass, J.J. and Newman, D.A., "An In-Situ Technique for the Assessment of Failure in Coal Pillars," Proc. 26th U.S. Symp. on Rock Mech., Ashworth ed., Univ. of S. Dakota, Rapid City, 1985, pp. 1181-1188.

Newman, D.A., "A Modified Version of the Geomechanics Classification for Use in Coal Mines," Proc. 2nd Conf. on Ground Control in the Illinois Basin, Chugh, ed., S. Ill. Univ., Carbondale, 1985, pp. 64-72.

Newman, D.A., "Coal Mine Ground Control - The Effect of Geology," Proc. 12th Ann. Meeting Eastern Sec. Amer. Assoc. Petrol. Geol., S. Ill. Univ., Carbondale, 1983, pp. 68-74.

Bieniawski, Z.T., Rafia, F., and Newman, D.A., "Ground Control Investigations for Assessment of Roof Conditions in Coal Mines," Proc. 21st U.S. Symp. on Rock Mech., Missouri-Rolla, 1980, pp. 693-700.

Bieniawski, Z.T., Rafia, F., and Newman, D.A., "Performance Evaluation of Automated Extraction System, Vol. 5, Geotechnical Investigations of the Roof Conditions in the Area Mined by the AES Machine," Final Technical Report, DOE Contract ET-77-C-01-9144, 1980, 73 p.

APPENDIX C

RESUMES

NAME James D. Alto, P. E.

TITLE Manager, Environmental Services

SUMMARY OF EXPERIENCE

Over 17 years experience in a variety of engineering roles in the mining and environmental fields. Licensed professional engineer and registered environmental manager with more than seven years management experience in environmental and engineering consulting. Extensive background in environmental compliance auditing, preparation of Plans and Operations, site reclamation design and bond calculations, financial analysis, project feasibility justification, project management, proposal development, NEPA, RCRA, and CERCLA. Proven leadership abilities with commitment toward the quality process and team management principles.

ACADEMIC AND PROFESSIONAL QUALIFICATIONS

B.S., Mining Engineering, University of Utah
Licensed Engineer, State of Utah
Registered Environmental Manager
Certified Environmental Auditor
Member Elect - Mining and Metallurgical Society of America (MMSA)
Past Chair - Utah Section, Society of Mining Engineers (SME of AIME)

PROFESSIONAL HISTORY

1997-Present
NorWest Mine Services, Inc., Salt Lake City, UT
MANAGER, ENVIRONMENTAL SERVICES: Responsible for project management and engineering for a wide variety of mining and environmental projects.

1990 - 1997
JBR Environmental Consultants, Salt Lake City, Utah
MANAGER, ENGINEERING & INVESTIGATION TEAM LEADER: Senior level management responsibility for all contracted environmental engineering projects including: tailings impoundment and heap each design, permitting and project management; ancillary facilities design and construction management; and design, installation and operation of environmental remediation systems. Directed engineering marketing efforts and long-range and short-range strategic planning. Staff totaled nine full time engineers, geologists, designers and drafters with annual revenues of over $900,000.

- Manager of Engineering for multi-phased tailings impoundment retrofit project resulting in client savings of more than $6 million in capital expenditures.
- Co-author of Utah's Division of Water Quality's Guidelines for Design, Construction and Operation of Heap Leach Facilities.
- Project Manager for renewal of three discharge permits for a major gold mine in central Nevada. Permit renewals submitted to and approved by Nevada's DEP.

1990 - 1991
Plexus Resources Corporation, Salt Lake City, Utah
MANAGER, PERMITTING AND ENVIRONMENTAL AFFAIRS:
Directed evaluations of environmental and regulatory requirements for properties and projects presented to company for purposes of joint ventures and acquisition consideration. Responsible for coordination of company's efforts for acquisition of permits for underground polymetallic mine which included cooperative involvement with federal (USFS) state and county agencies. Responsible for environmental compliance auditing of 110,000 ounce/yr gold operation in western Nevada.

1988 - 1990
Plexus Resources Corporation, Salt Lake City, Utah
MINING ENGINEER: Responsible for all ore reserve calculations,, mine planning, metallurgical evaluation, capital and operating expense cost estimation, and feasibility analysis for preparation of recommendations for future of properties and projects. Responsible for review, analysis and reporting of findings of mine plan efficiencies and operating performance of 110,000 ounce/yr gold mine in western Nevada.

1981 - 1988
Arentz Mining Engineers, Salt Lake City, Utah
MINING ENGINEER: Directed development and on-site implementation of gold tailings retreatment heap leaching project in Sonora, Mexico. Performed ore reserve calculations, mine planning and feasibility analysis on numerous national and international consulting assignments.

1980
Ranchers Exploration & Development Corp., Escalante Silver Mine
JUNIOR MINING ENGINEER

1979
Black Butte Coal Company, Black Butte Mine
JUNIOR MINING ENGINEER

NAME	Dr. C.B. (Conrad) Houser
TITLE	Vice President
SUMMARY OF EXPERIENCE	Internationally experienced mining engineer and manager with broad engineering, environmental, legal, marketing, planning, and financial experience as well as focussed skills in surface and underground mining of coal, oil shale and trona.
ACADEMIC AND PROFESSIONAL QUALIFICATIONS	M.S. (civil engineering - Rice University, Houston, Texas, 1969 B.S., U.S. Air Force Academy, Colorado Springs, Colorado, 1967 MBA course work, University of Utah, Salt Lake City, Utah, 1977 J.D. (Cum Laude), J. Reuben Clark Law School at BYU, Provo, Utah, 1975 Member of Utah State Bar U.S. Patent License Registered Professional Engineer in Colorado and Wyoming Certificated in Total Quality Management, Financial Analysis of Investments, Project Management, International Finance, Industrial Relations, Safety Supervision, Negotiation Techniques
PROFESSIONAL HISTORY	**1996 - Present** **NorWest Mine Services, Inc., Salt Lake City, Utah** VICE PRESIDENT: Provides mining, financial services, and project management. Recent assignments include preparing final EPC and contract mining documents for an Indian coal project; due diligences studies and appraisals; and project manager on Brazilian underground mining project. **1995 - 1996** **Rocky Mountain Leadership Institute, Casper, Wyoming** PRESIDENT: Consulting and training for businesses and governmental entities. Acquisition analysis and due diligence. Asset maximization. Marketing realignment. Strategic planning. **1993 - 1995** **Wold Trona Company, Inc., Casper, Wyoming** VICE PRESIDENT, CHIEF OPERATING OFFICER: Overall responsibility for integration of $200 million new mineral process technology development, design, financing, permitting, marketing, administration, and legal affairs.

MARKETING: Pre-sold 80% of initial 10 year's production via letters of intent: established strategy, introduced new project to market, initiated revision of industry specifications, established customer relations all leading to project revenue base loading.

ADMINISTRATION: Organized all office functions from ground zero to produce synergistic MIS, planning, accounting, budgeting, and associated functions.

PERMITTING: Orchestrated all aspects of permit preparation, review, and approval at minimal cost and record speed to clear the way for project construction.

ENGINEERING: Participated in process development, capital and operating cost reduction, process and mine design and engineering, construction of demonstration plant, preparation of bid packages, leading to success ful posturing of Engineering Procurement - Construction contract.

LEGAL: Developed in-house and through outside counsel partnership agreements (Limited Liability companies and Limited Partnerships) sales, contracts, Interior Board of Land Appeals defence, patent applications, engineering contracts, and the project financial prospectus.

1992
Drummond, Gillette, Wyoming
ENGINEERING & ENVIRONMENTAL MANAGER: After purchase of Mobil operations by Drummond, responsibilities included development of plans and permits to transition the Caballo Rojo Mine from truck and shovel to dragline operations.

1977 - 1991
Mobil Corporation
VICE PRESIDENT - ENGINEERING MANAGER, DENVER, COLORADO (1988 - 1991): Operations in Wyoming's Powder River Basin and Indonesia. Complete engineering, environmental, strategic planning and financial responsibility. Key participant in Booz, Allen, Hamilton strategic posturing project in New York City to determine whether Mobil should remain in the coal business. Recommended Mobil discontinue its coal focus unless it was willing to become a major player. Played a major role in the solicitation of buyers and the sale of Mobil's coal interests, netting $80 million in asset recovery. Quarterbacked lawsuit defending Mobil's integrity against claims of tortuous contract interference by a competitor.

ENGINEERING & ENVIRONMENTAL MANAGER, GILLETTE, WYOMING (1985 - 1987): Created $3 million unanticipated profit enhancement by changing mining location to better optimize returns from the operation - requires complete revision of both short and long term mining plans as well as major permit revision in record time. Made major operating changes to match coal quality to customer needs - necessitated changing both vertical and horizontal mining orientations. Development drilling techniques were significantly enhanced. Developed special software for selection of coal to yield increased profits though proper shipment scheduling. Truck and shovel operations were optimized.

Negotiated a win-win agreement out of deadlocked conflict saving over $1.3 million. Actively participated in marketing of coal. Led an environmental team to the only perfect record (zero notices of violation) in U.S. fossil fuelled mining history (over 280 inspections). Revitalized and empowered a stagnant engineering and environmental staff.

1982 - 1985
Mobil Synfuels, Denver, Colorado
VENTURE SERVICES ADVISOR: Led matrix organization including all reserve definition and underground mine planning supporting $6 billion project. Complete infrastructure alignment with mining and processing operations.

1980 - 1981
Mobil Corporation, Ndola, Zambia
MANAGING DIRECTOR/GENERAL MANAGER: Originated program for converting wasted flare-gas into replacement fuel for transportation with national hard currency savings estimated at $4 million per year. Pioneered transfer of wholesale metered distribution system into developing country, saving over $180,000 in annual operating cost. Coordinated legal, financial, and engineering activities for EPC blending and packaging plant in Zambia with revenue contribution projected at $8 million per year.

1977 - 1980
Australia Marketing Operations; Manager, Queensland, Brisbane
TERMINAL MANAGER: Dramatically improved customer and marketing support services and responsiveness. Resolved hot union conflicts and sustained peaceful and productive relationships, avoiding work stoppages and their attendant loss of revenue and market share. Reorganized production practices to dramatically reduce losses and costs.

1975 - 1977
Spafford, Nixon & Houser; Salt Lake City, Utah
LAW FIRM PARTNER

1971 - 1973
Nelson, Haley, Patterson & Quirk; Greeley, Colorado
ENGINEERING COORDINATOR

1968 - 1971
Captain, US Air Force; Tokyo, Japan
Headquarters Fifth Air Force
BASE ENGINEER

NorWest
Mine Services, Inc.

Conrad B. Houser
Vice President

FEB 9 2001

February 8, 2001

File No. 00-2439

Carter Reed
Forest Geologist
USDA Forest Service
599 West Price River Drive
Price, UT 84501

Dear Carter:

Enclosed is the final Addendum to the Technical Surface Water Report in both hard and electronic formats.

Please let me know if this doesn't complete the project.

Also, please confirm to Canyon Fuel that the project is now complete and ready for disbursement of retained funds to NorWest.

Sincerely,

NORWEST MINE SERVICES, INC.

for Conrad B. Houser
Vice President

136 East South Temple, 12th Floor
Salt Lake City, Utah 84111 USA
Tel (801) 539-0044
USA (800) 266-6351
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TECHNICAL REPORT SURFACE-WATER AND GROUNDWATER RESOURCES IN THE FLAT CANYON AREA

ADDENDUM 1

Submitted to:

MANTI-LA SAL NATIONAL FOREST

AND

BUREAU OF LAND MANAGEMENT, UTAH STATE OFFICE

January 21, 2001

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Mine Services, Inc.

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IMPACTS TO RECEIVING WATER QUALITY

Sections 5.1.3 and 5.1.4 of the technical report describe the potential impacts to water quality of Eccles Creek and Electric Lake as a result of discharge of mine water to these watercourses. Table D-2 in the technical report presents a comparison of the State of Utah Beneficial Use Standard to historic water quality of discharge from the Skyline Mine. Based on this comparison, nine water quality parameters have been identified that have, at some time, exceeded the most stringent Beneficial Use Standards in the mine discharge water. The water quality history of these nine parameters has been further reviewed and is summarized in Table AD1.1 below. Also reported in the table below is a determination of the qualitatively estimated impact that discharge of mine water poses to the quality of the receiving water.

Table AD1.1
Skyline Mine Discharge Water Quality History for Parameters that Have Exceeded Beneficial Use Standards

Parameter	Comments	Qualitatively Estimated Impact
BOD	Only sampled once in CS-12 and UPDES outfall—both exceeded standard.	Of concern
Boron	Standard exceeded only once in 13 samples at CS-12; Not exceeded in any of 10 samples at CS-14 or the one sample at UPDES outfall.	Not of concern
Cyanide	Only detected once in 13 samples at CS-12; not detected in 10 samples at CS-14; only sampled once at UPDES outfall—standard exceeded.	Not of concern
Lead-D	Detected only once in seven samples at both CS-12 and CS-14. Both detections occurred on the same date and at the same concentration, which suggests lab or sampling error.	Not of concern
Mercury-D	Dissolved mercury never sampled at discharge points. Total Mercury sampled only once at UPDES outfall and standard exceeded; never sampled at CS-12 or CS-14.	Of possible concern
Nitrate	Standard only exceeded once in 20 samples at CS-14; 29 samples at CS-12 and one sample at UPDES outfall in compliance with standard.	Not of concern
Phenol	Detected four times in 20 samples at CS-12; detected six times in 18 samples at CS-14. All detections exceeded standard.	Of concern
Phosphorous-T	Standard exceeded in 12 of 38 samples at CS-12 and in 10 of 19 samples in CS-14; sample exceeded in the one sampling event at UPDES outfall	Of concern
TDS	Standard exceeded in CS-12 and CS-14 beginning in early 1990s. Exceedences attributed to use of gypsum rock dust (see 4.2). Practice has been discontinued and discharge water is generally in compliance	Not of concern

Based on the analysis above, four parameters—BOD, dissolved mercury, phenol, and total phosphorous—are of concern in the analysis of possible water quality impacts to Eccles Creek and

downstream watercourses or Electric Lake. To assess the degree to which the quality of receiving waters could be impacted, water quality of receiving waters has been reviewed. Water quality data for Scofield Reservoir and Electric Lake have been collected by the Department of Environmental Quality, Division of Water Quality (DWQ). These data were obtained from the EPA's STORET database. Water quality data for Eccles Creek was obtained from UDOGM's mining hydrology database. Summary data for the parameters of concern are presented in Table AD1.2. Raw data are being submitted in electronic format as part of the project file.

ECCLES CREEK/ SCOFIELD RESERVOIR

Water quality is measured on Eccles Creek by Skyline Mine at CS-2. This monitoring station is located at the USFS boundary and above the mine discharge point. The DWQ has collected information from 18 sites on Scofield Reservoir. Two sites on the southern end of the reservoir, where Mud Creek enters the reservoir, were utilized in this analysis.

BOD

BOD has been measured at CS-2 on one occasion and the result did not exceed the Beneficial Use Standard. BOD has been measured in Scofield Reservoir on 7 occasions and the Beneficial Use Standard was exceeded on one occasion.

The limited data from the mine discharge water do not allow a good characterization of BOD in mine discharge water. However, it is expected that BOD would be satiated in a well-aerated stream such as Eccles Creek.

Dissolved Mercury

Dissolved mercury has not been measured at CS-2. However, total mercury has been measured on one occasion at CS-2 and the result was non-detect.

If the Beneficial Use Standard for mercury is exceeded in mine discharge water, there is a potential that the receiving waters could become impaired. However, it is likely that if more measurements of mercury in mine discharge water were made, the results would indicate that mercury is not a parameter of concern.

Phenol

Phenol has been measured 29 times at CS-2 and was detected on six occasions. The maximum measured concentration is 350 mg/l. Phenol has not been measured in Scofield Reservoir by DWQ.

Table AD1-2 Trace Constituent Water Quality

Station	Description	BOD			Dissolved Mercury			Phenol			Total Phosphorous			Data Source
		n	avg mg/l	max mg/l	n	avg ug/l	max ug/l	n	avg mg/l	max mg/l	n	avg mg/l	max mg/l	
CS-2	Eccles Creek at USFS boundary	1	3.6	3.6	1	ND*	ND*	22	29	350	42	0.324	9.30	DOGM
593099	SCOFIELD RES S BAY 03	7	2.3	6	0	---	---	0	---	---	114	0.035	0.16	STORET
593102	SCOFIELD RES S END OF RES 06	0	---	---	0	---	---	0	---	---	2	0.06	0.11	STORET
UPL-10	Upper Huntington Creek	0	---	---	1	ND*	ND*	2	0	0	26	0.101	0.80	DOGM
493119	ELECTRIC L AB DAM 01	* 0	---	---	4	ND	ND	0	---	---	47	0.012	0.09	STORET
493120	ELECTRIC L MIDWAY UP LAKE 02	0	---	---	0	---	---	0	---	---	22	0.146	3.00	STORET

*Total used because dissolved data not availble

Phenol is generally considered an industrial waste and is not expected to occur naturally in surface water or groundwater. The source of phenol in Eccles Creek or Skyline Mine discharge water has not been investigated.

Phenol has been detected in mine discharge water during less than 25% of the sampling events and appears to be an occasional rather than a constant nuisance. Nevertheless, when phenol does occur in mine water discharge, it can easily cause the receiving water to be impaired. For instance, assuming a mine discharge rate of 3,000 gpm, a minimum discharge rate in the receiving stream of 3,000,000 gpm of phenol-free water would be required to dilute the lowest measured phenol concentration in Skyline Mine discharge water—10 mg/l—to the Beneficial Use Standard.

Total Phosphorous

Total phosphorous at CS-2 (Eccles Creek at the USFS boundary and above the mine discharge point) has been measured 42 times. Total phosphorous was not detected on twelve of these events. The maximum recorded total phosphorous concentration was 9.3 mg/l. This concentration is anomalous because the next highest concentration is 0.83 mg/l. If the 9.3 mg/l concentration is excluded, the average total phosphorus concentration at CS-2 is 0.105 mg/l, which exceeds the Beneficial Use Standard by 11 fold.

The average total phosphorous concentrations of mine discharge waters are 0.04 mg/l at CS-12 and 0.13 mg/l at CS-14. The maximum concentrations at these sites are 0.21 mg/l and 0.99 mg/l. The average and maximum concentrations of mine discharge waters are consistent with the average and maximum concentrations of water in Eccles Creek. Thus, while the total phosphorous Beneficial Use Standard is occasionally exceeded in mine discharge water, the potential for water quality degradation of Eccles Creek water is not great because of the elevated background concentrations in Eccles Creek.

Total phosphorous has historically been a concern for Scofield Reservoir. The reservoir is listed as impaired relative to the Beneficial Use Standard for total phosphorous per Section 303d of the Clean Water Act. A total maximum daily load (TMDL) analysis of the reservoir has been completed by DWQ. According to the DWQ, sediment erosion in the Scofield Reservoir watershed is the major source of pollution into Scofield Reservoir. Intense livestock grazing, grazing within the riparian zone, road

construction, summer home construction, and mining activities have been identified as accelerating the erosion process.

The effects of elevated phosphorous concentrations in mine water discharge have been assessed in terms of loading rather than by direct comparison to water quality in the lake, which varies with depth, location, and time. The Scofield Reservoir TMDL reports the current total phosphorous load to the reservoir as 6,723 kg/year and set a target load of 4,842 kg/year. If it is assumed that Skyline Mine continuously discharges 3,000 gpm of water and this water has an average total phosphorous concentration of 0.13 mg/l (which is the average concentration at CS-14), the additional total phosphorous load from mine water discharge is 776 kg/year. This additional load is notable relative to the target load set by the TMDL. However, the addition of 3,000 gpm of continuous discharge would increase inflow to the reservoir by 4,840 ac-ft/year. The model used to determine the target load for Scofield Reservoir assumed a contribution from the Mud Creek drainage of 8,441 ac-ft/year. Thus mine water represents a 57% increase in the annual water contribution from Mud Creek and lessens the severity of the increased total phosphorous load.

ELECTRIC LAKE

Water quality is measured on Upper Huntington Creek by Skyline Mine at UPL-10. This monitoring station is located at the high water line of Electric Lake. The DWQ has collected information from 2 sites on Electric Lake.

BOD

BOD has not been measured at UPL-10 or in Electric Lake.

The limited data from the mine discharge water do not allow a good characterization of BOD in mine discharge water. If the Beneficial Use Standard is consistently exceeded in mine water discharge there could be an impact to water quality if mine water were discharge directly to Electric Lake.

Dissolved Mercury

Dissolved mercury has not been measured at UPL-10. However, total mercury has been measured on one occasion at UPL-10 and the result was non-detect. Dissolved mercury has been measured four times in Electric Lake by DWQ and the results were non-detect.

If the Beneficial Use standard for mercury is exceeded in mine discharge water there is a potential that the receiving waters could become impaired. However, it is likely that if more measurements of mercury in mine discharge water were made, the results would indicate that mercury is not a parameter of concern.

Phenol

Phenol has been measured two times at UPL-10 and not detected on either occasion. Phenol has not been measured in Electric Lake by DWQ. Phenol is generally considered an industrial waste and is not expected to occur naturally in surface water or groundwater. The source of phenol in Skyline Mine discharge water has not been investigated.

Phenol has been detected in mine discharge water during less than 25% of the sampling events and appears to be an occasional rather than a constant nuisance. Nevertheless, when phenol does occur in mine water discharge, it can easily cause the receiving water to be impaired. For instance, assuming a mine discharge rate of 3,000 gpm, a minimum discharge rate in the receiving stream of 3,000,000 gpm of phenol-free water would be required to dilute the lowest measured phenol concentration in Skyline Mine discharge water—10 mg/l—to the Beneficial Use Standard.

Total Phosphorous

Concentrations of total phosphorous at UPL-10 (Upper Huntington Creek at Electric Lake) have ranged from non detect to 0.80 mg/l with an average concentration of 0.101 mg/l. Total phosphorus has been measured during 26 sampling events, 14 of which were non-detect for total phosphorous. Similar to the history at Eccles Creek, the average and maximum total phosphorous concentrations on Upper Huntington Creek are consistent with the average and maximum concentrations observed in water discharges from the Skyline Mine. Thus, while the total phosphorous Beneficial Use Standard is occasionally exceeded in mine discharge water, the potential for water quality degradation of Electric Lake is not great because of elevated background concentrations.

Total phosphorous concentration at the DWQ sampling location 'Electric Lake Midway Up Lake 02' averages 0.146 mg/l, a 29-fold increase over the Beneficial Use Standard. Annual loading calculations described above indicate that the total phosphorous load to Electric Lake could increase by 776 kg/year.

BURNOUT CREEK BASEFLOW

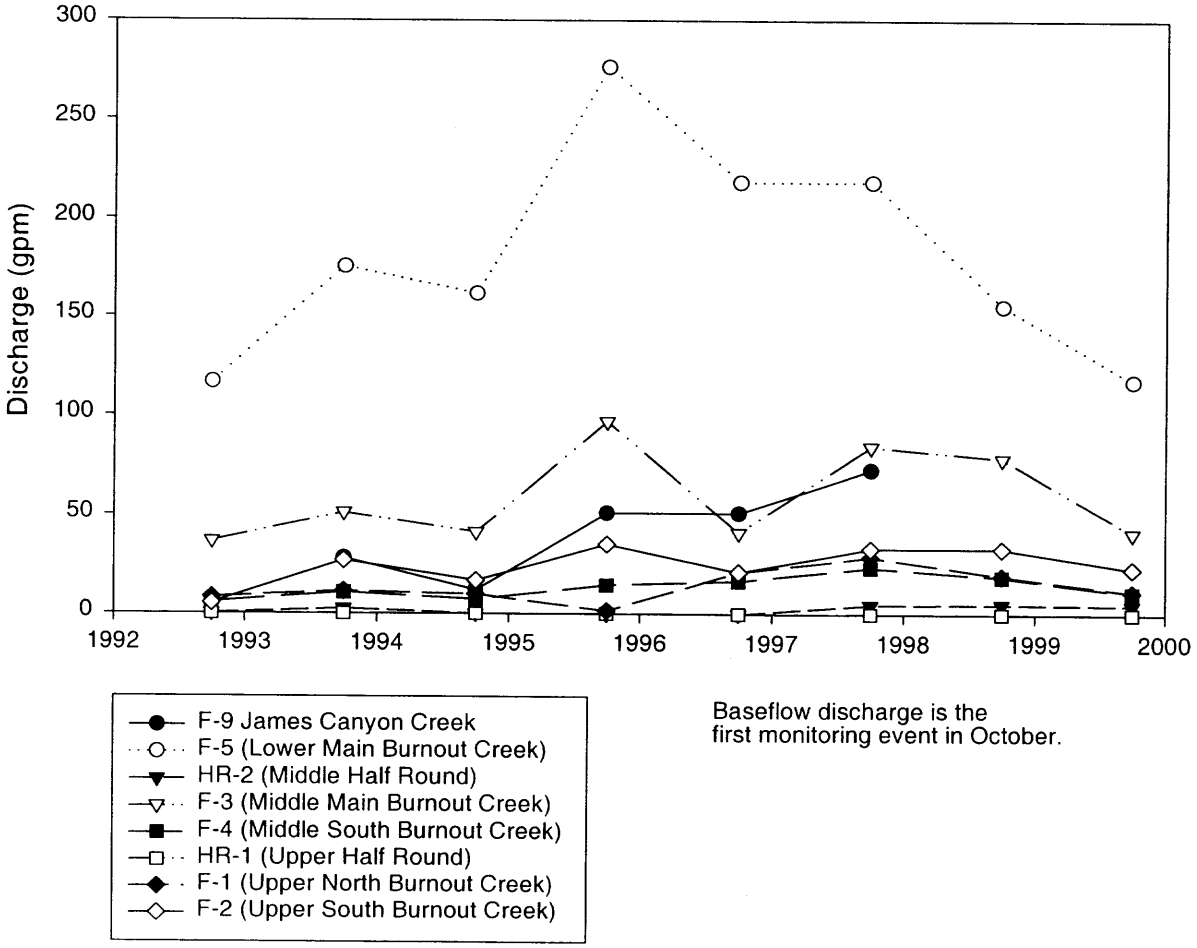
The baseflow and peak discharge characteristics of Burnout Creek during the period it underwent longwall mining were discussed in Section 4.1.3 of the Technical Report. To facilitate a more detailed analysis of the baseflow characteristics of Burnout Creek during this period, the annual October baseflow discharge at each of the monitoring stations was plotted for the years 1992-1999 (Figure AD1.1). To determine the baseflow discharge, the first monitoring event during the month of October was utilized. The month of October was chosen because 1) it is the end of the water year and discharges during this month were usually the lowest of the year, and 2) it was usually the last month of the year that discharge measurements were routinely measured.

Inspection of Figure AD1.1 indicates that, although some anticipated fluctuations in yearly baseflow have occurred, over the long-term, baseflow discharge rates in Burnout Creek have remained more or less constant. At each monitoring station, the baseflow discharge measured during 1999 is slightly greater than that measured at the beginning of the monitoring program in 1992. The intervening years are marked by periodic increases and declines in baseflow discharge rate. This suggests that, relative to the discharge rates at the beginning of the routine monitoring, mining beneath the Burnout Canyon area has not resulted in any lasting detrimental impacts to baseflow discharge rates at a scale that could be detected by this analysis.

It should be noted that the 1992 baseflow measurement occurred during a period of moderate drought (Technical Report, Figure 2.1). However, the 1999 measurement also occurred as the region was entering a similar period of moderate drought. Thus, because the climatic conditions during 1992 and 1999 are similar, comparison of the 1992 and 1999 baseflow discharge rates seems reasonable.

It is true that during the period from late 1986 to late 1991 the region was in a protracted, severe drought while the climatic conditions in the five years prior to 1999 were relatively wet. However, as discussed in the Technical Report, the near-surface rocks of the Blackhawk Formation do not accommodate much groundwater storage from year to year. This is evident in the Burnout Creek hydrographs, which show very sharp annual peaks with rapidly declining flows during the summer and fall months. Thus, because the most or all of the recharge to the basin exits the basin each year, the effect on future year's discharge rates resulting from the climatic conditions of previous years is minimal.

Figure AD1.1
Baseflow Hydrographs for Burnout and James Creeks



Baseflow discharge is the first monitoring event in October.

SEDIMENT TRANSPORT IN ECCLES CREEK AND MUD CREEK

Section 5.1.3 of the technical report describe the potential impacts of discharging mine discharge water to Eccles Creek. This section provides further information regarding erosion potential as a result of increased flows in Eccles Creek and Mud Creek resulting from mine water discharge.

Relationships have been described (Buffington, 1995; Emmett, 1999) that relate the initiation of the bedload sediment transport in armored stream channels. In general, at streamflows greater than about 60 – 70% of the bankfull discharge, streampower becomes adequate to move armoring sizes of bed material. In the absence of field observations to determine bankfull flow rates, it is generally accepted that bankfull discharge can be estimated by determining the 1.5-year flood frequency. Table AD1.3 below reports the estimated 1.5-year flood frequency and the threshold level for bedload sediment transport.

Table AD1.3
Flood Frequency and Threshold Sediment Transport Flow Rates

	1.5-Year Flood Frequency Flow Rate (cfs)	Threshold Bedload Sediment Transport Flow Rate (cfs)
Eccles Creek	1.5	1.05
Mud Creek	5.9	4.13

The proposed maximum mine water discharge would be 6.68 cfs, which represents an increase of 5.57 cfs over current levels. The 5.57 cfs increase is greater than the threshold rate for bedload sediment transport. This suggests that the proposed increase in the mine water discharge rate has the potential to cause transport of the armoring sizes of bedload materials in both Eccles Creek and Mud Creek.

Because the analysis presented above relies on generalized estimations, field investigations to determine channel substrate composition and bankfull flow rates would certainly refine these calculations.

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TECHNICAL REPORT SURFACE-WATER AND GROUNDWATER RESOURCES IN THE FLAT CANYON AREA

ADDENDUM 1

Submitted to:

MANTI-LA SAL NATIONAL FOREST

AND

BUREAU OF LAND MANAGEMENT, UTAH STATE OFFICE

January 21, 2001

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IMPACTS TO RECEIVING WATER QUALITY

Sections 5.1.3 and 5.1.4 of the technical report describe the potential impacts to water quality of Eccles Creek and Electric Lake as a result of discharge of mine water to these watercourses. Table D-2 in the technical report presents a comparison of the State of Utah Beneficial Use Standard to historic water quality of discharge from the Skyline Mine. Based on this comparison, nine water quality parameters have been identified that have, at some time, exceeded the most stringent Beneficial Use Standards in the mine discharge water. The water quality history of these nine parameters has been further reviewed and is summarized in Table AD1.1 below. Also reported in the table below is a determination of the qualitatively estimated impact that discharge of mine water poses to the quality of the receiving water.

Table AD1.1
Skyline Mine Discharge Water Quality History for Parameters that Have Exceeded Beneficial Use Standards

Parameter	Comments	Qualitatively Estimated Impact
BOD	Only sampled once in CS-12 and UPDES outfall—both exceeded standard.	Of concern
Boron	Standard exceeded only once in 13 samples at CS-12; Not exceeded in any of 10 samples at CS-14 or the one sample at UPDES outfall.	Not of concern
Cyanide	Only detected once in 13 samples at CS-12; not detected in 10 samples at CS-14; only sampled once at UPDES outfall—standard exceeded.	Not of concern
Lead-D	Detected only once in seven samples at both CS-12 and CS-14. Both detections occurred on the same date and at the same concentration, which suggests lab or sampling error.	Not of concern
Mercury-D	Dissolved mercury never sampled at discharge points. Total Mercury sampled only once at UPDES outfall and standard exceeded; never sampled at CS-12 or CS-14.	Of possible concern
Nitrate	Standard only exceeded once in 20 samples at CS-14; 29 samples at CS-12 and one sample at UPDES outfall in compliance with standard.	Not of concern
Phenol	Detected four times in 20 samples at CS-12; detected six times in 18 samples at CS-14. All detections exceeded standard.	Of concern
Phosphorous-T	Standard exceeded in 12 of 38 samples at CS-12 and in 10 of 19 samples in CS-14; sample exceeded in the one sampling event at UPDES outfall	Of concern
TDS	Standard exceeded in CS-12 and CS-14 beginning in early 1990s. Exceedences attributed to use of gypsum rock dust (see 4.2). Practice has been discontinued and discharge water is generally in compliance	Not of concern

Based on the analysis above, four parameters—BOD, dissolved mercury, phenol, and total phosphorous—are of concern in the analysis of possible water quality impacts to Eccles Creek and

downstream watercourses or Electric Lake. To assess the degree to which the quality of receiving waters could be impacted, water quality of receiving waters has been reviewed. Water quality data for Scofield Reservoir and Electric Lake have been collected by the Department of Environmental Quality, Division of Water Quality (DWQ). These data were obtained from the EPA's STORET database. Water quality data for Eccles Creek was obtained from UDOGM's mining hydrology database. Summary data for the parameters of concern are presented in Table AD1.2. Raw data are being submitted in electronic format as part of the project file.

ECCLES CREEK/ SCOFIELD RESERVOIR

Water quality is measured on Eccles Creek by Skyline Mine at CS-2. This monitoring station is located at the USFS boundary and above the mine discharge point. The DWQ has collected information from 18 sites on Scofield Reservoir. Two sites on the southern end of the reservoir, where Mud Creek enters the reservoir, were utilized in this analysis.

BOD

BOD has been measured at CS-2 on one occasion and the result did not exceed the Beneficial Use Standard. BOD has been measured in Scofield Reservoir on 7 occasions and the Beneficial Use Standard was exceeded on one occasion.

The limited data from the mine discharge water do not allow a good characterization of BOD in mine discharge water. However, it is expected that BOD would be satiated in a well-aerated stream such as Eccles Creek.

Dissolved Mercury

Dissolved mercury has not been measured at CS-2. However, total mercury has been measured on one occasion at CS-2 and the result was non-detect.

If the Beneficial Use Standard for mercury is exceeded in mine discharge water, there is a potential that the receiving waters could become impaired. However, it is likely that if more measurements of mercury in mine discharge water were made, the results would indicate that mercury is not a parameter of concern.

Phenol

Phenol has been measured 29 times at CS-2 and was detected on six occasions. The maximum measured concentration is 350 mg/l. Phenol has not been measured in Scofield Reservoir by DWQ.

Table AD1.2

Phenol is generally considered an industrial waste and is not expected to occur naturally in surface water or groundwater. The source of phenol in Eccles Creek or Skyline Mine discharge water has not been investigated.

Phenol has been detected in mine discharge water during less than 25% of the sampling events and appears to be an occasional rather than a constant nuisance. Nevertheless, when phenol does occur in mine water discharge, it can easily cause the receiving water to be impaired. For instance, assuming a mine discharge rate of 3,000 gpm, a minimum discharge rate in the receiving stream of 3,000,000 gpm of phenol-free water would be required to dilute the lowest measured phenol concentration in Skyline Mine discharge water—10 mg/l—to the Beneficial Use Standard.

Total Phosphorous

Total phosphorous at CS-2 (Eccles Creek at the USFS boundary and above the mine discharge point) has been measured 42 times. Total phosphorous was not detected on twelve of these events. The maximum recorded total phosphorous concentration was 9.3 mg/l. This concentration is anomalous because the next highest concentration is 0.83 mg/l. If the 9.3 mg/l concentration is excluded, the average total phosphorus concentration at CS-2 is 0.105 mg/l, which exceeds the Beneficial Use Standard by 11 fold.

The average total phosphorous concentrations of mine discharge waters are 0.04 mg/l at CS-12 and 0.13 mg/l at CS-14. The maximum concentrations at these sites are 0.21 mg/l and 0.99 mg/l. The average and maximum concentrations of mine discharge waters are consistent with the average and maximum concentrations of water in Eccles Creek. Thus, while the total phosphorous Beneficial Use Standard is occasionally exceeded in mine discharge water, the potential for water quality degradation of Eccles Creek water is not great because of the elevated background concentrations in Eccles Creek.

Total phosphorous has historically been a concern for Scofield Reservoir. The reservoir is listed as impaired relative to the Beneficial Use Standard for total phosphorous per Section 303d of the Clean Water Act. A total maximum daily load (TMDL) analysis of the reservoir has been completed by DWQ. According to the DWQ, sediment erosion in the Scofield Reservoir watershed is the major source of pollution into Scofield Reservoir. Intense livestock grazing, grazing within the riparian zone, road

construction, summer home construction, and mining activities have been identified as accelerating the erosion process.

The effects of elevated phosphorous concentrations in mine water discharge have been assessed in terms of loading rather than by direct comparison to water quality in the lake, which varies with depth, location, and time. The Scofield Reservoir TMDL reports the current total phosphorous load to the reservoir as 6,723 kg/year and set a target load of 4,842 kg/year. If it is assumed that Skyline Mine continuously discharges 3,000 gpm of water and this water has an average total phosphorous concentration of 0.13 mg/l (which is the average concentration at CS-14), the additional total phosphorous load from mine water discharge is 776 kg/year. This additional load is notable relative to the target load set by the TMDL. However, the addition of 3,000 gpm of continuous discharge would increase inflow to the reservoir by 4,840 ac-ft/year. The model used to determine the target load for Scofield Reservoir assumed a contribution from the Mud Creek drainage of 8,441 ac-ft/year. Thus mine water represents a 57% increase in the annual water contribution from Mud Creek and lessens the severity of the increased total phosphorous load.

ELECTRIC LAKE

Water quality is measured on Upper Huntington Creek by Skyline Mine at UPL-10. This monitoring station is located at the high water line of Electric Lake. The DWQ has collected information from 2 sites on Electric Lake.

BOD

BOD has not been measured at UPL-10 or in Electric Lake.

The limited data from the mine discharge water do not allow a good characterization of BOD in mine discharge water. If the Beneficial Use Standard is consistently exceeded in mine water discharge there could be an impact to water quality if mine water were discharge directly to Electric Lake.

Dissolved Mercury

Dissolved mercury has not been measured at UPL-10. However, total mercury has been measured on one occasion at UPL-10 and the result was non-detect. Dissolved mercury has been measured four times in Electric Lake by DWQ and the results were non-detect.

If the Beneficial Use standard for mercury is exceeded in mine discharge water there is a potential that the receiving waters could become impaired. However, it is likely that if more measurements of mercury in mine discharge water were made, the results would indicate that mercury is not a parameter of concern.

Phenol

Phenol has been measured two times at UPL-10 and not detected on either occasion. Phenol has not been measured in Electric Lake by DWQ. Phenol is generally considered an industrial waste and is not expected to occur naturally in surface water or groundwater. The source of phenol in Skyline Mine discharge water has not been investigated.

Phenol has been detected in mine discharge water during less than 25% of the sampling events and appears to be an occasional rather than a constant nuisance. Nevertheless, when phenol does occur in mine water discharge, it can easily cause the receiving water to be impaired. For instance, assuming a mine discharge rate of 3,000 gpm, a minimum discharge rate in the receiving stream of 3,000,000 gpm of phenol-free water would be required to dilute the lowest measured phenol concentration in Skyline Mine discharge water—10 mg/l—to the Beneficial Use Standard.

Total Phosphorous

Concentrations of total phosphorous at UPL-10 (Upper Huntington Creek at Electric Lake) have ranged from non detect to 0.80 mg/l with an average concentration of 0.101 mg/l. Total phosphorus has been measured during 26 sampling events, 14 of which were non-detect for total phosphorous. Similar to the history at Eccles Creek, the average and maximum total phosphorous concentrations on Upper Huntington Creek are consistent with the average and maximum concentrations observed in water discharges from the Skyline Mine. Thus, while the total phosphorous Beneficial Use Standard is occasionally exceeded in mine discharge water, the potential for water quality degradation of Electric Lake is not great because of elevated background concentrations.

Total phosphorous concentration at the DWQ sampling location 'Electric Lake Midway Up Lake 02' averages 0.146 mg/l, a 29-fold increase over the Beneficial Use Standard. Annual loading calculations described above indicate that the total phosphorous load to Electric Lake could increase by 776 kg/year.

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The baseflow and peak discharge characteristics of Burnout Creek during the period it underwent longwall mining were discussed in Section 4.1.3 of the Technical Report. To facilitate a more detailed analysis of the baseflow characteristics of Burnout Creek during this period, the annual October baseflow discharge at each of the monitoring stations was plotted for the years 1992-1999 (Figure AD1.1). To determine the baseflow discharge, the first monitoring event during the month of October was utilized. The month of October was chosen because 1) it is the end of the water year and discharges during this month were usually the lowest of the year, and 2) it was usually the last month of the year that discharge measurements were routinely measured.

Inspection of Figure AD1.1 indicates that, although some anticipated fluctuations in yearly baseflow have occurred, over the long-term, baseflow discharge rates in Burnout Creek have remained more or less constant. At each monitoring station, the baseflow discharge measured during 1999 is slightly greater than that measured at the beginning of the monitoring program in 1992. The intervening years are marked by periodic increases and declines in baseflow discharge rate. This suggests that, relative to the discharge rates at the beginning of the routine monitoring, mining beneath the Burnout Canyon area has not resulted in any lasting detrimental impacts to baseflow discharge rates at a scale that could be detected by this analysis.

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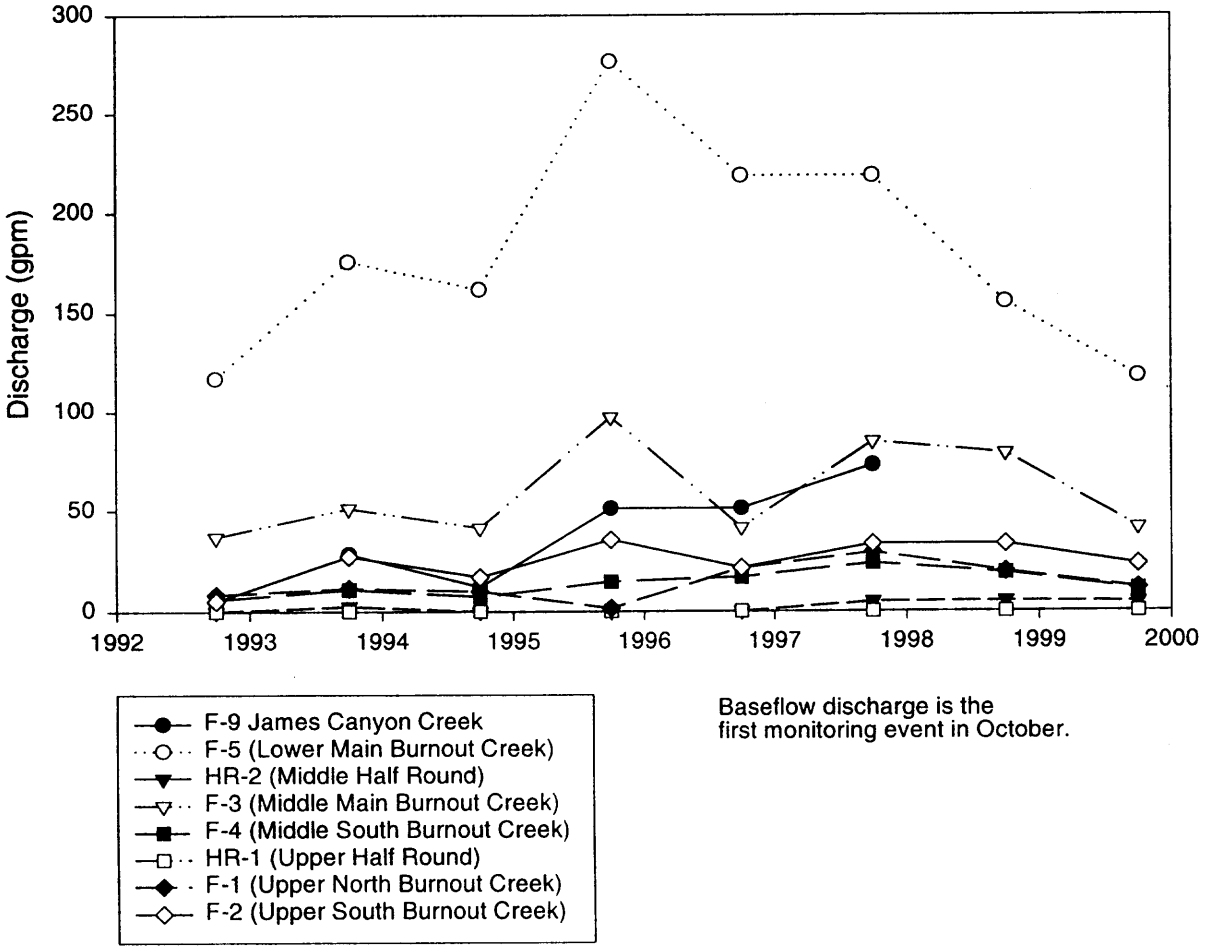

Baseflow discharge is the first monitoring event in October.

SEDIMENT TRANSPORT IN ECCLES CREEK AND MUD CREEK

Section 5.1.3 of the technical report describe the potential impacts of discharging mine discharge water to Eccles Creek. This section provides further information regarding erosion potential as a result of increased flows in Eccles Creek and Mud Creek resulting from mine water discharge.

Relationships have been described (Buffington, 1995; Emmett, 1999) that relate the initiation of the bedload sediment transport in armored stream channels. In general, at streamflows greater than about 60 – 70% of the bankfull discharge, streampower becomes adequate to move armoring sizes of bed material. In the absence of field observations to determine bankfull flow rates, it is generally accepted that bankfull discharge can be estimated by determining the 1.5-year flood frequency. Table AD1.3 below reports the estimated 1.5-year flood frequency and the threshold level for bedload sediment transport.

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	1.5-Year Flood Frequency Flow Rate (cfs)	Threshold Bedload Sediment Transport Flow Rate (cfs)
Eccles Creek	1.5	1.05
Mud Creek	5.9	4.13

The proposed maximum mine water discharge would be 6.68 cfs, which represents an increase of 5.57 cfs over current levels. The 5.57 cfs increase is greater than the threshold rate for bedload sediment transport. This suggests that the proposed increase in the mine water discharge rate has the potential to cause transport of the armoring sizes of bedload materials in both Eccles Creek and Mud Creek.

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Table AD1-2 Trace Constituent Water Quality

Station	Description	BOD			Dissolved Mercury			Phenol			Total Phosphorous			Data Source
		n	avg mg/l	max mg/l	n	avg ug/l	max ug/l	n	avg mg/l	max mg/l	n	avg mg/l	max mg/l	
CS-2	Eccles Creek at USFS boundary	1	3.6	3.6	1	ND*	ND*	22	29	350	42	0.324	9.30	DOGM
593099	SCOFIELD RES S BAY 03	7	2.3	6	0	---	---	0	---	---	114	0.035	0.16	STORET
593102	SCOFIELD RES S END OF RES 06	0	---	---	0	---	---	0	---	---	2	0.06	0.11	STORET
UPL-10	Upper Huntington Creek	0	---	---	1	ND*	ND*	2	0	0	26	0.101	0.80	DOGM
493119	ELECTRIC L AB DAM 01	0	---	---	4	ND	ND	0	---	---	47	0.012	0.09	STORET
493120	ELECTRIC L MIDWAY UP LAKE 02	0	---	---	0	---	---	0	---	---	22	0.146	3.00	STORET

*Total used because dissolved data not availble

ECCLES CREEK

	INPUT				OUTPUT
Parameter	X_{US} Upstream Concentration (mg/l)	X_M Mine Concentration (mg/l)	Q_M Mine Discharge (cfs)	X_{DS} Downstram Concentration (mg/l)	Q_{US} Upstream Discharge (cfs)
Boron	0.246	0.8	6.7	0.75	0.7
Cynanide	0.003	0.014	6.7	0.0052	26.7
Dissolved Lead	0.002	0.008	6.7	0.0032	26.7
Dissolved Mercury	0	0.2	6.7	0.012	104.7
Total Phosphorous	0.324	0.62	6.7	0.05	-13.9
Phenol	0	10	3000	0.01	2997000.0

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Parameter	Comments	Qualitatively Estimated Impact
BOD	Only sampled once in CS-12 and UPDES outfall—both exceeded standard.	Of concern
Boron	Standard exceeded only once in 13 samples at CS-12; Not exceeded in any of 10 samples at CS-14 or the one sample at UPDES outfall.	Not of concern
Cyanide	Only detected once in 13 samples at CS-12; not detected in 10 samples at CS-14; only sampled once at UPDES outfall—standard exceeded.	Not of concern
Lead-D	Detected only once in seven samples at both CS-12 and CS-14. Both detections occurred on the same date and at the same concentration, which suggests lab or sampling error.	Not of concern
Mercury-D	Dissolved mercury never sampled at discharge points. Total Mercury sampled only once at UPDES outfall and standard exceeded; never sampled at CS-12 or CS-14.	Of possible concern
Nitrate	Standard only exceeded once in 20 samples at CS-14; 29 samples at CS-12 and one sample at UPDES outfall in compliance with standard.	Not of concern
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Phosphorous-T	Standard exceeded in 12 of 38 samples at CS-12 and in 10 of 19 samples in CS-14; sample exceeded in the one sampling event at UPDES outfall	Of concern
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BOD

BOD has been measured at CS-2 on one occasion and the result did not exceed the Beneficial Use Standard. BOD has been measured in Scofield Reservoir on 7 occasions and the Beneficial Use Standard was exceeded on one occasion.

The limited data from the mine discharge water do not allow a good characterization of BOD in mine discharge water. However, it is expected that BOD would be satiated in a well-aerated stream such as Eccles Creek.

Dissolved Mercury

Dissolved mercury has not been measured at CS-2. However, total mercury has been measured on one occasion at CS-2 and the result was non-detect.

If the Beneficial Use Standard for mercury is exceeded in mine discharge water, there is a potential that the receiving waters could become impaired. However, it is likely that if more measurements of mercury in mine discharge water were made, the results would indicate that mercury is not a parameter of concern.

Phenol

Phenol has been measured 29 times at CS-2 and was detected on six occasions. The maximum measured concentration is 350 mg/l. Phenol has not been measured in Scofield Reservoir by DWQ.

Table AD1-2 Trace Constituent Water Quality

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		n	avg mg/l	max mg/l	n	avg ug/l	max ug/l	n	avg mg/l	max mg/l	n	avg mg/l	max mg/l	
CS-2	Eccles Creek at USFS boundary	1	3.6	3.6	1	ND*	ND*	22	29	350	42	0.324	9.30	DOGM
593099	SCOFIELD RES S BAY 03	7	2.3	6	0	---	---	0	---	---	114	0.035	0.16	STORET
593102	SCOFIELD RES S END OF RES 06	0	---	---	0	---	---	0	---	---	2	0.06	0.11	STORET
UPL-10	Upper Huntington Creek	0	---	---	1	ND*	ND*	2	0	0	26	0.101	0.80	DOGM
493119	ELECTRIC L AB DAM 01	0	---	---	4	ND	ND	0	---	---	47	0.012	0.09	STORET
493120	ELECTRIC L MIDWAY UP LAKE 02	0	---	---	0	---	---	0	---	---	22	0.146	3.00	STORET

*Total used because dissolved data not availble

Phenol is generally considered an industrial waste and is not expected to occur naturally in surface water or groundwater. The source of phenol in Eccles Creek or Skyline Mine discharge water has not been investigated.

Phenol has been detected in mine discharge water during less than 25% of the sampling events and appears to be an occasional rather than a constant nuisance. Nevertheless, when phenol does occur in mine water discharge, it can easily cause the receiving water to be impaired. For instance, assuming a mine discharge rate of 3,000 gpm, a minimum discharge rate in the receiving stream of 3,000,000 gpm of phenol-free water would be required to dilute the lowest measured phenol concentration in Skyline Mine discharge water—10 mg/l—to the Beneficial Use Standard.

Total Phosphorous

Total phosphorous at CS-2 (Eccles Creek at the USFS boundary and above the mine discharge point) has been measured 42 times. Total phosphorous was not detected on twelve of these events. The maximum recorded total phosphorous concentration was 9.3 mg/l. This concentration is anomalous because the next highest concentration is 0.83 mg/l. If the 9.3 mg/l concentration is excluded, the average total phosphorus concentration at CS-2 is 0.105 mg/l, which exceeds the Beneficial Use Standard by 11 fold.

The average total phosphorous concentrations of mine discharge waters are 0.04 mg/l at CS-12 and 0.13 mg/l at CS-14. The maximum concentrations at these sites are 0.21 mg/l and 0.99 mg/l. The average and maximum concentrations of mine discharge waters are consistent with the average and maximum concentrations of water in Eccles Creek. Thus, while the total phosphorous Beneficial Use Standard is occasionally exceeded in mine discharge water, the potential for water quality degradation of Eccles Creek water is not great because of the elevated background concentrations in Eccles Creek.

Total phosphorous has historically been a concern for Scofield Reservoir. The reservoir is listed as impaired relative to the Beneficial Use Standard for total phosphorous per Section 303d of the Clean Water Act. A total maximum daily load (TMDL) analysis of the reservoir has been completed by DWQ. According to the DWQ, sediment erosion in the Scofield Reservoir watershed is the major source of pollution into Scofield Reservoir. Intense livestock grazing, grazing within the riparian zone, road

construction, summer home construction, and mining activities have been identified as accelerating the erosion process.

The effects of elevated phosphorous concentrations in mine water discharge have been assessed in terms of loading rather than by direct comparison to water quality in the lake, which varies with depth, location, and time. The Scofield Reservoir TMDL reports the current total phosphorous load to the reservoir as 6,723 kg/year and set a target load of 4,842 kg/year. If it is assumed that Skyline Mine continuously discharges 3,000 gpm of water and this water has an average total phosphorous concentration of 0.13 mg/l (which is the average concentration at CS-14), the additional total phosphorous load from mine water discharge is 776 kg/year. This additional load is notable relative to the target load set by the TMDL. However, the addition of 3,000 gpm of continuous discharge would increase inflow to the reservoir by 4,840 ac-ft/year. The model used to determine the target load for Scofield Reservoir assumed a contribution from the Mud Creek drainage of 8,441 ac-ft/year. Thus mine water represents a 57% increase in the annual water contribution from Mud Creek and lessens the severity of the increased total phosphorous load.

ELECTRIC LAKE

Water quality is measured on Upper Huntington Creek by Skyline Mine at UPL-10. This monitoring station is located at the high water line of Electric Lake. The DWQ has collected information from 2 sites on Electric Lake.

BOD

BOD has not been measured at UPL-10 or in Electric Lake.

The limited data from the mine discharge water do not allow a good characterization of BOD in mine discharge water. If the Beneficial Use Standard is consistently exceeded in mine water discharge there could be an impact to water quality if mine water were discharge directly to Electric Lake.

Dissolved Mercury

Dissolved mercury has not been measured at UPL-10. However, total mercury has been measured on one occasion at UPL-10 and the result was non-detect. Dissolved mercury has been measured four times in Electric Lake by DWQ and the results were non-detect.

If the Beneficial Use standard for mercury is exceeded in mine discharge water there is a potential that the receiving waters could become impaired. However, it is likely that if more measurements of mercury in mine discharge water were made, the results would indicate that mercury is not a parameter of concern.

Phenol

Phenol has been measured two times at UPL-10 and not detected on either occasion. Phenol has not been measured in Electric Lake by DWQ. Phenol is generally considered an industrial waste and is not expected to occur naturally in surface water or groundwater. The source of phenol in Skyline Mine discharge water has not been investigated.

Phenol has been detected in mine discharge water during less than 25% of the sampling events and appears to be an occasional rather than a constant nuisance. Nevertheless, when phenol does occur in mine water discharge, it can easily cause the receiving water to be impaired. For instance, assuming a mine discharge rate of 3,000 gpm, a minimum discharge rate in the receiving stream of 3,000,000 gpm of phenol-free water would be required to dilute the lowest measured phenol concentration in Skyline Mine discharge water—10 mg/l—to the Beneficial Use Standard.

Total Phosphorous

Concentrations of total phosphorous at UPL-10 (Upper Huntington Creek at Electric Lake) have ranged from non detect to 0.80 mg/l with an average concentration of 0.101 mg/l. Total phosphorus has been measured during 26 sampling events, 14 of which were non-detect for total phosphorous. Similar to the history at Eccles Creek, the average and maximum total phosphorous concentrations on Upper Huntington Creek are consistent with the average and maximum concentrations observed in water discharges from the Skyline Mine. Thus, while the total phosphorous Beneficial Use Standard is occasionally exceeded in mine discharge water, the potential for water quality degradation of Electric Lake is not great because of elevated background concentrations.

Total phosphorous concentration at the DWQ sampling location 'Electric Lake Midway Up Lake 02' averages 0.146 mg/l, a 29-fold increase over the Beneficial Use Standard. Annual loading calculations described above indicate that the total phosphorous load to Electric Lake could increase by 776 kg/year.

BURNOUT CREEK BASEFLOW

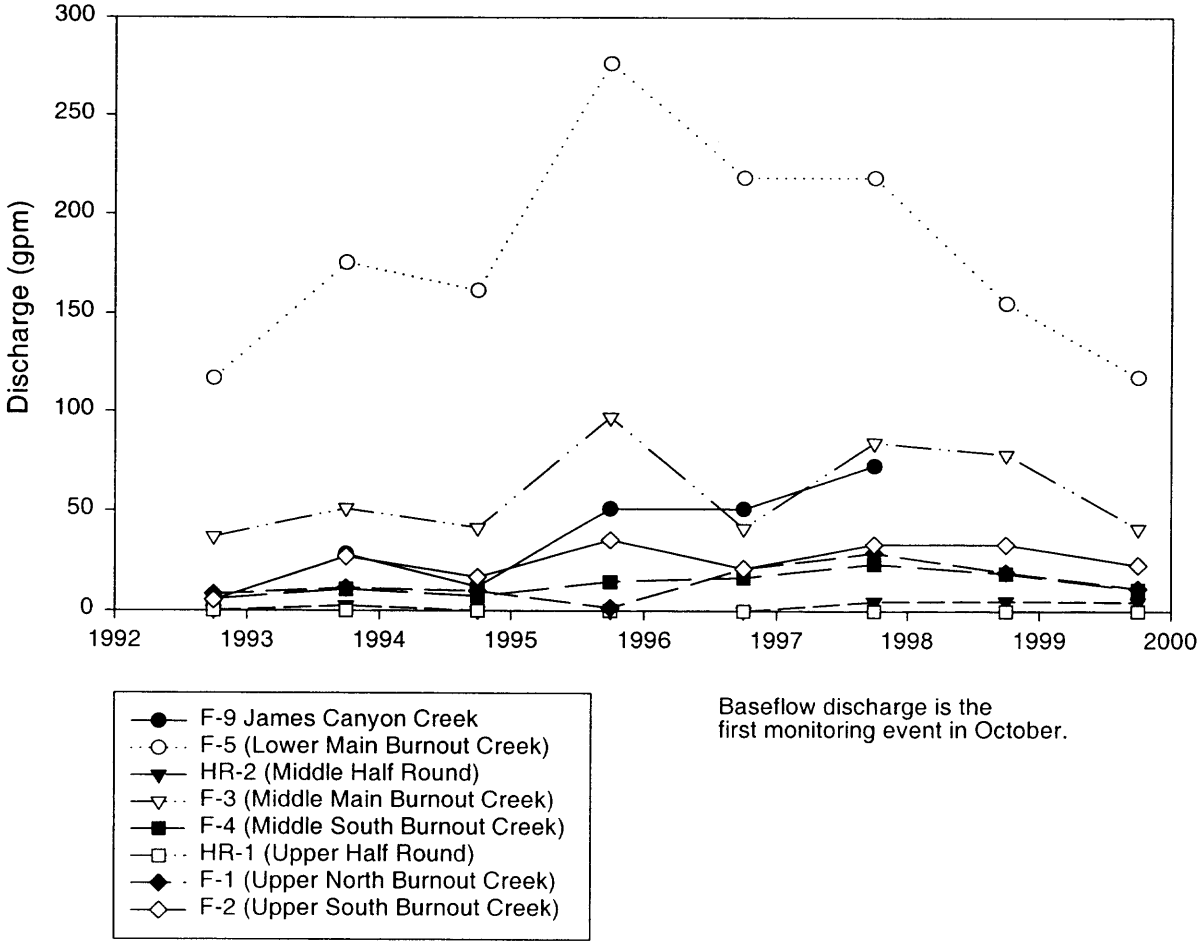
The baseflow and peak discharge characteristics of Burnout Creek during the period it underwent longwall mining were discussed in Section 4.1.3 of the Technical Report. To facilitate a more detailed analysis of the baseflow characteristics of Burnout Creek during this period, the annual October baseflow discharge at each of the monitoring stations was plotted for the years 1992-1999 (Figure AD1.1). To determine the baseflow discharge, the first monitoring event during the month of October was utilized. The month of October was chosen because 1) it is the end of the water year and discharges during this month were usually the lowest of the year, and 2) it was usually the last month of the year that discharge measurements were routinely measured.

Inspection of Figure AD1.1 indicates that, although some anticipated fluctuations in yearly baseflow have occurred, over the long-term, baseflow discharge rates in Burnout Creek have remained more or less constant. At each monitoring station, the baseflow discharge measured during 1999 is slightly greater than that measured at the beginning of the monitoring program in 1992. The intervening years are marked by periodic increases and declines in baseflow discharge rate. This suggests that, relative to the discharge rates at the beginning of the routine monitoring, mining beneath the Burnout Canyon area has not resulted in any lasting detrimental impacts to baseflow discharge rates at a scale that could be detected by this analysis.

It should be noted that the 1992 baseflow measurement occurred during a period of moderate drought (Technical Report, Figure 2.1). However, the 1999 measurement also occurred as the region was entering a similar period of moderate drought. Thus, because the climatic conditions during 1992 and 1999 are similar, comparison of the 1992 and 1999 baseflow discharge rates seems reasonable.

It is true that during the period from late 1986 to late 1991 the region was in a protracted, severe drought while the climatic conditions in the five years prior to 1999 were relatively wet. However, as discussed in the Technical Report, the near-surface rocks of the Blackhawk Formation do not accommodate much groundwater storage from year to year. This is evident in the Burnout Creek hydrographs, which show very sharp annual peaks with rapidly declining flows during the summer and fall months. Thus, because the most or all of the recharge to the basin exits the basin each year, the effect on future year's discharge rates resulting from the climatic conditions of previous years is minimal.

Figure AD1.1
Baseflow Hydrographs for Burnout and James Creeks



Baseflow discharge is the first monitoring event in October.

SEDIMENT TRANSPORT IN ECCLES CREEK AND MUD CREEK

Section 5.1.3 of the technical report describe the potential impacts of discharging mine discharge water to Eccles Creek. This section provides further information regarding erosion potential as a result of increased flows in Eccles Creek and Mud Creek resulting from mine water discharge.

Relationships have been described (Buffington, 1995; Emmett, 1999) that relate the initiation of the bedload sediment transport in armored stream channels. In general, at streamflows greater than about 60 – 70% of the bankfull discharge, streampower becomes adequate to move armoring sizes of bed material. In the absence of field observations to determine bankfull flow rates, it is generally accepted that bankfull discharge can be estimated by determining the 1.5-year flood frequency. Table AD1.3 below reports the estimated 1.5-year flood frequency and the threshold level for bedload sediment transport.

Table AD1.3
Flood Frequency and Threshold Sediment Transport Flow Rates

	1.5-Year Flood Frequency Flow Rate (cfs)	Threshold Bedload Sediment Transport Flow Rate (cfs)
Eccles Creek	1.5	1.05
Mud Creek	5.9	4.13

The proposed maximum mine water discharge would be 6.68 cfs, which represents an increase of 5.57 cfs over current levels. The 5.57 cfs increase is greater than the threshold rate for bedload sediment transport. This suggests that the proposed increase in the mine water discharge rate has the potential to cause transport of the armoring sizes of bedload materials in both Eccles Creek and Mud Creek.

Because the analysis presented above relies on generalized estimations, field investigations to determine channel substrate composition and bankfull flow rates would certainly refine these calculations.

REFERENCES

Buffington, J.M., 1995, Effects of hydraulic roughness and sediment supply on surface textures of gravel-bedded rivers. Timber, Fish & Wildlife, Document TFW-SH10-95-002.

Emmett, W.W., 1999, Quantification of channel-maintenance flows for gravel-bed rivers, in Olsen D.S. and Potyondy, J.P., eds., Wildland Hydrology. American Water Resources Association, Herndon, VA, TPS-99-3, 536 p.