CASTLEGATE SANDSTONE CLIFF STABILITY STUDY
RILDA CANYON AREA

In 1987 the Castlegate Sandstone cliffs surrounding the southern end of East Mountain were mapped to gain a better understanding of cliff stability and the effect that undermining of the cliffs would have on their stability. Although the Castlegate Sandstone also forms a cliff in the Rilda Canyon area, the nature of the cliff and the topographic setting appears to be much different than in the Cottonwood area; therefore, there is reason to believe that, when the Castlegate cliff is undermined in Rilda Canyon, it will be affected differently. In October 1988 the cliffs in the Rilda Canyon area were mapped, and data similar to that collected in 1987 in the Cottonwood Lease area were gathered. This report summarizes the data collected and compares it to the data collected in 1987.

DATA COLLECTION

In order to make a comparison of the differences and similarities of the conditions of the Castlegate cliff in Rilda Canyon versus the Cottonwood area, it was necessary to collect the same type of data in both areas. Therefore, joints, including joint orientation, continuity (both vertical and horizontal), and spacing, were mapped in the Rilda Canyon area. Total measurements made in the Cottonwood area totaled 288, in the Rilda Canyon area, 177. The density of data points in the two areas is similar. The Castlegate Sandstone outcrop covers less area in Rilda Canyon than in the Cottonwood area, and a large portion of the outcrop is not a cliff but is covered by soil and dense vegetation.

DATA INTERPRETATION

The important factors influencing the stability of the Castlegate Sandstone cliff include the lithology of the sandstone itself, topography, orientation of the joints in respect to the escarpment, and the stability of the subsurface material which includes the presence of burned coal or underground mine workings. All of these factors have been included in this interpretation.

Stratigraphy and Lithology

The Castlegate Sandstone is one of the upper members of the Mesa Verde Group and overlies the Blackhawk Formation unconformably. Because of the unconformable contact, the thickness of the formation changes throughout the East Mountain area. In the Cottonwood area, where the cliffs are more pronounced than in Rilda Canyon, the formation ranges in thickness from 260 to 380 feet. In Rilda Canyon the formation ranges in thickness from 100 to 210 feet. This is an important difference in the comparison of the cliffs in the two areas. The greater thickness in the Cottonwood area contributes to steeper topography than in the Rilda Canyon area. In fact, it is not uncommon to find no cliff exposure in the Castlegate strata in Rilda Canyon. This is particularly true of the north-facing slopes, which usually have a steep, heavily vegetated slope through this interval.

In Rilda Canyon the upper portion of the formation appears to be a fairly uniform, medium-grained sandstone. Where the formation is thin, it appears to be fairly massive as well. In the areas where the Castlegate Sandstone is thicker, there is, in places, a mudstone unit up to ten feet in thickness located about thirty feet from its base. In these areas up to 150 feet of sandstone may be present above the mudstone, which may contribute to foundation failure as described in the 1987 report on the Cottonwood area.

Jointing

The joints dissecting the Castlegate Sandstone were mapped and plotted as compass rose diagrams (see attached map). In all, 177 joints were measured in three areas. Compass rose diagrams were plotted for each area, and a composite compass rose was made for all areas. The most striking observation is the consistency of the joints in the Rilda Canyon area. Over ninety percent of the joints measured trend between N 10° E to N 10° W. This is very different from the jointing in the Cottonwood area which showed more variability in trends.

The spacing and continuity of the joints in the various areas were also measured and are shown in Table 1.

TABLE 1

Area	No. of Joints	Average Continuity Strike	Dip	Average Joint Spacing
1	68	21.8	10.3	5.3
2	60	14.5	19.9	6.2
3	49	10.5	37.1	14.1
Total	177	16.2	21.0	8.0

The nature of the jointing in Rilda Canyon is much different from that in the Cottonwood area and, as a result, its contribution to cliff instability is felt to be much different.

Orientation of Jointing to Cliff Face

In the Cottonwood area, jointing was found at several different orientations and was variable between areas. It is not uncommon to find the jointing parallel to the cliff face, in which case slabs of the cliff have become unstable when undermined. In Rilda Canyon the cliffs generally trend in an east-west direction. Where side canyons are present, the trend of the cliff does not depart from the east-west trend by more than forty-five degrees. In this area the jointing normally trends in a north-south direction; therefore, the jointing usually will not be parallel to the cliff face. When the joints are normal to the cliff face, the cliff will have fewer stability problems when undermined than when the joints are parallel to the cliff.

RILDA CANYON JOINT STUDY

JOINT NO.	AREA	ORIENTATION STRIKE	DIP	CONTINUITY STRIKE	DIP	SPACING
1	1	357	89 E	75	20	5
2	1	275	89 E	10	20	15
3	1	357	89 E	75	15	3
4	1	5	89 E	20	40	3
5	1	88	89 E	20	25	5
6	1	19	85 W	8	4	2
7	1	1	89 E	15	6	5
8	1	7	89 E	10	5	2
9	1	287	89 E	4	4	4
10	1	355	89 E	10	3	5
11	1	287	89 E	2	2	3
12	1	0	89 E	60	5	3
13	1	358	89 E	5	3	8
14	1	15	89 E	5	4	10
15	1	5	89 E	40	5	10
16	1	355	89 E	99	8	8
17	1	299	89 E	15	10	3
18	1	356	89 E	99	5	10
19	1	14	89 E	20	4	3
20	1	294	68 W	10	10	5
21	1	18	89 E	20	5	20
22	1	359	85 W	10	3	3
23	1	76	89 E	5	5	1
24	1	20	89 E	99	50	3
25	1	285	89 E	10	4	8
26	1	1	89 E	60	50	6
27	1	6	86 W	50	20	2
28	1	358	89 E	5	2	5
29	1	0	89 E	99	50	5
30	1	280	82 W	5	5	1
31	1	90	89 E	75	10	4
32	1	83	89 E	2	2	2
33	1	20	89 E	5	4	2
34	1	278	87 W	30	4	6
35	1	357	82 W	15	5	10
36	1	85	89 E	10	10	15
37	1	349	87 E	2	2	2
38	1	88	82 E	8	10	6
39	1	11	89 E	6	10	6
40	1	85	84 E	15	10	10
41	1	355	89 E	10	12	2
42	1	280	89 E	4	3	4
43	1	352	87 E	75	15	5
44	1	273	89 E	4	2	4
45	1	272	89 E	8	4	1
46	1	8	89 E	2	4	2
47	1	280	89 E	15	10	10
48	1	5	89 E	10	4	3
49	1	294	89 E	2	5	2
50	1	357	89 E	10	30	5
51	1	292	80 W	4	2	3
52	1	349	89 E	20	10	8

RILDA CANYON JOINT STUDY

JOINT NO.	AREA	ORIENTATION STRIKE	DIP		CONTINUITY STRIKE	DIP	SPACING
53	1	275	89	E	15	20	6
54	1	0	89	E	10	4	4
55	1	80	89	E	15	4	3
56	1	354	85	E	20	4	5
57	1	280	77	W	15	20	6
58	1	357	89	E	30	6	8
59	1	305	85	W	5	6	5
60	1	350	89	E	10	20	3
61	1	88	89	E	6	8	8
62	1	356	89	E	20	10	6
63	1	345	89	E	20	10	6
64	1	82	89	E	2	1	2
65	1	274	89	E	5	10	5
66	1	9	89	E	6	8	4
67	1	350	89	E	4	4	4
68	1	271	89	E	4	4	4
		198.2			21.8	10.3	5.3

1	2	18	84	E	10	8	3
2	2	313	86	W	5	8	4
3	2	19	89	E	8	10	12
4	2	35	89	E	10	5	20
5	2	10	88	E	15	20	5
6	2	79	89	E	15	20	15
7	2	2	89	E	3	8	1
8	2	295	75	W	2	20	2
9	2	5	89	E	20	30	5
10	2	11	89	E	10	10	1
11	2	16	89	E	10	20	6
12	2	80	89	E	5	5	10
13	2	8	89	E	5	10	3
14	2	280	85	W	4	8	4
15	2	315	72	W	5	5	2
16	2	5	89	E	20	10	3
17	2	8	89	E	15	15	8
18	2	79	87	E	5	15	20
19	2	3	89	E	6	15	1
20	2	80	75	E	10	5	10
21	2	2	89	E	10	50	4
22	2	79	78	E	30	15	2
23	2	14	87	W	50	50	3
24	2	12	89	E	10	10	3
25	2	358	88	E	5	10	10
26	2	70	77	E	5	15	4
27	2	84	89	E	20	8	10
28	2	15	89	E	50	75	3
29	2	0	85	W	5	5	5
30	2	278	74	W	5	5	5
31	2	290	82	W	30	50	3

RILDA CANYON JOINT STUDY

JOINT NO.	AREA	ORIENTATION STRIKE	DIP	CONTINUITY STRIKE	DIP	SPACING
32	2	14	89 E	15	50	10
33	2	16	89 E	5	20	4
34	2	282	89 E	75	50	10
35	2	353	85 E	10	30	8
36	2	75	74 E	8	30	5
37	2	18	89 E	15	25	20
38	2	280	89 E	5	5	1
39	2	349	85 W	5	5	5
40	2	320	60 W	5	8	1
41	2	349	89 E	5	10	6
42	2	285	72 W	5	10	5
43	2	16	89 E	30	99	2
44	2	279	89 E	8	10	12
45	2	298	89 E	5	5	6
46	2	249	89 E	10	15	10
47	2	12	89 E	30	20	5
48	2	282	85 W	5	5	20
49	2	4	89 E	20	75	3
50	2	285	89 E	25	25	2
51	2	355	89 E	10	5	2
52	2	274	89 E	10	10	1
53	2	315	89 E	75	50	10
54	2	351	89 E	10	20	5
55	2	340	75 W	20	8	5
56	2	80	89 E	15	15	10
57	2	350	89 E	15	20	8
58	2	274	89 E	20	15	2
59	2	2	89 E	3	5	5
60	2	81	87 E	5	10	2
		150.9		14.5	19.9	6.2
1	3	356	89 E		30	6
2	3	15	89 E	20	30	30
3	3	356	89 E	30	50	15
4	3	353	89 E		30	2
5	3	17	89 E		5	10
6	3	89	89 E		60	15
7	3	4	89 E		40	3
8	3	267	89 E	20	50	10
9	3	356	89 E		0	0
10	3	1	89 E		50	10
11	3	359	89 E		50	8
12	3	85	89 E	99	50	8
13	3	15	71 E		25	5
14	3	359	89 E		30	7
15	3	14	89 E		40	7
16	3	358	89 E		40	7
17	3	5	89 E	30	50	15
18	3	6	89 E	15	10	15

RILDA CANYON JOINT STUDY

JOINT NO.	AREA	ORIENTATION STRIKE	DIP	CONTINUITY STRIKE	DIP	SPACING
19	3	6	78 E		20	6
20	3	351	89 E	30	70	10
21	3	63	84 E	20	15	10
22	3	4	89 E		50	10
23	3	2	89 E	20	50	8
24	3	355	89 E		12	10
25	3	75	89 E		20	20
26	3	1	89 E		60	5
27	3	355	89 E		60	16
28	3	8	89 E		60	8
29	3	8	89 E		70	12
30	3	6	89 E		30	20
31	3	278	89 E		20	40
32	3	295	89 E		20	15
33	3	6	89 E		20	10
34	3	12	89 E		15	5
35	3	280	89 E		30	30
36	3	4	89 E		50	10
37	3	352	89 E		70	3
38	3	356	89 E		40	10
39	3	285	89 E		30	50
40	3	355	89 E		15	10
41	3	356	89 E		50	30
42	3	4	89 E		30	30
43	3	8	89 E	30	30	15
44	3	356	89 E		20	20
45	3	354	89 E		40	20
46	3	5	89 E		50	20
47	3	6	89 E		50	15
48	3	275	89 E		60	40
49	3	6	89 E		20	8
		159.8		10.5	37.1	14.1

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CLIFF STABILITY JOINT STUDY

AREA	NO. OF JOINTS	CONTINUITY STRIKE	CONTINUITY DIP	JOINT SPACING
1	68	21.8	10.3	5.3
2	60	14.5	19.9	6.2
3	49	10.5	37.1	14.1
TOTAL	177	16.2	21.0	8.0

SOUTH LEASE JOINT STUDY

		ORIENTATION			CONTINUITY		
JOINT NO.	**AREA**	**STRIKE**	**DIP**		**STRIKE**	**DIP**	**SPACING**
1	1	5	87	E	10	10	10
2	1	296	88	W	10	10	10
3	1	358	85	E	20	20	3
4	1	355	90	E	20	50	7
5	1	280	85	W		10	15
6	1	357	89	E	5	5	3
7	1	274	79	W	10	10	3
8	1	274	78	W	10	10	10
9	1	354	90	E	8	10	1
10	1	80	68	E	15	8	1
11	1	285	82	W	20	15	5
12	1	1	90	E	8	3	2
13	1	351	90	E	8	8	5
14	1	298	88	W	15	10	3
15	1	294	88	W	80	30	3
16	1	350	90	E		30	3
17	1	78	77	E	10	20	3
18	1	358	85	E	15	8	4
19	1	286	72	W	10	10	5
20	1	357	89	W	5	5	3
21	1	354	87	W	3	3	1
22	1	77	88	E	10	6	3
23	1	355	90	E	8	4	1
24	1	319	86	W	30	30	15
25	1	8	88	W	5	5	2
26	1	288	80	E	20	20	25
27	1	299	71	W	15	15	8
28	1	76	90	E	5	5	2
29	1	348	90	E	5	5	2
30	1	345	85	W	15	10	2
31	1	292	77	W	15	10	8
32	1	89	88	E	5	10	3
33	1	350	88	E	20	20	6
34	1	80	77	E	40	10	3
35	1	63	85	E		2	4
36	1	3	86	E	8	10	1
37	1	70	87	E	10	15	2
38	1	274	84	W	10	20	0.5
39	1	17	89	E	3	3	2
40	1	355	90	E	3	3	1
41	1	351	90	E	5	5	2
42	1	83	88	E	3	8	4
43	1	357	88	W	10	15	5
44	1	280	88	W	3	10	3
45	1	72	87	E	5	5	2
46	1	340	90	E	8		3
47	1	353	61	E	5	8	10

SOUTH LEASE JOINT STUDY

JOINT NO.	AREA	ORIENTATION STRIKE	DIP		CONTINUITY STRIKE	DIP	SPACING
48	1	357	83	E	5	4	3
49	1	76	89	E	4	4	3
50	1	355	90	E	10	15	3
51	1	327	88	W	10	10	
52	1	348	90	E	3	4	1
53	1	273	90	W	3	1	2
54	1	353	87	W	5	5	2
55	1	87	87	E	3	4	3
56	1	5	89	E	10	10	1.5
57	1	57	83	E		8	1
58	1	60	86	E		8	10
59	1	352	89	W	30	8	
		AVERAGE			11.7	10.7	4.4
60	2	76	87	W	20	15	30
61	2	22	82	E	30	20	8
62	2	345	70	E	60	20	15
63	2	60	80	W	20	20	5
64	2	295	90	W	99	40	20
65	2	335	86	E	60	20	10
66	2	45	75	E	30	10	15
67	2	290	75	E	30	60	30
68	2	65	90	W	70	90	30
69	2	335	76	W	90	60	10
70	2	80	90	E	99	60	25
71	2	350	90	E	70	30	30
72	2	315	86	E	10	10	5
73	2	357	87	E	30	30	30
74	2	60	90	E	10	30	15
75	2	30	71	E	70	60	99
76	2	290	77	E	10	5	15
77	2	295	62	E	99	70	30
78	2	271	90	W	20	10	40
79	2	30	90	W	10	20	50
80	2	75	87	W	30	20	20
81	2	80	77	W	90	80	40
82	2	295	82	E	99	80	30
83	2	60	80	W	60	40	20
84	2	293	85	E	99	60	5
85	2	70	80	W	20	20	50
86	2	310	75	E	40	30	20
87	2	340	50	E	99	60	99
88	2	355	81	E	20	40	3
89	2	280	82	E	10	30	25
90	2	350	90	E	15	10	5
91	2	60	90	W	10	5	1

SOUTH LEASE JOINT STUDY

JOINT NO.	AREA	ORIENTATION STRIKE	DIP		CONTINUITY STRIKE	DIP	SPACING
92	2	60	90	W	25	20	20
93	2	355	65	E	10	15	99
94	2	40	90	E	20	20	10
95	2	70	85	W	5	10	99
96	2	40	87	E	5	5	99
97	2	6	90	E	5	5	30
98	2	320	65	E	30	20	15
99	2	50	80	E	20	30	20
100	2	330	85	E	15	10	99
101	2	5	85	E	5	5	1
102	2	345	80	E	40	60	50
103	2	350	77	E	60	80	10
104	2	350	76	E	50	60	10
105	2	80	77	E	10	30	99
106	2	280	90	W	20	20	20
107	2	280	90	E	10	5	20
108	2	355	90	W	10	10	5
109	2	280	72	E	15	30	20
110	2	354	86	E	20	30	5
111	2	300	85	E	10	30	20
		AVERAGE			36.8	31.7	30.4
112	3	6	90	W	20	10	5
113	3	24	90	E	25	3	3
114	3	50	90	W	10	3	4
115	3	336	77	E	15	3	4
116	3	68	87	W	4	3	3
117	3	78	90	W	5	3	
118	3	44	89	E	3	3	5
119	3	87	81	E	99	20	30
120	3	348	90	E	3	3	1
121	3	80	86	W	75	5	8
122	3	333	90	W	10	1	2
123	3	89	90	E	3	5	50
124	3	359	80	E	10	12	1
125	3	63	90	W	1	1	2
126	3	64	82	E	4	4	5
127	3	64	82	E	10	6	6
128	3	293	74	W	60	25	2
129	3	67	76	E	10	3	2
130	3	333	85	E	2	3	10
131	3	306	90	E	12	8	20
132	3	30	59	E	15	8	4
133	3	78	84	E		20	99
134	3	75	87	E		99	99
135	3	50	75	E	40	12	10

SOUTH LEASE JOINT STUDY

JOINT NO.	AREA	ORIENTATION STRIKE	DIP		CONTINUITY STRIKE	DIP	SPACING
136	3	25	84	E	20	20	2
137	3	6	90	W	5	3	2
138	3	38	78	E	20	5	3
139	3	84	90	E	3	4	5
140	3	354	85	E	2	3	3
141	3	30	83	E	5	3	3
142	3	60	81	E	1	1	0.3
143	3	354	90	E	1	1	1
144	3	24	90	W	20	6	2
145	3	89	90	E	8	4	4
146	3	305	83	W	10	7	1
147	3	14	82	E	8	15	30
148	3	37	86	E	10	2	1
149	3	37	86	E	10	10	5
150	3	306	88	E	6	15	15
151	3	62	88	W	3	5	2
152	3	328	88	W	15	20	10
153	3	83	71	E	5	5	1
154	3	60	82	W	10	8	5
155	3	52	85	E	15	8	6
156	3	6	90	W	2	2	0.5
157	3	315	67	W	15	8	1
158	3	72	82	E	10	6	2
159	3	75	87	E	5	15	15
160	3	274	81	W	10	6	4
161	3	62	87	W	5	3	2
162	3	50	90	E	4	4	2
163	3	286	71	W	40	8	8
164	3	60	87	W	5	8	2
165	3	290	76	W	99	20	4
		AVERAGE			15.5	9.0	10.4
166	4	300	35	W	99	30	30
167	4	300	85	W	50	30	30
168	4	313	85	W	50	50	20
169	4	30	90	W	20	50	20
170	4	24	90	E	10	20	4
171	4	27	85	E	10	20	2
172	4	318	90	E	10	3	6
173	4	47	90	W	8	3	
174	4	345	90	E	5	3	1
175	4	24	90	W	20	15	20
176	4	70	90	W	10	1	4
177	4	87	90	W	20	15	3
178	4	33	90	E	5	8	10
179	4	354	87	E	2	5	0.5

SOUTH LEASE JOINT STUDY

		ORIENTATION			CONTINUITY		
JOINT NO.	AREA	STRIKE	DIP		STRIKE	DIP	SPACING
180	4	70	80	E	99	99	5
181	4	325	90	W	20	20	15
182	4	25	90	E	8	3	3
183	4	40	90	W	25	6	10
184	4	315	85	W	8	4	10
185	4	36	90	E	8	4	15
186	4	315	90	E	10	4	5
187	4	280	90	W	20	10	3
188	4	340	90	W	4	4	3
189	4	320	90	E	40	30	10
190	4	30	90	W	20	30	15
191	4	60	90	W	20	30	
192	4	304	90	E	10	8	8
193	4	30	90	W	10	8	8
194	4	315	90	E	20	3	5
195	4	4	90	W	3	2	1
196	4	63	90	E	10	6	4
197	4	73	87	E	30	20	10
198	4	52	90	W	10	2	3
199	4	26	90	W	5	2	4
200	4	352	90	E	3	2	2
201	4	78	87	E	30	99	10
202	4	65	90	W	5		3
203	4	72	90	E	10	5	5
204	4	75	90	W	15	99	20
205	4	2	90	E	8	4	10
206	4	89	90	W	5	4	3
207	4	336	90	E	15	5	8
208	4	71	90	W	4	4	15
209	4	82	90	W	4	2	4
210	4	3	90	E	20		15
211	4	81	79	E	30	50	10
212	4	308	90	W	10	3	2
213	4	277	80	E	20	4	5
214	4	354	90	E	5	5	8
215	4	63	90	W	15	2	5
216	4	329	90	W	6	2	4
217	4	335	90	E	6	4	3
218	4	35	90	E	15	6	2
219	4	52	90	E	8	8	5
220	4	50	90	W	8	5	2
221	4	40	90	W	6	6	5
222	4	340	90	E	10	6	3
223	4	338	90	E	10	3	6
224	4	36	90	W	8		5
225	4	299	83	W	25	8	15
226	4	9	90	W	2	1	6

SOUTH LEASE JOINT STUDY

JOINT NO.	AREA	ORIENTATION STRIKE	ORIENTATION DIP		CONTINUITY STRIKE	CONTINUITY DIP	SPACING
227	4	325	90	E	4	1	2
228	4	73	80	E	10	5	5
229	4	350	90	W	3	4	6
230	4	63	90	E	10	5	3
231	4	70	90	W	5	5	4
232	4	1	81	E	5	5	5
233	4	34	86	E	6	6	5
234	4	295	84	W	5	4	3
		AVERAGE			15.2	13.9	7.5
235	5	337	75	W	10	20	10
236	5	30	90	E	5	15	1
237	5	46	79	W	30	20	1
238	5	84	90	E	3	10	8
239	5	10	75	W	15	30	5
240	5	36	90	W	20	15	5
241	5	278	82	W	5	5	3
242	5	341	73	W	15	30	30
243	5	85	79	E	4	5	3
244	5	352	83	W	4	5	3
245	5	284	90	E	20	10	8
246	5	35	90	W	12	10	4
247	5	282	90	E	5	5	5
248	5	295	80	W	10	6	4
249	5	50	81	E	10	15	
250	5	308	84	W	15	15	3
251	5	290	73	W	10	15	15
252	5	35	82	W	5	10	12
253	5	28	90	W	10	20	15
254	5	291	87	W	15	15	10
255	5	12	90	W	5	10	4
256	5	315	77	W	20	15	10
257	5	30	90	E	40	20	20
258	5	320	61	W	15	10	20
259	5	330	76	W	25	15	10
260	5	20	90	W	10	12	5
261	5	335	80	W	10	10	
262	5	28	90	E	99	10	50
263	5	12	58	W	15	15	15
264	5	275	85	E	15	15	3
		AVERAGE			15.9	13.6	9.7
265	6	25	90	W	5	10	5
266	6	284	90	E	5	10	4
267	6	21	90	W	15	15	4

SOUTH LEASE JOINT STUDY

JOINT NO.	AREA	ORIENTATION STRIKE	DIP		CONTINUITY STRIKE	DIP	SPACING
268	6	308	74	W	15	15	5
269	6	26	89	W	15	10	10
270	6	40	90	W	10	30	10
271	6	15	80	W	10	15	15
272	6	348	78	W	30	15	15
273	6	60	90	E	1	2	2
274	6	352	90	E	5	4	1
275	6	86	68	E	10	3	2
276	6	29	81	E	5	10	15
277	6	11	90	W	5	10	2
278	6	285	69	W	10	20	2
279	6	82	80	E	20	40	8
280	6	25	90	W	4	4	1
281	6	82	68	E	10	10	3
282	6	18	90	E	4	2	2
283	6	20	90	W	50	60	4
284	6	282	78	W	15	20	10
285	6	30	90	E	10	10	5
286	6	88	90	W	3	2	1
287	6	25	90	E	1	1	1
288	6	275	83	W	3	3	1
		AVERAGE			10.9	13.4	5.3

SOUTH LEASE JOINT STUDY

NEWBERRY CANYON

JOINT NO.	ORIENTATION STRIKE	DIP		CONTINUITY STRIKE	DIP	SPACING
1	5	87	E	10	10	10
2	296	88	W	10	10	10
3	358	85	E	20	20	3
4	355	90	E	20	50	7
5	280	85	W		10	15
6	357	89	E	5	5	3
7	274	79	W	10	10	3
8	274	78	W	10	10	10
9	354	90	E	8	10	1
10	80	68	E	15	8	1
11	285	82	W	20	15	5
12	1	90	E	8	3	2
13	351	90	E	8	8	5
14	298	88	W	15	10	3
15	294	88	W	80	30	3
16	350	90	E		30	3
17	78	77	E	10	20	3
18	358	85	E	15	8	4
19	286	72	W	10	10	5
20	357	89	W	5	5	3
21	354	87	W	3	3	1
22	77	88	E	10	6	3
23	355	90	E	8	4	1
24	319	86	W	30	30	15
25	8	88	W	5	5	2
26	288	80	E	20	20	25
27	299	71	W	15	15	8
28	76	90	E	5	5	2
29	348	90	E	5	5	2
30	345	85	W	15	10	2
31	292	77	W	15	10	8
32	89	88	E	5	10	3
33	350	88	E	20	20	6
34	80	77	E	40	10	3
35	63	85	E		2	4
36	3	86	E	8	10	1
37	70	87	E	10	15	2
38	274	84	W	10	20	0.5
39	17	89	E	3	3	2
40	355	90	E	3	3	1
41	351	90	E	5	5	2
42	83	88	E	3	8	4
43	357	88	W	10	15	5
44	280	88	W	3	10	3
45	72	87	E	5	5	2
46	340	90	E	8		3

SOUTH LEASE JOINT STUDY

	ORIENTATION			CONTINUITY		
JOINT NO.	STRIKE	DIP		STRIKE	DIP	SPACING
47	353	61	E	5	8	10
48	357	83	E	5	4	3
49	76	89	E	4	4	3
50	355	90	E	10	15	3
51	327	88	W	10	10	
52	348	90	E	3	4	1
53	273	90	W	3	1	2
54	353	87	W	5	5	2
55	87	87	E	3	4	3
56	5	89	E	10	10	1.5
57	57	83	E		8	1
58	60	86	E		8	10
59	352	89	W	30	8	
	AVERAGE			11.7	10.7	4.4

COTTONWOOD CANYON

166	300	35	W	99	30	30
167	300	85	W	50	30	30
168	313	85	W	50	50	20
169	30	90	W	20	50	20
170	24	90	E	10	20	4
171	27	85	E	10	20	2
172	318	90	E	10	3	6
173	47	90	W	8	3	
174	345	90	E	5	3	1
175	24	90	W	20	15	20
176	70	90	W	10	1	4
177	87	90	W	20	15	3
178	33	90	E	5	8	10
179	354	87	E	2	5	0.5
180	70	80	E	99	99	5
181	325	90	W	20	20	15
182	25	90	E	8	3	3
183	40	90	W	25	6	10
184	315	85	W	8	4	10
185	36	90	E	8	4	15
186	315	90	E	10	4	5
187	280	90	W	20	10	3
188	340	90	W	4	4	3
189	320	90	E	40	30	10
190	30	90	W	20	30	15
191	60	90	W	20	30	
192	304	90	E	10	8	8
193	30	90	W	10	8	8

SOUTH LEASE JOINT STUDY

	ORIENTATION			CONTINUITY		
JOINT NO.	STRIKE	DIP		STRIKE	DIP	SPACING
194	315	90	E	20	3	5
195	4	90	W	3	2	1
196	63	90	E	10	6	4
197	73	87	E	30	20	10
198	52	90	W	10	2	3
199	26	90	W	5	2	4
200	352	90	E	3	2	2
201	78	87	E	30	99	10
202	65	90	W	5		3
203	72	90	E	10	5	5
204	75	90	W	15	99	20
205	2	90	E	8	4	10
206	89	90	W	5	4	3
207	336	90	E	15	5	8
208	71	90	W	4	4	15
209	82	90	W	4	2	4
210	3	90	E	20		15
211	81	79	E	30	50	10
212	308	90	W	10	3	2
213	277	80	E	20	4	5
214	354	90	E	5	5	8
215	63	90	W	15	2	5
216	329	90	W	6	2	4
217	335	90	E	6	4	3
218	35	90	E	15	6	2
219	52	90	E	8	8	5
220	50	90	W	8	5	2
221	40	90	W	6	6	5
222	340	90	E	10	6	3
223	338	90	E	10	3	6
224	36	90	W	8		5
225	299	83	W	25	8	15
226	9	90	W	2	1	6
227	325	90	E	4	1	2
228	73	80	E	10	5	5
229	350	90	W	3	4	6
230	63	90	E	10	5	3
231	70	90	W	5	5	4
232	1	81	E	5	5	5
233	34	86	E	6	6	5
234	295	84	W	5	4	3
235	337	75	W	10	20	10
236	30	90	E	5	15	1
237	46	79	W	30	20	1
238	84	90	E	3	10	8
239	10	75	W	15	30	5
240	36	90	W	20	15	5
241	278	82	W	5	5	3

SOUTH LEASE JOINT STUDY

	ORIENTATION			CONTINUITY		
JOINT NO.	STRIKE	DIP		STRIKE	DIP	SPACING
242	341	73	W	15	30	30
243	85	79	E	4	5	3
244	352	83	W	4	5	3
245	284	90	E	20	10	8
246	35	90	W	12	10	4
247	282	90	E	5	5	5
248	295	80	W	10	6	4
249	50	81	E	10	15	
250	308	84	W	15	15	3
251	290	73	W	10	15	15
252	35	82	W	5	10	12
253	28	90	W	10	20	15
254	291	87	W	15	15	10
255	12	90	W	5	10	4
256	315	77	W	20	15	10
257	30	90	E	40	20	20
258	320	61	W	15	10	20
259	330	76	W	25	15	10
260	20	90	W	10	12	5
261	335	80	W	10	10	
262	28	90	E	99	10	50
263	12	58	W	15	15	15
264	275	85	E	15	15	3
	AVERAGE			15.4	13.4	8.2

TRAIL MOUNTAIN JOINT STUDY
1997

JOINT NO.	AREA	ORIENTATION STRIKE		DIP		CONTINUITY STRIKE	CONTINUITY DIP	SPACING
1	1	3	E	76	S	4	2	
2	1	6	E	85	S	3	2	
3	1	24	E	80	S	10	4	
4	1	25	E	78	S	3	2	6
5	1	61	W	80	N	3	3	
6	1	5	E	89	E	2	2	
7	1	10	W	70	E	10	2	10
8	1	13	W	73	E	6	4	10
9	1	80	E	78	S	6	6	10
10	1	5	E	87	E	5	6	8
11	1	11	E	63	E	3	4	4
12	1	80	E	89	S	1	1	
13	1	25	E	78	N	10	2	5
14	1	43	W	86	E	4	1	
15	1	62	E	79	SW	5	4	15
16	1	33	W	90	S	10	6	6
17	1	45	E	81	SE	5	5	
18	1	34	E	65	SE	2	2	
19	1	51	E	84	SE	1	1	
20	1	38	W	90	SE	2	1	10
		AVERAGE				4.8	3.0	8.4
21	2	15	E	76	SE	3	3	12
22	2	51	W	88	NE	6	10	
23	2	14	E	83	SE	6	5	
24	2	40	E	83	SE	5	5	
25	2	10	E	64	SE	10	7	
26	2		W	90		2	3	3
27	2	15	E	65	SE	15	8	
28	2	10	W	81	NE	6	6	6
29	2	80	W	90		3	5	
30	2	15	W	70	W	20	3	
31	2	72	E	82	SE	5	3	
32	2	11	E	90		4	1	1
33	2	16	E	90		1	1	
34	2	5	E	85	E	1	1	
35	2	8	E	80	E	10	10	15
36	2	10	E	90		15	6	
		AVERAGE				7.0	4.8	7.4
37	3	80	W	80	N	4	4	
38	3	35	W	85	E			
39	3	5	E	77	E	10	10	
40	3	80	W	86	N	15	6	
41	3	5	E	78	E	5	5	
42	3	40	E	80	S	5	5	
43	3	85	E	85	S	10	1	
44	3	13	W	89	E	20	99	
45	3		W	90		10	10	
46	3	5	E	89	E	10	10	
47	3		W	84	S	7	6	
48	3		S	84	E	5	5	
49	3	50	E	77	S	50	20	
50	3	45	E	66	S	30	20	
51	3	71	E	77	S	6	4	
		AVERAGE				13.4	14.6	
52	4	15	W	75	SW	5	4	
53	4	40	E	75	W	20	8	
54	4	52	W	90		10	15	
55	4	80	E	90		8	1	
56	4	5	E	75	W	99	99	
57	4	70	W	90		20	20	
58	4	35	E	85	W	5	15	
59	4	43	E	83	E	10	5	6
60	4	38	W	82	W	25	5	
61	4	65	W	65	S	4	2	
62	4	40	W	85	W	5	6	15
63	4	85	E	85	E	6	20	
64	4	40	W	65	SW	7	3	
65	4		W	90		1	1	
66	4		W	90		3	3	

ENERGY WEST MININIG COMPANY

AREA	NO. OF JOINTS	CONTINUITY STRIKE	CONTINUITY DIP	JOINT SPACING
1	20	11.7	10.7	4.4
2	16	36.8	31.7	30.4
3	15	15.5	9.0	10.4
4	27	15.2	13.9	7.5
TOTAL	78	19.8	16.3	13.2

TRAIL MOUNTAIN JOINT STUDY
1997

		ORIENTATION				CONTINUITY		
JOINT NO.	AREA	STRIKE		DIP		STRIKE	DIP	SPACING
67	4	20	W	63	SW	5	5	
68	4		W	63	SW	10	10	8
69	4		W	90		10	10	15
70	4		W	70	SW	99	8	8
71	4		W	80	SE	4	2	
72	4		W	80	SE	8	10	
73	4	85	W	80	SE	10	10	
74	4	10	W	80	W	10	15	25
75	4	50	E	90		99	99	
76	4	30	E	75	E	10	5	
77	4	50	E	90		20	2	
78	4	35	W	90		3	2	20
		AVERAGE				19.1	14.3	13.9

SURFACE RESOURCE IMPACT ASSESSMENT ASSOCIATED WITH MINING BENEATH THE CASTLEGATE SANDSTONE ESCARPMENT TRAIL MOUNTAIN - 5TH EAST

October 1997

INTRODUCTION

The preceding reports discuss various aspects regarding failure of the Castlegate Sandstone escarpment as a result of longwall mining the 5th East longwall panel in the Trail Mountain Mine. This report identifies some of the surface resources associated with the area of escarpment failure and assesses actual impacts to the identified resources.

Various federal, state and local agencies; including the Bureau of Land Management (BLM), Forest Service (USFS), Utah Division of Wildlife Resources (UDWR), Utah Division of Water Rights (State Engineer), Utah Department of Transportation (UDOT), Utah Division of Oil, Gas and Mining (UDOGM), Emery County and other local entities, have jurisdiction and/or vested interests in the surface resources. Therefore, the resources are identified and assessed accordingly. The land associated with the surface resources addressed herein extends from the base of the Castlegate Sandstone escarpment to County Road 00506 in Cottonwood Canyon and State Highway 29 in Straight Canyon, east of the Forest boundary.

LANDS INVOLVED

The area associated with the extension of the Trail Mountain Mine 5th East longwall panel beyond the Castlegate Sandstone escarpment is located within Section 1, T. 1 8 S., R.6 E. and Section 6, T. 18 S., R.7 E., SLBM, in Emery County, approximately seven miles northwest of Orangeville, Utah. The entire surface and mineral estates are in federal ownership administered by USFS, Manti-LaSal NF and BLM. The Castlegate Sandstone escarpment is located on USFS land but the majority of impacts affected BLM land.

The stratigraphy of the area is described in the preceding report titled: **Castlegate Sandstone Cliff Stability, Trail Mountain – 5th East.**

SURFACE RESOURCES

Soils[5]

The soil type associated with the area is Gerst-Strych-badland complex. This complex is characterized as follows:

The Gerst soil occurs on steep hillsides underlain by shale. It is shallow and well drained with slow permeability. Runoff occurs rapidly. Water erosion hazard is severe. Wind erosion hazard is moderate. Strych soil occurs on steep north and west facing hillsides. It is very deep and well drained. Permeability is moderately rapid. The hazard of water erosion is moderate and the hazard of wind erosion is slight. Badland is steep or very steep nearly barren areas of shale that are dissected by many intermittent drainage channels. Some areas are interbedded with sandstone. Runoff is very rapid and geologic erosion is active. The Gerst-Strych-badland complex is included in the critical soils area in the BLM San Rafael Resource Management Plan (RMP).

Vegetation

Ecological Sites and Status (BLM)[5]

A vegetative inventory was completed in 1985 which delineated Site Write-up Areas (SWAs) for the entire San Rafael Resource Area. From SWAs, major ecological sites and the status of the sites was determined. The BLM land in the vicinity of the 5th East panel was designated E90, semi-desert shallow loam (P-J). The ecological status of this area was identified as Fair/Mid-Seral.

The vegetation associated with the semi-desert shallow loam sites consists of Utah juniper *(Juniperus osteosperma)* and Pinyon-pine *(Pinus edulis)* overstory with a black sagebrush *(Artemisia nova)* and Salina wildrye *(Elymus salina)* understory. Slopes vary from 15 to 50 percent and vegetative production (air-dry) is poor (100 to 250 pounds per acre).

Field visits indicate that additional BLM site designations are applicable to portions of the area. These designations are semi-desert stony loam and upland very steep loam.

Vegetation associated with semi-desert stony loam consists of Utah juniper and Pinyon-pine overstory and Salina wildrye understory. These sites occur on fan terraces and fan remnants with an average slope of 15 to 50 percent. Vegetation Production (air-dry) is from 350 to 700 pounds per acre due to the presence of pinyon and juniper.

The upland very steep loam occurs on pediment back slopes and canyon side slopes with an average slope of 50 to 80 percent. The vegetation consists of Utah juniper and Pinyon-pine overstory and needle-and-thread grass *(Stipa comata)* and mountain mahogany (Cercocarpus spp.) understory. The production (air-dry) is from 180 to 360 pounds per acre also due to the presence of pinyon and juniper.

In the vicinity of the extension of the 5th East longwall panel, a transitional pinyon-juniper and spruce-fir mixed conifer vegetation community exists.

A narrow band of riparian vegetation boarders the intermittent stream channel adjacent to the county road in Cottonwood Canyon. The dominant species associated with this community include Narrowleaf cottonwood *(Populus angustifolia)* and Wood rose (Rose *woodsii)*. No riparian of aquatic Areas of Critical Environmental Concern (ACEC) are associated with this community.

Canyon sweetvetch *(Hedysarum occidentale var. canone),* a candidate plant species for listing on the Federal and state threatened and endangered lists occurs in the area. The location of an identified population, of greater than 50 plants, is shown on Drawing TMS #1705D.

According to information in **Utah Endangered, Threatened and Sensitive Plant Field Guide,** published by the USFS Intermountain Region, Low hymenoxys (Hymenoxys depressa) and Creutzfeldt catseye *(Cryptantha creutzfeldtii)* may also occur within the area.[1] The necessary habitat exists to support these species; however, a survey for them has not been conducted.

Hydrology

The area is contained within Hydrologic Area 56, as defined in the Northern Great Plains and Rocky Mountain Coal Province (USGS Open-File Report 83-38). Annual precipitation in the general area varies widely; from less than 6 inches in the low areas, to more than 40 inches along the top of the Wasatch Plateau. Winter precipitation is primarily snow, resulting from frontal-type storms which move across the area, primarily from west to east. The snowpack is the principal source of late spring and early summer runoff in the area. Summer precipitation generally results from thunderstorms moving through the area from the southwest. These storms are usually localized, short duration but high intensity events, which may result in flash flooding.[7]

No seeps or springs exist in the area of extension of the 5th East longwall panel. An intermittent stream, is located adjacent to the County Road in Cottonwood Canyon and a perennial stream is located in Straight Canyon to the south of the area.

The area is identified in the BLM Resource Management Plan as Critical Watershed Area. Water rights exist for flows associated with the streams in the vicinity of the area.

Grazing

The area is located within the Peacock cattle grazing allotment. The seasonal use of the allotment is from April 1 to June 10 with an optimal and average use of 56 AUMs.[7]

Wildlife

The area associated with the extension of the 5th East longwall panel includes the following classifications for wildlife uses:

UDWR - Critical Mule Deer Winter Range
Limited Elk Winter Range
Substantial Mountain Cottontail Rabbit Yearlong Range
BLM - Elk and Mule Deer Winter Habitat.

The area supports the following BLM wildlife habitats: barren areas (cliffs and talus), pinyon-juniper woodland and saltbush-grass. Cliffs within the barren habitat provide potential nesting areas for various raptor species. The area has been included in annual raptor surveys since 1986. No raptor nests have been observed along the escarpment associated with the extension area. The nearest raptor nest, a small stick nest (buteo/raven), is located approximately 2,000 feet southwest of the area. This nest has not been found to be active during the annual raptor surveys. No cliff swallow nests have been observed on the escarpment in the extension area. No indications of bat activity have been observed in the area.

Six species of amphibians are known to occur within the general area of the Wasatch Plateau.[7] These species are classified as common in occurrence, but limited to mesic areas. They may be present in some areas of the riparian habitat associated with the stream channels.

There are ten species of reptiles known to inhabit the region.[7] Habitat exists within the area to support at least some of the species. No surveys have been conducted for these species.

There are approximately one hundred eighty bird species that may be yearlong residents or may frequent the region during portions of the year.[7] Surveys have been conducted only for raptors. The pinyon-juniper and riparian communities provide the necessary habitat for various bird species; but, these habitat types are not known to be a limiting factor for any of the species that may be in the area.

Ninety-two species of mammals are known to exist in, or potentially could inhabit the region.[7] Of these species, only mule deer (Odocoileus hemionus), elk (Cervus elaphus) and cottontail rabbit species (Sylvilagus spp.) have been identified to be of significant importance in the area of panel extension.

The perennial stream in Straight Canyon supports three species of game fish and seven non-game species. The stream down-canyon from the confluence with Cottonwood Canyon is classified as a high priority use stream, providing yearlong habitat for fish species. This portion of the stream is managed as a Class 3 (important) cold water fishery. The portion of the stream from the Cottonwood Canyon to Joe's Valley Reservoir is identified as a crucial/critical use area and is managed as a Class 2 (great importance) cold water fishery.

The section of intermittent stream in Cottonwood Canyon, adjacent to the area of proposed mining, supports no macroinvertebrate or fish species.

Special Status Wildlife Species associated with the area include Bald eagle (Haliaeetus leucocephalus), a listed species and Ferruginous hawk (Buteo regales), a candidate species. These species are present primarily during winter and spring migration.[7]

Visual Resources

Visual Resource Management (BLM)

The visual resource evaluation and management process is a classification of visual resources according to visual sensitivity, distance from viewers and man-made intrusions present. Based on these criteria, all areas are placed in one of four classes. These management classes are designed to maintain or enhance visual quality and describe acceptable degrees of change to landscape elements. In general, the lower the class, the fewer impacts are allowed. The overall objective of the Visual Resource Management (VRM) system is to manage areas so that impacts occurring within a class area are not significant enough to alter the overall class rating of that area.[5] The BLM lands associated with the extension of the 5th East longwall panel are managed as VRM Class III. Changes in the basic elements caused by management activities should be moderate. Management activities may attract attention but should not dominate the view of the casual observer. Changes under this class should repeat the basic elements found in the predominant natural features of the characteristic landscape.[7]

Visual Resource (USFS)[4]

The Manti Division provides varied quality in viewing. Above average views are composed at high elevation plateaus, in canyons displaying a high degree of visual landscape diversity, around moderate to large size water impoundments, and at areas containing large, near vertical cliff escarpments.

Many areas on the Manti Division are visually sensitive because of the significant visual variety which is viewed by large numbers of recreation oriented visitors. These are areas where certain management activities would be highly visible and could cause a high degree of man-made visual contrast. Developed and dispersed recreation environments in Huntington Canyon, Joe's Valley (including Straight Canyon), Ferron Reservoir, Skyline Drive, Forest border slopes and escarpments are in this category. The Forest lands associated with the extension of the 5th East longwall panel are classified as mg2B (middleground viewed, medium sensitivity level, common variety class).[4]

Recreation

The subject BLM lands are classified Roaded Natural Areas.[6] This designation is assigned to areas characterized by a generally natural environment with moderate evidence of the sights and sounds of man, The sights and sounds of man and utilization generally harmonize with the natural surroundings.[5]

The area provides opportunity for hiking and hunting. Evidence of rock climbing activities has been observed in the area. The Forest lands are designated Semi-primitive Motorized. Areas, so designated, provide some isolation from the sights and sounds of humans, independence, closeness to nature, tranquillity and self-reliance through the application of woodsman and outdoor skills in an environment that offers challenge and risk. Opportunity exists to use motorized equipment while in the area.[4]

Two paved roads are located in the vicinity of the panel extension area; State Road 29 in S-traight Canyon and County Road 00506 in Cottonwood Canyon.

Cultural Resources

An intensive cultural resource evaluation was conducted in the area by Archeological Environmental Research Corporation. The evaluation was conducted on December 26th and 27th, 1995 and involved the intensive examination of approximately 150 acres and a visual reconnaissance of another 200 acres that were too steep for access on the southeast escarpment of Trail Mountain.

A copy of the resulting report titled: **Cultural Resource Evaluation of an Escarpment & Talus Zone at the Entrance to Cottonwood Canyon in Emery County, Utah.** is attached. The results of the inventory indicate that no historic or prehistoric cultural loci were observed or identified. No diagnostic isolated artifacts were observed or collected from the project area. No paleontological loci were observed or recorded during the evaluation.

IMPACT ASSESSMENT

Full extraction longwall mining beneath the Castlegate Sandstone escarpment in the vicinity of the 5th East longwall panel resulted in the failure of the escarpment face (see Photo #2 and Drawing #1705D). The maximum distance the talus traveled from the base of the Castlegate Sandstone escarpment was approximately 500 feet on an 30 degree slope (See Drawing # TMS1721A). The talus deposition zone covers approximately 3.5 acres.

The greatest impact resulting from Castlegate Sandstone escarpment failure and talus deposition zone in the vicinity of the 5th East longwall panel was the destruction of the pinyon-juniper/mixed conifer communities. Grasses and forbs have already began to re-establish themselves within the area of disturbance. The Hedysarum population was not in the path of talus deposition and was therefore unaffected.

No boulders or debris made it to the intermittent stream in Cottonwood Canyon. If any increase in suspended solids has occurred as a result of runoff from the talus deposition area, it has not been of any notable consequence, particularly because this stream is not known to support any fish, macroinvertebrate or amphibian species.

Grazing was not affected by the escarpment failure and talus deposition as grazing is limited, in the area where talus deposition occurred, by the steepness of the slopes.

Impacts to wildlife will primarily affect mule deer and elk as 3.5 acres of wintering lands have been temporarily destroyed. The fishery associated with Straight Canyon is approximately one mile from the area of talus deposition zone. It is very unlikely that any increased sediment load has or will be experienced by the fishery as a result of the Castlegate Sandstone escarpment failure.

The most significant impact of the escarpment failure is to the visual aesthetics of the area. The area is visible at various locations along Highway 29; which is the major access route to Joe's Valley Reservoir. However, the failure does not appear to be out place since failure of the Castlegate Sandstone escarpment is a natural occurance facilitated by the erosional forces of nature. This process has been slowly occurring for thousands of years, mining underneath the Castlegate Sandstone accelerates the failure process.

Rock climbing sites have been noted in the vicinity of the Castlegate Sandstone escarpment. For the most part these sites have been left intact. However, signs warning of the potential rockfalls in the this area are in place to protect would be rock climbers from rockfall hazards and will remain in place for some time.

No cultural resources have been affected by escarpment failure.

CONCLUSIONS

Full extraction longwall mining beneath the Castlegate Sandstone escarpment results in escarpment failure and deposition of talus. The extent of failure associated with the Trail Mountain Mine 5th East longwall panel was minimal. The most significant impacts associated with the extraction of the Trail Mountain longwall panel was the affect on visual resources, recreation, and mule deer and elk winter habitat.

REFERENCE MATERIAL & MAPS

- Appendix A: Cultural Resource Evaluation of an Escarpment & Talus Zone at the Entrance to Cottonwood Canyon in Emery County, Utah
- Appendix B: Environmental Assessment for PacifiCorp dba Utah Power & Light Right-of-Way Application UTU-70447, EA No. 067-95-1 1.
- Maps: Drawing # TMS1705D Trail Mountain Mine: Escarpment Modeling Study 1997
  Drawing # TMS1721A Trail Mountain Mine: Escarpment Study Cross Section
- Photos TRAIL MOUNTAIN MINE: 5TH EAST CASTLEGATE STUDY AREA - 12/96

REFERENCES

1 Atwood, Duane et al. 1991. Utah Endangered, Threatened and Sensitive Plant Field Guide, USFS Intermountain Region, Ogden, Ut.

2 Dalton, L.B., J.S. Price and L.A. Romin. 1990. Fauna of Southeastern Utah and Life Requisites Regarding Their Ecosystems. Publication No. 90-1 1, Division of Wildlife Resources in cooperation with Utah Department of Natural Resources. Salt Lake City, Ut.

3 Hauck, F.R. 1995. Cultural Resource Evaluation of an Escarpment & Talus Zone at the Entrance to Cottonwood Canyon in Emery County, Utah. Prepared for Energy West (UPL-95-5). Archeological-Environmental Research Corporation, Bountiful, Ut.

4 USDA, Forest Service. 1986. Land and Resource Management Plan, Manti-La Sal National Forest, USFS Intermountain Region, Ogden, Ut.

5 USDI, Bureau of Land Management, San Rafael Resource Area. 1988. Cottonwood Mine Escarpment Study, Cottonwood Coal Mine - Emery County, Ut.

6 1991. San Rafael Final Resource Management Plan. Moab District Office. Moab, Ut.

7 1995. Environmental Assessment for PacifiCorp dba Utah Power & Light Right-of-Way Application UTU-70447, EA No. 067-95-1 1.

CULTURAL RESOURCE EVALUATION

OF ESCARPMENTS

IN THE RILDA CANYON LOCALITY

OF EMERY COUNTY, UTAH

Report Prepared for Energy West Mining Company

AERC Project 1579 (EWM-97-1)

Utah State Project No.: UT-97-AF-0487f

Principal Investigator
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Author of the Report
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ARCHEOLOGICAL-ENVIRONMENTAL RESEARCH CORPORATION

181 North 200 West, Suite 5
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August 11, 1997

ABSTRACT

A cultural resource evaluation has been conducted for Energy West Mining Company of a series of escarpment locations situated in Rilda Canyon, Emery County, Utah. Surface areas involved in this study are administered by Price Ranger District of the Manti-LaSal National Forest. This series of evaluations involved initial reconnaissance conducted by Glade Hadden on July 17, and intensive escarpment investigations performed by Glade Hadden and Brian Mueller on August 7, 1997. The intensive field investigations included ca. 27 acres within this canyon.

No previously recorded significant or National Register eligible cultural resources will be adversely affected by the proposed development.

No diagnostic isolated artifacts were collected or observed during the evaluation.

No historic or prehistoric cultural resource loci were identified and recorded during the evaluations.

No newly identified paleontological loci were discovered during the examination.

AERC recommends project clearance based on adherence to the stipulations noted in the final section of this report.

TABLE OF CONTENTS

LIST OF MAPS OF THE PROJECT AREA

GENERAL INFORMATION

On July 17, 1997, AERC archaeologist, Glade Hadden conducted a remote reconnaissance cultural resource evaluation for Energy West Mining Company (hereafter EWMCo) involving the escarpment and talus slope zone in the North Rilda Lease Area associated with Rilda Canyon in Emery County, Utah (see Maps 1 and 2). Forest Service (Price Ranger District of the Manti-LaSal National Forest) and Division of Oil, Gas, and Mining (DOGM) requirements relative to the development of the North Rilda Lease Area included a request for assessment of any escarpment zones that could contain significant cultural resources that would be endangered by mining related escarpment/surface failure. Accordingly, EWMCo requested that AERC conduct an assessment of potential resource areas within the project area that could be endangered by future subsidence. AERC's initial assessments included a Class I inventory of known cultural resources in the locality and Mr. Hadden's visual reconnaissance of the canyon walls on July 17. The visual reconnaissance from the canyon floor was used to determine whether any escarpment areas might register the potential for containing rock shelter and terrace site loci that could only be identified through an intensive (Class III) evaluation on the canyon wall.

A letter including AERC recommendations was sent to EWMCo (Robert W. Willey) and the Forest Service (Stan McDonald) on July 22 stating that four potential resource areas were identified during the July 17 reconnaissance (Hauck 1997). Two of these areas were determined to be situated on National Forest lands and two were situated on privately owned lands. AERC recommended that the two zones on federal lands be intensively evaluated and requested a determination from the Forest Service relative to initiating archaeological examinations on the private lands. After consultation among the client, Forest Service, and DOGM offices, a recommendation was subsequently returned to AERC from EWMCo that all four potential resource areas situated in the Rilda Canyon escarpments be intensively examined to determine resource presence or absence.

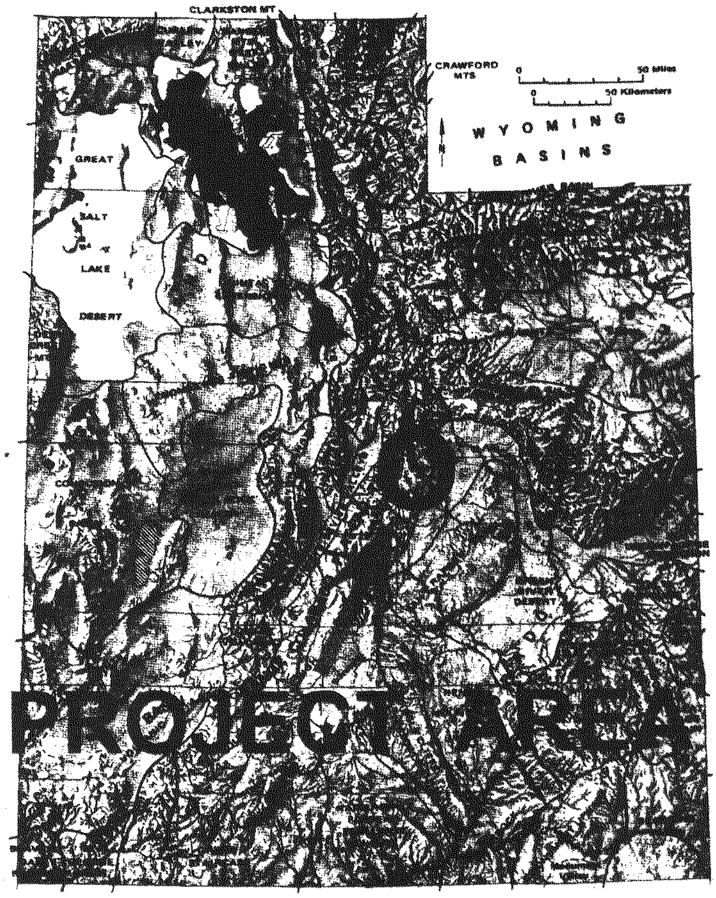
Accordingly, Glade Hadden and Brian Mueller conducted an intensive investigation of all four areas on August 7, 1997. Map 2 shows the project locality and the four areas where the archaeological evaluations were conducted. Because of the steepness of the associated slopes, the inventory of areas 3 and 4 were linked as shown on the map. About 10 acres were examined in areas 1 and 3/4 with ca. 7 acres examined in area 2. Thus, ca. 27 acres were evaluated using these methods.

The purpose of the field study and this report is to identify and document cultural site presence and assess National Register potential significance relative to established criteria (cf., Title 36 CFR 60.6). The development of the North Rilda Lease Area requires an archaeological evaluation in compliance with U.C.A. 9-8-404, the Federal Antiquities Act of 1906, the Reservoir Salvage Act of 1960-as amended by P.L. 93-291, Section 106 of the National Historic Preservation Act of 1966-as amended, the National Environmental Policy Act of 1969, the Federal Land Policy and Management Act of 1979, the Archaeological Resources Protection Act of 1979, the Native American Religious Freedom Act of 1978, the Historic Preservation Act of 1980, and Executive Order 11593.

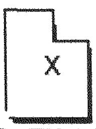
MAP 1: GENERAL PROJECT LOCALITY
IN
EMERY COUNTY
UTAH

N

PROJECT: EWM - 97 - 1
SCALE: see below
QUAD: see below
DATE: August 11, 1997



UTAH GEOLOGICAL AND MINERAL SURVEY
MAP 43 1977
PHYSIOGRAPHIC SUBDIVISIONS OF UTAH
BY W.L. STOKES



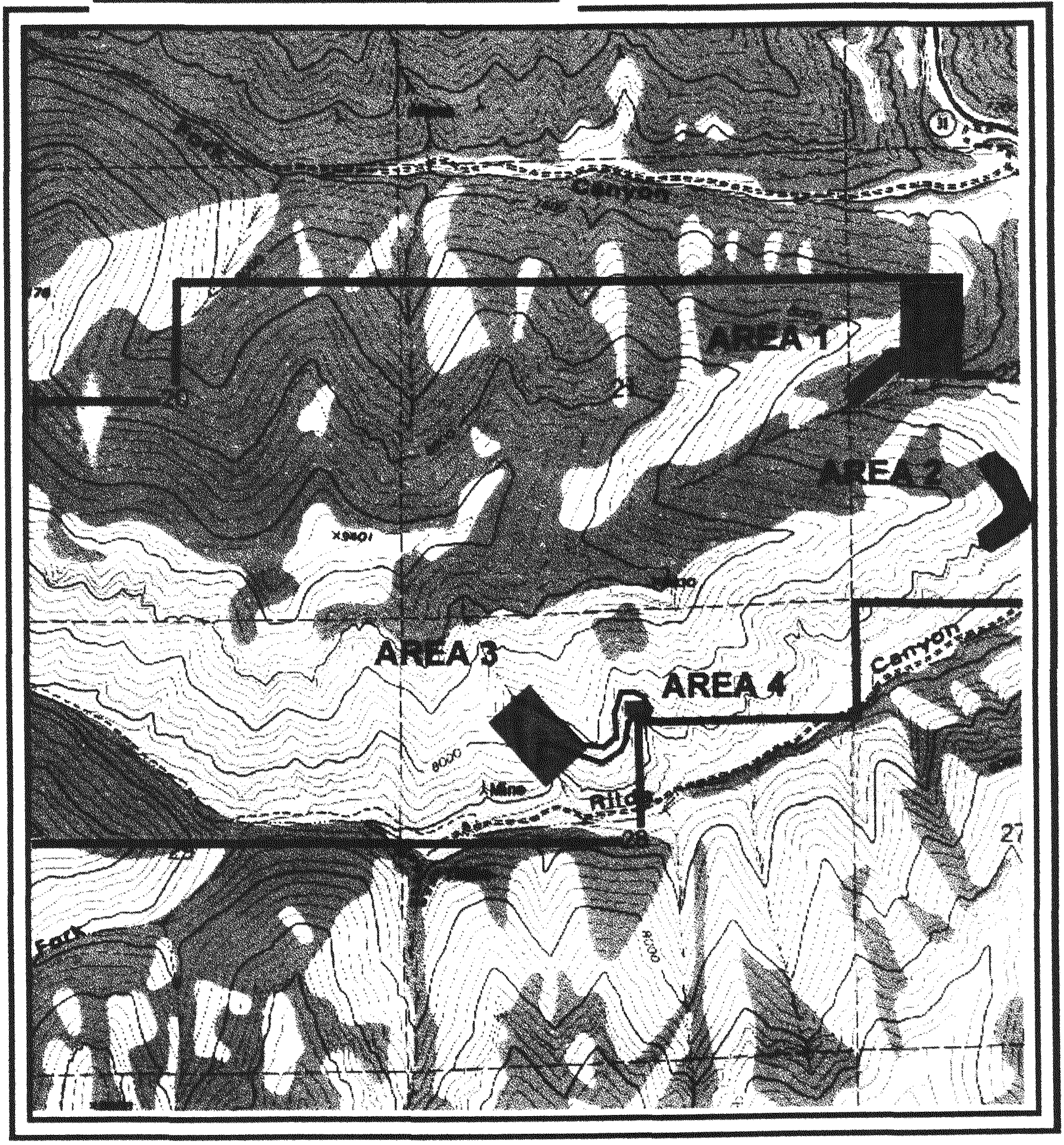
UTAH

TOWNSHIP: MULTIPLE
RANGE: MULTIPLE
MERIDIAN: SALT LAKE & UINTAH B. & M.

MAP 2: CULTURAL RESOURCE SURVEY OF POTENTIAL SUBSIDENCE/RESOURCE LOCALITIES IN THE NORTH RILDA AREA IN EMERY COUNTY, UTAH

N

PROJECT: EWM - 97 -1
SCALE: 1 : 24,000
QUAD: Rilda Canyon, Utah
DATE: August 11, 1997



LEGEND

Potential (low) Resource Area

North Rilda Area Boundary

Intensive Survey Zone

UTAH

TOWNSHIP: 16 South
RANGE: 7 East
MERIDIAN: Salt Lake B. & M.

In addition to documenting cultural identity and significance, mitigation recommendations relative to the preservation of cultural data and materials can be directed to the Utah State Historical Preservation Office, Antiquities Section and to the Manti-LaSal National Forest Supervisor's office in Price, Utah.

Project Location

The study area is situated on the talus slopes and escarpments associated Rilda Canyon on the eastern slope of East Mountain in central Utah. As Map 2 demonstrates, the four potential resource loci are situated at the 7400 to 8200 foot elevation on the south and east facing wall of Rilda Canyon situated about 200 to 1000 feet above the canyon floor. These four areas are situated in Sections 22 and 28 of Township 16 South, Range 7 East. Area 1 is in the northwest quarter of Section 22; area 2 is in the southwest quarter of Section 22; areas 3 and 4 are linked in the northwest quarter of Section 28.

The project location is located on the Rilda Canyon, Utah 7.5 minute topographic quad.

Environmental Description

The project area is situated between the 7400 and the 8200 foot elevation zone above sea level. Ponderosa/Fir stands and Aspen communities are associated with these upper terraces on Trail Mountain. Pinyon-Juniper and transitional woodlands are common to the lower slopes and terraces. Within the present project area, the vegetation communities consist of transitional woodlands and Fir/Aspen woodlands in association with the canyon walls.

The vegetation in the project area consists mainly of high elevation rangeland species including *Chrysothamnus spp., Artemisia spp., Lupinus, Achillea, Penstemon, Berberis* and a variety of grasses. Stands of Aspen *(Populus tremuloides)*, Mountain Mahogany *(Cercocarpus montanus)*, and Douglas-Fir *(Pseudotsuga menziesii)* can be found on the north-facing slopes of these canyons.

The geological associations within the project area consist of the Price River, Castlegate and Black Hawk Formations of upper Cretaceous age.

PREVIOUS RESEARCH IN THE LOCALITY

File Search

Records searches of the site files and maps at the Antiquities Section of the State Historic Preservation Office in Salt Lake City on July 11, 1997. The AERC database developed from these and other sources was also consulted for data concerning the known archaeological sites in this locality. A file search was also conducted in the Forest Service offices in Price in late July. The

National Register of Historic Places has been consulted and no registered historic or prehistoric properties will be affected by the proposed developments.

A variety of known cultural sites are situated in Cottonwood Canyon, on Trail Mountain, on East Mountain, and in Huntington Canyon to the north as reported over the years by a number of archaeologists.

Archaeological studies of importance that have been conducted in this general locality include the 1974 Forest Service preliminary excavations at Joes Valley Alcove or Site 42EM 693/1932 (DeBloois, Green, and Wylie 1979). This valuable site was found to contain stratigraphic occupations that date to the Middle and Late Archaic and Formative Stages. Recently, the University of Utah has conducted field school excavations at that same site (McDonald 1990: personal communication, Barlow and Metcalfe 1993) resulting in the discovery of cultural materials that provide pertinent information on prehistoric subsistence in the locality.

AERC has completed numerous archaeological programs within and adjacent to the present project area for Utah Power & Light Company, accomplished between 1979 and the present. The 1979 project involved both intensive surface evaluations and excavation on private and BLM administered lands on East Mountain and its associated canyons. Among the sites recorded in Cottonwood Canyon during that program, Sites 42EM 959 (Harvest Moon Shelter) and 42EM 960 (Peephole Site) were subsequently excavated by AERC (Hauck and Weder 1982). Both shelters were found to contain Archaic and Formative occupational components.

In 1980, AERC conducted a 15% sample survey program of 18,000 acres for Utah Power & Light Company in the southern portion of East Mountain. This survey resulted in the identification and reporting of cultural resource sites 42EM 1307 through 42EM 1310 and a variety of isolated artifacts which demonstrate the presence of Archaic, Formative, and Late Prehistoric occupations in the locality (Hauck and Weder 1980).

AERC returned to Cottonwood Canyon in 1983 to provide Utah Power & Light Company a preliminary assessment of significance for the Old Johnson Mines, Site 42EM 1633 (Hauck 1983b).

An intensive surface inventory (Class III) of 2280 acres on East Mountain was initiated in 1990 by AERC for Utah Power & Light Company (see Norman 1990). This study resulted in the identification and recording of three prehistoric sites (42EM 2222 through 2224) and isolated artifacts that are associated with both Archaic and Late Prehistoric activities.

During the fall of 1991, AERC conducted a 15% sample survey on Trail Mountain and in upper Cottonwood Canyon of 8,025 acres (Hauck 1991b). A total of 15 sites, 14 of them containing prehistoric components was recorded during that Class II survey. Those sites included 42EM 2258 through 42EM 2272 featuring a historic wagon trail in Cottonwood Canyon, a prehistoric hunting blind, and a variety of lithic scatters and open occupations.

In 1992, AERC completed a sample survey of the northern portion of East Mountain for Genwal Coal Company (Hauck 1992b). Seven prehistoric cultural resource activity loci (Sites 42EM 2296 through 42EM 2302) and a variety of isolated diagnostic artifacts were observed and recorded during that program. Anasazi Gray Ware (Tusayan Corrugated) vessel fragments were observed and documented on two separate high-altitude sites. The full range of diagnostic artifacts identified during this inventory demonstrate definite Late Archaic and Formative occupations within the locality.

AERC has also conducted numerous small-scale evaluations on Trail Mountain, in Huntington Canyon and on adjacent East Mountain. Trail Mountain evaluations were initiated in 1983, 1987 and, 1988 for exploratory drill locations and access routes (see Hauck 1983a, 1987, 1988a, 1988b). Several isolated artifacts were observed and recorded during several of these surveys. These artifacts include a Rose Spring arrow point (Hauck 1987) and a non-diagnostic dart point fragment (Hauck 1988b). Beginning in 1990, AERC returned to Trail Mountain to conduct surface evaluations for Utah Power & Light Company of a series of proposed coal exploratory drilling locations and access routes (Hauck 1990a, 1990b, and 1993a, 1993b). Richard Beaty identified several isolated artifacts west of North Point Spring during one of these surveys and a cultural activity locus at that spring was hypothesized on the basis of that association (Hauck 1990b). In 1991, AERC conducted a sample survey project on Trail Mountain and in Cottonwood Canyon for Utah Power involving about 1000 acres of intensive survey. A total of 15 cultural resource sites including one historic trail and wagon road was recorded including Sites 42EM 2258 through 42EM 2272 (Hauck 1991b). More recently, Sites 42EM 2330 (a lithic scatter possibly of Early Archaic derivation), 42EM 2349 (late Archaic) 42EM 2350, and several isolated artifacts have been recorded on the southern end of Trail Mountain (Hauck 1993a, 1993b).

Since 1976, AERC has conducted a total of 30 cultural resource evaluations for Utah Power & Light Company on the southern and central portions of East Mountain and in the adjacent canyons (Norman 1990:4). This firm has also initiated a roadway and well pad survey for Meridian Oil Company adjacent to the Genwal lease area (Hauck 1987), for Coal Systems/Nevada Electric Investment Company within the Genwal lease area (Hauck 1989), evaluations of the Genwal transmission line corridors in 1989 resulted in the recording of Sites 42EM 2185, 2186, and 2187 (Norman 1989), and for drilling locations on the mountain related to the development of Genwal Coal Company (Hauck 1991a).

Other firms have also initiated archaeological investigations in this general locality. A survey in Rilda Canyon resulted in the identification of Sites 42EM 1330, 1331, and 1332 (Farmer 1980). In 1982 a Class II sample survey in the Crandall Canyon and Mill Fork Canyon was initiated by Utah Archaeological Research Corporation without significant results (Cook 1982). Keith Montgomery conducted surface evaluations in 1988 for Meridian Oil Company in the bottom of Cottonwood canyon but encountered no cultural resources (Montgomery 1988). Other investigations in this locality have yielded limited results (cf., Christensen 1980, Cook 1980, Gillio 1975, Howell 1980, 1981, 1982).

Archaeological excavations in the general project area include U.S. Forest Service and University of Utah excavations at the Joes Valley Rock Shelter (Debloois, Green and Wylie 1979, Barlow and Metcalfe 1993), AERC's 1980 excavations of occupation sites 42EM 959 and 42EM 960 in Cottonwood Canyon (Hauck and Weder 1982), Forest Service test excavations at Sherman Shelter or Site 42EM 722 in Crandall Canyon (Wikle 1981, 1988) and the more recent excavations in Huntington Canyon conducted by Abajo Archaeology (Howell, Davis and Peterson 1986).

Prehistory and History of the Cultural Region

Currently available information indicates that the Wasatch Plateau and adjacent Colorado Plateau Cultural Regions have been occupied by a variety of cultures beginning perhaps as early as 10,000 B.C. These cultures, as identified by their material remains, demonstrate a cultural developmental process that begins with the earliest identified Paleoindian peoples (10,000 -- 7,000 B.C.) and extends through the Archaic (ca. 7,000 B.C. -- A.D. 300), and Formative (ca. A.D. 400 -- 1100) Stages, and the Late Prehistoric-Protohistoric periods (ca. A.D. 1200 -- 1850) to conclude in the Historic-Modern period which was initiated with the incursion of the Euro-American trappers, explorers, and settlers. Basically, each cultural stage -- with the possible exception of the Late Prehistoric hunting and gathering Shoshonean bands -- features a more complex life-way and social order than occurred during the earlier stage of development (Hauck 1991:53). For a more comprehensive treatment of the prehistory and history of the adjacent cultural area see Archaeological Evaluations in the Northern Colorado Plateau Cultural Area (Hauck 1991).

Site Potential in the Project Development Zone

Previous archaeological evaluations in the general project area have resulted in the identification and recording of a variety of cultural resource sites having eligibility for potential nomination to the National Register of Historic Places (NRHP). The majority of these sites are lithic scatters containing biface thinning and reduction materials generally procured in this highland mountain/plateau complex. Occupations are also frequently identified in this locality. Sites associated with the rock shelters on the main canyon floors and open occupations on the mountain ridges and upper slopes generally appear to have been occupied during the Middle and Late Archaic Stages with occasional indications of Formative Stage activity based on radiometric dates and the recovery of associated artifacts. The major canyons appear to have been more actively occupied during the Formative Stage by the Fremont peoples based on the Huntington Canyon and Cottonwood Canyon excavations. To-date, very sparse evidence of Late Prehistoric (Numa) activity has been documented in the general area.

Site density appears to range from zero to five sites per section based on topographic factors. Sections which feature steep slopes and narrow canyons appear to have little potential for containing significant prehistoric or historic activity loci. Sections which feature ridge tops and knolls associated with springs and seeps and sections which contain the broader canyons and valleys with flowing streams have the greatest potential for containing significant sites.

The 1991 and 1992 archaeological evaluations in the East Mountain and Trail Mountain sample units have resulted in the identification of a significantly higher site density in the upland areas than was previously recognized within this locality. The 1980 AERC sample survey of 2705 acres on the southern portion of East Mountain resulted in the discovery of three prehistoric sites for a Site/Acre Ratio of 1:760 (cf., Hauck and Weder 1980). In 1990, AERC returned to East Mountain and completed a 2280 acre intensive survey on the central portion of the mountain spine. That study resulted in the documentation of four sites for a Site/Acre Ratio of 1:676 (cf., Norman 1990). The 715 acres associated with the 1991 Trail Mountain highland sample unit study contained a total of 11 prehistoric sites resulting in a Site/Acre Ratio of 1:65. This statistic suggests that in comparison with East Mountain, Trail Mountain has 10 times the site density (Hauck 1991c:27). (For additional information on Site/Acre Densities in other regions see Hauck 1991b).

FIELD EVALUATIONS

Methodology

The intensive evaluation of the ca.27 acres associated with the four Rilda Canyon escarpment and talus slope areas consisted of the archaeological team walking a series of 10 to 15 meter-wide transects throughout each potential resource area as shown on Map 2.

Observation of cultural materials results in intensive examinations to determine the nature of the resource (isolate or activity locus). The analysis of each specific cultural site results in its subsequently being sketched, photographed, and appropriately recorded on standard Intermountain Antiquities Computer System (IMACS) forms.

Cultural sites are then evaluated by the Principal Investigator for depth potential utilizing AERC's portable ground penetrating radar (GPR) computerized system (SIR-2 manufactured by Geophysical Survey Systems, Inc. [GSSI] of North Salem, New Hampshire). Radar assessment within archaeological sites is accomplished by one team member pulling the radar antenna across the site's surface while the Principal Investigator "reads" data directly observable on a battery powered computer's monitor that is directly linked to the antenna. GPR is a valuable tool for determining the presence and density of any buried materials, features or strata whether cultural or natural, but it is particularly valuable in ascertaining archaeological depth potential on a site because it provides an immediate view on the computer's monitor of the buried strata and features. In addition, ground penetrating radar is a non-intrusive and non-destructive method of verifying site depth potential -- an important consideration in ensuring the protection and integrity of the rare, non-replaceable, non-renewable cultural resources.

With depth of deposit and feature/strata information provided by GPR, the standards described in the section below are used by the Principal Investigator to establish site significance.

GPR data reflecting the buried potential of the resource coupled with the Principal Investigator's surface evaluation of the site results in the determination whether a particular site is a significant resource, i.e., whether it satisfies one or more of the criteria established in Title 36 CFR 60 as explained below. The Principal Investigator then develops one or more mitigation actions as recommendations that can aid federal and state cultural resource administrators in facilitating the preservation of any given significant resource which may be situated within the potential development zone.

Site Significance Criteria

Prehistoric and historic cultural sites which can be considered as eligible for nomination to the National Register of Historic Places have been outlined as follows in the National Register's Criteria for Evaluation as established in Title 36 CFR 60.6:

The quality of significance in American ... archaeology ... and culture is present in ... sites ... that possess integrity of location, design, setting, materials, workmanship, feeling, and association and:

a. That are associated with events that have made a significant contribution to the broad patterns of our history; or

b. that are associated with the lives of persons significant in our past; or

c. that embody the distinctive characteristics of a type, period, or method of construction ... ; or

d. that have yielded, or may be likely to yield, information important in prehistory or history.

In addition to satisfying one or more of these general conditions, a significant cultural resource site in Utah will generally be considered as being eligible for inclusion in the National Register if it should advance our current state of knowledge relating to chronology, cultural relationships, origins, and cultural life ways of prehistoric or historic groups in the area.

In a final review of any site's cultural significance, the site must possess integrity and at least one of the above criteria to be considered eligible for nomination to the National Register of Historic Places.

Results of the Inventory

No previously recorded cultural sites will be adversely affected within this project area.

No historic or prehistoric cultural loci were observed or identified within the four intensive survey areas and there exists little to no potential for significant resources within all the other talus slope and escarpment areas in the North Rilda Lease Area.

No diagnostic isolated artifacts were observed or collected from the project area.

No paleontological loci were observed or recorded during the evaluation.

CONCLUSION AND RECOMMENDATIONS

There is no potential for significant cultural resources within the four potential areas (areas 1 through 4) involved in this evaluation.

AERC recommends that a cultural resource clearance be granted to Energy West Mining Company based upon adherence to the following stipulation: the authorized official should be consulted should cultural remains from subsurface deposits be exposed as a result of subsidence activities related to future mining development within the North Rilda Lease Area.

F. Richard Hauck, Ph.D.
President and Principal
Investigator

REFERENCES

Barlow, K.R. and D. Metcalfe

1993 1990 Archaeological Excavations at Joes Valley Alcove. University of Utah Archaeological Center, Reports of Investigations 93-1. University of Utah, Salt Lake City.

Christensen, Diane

1980 Archaeological Reconnaissance for Proposed Coal Mine Expansions in and Near Huntington Canyon, Emery County, Utah. Utah Archaeological Research Corporation, Provo.

Cook, Clayton W.

1980 Archeological Reconnaissance of Ten Drill Hole Locations in the Huntington Canyon and Clear Creek Areas, Emery County, Utah. Utah Archaeological Research Corporation, Provo.

1982 Class I and Class II Survey of the Beaver Creek Coal Company Huntington Canyon No. 4 Mine Emergence Lease Tract, Crandall Canyon, Emery County, Utah. Utah Archaeological Research Corporation, Provo.

Debloois, Evan I., Dee Green, and Jerry Wylie

1979 Joes Valley Alcove: An Archaic-Fremont Site in Central Utah. U.S. Forest Service, Ogden. Manuscript on file.

Farmer, T. Reid

1980 Archeological Survey of Rilda Canyon Mine Complex. Science Applications, Inc., Boulder.

Gillio, David

1975 Archeological Survey of Crandall Canyon Mine Road. Letter to Forest Supervisor, Manti-LaSal National Forest from the Fishlake Forest Servicee Offices, Richfield.

Hauck, F.R.

1979a An Intensive Inventory of the Proposed UPL Cottonwood Creek-Wilberg Mine Portal. Report Prepared for Utah Power and Light Company (UPL-79-5). Archeological-Environmental Research Corporation, Bountiful.

1979b Cultural Resource Evaluation in Central Utah - 1977. Cultural Resource Series, No.3, Bureau of Land Management, Salt Lake City.

1983a Cultural Resource Evaluations of Three Proposed Exploratory Drilling Locations in the Trail Mountain Locality of Emery County, Utah. Report Prepared for Natomas Coal Company (NCC-83-1). Archeological-Environmental Research Corporation, Bountiful.

1983b Addendum to AERC Paper No. 22, "Archeological Sample Survey and Cultural Resource Evaluations of the East Mountain Locality in Emery County, Utah." Report prepared for Utah Power & Light Company (UPL-83-2). Archeological-Environmental Research Corporation, Bountiful.

1987a Cultural Resource Examination of Three Proposed Coal Exploratory Well Locations in the Trail Mountain Locality of Emery County, Utah. Report Prepared for the Trail Mountain Coal Company (TMCC-87-1). Archeological-Environmental Research Corporation, Bountiful.

1987b Cultural Resource Evaluation of a Proposed Well Location, Gravel Barrow Area, and Access Route Alignments in the East Mountain Locality of Emery County, Utah. (MOC-87-1) Archeological-Environmental Research Corporation, Bountiful.

1988a Cultural Resource Evaluation of a Proposed Exploratory Well - TM-DH-4 - in the Trail Mountain Locality of Emery County, Utah. Report Prepared for the Beaver Creek Coal Company (BCCC-88-1). Archeological-Environmental Research Corporation, Bountiful.

1988b Cultural Resource Evaluation of Nine Exploratory Well Locations and Access Routes in the Trail Mountain Locality of Emery County, Utah. Report Prepared for the Beaver Creek Coal Company (BCCC-88-2). Archeological-Environmental Research Corporation, Bountiful.

1989 Cultural Resource Evaluation of Proposed Coal Exploration Drill Locations in the East Mountain Locality of Emery County, Utah. Report Prepared for Nevada Electric Investment Company/Coal Systems, Inc. (CSI-89-1). Archeological-Environmental Research Corporation, Bountiful.

1990a An Archeological Evaluation of Six Proposed Coal Exploratory Locations and Associated Access Routes in the Trail Mountain Locality of Emery County, Utah. Report Prepared for the Utah Power & Light Company (UPL-90-1). Archeological-Environmental Research Corporation, Bountiful.

1990b Cultural Resource Evaluation of Two Proposed Coal Exploratory Locations on Trail Mountain in Emery County, Utah. Report Prepared for the Utah Power & Light Company (UPL-90-4). Archeological-Environmental Research Corporation, Bountiful.

1990a Cultural Resource Evaluation of A Proposed Coal Exploratory Well Location in the Horse Canyon Locality on East Mountain in Emery County, Utah. Report Prepared for the Genwal Coal Company (GCC-91-1). Archeological-Environmental Research Corporation, Bountiful.

1991b Archaeological Evaluations on the Northern Colorado Plateau Cultural Area, AERC Paper No. 45, Archeological-Environmental Research Corporation, Bountiful.

1991c Prehistoric Occupations in the Trail Mountain Locality of Emery County, Utah, AERC Paper No. 48, Archeological-Environmental Research Corporation, Bountiful.

1992a Archaeological Excavations in the Rilda Canyon Locality of Huntington Canyon in Emery County, Utah. AERC Paper No. 51, Archeological-Environmental Research Corporation, Bountiful.

1992b A Class II Cultural Resource Evaluation of Sample Units in the East Mountain Locality of Emery County, Utah. AERC Paper No. 53, Archeological-Environmental Research Corporation, Bountiful.

1993a Cultural Resource Evaluation of Seven Proposed Exploratory Drilling Locations & Access Routes in the Trail Mountain Locality of Emery County, Utah. Prepared for Energy West (UPL-93-7). Archeological-Environmental Research Corporation, Bountiful.

1993b Cultural Resource Evaluation of Thirteen Proposed Exploratory Drilling Locations & Access Routes in the Trail Mountain Locality of Emery County, Utah. Prepared for Energy West (UPL-93-14). Archeological-Environmental Research Corporation, Bountiful.

1993c Cultural Resource Evaluation of a Proposed Portal Area in the Cottonwood Canyon Locality of Emery County, Utah. Prepared for Energy West (UPL-93-17). Archeological-Environmental Research Corporation, Bountiful.

1995a Cultural Resource Evaluation of a Subsidence Reclamation Location on East Mountain in Emery County, Utah. Prepared for Energy West (UPL-95-4). Archeological-Environmental Research Corporation, Bountiful.

1995b Cultural Resource Evaluation of an Escarpment & Talus Zone at the Entrance to Cottonwood Canyon in Emery County, Utah. Prepared for Energy West (UPL-95-5). Archeological-Environmental Research Corporation, Bountiful.

1997 Letter of recommendations. Archeological-Environmental Research Corporation, Bountiful.

Hauck, F. R. and Glade Hadden

1994 Cultural Resource Evaluation of a Potential Subsidence Zone in the Rilda Canyon Locality of Emery County, Utah. Prepared for Energy West (UPL-94-4). Archeological-Environmental Research Corporation, Bountiful.

1995a Cultural Resource Evaluation of a Proposed Powerline Right-of-way in the Wilberg Mine/Cottonwood Canyon Locality of Emery County, Utah. Prepared for Energy West (UPL-95-1). Archeological-Environmental Research Corporation, Bountiful.

1995b Cultural Resource Evaluation of a Proposed Exploratory Drill Location in the Trail Mountain Locality of Emery County, Utah. Prepared for Energy West (UPL-95-3). Archeological-Environmental Research Corporation, Bountiful.

Hauck, F.R.. and G. Norman

1989 Cultural Resource Evaluation of Genwal Transmission Line Alternative Corridors in the Huntington Canyon Locality of Emery County, Utah. Report Prepared for Utah Power & Light Company (UPL-89-3), Archeological-Environmental Research Corporation, Bountiful.

1990 Archaeological Studies on East Mountain: A Prehistoric Highland-Lowland Occupation Hypothesis. AERC Paper No. 46, Archeological-Environmental Research Corporation, Bountiful.

Hauck, F.R. and D. Weder

1980 Archeological Sample Survey and Cultural Resource Evaluations of the East Mountain Locality in Emery County, Utah. AERC Paper No. 22, Archeological-Environmental Research Corporation, Bountiful.

1982 Archeological Excavations in Cottonwood Canyon, Emery County, Utah. AERC Paper No. 37, Archeological-Environmental Research Corporation, Bountiful.

Holmer, Richard N.

1978 A Mathematical Typology for Archaic Projectile Points in the Eastern Great Basin. Dissertation, University of Utah Department of Anthropology, Salt Lake City.

Holmer, Richard N. and Dennis Weder

1980 Common Post-Archaic Projectile Points of the Fremont Area. Antiquities Section Selected Papers, Volume VII, No. 16, Division of State History, Salt Lake City.

Howell, Wayne

1980 Archeological Reconnaissance in the Crandall Canyon Vicinity, Emery County, Utah. Utah Archaeological Research Corporation, Provo.

1981 Archeological Reconnaissance of a Proposed Seismic Line and Velocity Hole on Mill Fork Ridge, Emery County, Utah. Utah Archaeological Research Corporation, Provo.

1982 DOE Cultural Resource Inventory of Highway 31 Improvement Project in Huntington Canyon, Emery County, Utah. Utah Archaeological Research Corporation, Provo.

Howell, Wayne, William E. Davis, and Michael Peterson

1986 Cultural Resource Inventory of the Utah Department of Transportation Highway 31 Improvement Project in Huntington Canyon, Emery County, Utah. Abajo Archaeology, Bluff.

McDonald, Stan

1990 Personal Communication.

1991 Personal Communication -- letter to AERC dated December 19, 1991.

Montgomery, Keith

1988 Cultural Resource Inventory of Expansions and Alterations of the Proposed Meridian Well Location East Mountain No. 3223, Associated Access Route and Materials Borrow Area in Cottonwood Canyon, Emery County, Utah. Abajo Archaeology, Bluff. Manti-LaSal National Forest CRM Report No. ML-88-477. Manuscript on file at the Forest Supervisor's Office, Price, Utah.

Stokes, William Lee

1977 Subdivisions of the Major Physiographic Provinces in Utah. Utah Geology, Vol. 4, No. 1, Utah Geological and Mineral Survey. Salt Lake City.

U.S. Geological Survey

n.d. Chart - Normal Annual and May-September Precipitation 1931 - 1960 for the State of Utah.

Wikle, Les

1981 Crandall Canyon (Genwal Coal Company) Road Proposal, Manti-LaSal National Forest. (Sherman Shelter 42EM 722 test excavation) Monticello Ranger District Cultural Resource Report 81-1, Monticello.

1988 Crandall Canyon Coal Lease Survey #U-54762. Cultural Resource Report No. ML-89-0491, Monticello.

ENVIRONMENTAL ASSESSMENT

for the

Underground Accessway
and
Undermining of Escarpment

Trail Mountain Mine

Emery County, Utah

USDA, Forest Service, Region 4
Manti-La Sal National Forest
Ferron/Price Ranger District

Responsible Officials: Janette S. Kaiser, Forest Supervisor
USDA, Forest Service
Manti-LaSal National Forest
599 West Price River Drive
Price, Utah 84501

and

Mark Bailey, Area Manager
Price River Resource Area
125 S. 600 W
Price, Utah 84501

Cooperating Agency: Office of Surface Mining
Reclamation and Enforcement
1999 Broadway, Suite 332
Denver, Colorado 80202

For Further Information Contact: Jeff DeFreest, District Geologist
Ferron/Price Ranger District
Manti-La Sal National Forest
599 W. Price River Drive
Price, Utah 84501

Environmental Assessment
Underground Accessway
and
Undermining of Escarpment

Trail Mountain Mine

PURPOSE AND NEED FOR ACTION

A. Introduction

PacifiCorp has submitted a revised Resource Recovery and Protection Plan and Mine Plan Amendment to increase coal recovery at their Trail Mountain Mine on Trail Mountain, Emery County. The proposal includes extending the 4th and 5th East longwall panels to the east under the west canyon cliff or escarpment of Cottonwood Canyon, which will cause subsidence, and potentially trigger rock falls or slides. They have also applied for a Forest Service special-use permit to allow them to drive underground accessways under unleased National Forest System lands to allow increased coal recovery in longwall panels planned within the mine permit area (leased lands). Map A shows the respective locations.

B. Decision to be made

The Forest Supervisor, Manti-La Sal National Forest, must decide whether or not to consent to the Resource Recovery and Protection Plan and resulting Mine Plan amendment by the Bureau of Land Management and Utah Division of Oil, Gas and Mining under the Mineral Leasing Act of 1920, as amended; Coal Leasing Amendments Act of 1975; and Surface Mining Control and Reclamation Act of 1977. This involves the granting of an exception to a stipulation attached to the lease. Additionally, the Forest Supervisor must decide whether or not to issue a Forest Service special-use permit for the proposed underground accessways under the Federal Land Policy and Management Act of 1976.

C. Description of the Land

Cottonwood Canyon is a drainage between Trail Mountain and East Mountain. The project area is within Federal Coal Lease U-64375 on the southeast flank of Trail Mountain.

D. Coal Mining History and Relationship to Adjacent Workings

Lease U-64375 is included within the permit area for the Trail Mountain Mine. Mining at what is now known as the Trail Mountain Mine was initiated in 1898, becoming the Johnson Mines in 1909, which operated 3 mines through 1948. In 1946, 3 additional mines were opened in the vicinity, and activity at the Trail Mountain Mine continued through 1967. After a 10 year shutdown, it was reopened under the ownership of Mr. John Bell. The mine was then purchased by the Fetterolf Group in 1979, and operated until it was sold to Natomas Trail Mountain Coal Co. in 1981. The property was subsequently purchased and operated by: Diamond Shamrock, Arch Minerals Corp, Beaver Creek Coal Co, and finally purchased by PacifiCorp in 1992. It is currently owned and operated by PacifiCorp and its subsidiary company, Energy West.

Underground mining facilities within the lease include main entries for access within the Trail Mountain Mine. There are no surface facilities. All mining within the lease has been within the Hiawatha seam.

The Forest Service prepared an Environmental Analysis for the lease, U-64375, but the surface facilities are on fee (private) land.

Operations on this lease have been authorized under the approved Trail Mountain Mine Mining and Reclamation Plan (MRP). Subsidence and hydrologic monitoring are being conducted under the MRP. These documents are contained in the Forest Service project files and can be referred to for additional information.

E. Scoping

The project scoping was initiated on January 19, 1996. Scoping letters were sent to identified interested parties, a scoping package was routed through the Supervisor's Office and Ferron-Price Ranger District, and a legal notice was submitted for publication in the Sun Advocate in their January 23 issue.

Notice of preparation of this environmental assessment was printed in the Sun Advocate newspaper. Letters were also sent to the individuals and organizations listed in the project file. These concerns have been considered during preparation of this document. Intensity of public interest was relatively low, since only seven letters were received, and of those, four were from government agencies. Copies of these letters are included in the project file.

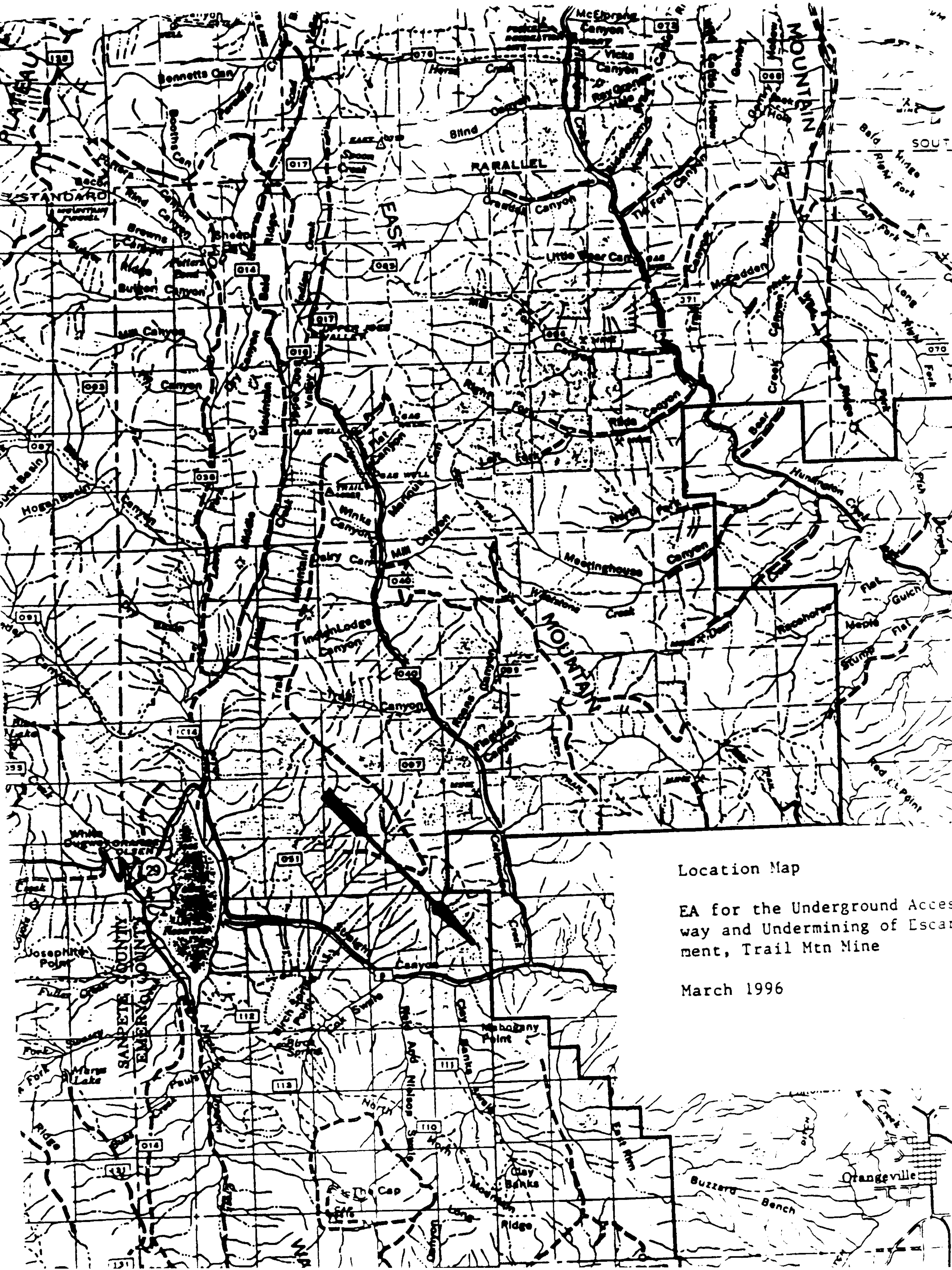
Three people interested in or affected by the proposed action responded by contacting the Ranger with their concerns.

Mr. Kenneth May, Vice President and General Manager for Southern Utah Fuel Co, commented on his company's success in undermining escarpments with only minor impact to similar terrain at the southern end of the Wasatch Plateau on their Quitchupah tract.

Mr. Eugene Johansen, Chairman, Emery Water Conservancy District and Mr. Kent Petersen, Chairman, Emery County Board of Commissioners, shared concerns over water issues which include:

What effect will this mining operation have on water in Joe's Valley Reservoir?

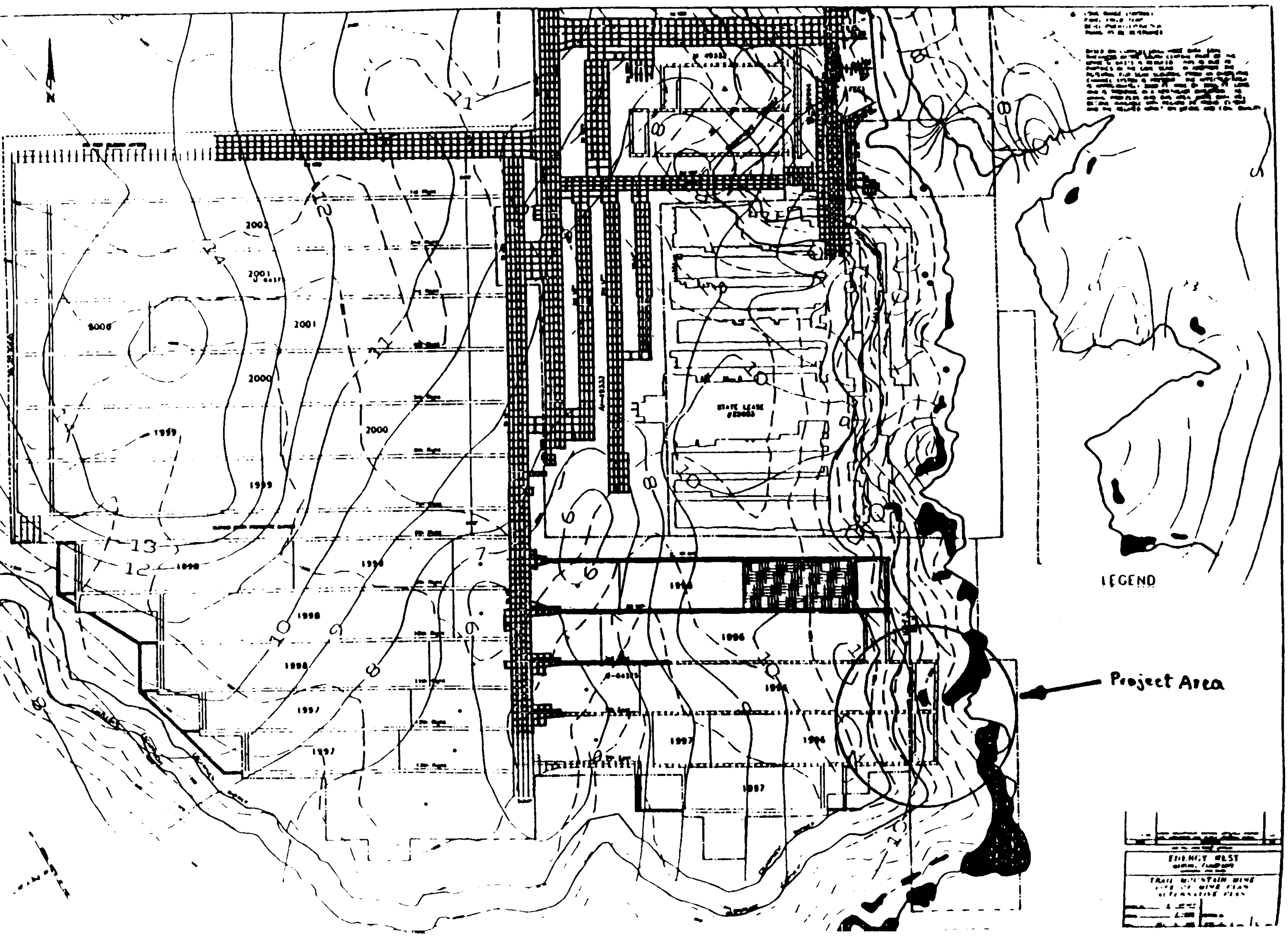
Will the mine operators be held responsible for replacement of culinary, domestic, wildlife, livestock, and agricultural waters?



Location Map

EA for the Underground Acces[illegible] way and Undermining of Escar[illegible] ment, Trail Mtn Mine

March 1996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Four agencies interested in or affected by the proposed action responded by contacting the Ranger with issues and concerns.

The Utah Division of Wildlife Resources had comments addressing raptor nesting habitat, though no nests are recorded in the potentially affected area. They requested that if nests were encountered, that we require work to be halted until mitigation measures could be accomplished as determined by their agency in cooperation with the USFWS.

The Utah Division of Oil, Gas, and Mining commented that the proposed mining would require an amendment to the current mining and reclamation plan.

The Utah Department of Transportation expressed concern over the potential rockfall hazard to motorists on SR-29 (road to Joe's Valley Reservoir).

The Office of Surface Mining requested an opportunity to participate in the analysis as a cooperating agency, and have the opportunity to review and provide comments on preliminary NEPA documents prepared for this project.

In addition to the above concerns, the following concerns/issues were identified by the ID Team for evaluation in this environmental assessment.

Subsidence of the steep canyon escarpment could dislodge sections of the Castlegate Sandstone outcrop.

Rockfalls could destroy vegetation on the canyon slope. Sensitive plant species Hedysarum Occidentalis var. canone occurs along the canyon slope.

Rockfalls could reach the Cottonwood Canyon road presenting a potential hazard to motorists, hunters, and rock climbers in the area, and damage road facilities.

Rockfalls may alter the existing visual landscape as viewed from the Cottonwood Canyon Road, State Hwys. 29 and 10, and the town of Orangeville.

Rockfalls could destroy vegetation along the canyon slope, resulting in an increase in sediment in Cottonwood Canyon. Large rocks/boulders rolling downslope into the creek could change stream channel morphology.

Protection of escarpment integrity could cause loss of recoverable coal reserves and could affect maximum economic recovery and result in loss of royalties to the Federal government.

F. Issues

On March 1, 1996, the Forest Supervisor approved the following issues. Each issue statement includes an evaluation criteria or method to measure responsiveness (effects) to the issue. The following significant issues (40 CFR 1500.4 (g), FSH 1909.15 12.3) will be used to focus the environmental analysis, develop alternatives to the proposed action, and develop measures to mitigate and monitor anticipated environmental effects.

A. Potential rockfall hazard to motorists on SR-29 (road to Joe's Valley Reservoir).

Evaluation Criteria

PacifiCorp has applied the Colorado Rockfall Simulation Program. The simulation shows that a 20 foot diameter boulder dislodged from the Castlegate Sandstone could roll down to the road. Risk (probability of failure) and potential mitigation measures will be discussed with the UDOT engineer.

B. Rockfalls may alter the existing visual landscape as viewed from the Cottonwood Canyon Road, State Hwys. 29 and 10, and the town of Orangeville.

Evaluation Criteria

The landscape architect evaluated the area potentially subject to failure relative to forest plan visual quality objectives (VQO). The predicted area of the potential failure lies primarily in an area designated as modification. BLM has a similar visual constraint called VRM Class III. An edge of the potential failure at the south end of the proposed project area on Forest Service lands may lie within an area designated as retention. Given the anticipated small magnitude of this scar, and its position relative to highway 29, it will not be noticeable from this sensitive corridor. Distant views from Orangeville and Highway 10 will remain natural in appearance.

The potential failure area will be analyzed considering impacts to the visual elements: form, color, texture, and line.

C. Protection of escarpment integrity could cause loss of recoverable coal reserves and could affect Maximum Economic Recovery and result in loss of royalties to the Federal government.

Evaluation Criteria

The BLM is preparing a an analysis of the coal that would be bypassed and the associated value of lost royalties.

D. Threatened, Endangered, or Sensitive wildlife and plant species (FSM 2670)

Rockfalls destroy vegetation on the canyon slope. Sensitive plant species Hedysarum Occidentalis var. canone occurs along the canyon slope.

Evaluation Criteria
Individuals and habitat effected.

ISSUES RAISED BUT NOT ANALYZED IN FURTHER DETAIL

These issues were either resolved through minimal analysis, mitigation, or found to be outside of the scope of this analysis.

E. Heritage resources (FSM 2360)

The proposed action may impact existing or eligible National Historic Register sites. (project file)

Evaluation Criteria
The area has been surveyed, and no known sites have been identified.

F. Subsidence of the steep canyon escarpment could dislodge sections of the Castlegate Ss. outcrop.

Evaluation Criteria
Rockfall in itself was decided not to be an issue, but effects related to rockfall were analyzed in other issue statements (A, B, G, H).

G. Rockfalls could reach the Cottonwood Canyon road presenting a potential hazard to motorists, hunters, and rock climbers in the area and damage road facilities.

Evaluation Criteria
The Colorado Rockfall Simulation Program (CRSP) was applied to determine if rocks of a given size would roll on the existing slope to the road. The model was calibrated to a rock slide associated with mining in similar geology to establish its validity and to establish the rock size to run the model.

Data provided to the Forest Service by PacifiCorp (Trail Mtn. Mine) suggests that rocks dislodged from the Castlegate Escarpment would not roll as far as the Cottonwood Canyon road, primarily because they would be funnelled into local topography, and then not have enough kinetic energy remaining to continue down the main slope.

Lastly there is some potential for rockfalls reaching areas traditionally used by rock climbers, hunters, and other recreationalists, at the base of the escarpment on the Cottonwood Canyon side.

H. **Rockfalls could destroy vegetation along the canyon slope, increase sediment in Cottonwood Canyon and large rocks/boulders could change stream channel morphology in Cottonwood Creek.**

Evaluation Criteria

The CRSP predicts few rocks would roll that far given the terrain. Since the BLM is the land management agency for the potentially impacted area, their hydrologist was consulted, the sediment was expected to increase only slightly, and a mitigation measure was suggested for the large boulder concern. If any rocks do roll as far as the creek, that may cause a diversion or change in channel morphology, the mining company will be required to remove it.

The ID team has determined that the approval of the proposed action will not cause significant adverse impacts on: wetlands, floodplains, and alluvial valley floors.

I. **Mr. Kenneth May, Vice President and General Manager for Southern Utah Fuel Co, commented on his company's success in undermining escarpments with only minor impact to similar terrain at the southern end of the Wasatch Plateau, at their Quitchupah tract.**

Evaluation Criteria

These comments were considered in conjunction with Forest Service observations made in the Quitchupah area. The evaluation of the minor effects is a valid but subjective in nature.

J. **Mr. Eugene Johansen, Chairman, Emery Water Conservancy District and Mr. Kent Petersen, Chairman, Emery County Board of Commissioners, shared concerns over water issues. What effect will this mining operation have on water in Joe's Valley Reservoir? Will the mine operators be held responsible for replacement of culinary, domestic, wildlife, livestock, and agricultural waters?**

Evaluation Criteria

A phone contact was made with Jay Humphrey of the Emery Water Conservancy District on Friday February 23, 1996 to discuss their concerns. He indicated that Mr Johansen did not address the proposals specifically suggested in the scoping letter. Mr. Humphrey acknowledged that their issues relative to the proposal at hand were addressed in the EA for the lease tract originally done in 1990. Mr. Humphrey did however express concern over the Lease By Application also proposed by PacifiCorp, for Trail Mtn Mine, and its potential effects on Joe's Valley Reservoir and local water sources. He wished to be informed of any action taken on the LBA.

K. The Utah Division of Wildlife Resources had comments addressing raptor nesting habitat, though no nests are recorded in the potentially affected area. They requested that if nests were encountered, that we require work to be halted until mitigation measures could be accomplished as determined by their agency in cooperation with the USFWS.

Evaluation Criteria

The mine conducts helicopter surveys for raptors and nests annually, as committed to in their Mining and Reclamation Plan.

L. The Utah Division of Oil, Gas, and Mining commented that the proposed mining would require an amendment to the current mining and reclamation plan (MRP).

Evaluation Criteria

This is a question of process and not an environmental issue requiring disclosure. All applicable State and Federal law and regulation must be met prior to implementation. The operator will be required to apply for amendments to their currently approved MRP.

M. The Office of Surface Mining requested an opportunity to review and provide comments on preliminary NEPA documents prepared for this project.

Evaluation Criteria

This is a question of process and not an environmental issue requiring disclosure. The OSM is a cooperative agency.

N. Prime farmland, rangeland, and timberland could be impacted (USDA land use policy DR 9500-3 and FSH 1909.15, section 65.2).

Evaluation Criteria

The project area does not contain prime farmland, rangeland, or timberland as defined by Section 65.2 (Forest Plan, page II-57).

G. Federal Permits, Licenses, etc.

Leasing and development are under the authority of the following authorizing actions: The Mineral Leasing Act of February 25, 1920, as amended; the Federal Land Policy and Management Act (FLPMA) of 1976; the Surface Mining Control and Reclamation Act (SMCRA) of 1977; the Multiple Minerals Development Act of August 4, 1977; the Federal Coal Leasing Amendments Act of 1976, as amended; regulations: Title 43 CFR Group 3400, and Title 30 CFR Group 700; and the Manti-La Sal National Forest Land and Resource Management Plan (FLRMP) and Final Environmental Impact Statement (FEIS), 1986.

The Trail Mountain Mine has been permitted under the Surface Mining Control and Reclamation Act of 1977 by the Office of Surface Mining, Reclamation and Enforcement and the Utah Division of Oil, Gas and Mining. Other required permits have been secured by PacifiCorp under their approved Mining and Reclamation Plan.

If either alternative 2 or 3 are approved, the Forest Service would issue a Special Use Permit for the underground accessway, and DOGM would need to approve the amendment to the Mining and Reclamation Plan.

II. DESCRIPTION OF ALTERNATIVES

Based on internal and public input the Line Officer approved the following alternatives. Each alternative addresses aspects of the issues to sharply define issues and potential effects and provide a full range of alternatives. Alternatives include mitigation and monitoring to address the issues and anticipated environmental effects.

ALTERNATIVES CONSIDERED IN DETAIL

Alternative 1

Forest Service would deny consent and remain consistent with the existing lease stipulations and the approved MRP. Alternative 1 addresses the need to provide a "No Action" alternative (40 CFR 1502.14). The operator would not be permitted to mine under the escarpment, nor would the special use permit for the underground accessway be granted.

No mitigation measures or monitoring would be required as part of this alternative, beyond what is already in the mining and reclamation plan.

Alternative 2 (Preferred Alternative)

Forest Service consent to subsidence of the escarpment as proposed by PacifiCorp with an exception to the lease stipulation, and Forest Service approval of the special use permit for the underground accessway subject to conditions of approval to mitigate impacts. The Bureau of Land Management and Utah Department of Oil, Gas, and Mining would approve PacifiCorp's amended R2P2 and mining plan respectively, with Forest Service stipulations.

Mitigation

Issues A, B, D, G, H, and K are highlighted in Alternative 2. Mitigation measures designed to address these issues and lessen potential adverse environmental effects are described below.

A. The Utah Department of Transportation expressed concern over the potential rockfall hazard to motorists on SR-29 (road to Joe's Valley Reservoir).

PacifiCorp will be required to post signs approved by the Utah Dept of Transportation and the Forest Service warning of rockfall hazard and that stopping or parking in the identified portion of Highway 29 is prohibited.

PacifiCorp will be required to install prisms to establish survey points on the escarpment above Highway 29 to be monitored for possible rotation or movement as mining occurs in the 5th east panel. The intent is to establish if any movement is occurring, and whether a hazard actually exists.

PacifiCorp must conduct modelling (3-dimensional finite element or equivalent) as recommended by PacifiCorp and Dr. W.G. [illegible] (Letter to Forest Service from PacifiCorp, dated February 6, 1991; Re: South Lease Escarpment Study Geotechnical Update) to develop a workable predictive model of the potential for mining induced subsidence to cause escarpment failures. The model for the specific area of proposed subsidence must be run with sufficient detail to project a potential level of escarpment failure and must be adjusted following actual mining to best emulate the actual level of escarpment failure that occurred. A final report must then be submitted to BLM and the Forest Service that describes the prediction made, failure observed, how well the prediction conformed to actual failures, and how the model was adjusted to best conform to actual conditions on the ground and the level of failure observed. An independent/qualified scientist acceptable to the BLM and Forest Service must oversee model development.

B. Rockfalls may alter the existing visual landscape as viewed from the Cottonwood Canyon Road, State Hwys. 29 and 10, and the town of Orangeville.

PacifiCorp will be responsible to perform oblique photo monitoring before, during and after mining activities.

D. Threatened, Endangered, or Sensitive wildlife and plant species (FSM 2670)

Known populations of Hedysarum occidentale var. canon are to be monitored as mining occurs. If they are being effected the authorized officer(s) are to be notified.

G. Rockfalls could reach the Cottonwood Canyon road presenting a potential hazard to motorists, hunters, and rock climbers in the area and damage road facilities.

The area beneath the escarpment in Cottonwood Canyon is to be signed, alerting recreationalists of the rockfall hazard. Design of the sign will be presented to the Forest Service for approval before being deployed. Sign density will be determined by the authorized officer(s).

H. Rockfalls could destroy vegetation along the canyon slope, increase sediment in Cottonwood Canyon and large rocks/boulders could change stream channel morphology in Cottonwood Creek.

Any large rocks that may roll into Cottonwood Creek will be reported to the Forest Service and BLM hydrologists. If channel morphology is being threatened, PacifiCorp will be responsible to remove the rock(s) and reestablish the original morphology.

K. The Utah Division of Wildlife Resources had comments addressing raptor nesting habitat, though no nests are recorded in the potentially affected area. They requested that if nests were encountered, that we require work to be halted until mitigation measures could be accomplished as determined by their agency in cooperation with the USFWS.

The area is to be surveyed for raptor nests prior to mining commencing under the escarpment. If nests are encountered, work that could cause further subsidence, leading to escarpment failure, is to be halted until mitigation measures can be accomplished as determined by the Utah DWR and the USFWS.

Monitoring

Implementation effectiveness monitoring will be performed to determine if the mitigation measures are effective and assure the desired results are achieved.

Alternative 3

Forest Service approves only the special use permit for the underground accessway, with conditions of approval. PacifiCorp would apply for a mine plan amendment and DOGM will likely approve the amendment. This alternative would provide access to otherwise lost coal reserves.

The two longwall panels proposed to extend underneath the escarpment will need to be shortened, and there would be a loss of recoverable coal. Subsidence of the escarpment would not be permitted, and therefore the issues relating to escarpment failure: A, B, D, E, F, G, H, and K would not apply.

No special mitigation measures or monitoring would be required as part of this alternative, beyond what is already in the mining and reclamation plan.

ALTERNATIVES CONSIDERED BUT NOT GIVEN DETAILED STUDY

Alternative 4

Forest Service consent to subsidence of the escarpment as proposed by PacifiCorp, and Forest Service approval of the special use permit for the underground accessway. The Bureau of Land Management would likely approve modification of the resource recovery and protection plan (R2P2) and the Utah Department of Oil, Gas, and Mining would approve PacifiCorp's amended mining plan to achieve maximum economic recovery, and the escarpment would be undermined with a potential for localized failures.

No requirements, constraints, or mitigations would be added to those already committed to in the proposal. No additional monitoring beyond that already committed to in the approved mining and reclamation plan would be required as part of this alternative.

Alternative 5

Forest Service approves only the undermining of the escarpment, allowing for the potential failure of the escarpment. This would permit the added length on the 2 longwall panels proposed, providing for coal recovery. The special use permit for the underground right of way would be denied in this alternative, leaving some coal reserves inaccessible.

This alternative was not considered in detail because it provides no advantage over the preferred alternative.

COMPARISON OF ALTERNATIVES

The following chart has been generated to display a comparison of alternatives relative to the identified issues and concerns. The issues and concerns are listed as elements. The rating system uses high, moderate, or low to display the level of risk to public safety; tons of coal and associated roylaties for socio-economics; and whether or not it meets the forest plan and BLM visual standards. Each element is discussed in greater detail in Section III, Description of Affected Environment and Section IV, Environmental Consequences (relative to each alternative).

Resource Element	Issue Reference	Alternatives 1	2	3
Public Safety Risk	A	Low	Moderate	Low
Meets VQO	B	Yes	Yes	Yes
Socio-Economics	C			
Additional Recoverable Coal (million tons)		0	1.9	1.5
Additional Royalties (million dollars)		0	3.0	2.4
Meets Maximum Economic Recovery		No	Yes	No
Effect on TE&S Plants		None	None	None
Effect on TE&S Wildlife		None	May	None

III. DESCRIPTION OF THE AFFECTED ENVIRONMENT

Affected Environment Relative to Issues

Public Safety

Rockfalls are a frequent natural occurence in the vicinity of the Castlegate Sandstone escarpment. Occasionally rocks fall and roll onto and across the Cottonwood Canyon Road and the Straight Canyon Road (State Highway 29). These natural rockfalls are commonly triggered by natural processes such as freeze-thaw cycles, run-off, and earthquakes. Mining induced subsidence of the escarpment or land immediately adjacent to it could also contribute to rockfalls.

Visual Resources

The characteristic landform of this area is steep narrow canyons of major escarpments. Flowing parallel to FDR 040 is Cottonwood Creek which has entrenched this particular canyon. This perennial stream is bordered by a narrow riparian corridor interspersed with cottonwoods. Thin rocky soils and a relatively arid climate have resulted in an open pinyon-juniper community established primarily on the less steep slopes to the east above the creek. These coarsely textured/vegetated slopes end abruptly at the base of the dominating Castlegate Sandstone outcrop. Soil colors are light brown to tan, consistant with this eroding parent sandstone material above.

The Manti-La Sal National Forest Land and Resource Management Plan (LRMP) has assigned a Visual Quality Objective to each area of the Forest reflecting the desired management emphasis of the specific area. The BLM has assigned similar objectives, known as Visual Resource Management Classes, to the lands they manage. Some of those objectives assigned by the LRMP allow a noticeable degree of change from the existing condition as determined during the visual assessment conducted in 1986 for subsequent use in Forest management activities and planning. This flexibility was incorporated into the Forest Plan to facilitate Forest management goals.

The term Visual Quality Objective refers to the degree of acceptable visual alteration of the Landscape and may be defined as follows: A desired level of scenic excellence based on physical and sociological characteristics of an area. Typically, more stringent VQO's are incorporated to protect the most highly visible and most frequently seen areas that have the greatest amount of variety in vegetation and other features which occur naturally.

After comparing the specific limits of the project area with the Forest Plan visual quality map, it was determined that any area of potential visual impact has been designated as Modification, on Forest Service lands, and VRM Class III on the BLM lands.

Under the less stringent VQO of Modification (or VRM Class III), management activities may visually dominate the original characteristic landscape. However, activities of vegetative and landform alteration must borrow from naturally established form, line, color, or texture so completely and at such a scale that its visual characteristics are those of natural occurrences within the surrounding area or character type. Additional parts of these activities such as structures and roads must remain visually subordinate to the proposed composition. Reduction in form, line, color, and texture should generally be accomplished in the first year.

In summary; this broad objective allows for most forms of management activity including those which are visually obtrusive, however the activity (especially associated roads and structures) must be designed to fit the context of the natural surroundings.

It should be noted that scenery is an important natural resource and recreational element in parts of the forest immediately adjacent to this area. It is primarily through their visual sense that most visitors perceive the Forest and its interrelated components. The project area -- although designated in the Forest Plan as Modification

.. still has high scenic value. Part of the public appeal of the landscape found in this area stems from the viewing opportunities associated with these Castlegate Sandstone escarpments. This escarpment is readily viewed from FDR 040, which travels up Cottonwood Canyon and serves as a gateway to the forest for many recreationists.

Socio-Economics

The Trail Mountain Mine is currently operating in the project area and produces 3.5 - 4 million tons per year. Employment is a total of 275 people; 215 of which are miners and 60 individuals in management.

The BLM has determined that the current Resource Recovery and Protection Plan (R2P2) does not provide for maximum economic recovery.

TE&S Plants

No listed threatened or endangered plant species are known to occur on the areas subject to escarpment failure. However, Hedysarum occidentale var. canon, a proposed threatened plant species, does have limited habitat in Cottonwood Canyon. (project file)

I. **TE&S Wildlife**

Several non-game mammals, birds, and reptile species inhabit the lease. These species have apparently somewhat adapted to mining activities. There is also raptor habitat in the escarpment, though there are no known nests on the portion likely to be failed. There are no threatened or endangered or sensitive wildlife species occupying the project area. (project file)

IV. ENVIRONMENTAL CONSEQUENCES

The effects of the mining operation were assessed in the Environmental Assessment for Beaver Creek Coal Co. Coal Lease Application UTU-64375 Trail Mountain Tract (4/90). This document discusses the existing and potential effects from surface facilities and mining induced subsidence. This analysis was done assuming conventional, room and pillar mining operations however. No subsidence of the escarpment was to be permitted, as stipulated in the lease. Mining operations were permitted and are regulated under the Surface Mining Control and Reclamation Act of 1977 and associated Federal and State regulations and programs. Facilities have been designed and constructed in accordance with required standards. Monitoring has shown that the effects of mining, to date, are consistent with those predicted in the referenced environmental documents.

Below, each alternative is analyzed relative to the elements developed from the issues for this environmental assessment.

A. Alternative 1 - No Action Alternative, Forest Service denies consent.

1. Direct and Indirect Effects

a. Public Safety

Mining induced subsidence would not be permitted and therefore there would be no mining induced failure.

b. Visual Resources

Mining induced subsidence would not be permitted and therefore there would be no mining induced failure. Natural rockslides would continue to occur.

c. Socio-Economics

Coal reserves would be bypassed. This alternative will sterilize approximately 1.9 million tons of coal with a resulting loss of 3 million dollars in royalties. Additionally, the life of the Trail Mountain Mine will be shortened by approximately 6 months.

d. TE&S Plants

Mining induced subsidence would not be permitted and therefore potential for escarpment failure would be no greater than already predicted in the EA for the lease, resulting in no change to the effect on Threatened, Endangered, and Sensitive Plants. (project file)

e. TE&S Wildlife

Mining induced subsidence would not be permitted and therefore potential for escarpment failure would be no greater than already predicted in the EA for the lease, resulting in no change to the effect on Threatened, Endangered, and Sensitive Wildlife. (project file)

2. Cumulative Effects

Historically man's activities in the lease area have included livestock grazing, recreational use, and coal production, which have resulted in changes in the topography, vegetation, and erosion. Cumulative effects resulting from mining coal could include the effects from subsidence and the human activity from continued operations as it exists on this lease and adjacent leases. PacifiCorp is monitoring the impacts of mining on the permit area as part of the Mining and Reclamation Plan. To date, the results of monitoring in the permit area indicate that no significant impacts to surface resources have occurred from mining. There would be no change in the existing condition.

B. Alternative 2 - Forest Service consent to subsidence of the escarpment and approval of the special use permit for the underdround accessway.

1. Direct and Indirect Effects

a. Public Safety

Mining induced subsidence would be permitted and therefore potential for escarpment failure would exist. The Colorado Rockfall Simulation Program (CRSP) and the support data provided by PacifiCorp does not show any rockfall reaching the Cottonwood Canyon Road (FDR 040), however, there is a remote chance of material disturbed by mining activity being dislodged and threatening the Straight Canyon Road (Hwy 29).

The CRSP was calibrated in PacifiCorp's analysis to a failure in similar geology and terrain in nearby Newberry Canyon, associated with their Cottonwood-Wilberg Mine complex. As part of their analysis, they observed the material of the Castlegate Sandstone that had failed and then modeled it to see what size material might be expected to fail in the subject mine plan amendment area.

All of the CRSP applications run for the Cottonwood Canyon side of the escarpment indicated any rock of the expected size would be funnelled in and trapped by local topography.

The escarpment on the Straight Canyon side, above State Hwy 29, is outside of the angle-of-draw by 125 feet. An initial run of the CRSP was done however to determine if any part of the escarpment subject to the strain of subsidence within the angle of draw might cause a rockfall. The CRSP model suggested that a spherical rock of 20' diameter could make it to the highway. Additional CRSP applications were requested and PacifiCorp analyzed their model calibration again. They analyzed the failure at Newberry Canyon, and found that at surveyed subsidence points, failure only occurred at points as mining occurred directly beneath the escarpment. The determination was made that the potential for any material to break loose was extremely remote. Mitigation measures will be reqired.

b. Visual Resources

Escarpment failure could visually affect lands on or near the east wall of Cottonwood Canyon. This potential visual effect is predicted to be consistent with other common naturally occuring failures viewed throughout this and all other similarly formed canyons. Accordingly, noticeable visual effect to the casual Forest visitor -- if any -- will fall well within the parameters outlined for the VQO of Modification.

Due to natural consistancy in form, line, color and texture; and considering other aesthetic variables, i.e., distance from the viewer, angle and duration of view, and scale of the potential failure. It is also predicted with a reasonable level of confidence that failure associated views from other federal, state, private and municipal lands, and transportation corridors will remain non-objectionable.

However, regardless of the small potential for obtrusive effect due to escarpment failure, the public's aesthetic expectations concerning this and other project related activity need to be taken into account. Fencing, barriers, berms, etc. -- although not planned for use within the Forest boundary -- will be in conflicting juxtaposition to the strong visual elements which define this landscape. This is particularly true for Straight Canyon. This primary travel corridor is highly scenic (Retention within the Forest boundary) and insensitively placed safety improvements can conspicuously advertize human-caused change. Although safety is of paramount concern, care should be taken to screen and later remove these obtrusive structures to the best visual advantage. The visual effect of escarpment failure is anticipated to be negligible when compared to that associated with these structures.

c. Socio-Economics

Recoverable coal reserves would be mined, and be consistemt with the BLM's maximum economic recovery mandate. This alternative would provide approximately 1.9 million tons of coal with a resulting 3 million dollars in royalties. Additionally, the life of the Trail Mountain Mine will be extended by approximately 6 months, providing jobs for the employees of the mine as well as the people in the support industries.

d. TE&S Plants

Mining induced subsidence would be permitted and therefore potential for escarpment failure would exist. There is potential for destruction of habitat for Hedysarum occidentale var. canon. Known populations are protected from direct impact by topography. (project file)

e. TE&S Wildlife

Mining induced subsidence would be permitted and therefore potential for escarpment failure would exist. Potential nesting habitat could be lost for raptors. No known nests exist, and PacifiCorp performs a helicopter raptor survey with the Utah Division of Wildlife Resources.

2. Cumulative Effects

Similar to the effects in Alternative 1, except that the magnitude of impacts could be increased. There will be an increase in erosion of the Castlegate Sandstone escarpment, primarily accelerated by the stresses placed on the rock by subsidence.

C. Alternative 3 - Forest Service approval of the special use permit for the underground accessway only

The direct, indirect, and cummulative effects of alternative 3 would be essentially the same as in the No Action alternative (Alternative 1) for the public safety, visual resources, and TE&S species issues.

1. Direct and Indirect Effects

c. Socio-Economics

Coal reserves of 400,000 tons would be bypassed, with an associated loss in royalties of $640,000. This alternative does not meet maximum economic recovery, but will isolate less coal than alternative 1, but not provide as much coal as alternative 2. Mine life will be shortened slightly.

V. INTERDISCIPLINARY TEAM

The joint Bureau of Land Management and Forest Service Interdisciplinary Team consisted of the following personnel:

Jeff DeFreest	Geologist (I.D. Team Leader)
George Tetrault	Mining Engineer
Wayne Ludington	Wildlife Biologist
Bob Thompson	Botonist
Kerry Flood	Hydrologist
Blaine Miller	Archeologist
Kevin Draper	Landscape Architect

APPENDIX A
BIOLOGICAL SUPPORT DOCUMENTS

MANTI-LA SAL NATIONAL FOREST

BIOLOGICAL ASSESSMENT
FOR
FEDERALLY LISTED PLANT AND ANIMAL SPECIES
FOR
TRAIL MOUNTAIN MINE PLAN AMENDMENT

Prepared by
Wayne Ludington
San Rafael Wildlife Biologist
San Rafael Resource Area
Moab District Office
Bureau of Land Management

Approved by:

Rod Player 3/18/96
Rod Player Date
Wildlife Biologist
Manti-La Sal National Forest

Robert M. Thompson 3/15/96
Robert M. Thompson Date
Botanist
Manti-La Sal National Forest

I. Introduction

The purpose of this biological assessment is to evaluate the potential impacts of modifying the Trail Mountain Mine Plan to allow longwall mining under the escarpment to those plant and animal species and their habitats Federally listed as Threatened, Endangered, and Proposed.

The Endangered Species Act of 1973 (PL 93-205), as amended) require federal agencies to insure that any activities they authorize, fund, or carry out, did not jeopardize the continued existence of any wildlife species federally listed as Threatened or Endangered (Section 7). This biological evaluation is an analysis of which Threatened, Endangered, or Proposed species may occur in the project area and whether any impacts on those species are anticipated. This biological evaluation is prepared using direction from the Forest Service manual 2672.4.

II. Proposed Action

Forest Service consent to subsidence of the escarpment as proposed by PacificCorp, and Forest Service approval of the special use permit for the under ground accessway subject to conditions of approval to mitigate impacts. The Bureau of Land Management and Utah Department of Oil, Gas, and Mining will approve PacificCorp's amended R2P2 and mining plan respectively, with Forest Service stipulations.

Further details can be found in the Environmental Assessment (EA) for the project. The EA will evaluate current resource and management information.

III. Species Potentially Impacted by The Project

Known or Suspected Threatened and Endangered, Plants and Animals on the Trail Mountain Mine Lease:

Species*	Classification
Bald Eagle (Haliaeetus leucocephalus)	Threatened
Peregrine Falcon (Falco peregrinus anatum)	Endangered
Colorado Squawfish (Ptychocheilus lucius)	Endangered
Bonytail Chub (Gila elegans)	Endangered
Humpback Chub (Gila cypha)	Endangered
Razorback Sucker (Xyrauchen texancus)	Endangered
Mexican Spotted Owl (Strix occidentalis lucida)	Threatened
Southwestern Willow Flycatcher (Empidonax traillii extimus)	Threatened
Heliotrope Milk-vetch (Astragalus montii)	Threatened

* The above species list were derived from a U.S. Fish and Wildlife Service (USFWS) list of threatened, endangered and proposed species that may be present in the general Wasatch Plateau area (List received April 12, 1995)

IV. Species Occurrences and Habitat Needs

Bald Eagles (Hallaeetus leucocephalus)

During the breeding season bald eagles are closely associated with water, along coasts, lakeshores, or river banks. During the winter bald eagles tend to concentrate wherever food is available. This usually means open water where fish and waterfowl can be caught. They also winter on more upland areas feeding on small mammals and deer carrion. At winter areas, bald eagles commonly roost in large groups. These communal roosts are located in forested stands that provide protection from harsh weather(Stalmaster, 1987).

Bald eagles can often be found near lakes and reservoirs as well as upland areas on the Manti Division during the late fall early winter. When lakes and reservoir freeze over most eagles will leave however those feeding in upland areas may stay late into the winter. A pair of nesting bald eagles has recently been located ten miles east of the Forest boundary near the town of Castle Dale. In 1994, a review of the nesting adults and fledglings indicated their foraging habits were within five mile radius from the nest tree. The eagles were not observed inhabiting the analysis area (Boshen, 1995). No bald eagles are known to nest on the forest.

Peregrine Falcon (Falco peregrinus anatum)

Peregrines occupy a wide range of habitats. They are typically found in open country near rivers, marshes, and coasts. cliffs are preferred nesting sites, although reintroduced birds now regularly nest on man-made structures such as tower and high-rise buildings. Peregrines are known to travel more than 18 miles from the nest site to hunt for food. However, a 10 mile radius around the nest is an average hunting area, with 80 percent of the foraging occurring within a mile of the nest. Peregrines prey on wide variety of birds including shorebirds, waterfowl, grouse, and pigeons (Ratcliffe 1980; and Cade et al. 1988).

Migrating or transient peregrines have been seen on the Wasatch Plateau (including Joes Valley) however, after numerous surveys, conducted over many years, the only peregrines found on the forest nest on the Monticello Ranger District. The San Rafael Resource Area, BLM does have a number of active falcon nests. the closest in approximately 40 miles southeast of the affected area.

Colorado Squawfish (Ptychocheilus lucius)

The Colorado squawfish had a historic range from Green River, Wyoming, to the Gulf of California, but the species is now confined to the upper Colorado River Basin mainstream and larger tributaries (USFWS 1987a). The lower Green River between the Price and San Rafael rivers contains abundant Colorado Squawfish (USFWS 1987b). The species decline can be attributed to direct loss of habitat, changes in water flow and temperature, blockage of migrations, and interactions with introduced fish species (USFWS 1987b). Colorado squawfish adults are thought to prefer deepwater eddies and pools or other areas adjacent to the main water current, whereas the young inhabit shallow, quiet backwaters adjacent to high flow areas. Colorado squawfish feed on invertebrates while young but gradually became piscivorous after one year (Woodling 1985). No Colorado squawfish have been located on the Forest but they are present in the drainage that receive water originating on the Forest.

Bonytail Chub (Gila elegans)

Historically bonytail chubs existed throughout the .colorado River drainage (Woodling 1985). Recently, isolated captures of bonytail chubs have been made in the Colorado River basin but recruitment to the population is extremely low or nonexistent. The decline of the bonytail chub is attributed to dam constructing and associated water temperature changes. Other factors contributing to the reduced numbers include flow depletion, hybridization, stream alterations associated with dam construction, and the introduction of non-native fish species. The bonytail chub generally inhabits eddies and pools over swift current areas (Woodling 1985). The chub is an omnivore, feeding mostly on terrestrial insects, plant debris and algae and begins to spawn at five to seven years of age (Behnke and Benson 1980).
No bonytail chubs have been located on the forest but they are present in drainage that receive water originating on the Forest.

Humpback Chub (Gila cypha)

The humpback chub is believed to have inhabited all of the large rivers of the upper Colorado River basin and canyons of the lower Colorado River basin (Ono, Williams, and Wagner 1983). Presently the humpback chub can be located in and above the Grand Canyon, Arizona, and the major tributaries to the Colorado River (Woodling 1985) The USFWS (1990) states stream alteration, including dewatering, dams and channelization, as factors causing the decline of the species. The humpback chub normally lives adjacent to high velocity flows, where they consume plankton and small invertebrates (USFWS 1990). The humpback chub has not been located on the Forest but they care present in drainage that receive water originating on the Forest.

Razorback Sucker (Xyrauchen texancus)

Historic distribution of the razorback sucker was mainly along the mainstream of the Colorado, Green and San Juan Rivers. They presently only occur in a portion of their former range in these rivers and are normally found in water four to ten feet deep with area of strong currents and backwaters (Woodling 1985). Spawning fish have been located over both sand and gravel/cobble bars (USFWS 1987b). The razor back sucker feeds on small invertebrates,and animals and organic debris on the river bottoms. Behnke and Benson (1980) link the decline of the razorback sucker to the land and water uses, particularly dam construction and the associated change of flow regimes and river channel characteristics.

The razorback sucker has not been located on the Forest but they are present in drainage that receive water originating on the Forest.

Mexican Spotted Owl (Strix occidentalis lucida)

The Mexican Spotted Owl is found in southwestern United States and extends into the extreme south portion of Utah. Distribution is patchy in mountains and canyons containing mixed conifers, pine-oak,and evergreen oak forests. They are found on steep slopes in mature forests with dense, uneven-aged stands and high canopy closure, high basal area, and many snags and downed logs. Nest sites are generally found in mature mixed conifer forests, mainly douglas-fir and to a lesser extent in ponderosa pine, gambel oak, and on cliff ledges. They forage in mature forests of mixed-conifer and gambel oak possibly due to the availability of preferred prey (rats and mice) and avoidance of great horned owls. The Mexican Spotted Owls or southeastern Utah have been fund in crevices and small canyons where nature conifer trees are scattered in the canyon bottoms.

Spotted Owls are sensitive to high summer temperature, therefore closed canopy forests or protected canyon sites may be the only suitable habitats available in the arid southwest. they are known to occur at approximately 30 sites on the Colorado Plateau and all of these sites are classified as narrow sandstone canyons. Spotted owls require areas with dense multi-layered mixed conifer stands or steep canyon with caves and crack systems in order to find protected nest/roost sites. It is likely that the spruce and ponderosa pine forest in southern

Utah do not provide the necessary stand configuration Mexican spotted owls require for nesting and roosting. Spotted owls are normally found within four-tenths of a mile of permanent water (Ganey 1988; Johnsgard 1988; Willey et al 1991; and Daw 1991).

Areas of suitable habitat on the Forest have been inventoried during the last three field seasons and the only Mexican spotted owls found have been on the La Sal Division.

Southwestern Willow Flycatcher (Empidonax traillii extimus)

The Southwestern willow flycatcher spends most of its time in the southwestern United States and is extending it's range to the lower one/fourth of the state of Utah. These flycatchers are closely associated with riparian habitats such as willow or alder thickets along streams, on the shores of ponds, or bordering marshy areas. They are also found in the brushy margins of fields, along mountain streams, and in shrubby floodplain areas. They prefer areas of high shrub densities interspersed with openings or meadows. The woody component of their habitat is almost exclusively deciduous including willows, alders, cottonwoods, aspens, and shrubs such as chokecherry, hawthorn, sumac and wild rose. As the name implies Southwestern Willow Flycatchers are insectivores eating wasps, bees, beetles, flies, moths and butterflies. (Unitt 1987)

After two years of surveys in areas of suitable habitat, no southwestern willow flycatchers have been located on the Wasatch Plateau.

Heliotrope Milk-vetch (Astragalus montii)

This plant occurs within the Ferron/Price Ranger District, where it is found only at high elevations (10,000 to 11,000 ft.) on Flagstaff limestone outcrops. Associated with low growing subalpine vegetation, populations are located on top of Heliotrope, Ferron and White Mountains. Taken from USDA Forest Service 1991a,b; and Manti-La Sal National Forest Supervisor office files.

V. Determination of Effects

Suitable Habitat -

The area affected by the proposed action does not contain suitable habitat (ie. elevation, vegetation, and/or geology) and known home ranges for many of the species in the above lists. Therefore, it is determined that there will be no effect upon them. These species (as listed below) are therefore eliminated from further analysis.

- Colorado Squawfish (Ptychocheilus lucius) - The area affected by the proposed action does not contain any of the endangered fish and the proposed action would not affect the amount or quality of water draining into the Colorado River Drainage.

- Bonytail Chub (Gila elegans) - The area affected by the proposed action does not contain any of the endangered fish and the proposed action would not affect the amount or quality of water draining into the Colorado River Drainage.

- Humpback Chub (Gila cypha) - The area affected by the proposed action does not contain any of the endangered fish and the proposed action would not affect the amount or quality of water draining into the Colorado River Drainage.

- Razorback Sucker (Xyrauchen texancus) - The area affected by the proposed action does not contain any of the endangered fish and the proposed action would not affect the amount or quality of water draining into the Colorado River Drainage.

- Mexican Spotted Owl (Strix occidentalis lucida) - The area affected by the proposed action is outside the range of these species. Refer to the Draft Recovery Plan for the Mexican owl. March 1995.

- Southwestern Willow Flycatcher (Empidonax traillii extimus) - The proposed action is outside the range of these species. Refer to the excerpts from the proposed rule that appeared in Federal Register, Vol. 58, No. 140, 7/23/93.

- Heliotrope Milk-vetch (Astragalus montii) - The area affected by the proposed action is outside the range of this species. The elevations and geology are not correct for the occurrence of this species.

Accordingly the potential for effects upon the following species will be analyzed further.

Bald Eagle (Haliaeetus leucocephalus)

American peregrine falcon (Falco peregrinus anatum).

Effects of the Project Proposal

Bald Eagles (Haliaeetus leucocephalus)

Bald Eagles can often be found near the lakes and reservoirs on the Manti Division during the late fall and early winter. Joes Valley Reservoir has been known to annually inhabit bald eagles from approximately mid October to early January. When the Reservoir freezes over, the eagles leave. A pair of bald eagles have been known to nest near the town of Castle Dale (Approximately 10 miles east of the Forest boundary near Straight Canyon). Reviews of the nesting eagles near Castle Dale indicate foraging habitat of adults and juveniles are within an approximate five mile radius from the nest site. The nesting eagles's home range was not identified to be within any of the area addressed in the Trail Mountain Mine Plan Amendment. No direct or indirect effects caused by the mine plan are expected. No bald eagles are known to inhabit the area.

Peregrine Falcon (Falco peregrinus anatum)

Peregrines prefer cliffs as nest sites. Existing cliff faces occur within the effected area. The Manti Division underwent intense aerial surveys for peregrine falcons. The survey were conducted by the U.S. Fish and Wildlife Service, Utah Division of Wildlife Resources, and local coal companies beginning approximately nine years ago. Additional follow-up surveys have been conducted every two or three years. Results included no sighting or identification of peregrine inhabiting the area. A falcon scrape has been identified south of the area impacted by this action. This scrape was identified as to the species using it, and has not be determined to be active for the past several years. No direct or indirect effects are expected to impact the peregrine falcon or its habitat.

VI. Listed Species Biological Assessment Summary of Conclusions of Effects

Project Name: BA for TRAIL MOUNTAIN MINE PLAN AMENDMENT

Alternative: Alternative II

Species	No Effect	May Effect - Not Likely to Adversely Affect	Likely To Adversely Affect	Beneficial Effect
Bald Eagle	X			
Peregrine Falcon	X			

Bald Eagles (Haliaeetus leucocephalus)

The proposed action will not contribute to loss of viability of the Bald Eagle for the following reasons:

1) Bald Eagles are known not to nest or reproduce within any of the proposed action areas.
2) No bald eagles are known to utilize any of the proposed project area.
3) Reviews of the nesting bald eagles near Castle Dale indicate foraging habits of adults and juveniles are not within the proposed action areas.

Peregrine Falcons (*Falco peregrinus anatum*)

The proposed action will not contribute to loss of viability of the peregrine falcon for the following reasons:

1) Past surveys conducted by the U.S. Fish and Wildlife Service, Utah Division of Wildlife Resources, and Energy West Coal Company indicated no sighting of peregrine falcons within the proposed project area.

2) The known falcon eyries in the San Rafael Swell are too far away to affect their foraging habitat.

VII. DOCUMENTATION

References used to determine the presence (or absence) of Threatened. Endangered, Proposed. and Sensitive Species as well as species characteristics and habitat information include:

Baxter, G.T. and J.R. Simon. 1970. Wyoming fishes. Wyoming Came and Fish Dept. bull. No. 4. Cheyenne. 168 pp.

Behnke, R.J. and D.E. Benson. 1980. Endangered and threatened fishes of the upper Colorado River Basin Coop. Ext. Serv., Colorado State Univ. , Fort Collins, Bull. 503A. 34 pp.

Boschen, Nelson. 1995. Bald Eagles in Southeastern Utah: 1994 Nesting Season.

Cade, T.J., J.H. Enderson, C.G. Thelander, and C.M. White. 1988. Peregrine falcon populations: their management and recovery. the Peregrine Fund, Inc., Boise. 949 pp.

Daw, S.K. 1991. Preliminary Mexican Spotted Owl Survey in Glen Canyon National Recreation Area. Unpublished Technical Report.

Caney. J.L. 1988. Distribution and habitat ecology of Mexican spotted owls in Arizona. M.S. Thesis. Northern Arizona Univ., Flagstaff. 229 pp.

Johnsgard, P.A. 1988. North American owls, biology and natural history. Smith. Instit. Press, Washington and London. 295 pp.

Ratcliffe, D.A. 1980. The peregrine falcon. Buteo Books, Vermillion, SD. 416 pp.

Sigler, W.F. and R.R. Miller. 1963. Fishes of Utah. Utah State Dept. of Fish and Game, Salt Lake City. 203 pp.

Stalmaster, M.V. 1987. The bald eagle. Universe Books, New York. 227 pp.

Unitt, P. 1987. Empidonax traillii extimus: an endangered subspecies. Western Birds 18:137-162

Welsh, Stanley L., ND. Atwood, S. Goodrich, and L.C. Higgins. 1987. A Utah Flora. Great Basin Naturalist Memoirs Number 9. 894 pp.

Willey, D., J. Willey, and D. Chapman. 1991. Final Report - Mexican Spotted Owl Surveys in Forested Highlands and Adjacent Canyonlands in Southern Utah. Forest Service Contract Nos: 53-8462-0-07007, and 53-8462-0-07008. 57 pp.

A. Forest Service References

District wildlife observation records. USDA Forest Service, Price Ranger District, Price, Utah.

Personal communications with Forest Service personnel.

USDA Forest Service. 1991a. Threatened, Endangered, and Sensitive Species of the Intermountain Region. USDA Forest Service, Intermountain Region. Ogden, UT.

USDA Forest Service. 1991. Utah Endangered, Threatened, and Sensitive Plant Field Guide. USDA Forest Service, Intermountain Region, Ogden, Utah.

B. State Wildlife Agency References

Personal communications with Bill Bates, Southeastern Regional Nongame Manager, Utah Division of Wildlife Resources, Price, UT.

Shirley D. Nongame Biologist Utah Division of Wildlife Resources. Personnel Communication with Rod Player, March 1991.

Utah Division of Wildlife Resources. 1980. Bats of Utah. UDWR Publication No.80-15.

Utah Division of Wildlife Resources. 1990. Fauna of Southeastern Utah and Life Requisites Regarding their Ecosystems. Publication No. 90-11.

C. U.S. Fish and Wildlife Service References

A phone call was made to the U.S.Fish and Wildlife Service (Susan Lanier) on April 10, 1995 relative to nesting Bald eagles near the town of Castle Dale.

A phone call was made to the U.S. Fish and Wildlife Service on April 3, 1992, to confirm the list of Threatened, Endangered, and Proposed Species that was already on hand.

U.S. Fish and Wildlife Service. 1995. Mexican Spotted Owl (Strix occidentalis lucida) recovery plan. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

U.S. Fish and Wildlife Service. 1995. Neliotrope milkvetch (Astragalus montii) recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado. 11pp.

Federal Register Vol. 58 No. 140, 7/23/93.

BIOLOGICAL EVALUATION

INTRODUCTION

The biological evaluation is an analysis of which sensitive species may occur in the project area and whether any impacts on those species are anticipated. Although not required under the Endangered Species Act, it is Forest Service policy to analyze potential impacts to sensitive species as well [Forest Service Manual (FSM) 2670.31-32]. Sensitive species are those identified by the Forest Service Regional Forester as "those...for which population viability is a concern, as evidenced by ...significant current or predicted downward trends in population numbers or density... "or" significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution." (FSM 2670.5).

SPECIES KNOWN OR POTENTIALLY IN THE AREA

Known or Suspected Sensitive Species on the Ferron/Price Ranger District

SPECIES*

Spotted bat	Euderma maculatum
Townsend's big-eared bat	Corynorhilus townsendii
Boreal owl	Aegolius funereus
Flammulated owl	Otus flammeolus
Northern Goshawk	Accipiter gentilis
Three-toed woodpecker	Picoides tridactylus
Spotted Frog	Rana pretiosa
Canyon Sweetvetch	Hedysarum occidentale var. canone

* The above species list were derived from the Forest Service (FS) Sensitive Species list for the Intermountain Region.

AFFECTED ENVIRONMENT

Spotted Bat (Euderma maculatum)

Spotted bats occur in scattered areas throughout Utah. They have been found in a variety of habitat types including open ponderosa pine, desert scrub, pinyon-juniper, and open pasture and hay fields. They roost alone in rock crevices high up on steep cliff faces. Cracks and crevices ranging in width from 0.8-2.2 inches in limestone or sandstone cliffs are critical roosting sites. There is some evidence that individuals show fidelity to roost sites. They are territorial and avoid each other while foraging. They are though to migrate south for winter hibernation.

Spotted bats are rare and may be limited by suitable roosting sites. they are found in relatively remote, undisturbed areas, suggesting that they may be sensitive to human disturbance.

Little is known of the spotted bats food habits. They are thought to feed mainly on moths. Their echolocation call is very effective for fast flight feeding on moths. They forage alone, after dark, and avoid each other by listening to the echolocation calls of others.(Leonard and Fenton 1983; Woodsworth et al 1981; and Watkins 1977)

To date the only known sightings of spotted bats on the forest have been on the Monticello, Moab, and Ferron/Price Ranger Districts. On the Ferron/Price Ranger District they have been located at Joe's Valley Reservoir and at Emerald Lake. Cottonwood and Straight Canyons were surveyed in 1992 by Robin A. Toone. The survey did not find any bats close to the project area. It did locate some echolocation bat calls similar to the spotted bat close to the Joe's Valley. The discovery was unconfirmed because of disturbance and was approximately 5 miles from the project area.

TOWNSEND'S BIG-EARED BAT (WESTERN BIG-EARED BAT) (Corynorhilus townsendii)

Townsend's or Western Big-eared bat uses a variety of scrub and forested habitats, throughout western North America. These bats use juniper/pine forests, shrub/steppe grasslands, deciduous forests and mixed coniferous forests from sea level to 10,000 foot elevation. They utilize colonial nurseries. Cool places such as caves, rock fissures, mines, and buildings are used for roosting and hibernation. Foraging of primarily moths. Is often done in open woodlands, along forest edges, and over water.

The Townsend's Big-eared bat occurs throughout western North America including Utah. During the winter they roost singly or in small clusters. They remain at these sites from October to February. Migration for these bats usually means a change in location in the same cave or to another nearby cave.

The Townsend's Big-eared Bat is very sensitive to human disturbance. It will readily abandon roosts when disturbed. Activities that will or may disturb caves or mines should be evaluated to determine potential impacts to this species. [Kunz and Martin 1982; and Utah Division of Wildlife Resources 1980]

Townsend's Big-eared Bats have been documented using inactive coal mines as hibernacula on the Ferron Ranger District during 1992. They have also been found roosting in buildings of the Ferron/Price Ranger District in the town of Ferron during late summer of 1992.

BOREAL OWL (Aegolius funereus)

The range of the boreal owl extends down into the extreme northern most counties of Utah. It is known to occur throughout the high elevation mountainous areas of Colorado. Boreal owls are closely associated with high elevation spruce-fir forests due to their dependence on this forest type for foraging year round. Nesting habitat structure consists of forests with a relatively high density of large trees, open understory, and multi-layered canopy. Owls nest in cavities excavated by large woodpeckers in mixed coniferous, aspen, Douglas-fir, and spruce-fir habitat types. In summer, owls roost in cool spruce-fir stands. Boreal owls prey primarily on small mammals such as voles, pocket gophers, and shrews. They are however, opportunistic and also eat insects, and birds. They avoid open areas, such as clearcuts and open meadows, except for occasional use of the edges for foraging. [Johnsgard 1988; Hayward 1989]

To date no boreal owls have been located on the Forest. If they do occur on the Forest it would most likely be on the Moab Ranger District, because of the proximity of boreal owls in Colorado.

FLAMMULATED OWL (Otus flammeolus)

Flammulated owls are found throughout the western United States including Utah. They can be found in the mixed pine forests, from pine mixed with oak and pinyon at lower elevations to pine mixed with spruce and fir at higher elevations. They have also been found in aspen and second growth ponderosa pine. However, they prefer mature Ponderosa Pine-Douglas fir forests with open canopies. Large diameter dead trees with cavities are important nest site characteristics. They avoid foraging in young dense stands where hunting is difficult. Flammulated owls are dependant upon mature conifer stands for nesting. They are also known to avoid cut-over areas. Flammulated owls are almost exclusively insectivorous, preying on small to medium sized moths, beetles, caterpillars, and crickets. [Reynolds and Linkhart 1987; Johnsgard 1988; and Bull et al 1990].

Many flammulated owls have been located on the Monticello and Moab Ranger Districts as part of Mexican Spotted Owl Inventories. They have also been found in the Quitchupah drainage and the head of the Muddy on the Ferron/Price Ranger District. All but one of these locations have been associated with ponderosa pine.

NORTHERN GOSHAWK (Accipiter gentilis)

In nesting or foraging, the goshawk is a raptor of the dense forest. Goshawks have been found in a variety of forest ecosystems including lodgepole pine, ponderosa pine, Douglas fir, mixed forests throughout much of the Northern hemisphere. They prey upon small mammals and birds (rabbits, squirrels, chipmunks, grouse, woodpeckers, jays, robins, grosbeaks, and etc.). Goshawk nest sites are usually located in mature forests, near water, and on benches of relatively little slope. Nests are often used year after year. Goshawks are very protective of their young in the nest and loudly defend them to intruders. They are very sensitive to human disturbance and have abandoned nests and young due to human activities that take place too close to their nest [Kennedy and Stahlecker 1989; and Hennessey 1978]

Goshawks have been found nesting on all Ranger Districts. These nests are associated with aspen, mixed conifer, and ponderosa pine.

THREE-TOED WOODPECKER (Picoides tridactylus)

Three-toed woodpeckers range across North America. They are found in northern coniferous and mixed forest types up to 9000 feet elevation. Forests containing spruce, grand fir, ponderosa pine, tamarack, and lodgepole pine are used. Nests may be found in spruce, tamarack, pine, cedar, and aspen trees. Three-toed woodpeckers forage mainly in dead trees, although they will feed in live trees. About 75% of their diet is woodboring insect larvae, mostly beetles, but they also eat moth larvae. They are major predators of the spruce bark beetle, especially during epidemics. They forage on a wide variety of tree species depending on location. In Colorado, they prefer to forage on old-growth and mature trees.

Fire or insect killed trees are major food sources. Forest fires and areas of insect outbreaks may lead to local increases in woodpecker numbers after 3-5 years. [Bull et al 1986; and Scott et al 1980]

Surveys for three toed woodpecker took place in suitable habitat on the Ferron/Price, Sanpete, and Moab/Monticello Ranger Districts in June and July of 1992. Further surveys during the 1993 and 1994 field seasons on the Ferron/Price District resulted in additional three-toed woodpecker findings. The species was found on all districts surveyed.

SPOTTED FROG (Rana pretiosa)

The Spotted frog ranges from Alaska south to scattered patches in northern Utah. These frogs are highly aquatic most likely found near permanent water such as marshy edges of ponds or lakes, in algae-grown overflow pools of streams, or near springs with emergent vegetation during the breeding period. They do not seem to occur in warm stagnant ponds overgrown with cattails. They may move considerable distances from water after breeding, often frequenting mixed conifer and subalpine forests, grasslands, and brushlands of sage and rabbitbrush. Spotted frogs feed on a wide variety of insects, and a few kinds of mollusks, crustaceans, and arachnids. Spotted frogs are thought to hibernate in holes near springs or other areas where water is unfrozen and constantly renewed. [Shirley 1991; Stebbins 1985; and Turner 1958]

Spotted frogs have been located west of the Manti Division near Fairview. However, no spotted frogs have been located on the Forest and they are only expected to occur on the west side on the Manti Division.

CANYON SWEETVETCH (Hedysarum occidentale var. canone)

Scattered populations of this plant occur in lower Huntington Canyon, Price District, in Straight Canyon, and near Joe's Valley, Ferron District. Plants are usually found on sites with a high water table, near springs or along stream beds, or riparian area in Pinyon-Juniper types. River birch and squawbush are plants most commonly associated with this species. The plant is usually found at elevations between 5500 and 7000 ft.

ALTERNATIVES

Eight sensitive species have been evaluated for potential impacts. The species are listed below with the impact potential.

SPOTTED BAT (Euderma maculatum)

There is a potential of an impact to the bat. The bats roosting habitat is located on mountain side slopes in cracks and crevices in rock outcrops and escarpments. The area has the potential of an escarpment failure that would remove some roosting habitat, and potentially result in the loss of a few bats. Past inventory of Cottonwood Canyon and Straight Canyon did not find any bats within five miles of the area impacted by this action.

TOWNSEND'S BIG-EARED BAT (Corynorhilus townsendii)

There is a potential of an impact to the bat. The bats roosting habitat is located on mountain side slopes in cracks and crevices in rock outcrops and escarpments. The bats roosting habitat is located on mountain side slopes in cracks and crevices in rock outcrops and escarpments. The area has the potential of an escarpment failure that would remove some roosting habitat, and potentially result in the loss of a few bats. Past inventory of Cottonwood Canyon and Straight Canyon did not find any bats within five miles of the area impacted by this action.

BOREAL OWL (Aegolius funereus)

Although no boreal owl surveys have been completed it is doubtful that any owls are in the affected area, The owl utilizes higher elevations with spruce fir forests. The affected areas is too low and does not have the preferred habitat for the owls. There would be no impact to the owl.

FLAMMULATED OWL (Otus flammeolus)

Although no flammulated owl surveys have been conducted within the project area it is possible that flammulated owls may exist here. The project area may provide some marginally suitable habitat, and if flammulated owls exits here they are most likely at very low population levels. No direct or indirect effects are anticipated.

NORTHERN GOSHAWK (Accipiter gentilis)

Wildlife surveys have located active goshawk nests on the Ferron/Price District, however none were found in the project area. The project area contains primarily pinyon-juniper and does not provide the habitat preferred by the goshawk. No direct or indirect effects are anticipated.

THREE-TOED WOODPECKER (Picoides tridactylus)

There would be no direct or indirect effects caused by the alternatives. Three-two woodpeckers exist here in low levels and large amounts of suitable habitat exist in surrounding areas.

SPOTTED FROG (Rana pretiosa)

There would be no direct or indirect effects caused by the alternatives. The area does not contain any perennial water sources that could support the frog.

CANYON SWEETVETCH (Hedysarum occidentale var. canone)

The canyon sweetvetch is present on a small ridge below and to one side of the projected rock slide route if the escarpment should fail. The plant will not be affected by this action.

CUMULATIVE EFFECTS

The failure of the escarpment would remove some cliff face and pinyon-juniper habitat. This would be a small loss to the bats as there is a large amount of this habitat available to them, and because they were not identified as using the area. There would be no cumulative effects to any of the other sensitive species.

SENSITIVE SPECIES BIOLOGICAL EVALUATION
SUMMARY OF CONCLUSION OF EFFECTS**

TRAIL MOUNTAIN MINE PLAN AMENDMENT

SPECIES	ALT 1	ALT 2	ALT 3
Spotted bat	NI	MIIH	NI
Townsend's big-eared bat	NI	MIIH	NI
Boreal owl	NI	NI	NI
Flammulated owl	NI	NI	NI
Northern Goshawk	NI	NI	NI
Three-toed woodpecker	NI	NI	NI
Spotted Frog	NI	NI	NI
Canyon Sweetvetch	NI	MIIH	NI

Prepared by /s/ [signature] /s/ ______________ Date: 3/15/96

Approved by /s/ [signature] 3/18/96 Wildlife Biologist /s/ ______________ Fisheries Biologist /s/ [signature] Botanist 3/15/96

NI - No Impact
MIIH - May Impact Individuals Or Habitat, But Will Not Likely Contribute To A Trend Towards Federal Listing Or Loss Of Viability To The Population Or Species

WIFV* - Will Impact Individuals Or Habitat With A Consequence That The Act ion May Contibute To A Trend Towards Federal Listing Or Cause A Loss Of Viability To The Population Or Species.

BI - Beneficial Impact

* Trigger for a Significant Action As Defined In NEPA

DOCUMENTATION

References used to determine the presence (or absence) of Sensitive Species as well as species characteristics and habitat information include:

Bull, E.L., A.L. Wright, and M.G. Henjum. 1990. Nesting habitat of flammulated Owls in Oregon. J.Raptor Res. 24(3):52.55.

Bull, E.L., S.R. Peterson, and J.W. Thomas. 1986. Resource partitioning among woodpeckers in north-eastern Oregon. Res. Note PNW-444. LeGrande, OR: U.S. Dept. of Agricul., For. Serv., Pacific Northwest Res. Sta. 19 pp.

Hayward, G.D. 1989. Habitat use and population biology of boreal owls in the northern Rocky Mountains, U.S.A. Ph.D dissertation. Univ. of Idaho, Moscow. 113 pp.

Hennessey, S.P. 1978. Ecological relationships of accipiters in northern Utah with special emphasis on effects of human disturbance. M.S. Thesis, Utah State University, Logan, Utah. 65 pp.

Johnsgard, P.A. 1988: North American owls, biology and natural history. Smith. Instit. Press, Washington and London. 295 pp.

Kennedy. P.L., and D.W. Stahlecker. 1989. Preliminary Northern Goshawk Inventory. Unpubished Protocol.

Kunz, T.H. and RA. Martin. 1982. *Plecotus townsendii*. Mammalian Species No. 175. 6 pp.

Leonard, M.L. and M.B. Fenton. 1983. Habitat use by spotted bats *(Euderma maculatum)*, Chiroptera: Vespertilionidae: roosting and foraging behavior. Can. J. Aool. 61:1487-1491.

Reynolds, R.T. and B.D. Linkhart. 1987. The nesting biojogy of flammulated Owls in Colorado. Pages 239-248 in A.W. Nero, R.J. Clark, R.J. Knapton.

Scott, V.E., J.E. Whelan, and P.L. Svoboda. 1980. Cavity nesting birds and forest management. Pages 311-324 in R.M. DeGraaf, tech. coord. Proc. of workshop on management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86. Intermountain For. and Range Exp. Sta., Ogden, UT,

Stebbins, R,C. 1985. A field guide to western reptiles and amphibians. Houghton Mifflin Company, Boston. 336 pp.

Turner, F.B. 1958. Life history of the western Spotted frog in Yellowstone National Park. Herpetological 14:96-100.

Watkins, L.C. 1977. Euderma maculatum. Mammalian Series No. 77. 4 pp.

Woodsworth, G.C., G,P. Bell, and M.8. Fenton. 1981. Observations of the echolocation, feeding behavior, and habitat use of Euderma maculatum (Chiroptera: Vespertilionidae) in south central British Columbia. Can, J, Zoo 59:1099-1102.

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November 14, 1997
290-1

Mr. L. J. Lafrentz
Senior Mining Engineer
Energy West Mining Company
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Huntington, UT 84528

RE: Technical Approach- Escarpment Study

Dear Mr. Lafrentz:

This letter with attachments was prepared to address the technical approach Maleki Technologies, Inc. (MTI), recommends for developing a predictive tool for assessing the stability of Castlegate Sandstone escarpments in the vicinity of Energy West's longwall operations near Huntington, Utah. After completing a through review of previous work by Energy West, the University of Utah, and the U.S. Bureau of Mines, we recommend a statistical approach for development of a mathematical model having predictive capabilities; such models are ideal for probabilistic risk analysis and for defining confidence intervals for the projected stability of the escarpments so that economic benefits of extracting coal reserves can be analyzed against the probability of escarpment instability.

Technical Approach

In engineering practice, the choice of analytical method depends on the objective of the study, the quality and quantity of data available, and the time and computational constraints under which routine evaluations need to be completed. The primary objective of the present study was to develop predictive methods that will allow Energy West to assess the stability of the Castlegate escarpment with regard to proposed full extraction longwall mining. Energy West could then use these methods in conjunction with geoenvironmental analyses on a routine basis to assess what possible impacts the proposed resource recovery may have on natural and cultural surface resources (i.e. escarpments, public roads, outcrops, scenic architecture, vegetation, hydrogeology, etc.).

There are two methods routinely used by engineers and researchers to help predict what conditions will be in the future: statistical and computational. Starfield and Cundall (1988) identify rock mechanics problems as "data- limited," that is, one seldom knows enough about a rock mass to use computational methods unambiguously. These methods, however, are extremely useful for studying failure mechanisms and testing different hypotheses on the cause of the failure. Statistical methods, on the other hand, are uniquely capable of being applied where there are good data, but a limited understanding of certain phenomena, such as the mechanism of escarpment failure (toppling, pure translation, or a combination of these and other mechanisms).

In the case of Energy West's escarpment study, there are years of mining and escarpment stability data available on Newberry Canyon, Corncob Canyon, Miller Canyon, Rialda Canyon, and other areas. Using the volume of failed rocks and travel distances as dependent variables, one can use a statistical approach to identify important parameters which contribute to escarpment stability and build confidence intervals. This mathematical model can then be used by mine personnel for routine assessment of escarpment stability in new mining areas given the variability in geologic conditions and geometry, including escarpment geometry, orientation of the escarpment with respect to the longwall face, joint density, and joint continuity among other factors.

Review of Past Studies

Various investigators from both the U.S. government and universities have used computational techniques for analyzing surface subsidence and escarpment stability. While successful in analyzing failure patterns and mechanisms, these studies have clearly identified the limitations of numerical modeling techniques in matching measured surface deformation. Below is a brief review of past studies in which a combination of two-dimensional, boundary-element, finite-element, and discrete-element formulations were used. Most of these studies focused on analyzing ground movement in Newberry Canyon, where the Castlegate escarpment and mining geometry lend themselves to two-dimensional analysis. The USBM also completed a few preliminary three-dimensional, finite-element modeling studies.

The University of Utah completed the most comprehensive assessment of escarpment stability and suggested that mining influence angles be limited to 15 degrees to satisfy needs for both stability and resource recovery. This work provided valuable insights for studying mechanisms that could have played a role in the escarpment failure during longwall mining. The results are in agreement with extensive studies in the Sydney Basin of Australia (Pells and others 1987). The work was completed in two phases between 1987 and 1994. The initial phase involved finite-element analyses (Jones and others 1990) based on typical material properties for lithologic units using the data provided by Terra-Tek (1987) and strength reduction factors of 10. The second phase benefited from core drilling and mechanical property tests from two coreholes located approximately 1.5 miles from the study site. A strength reduction factor of 2 was used. To overcome the limitations of using small strain, continuum, elastic-plastic code, finite-element deformation was imposed on a detailed discrete-element model of the escarpment and the mudstone foundation and incorporated both horizontal slip planes and vertical joints (Jones 1994). In the model, the escarpment blocks maintained static equilibrium after finite-elements displacements were imposed, which was inconsistent with field observations and measured horizontal deformation.

The following factors are believed to have influenced the finite-element results:

- Geologic conditions along the 4,000-ft-long modeled section can vary significantly, considering the depositional environment of the Blackhawk Formation in the Wasatch Plateau. The model was based on simplified stratigraphy and 75 ft of core from boreholes located approximately 1.5 miles from the section of interest. Furthermore, there were no data on the shear strength properties of bedding planes and joints.

- To account for the weakening effects of joints within the rock mass, strength reduction factors of 10 and 2 were used. It is uncertain what the actual in situ strength and deformation properties of the rock mass is and how these properties vary laterally and vertically.

- A gravity loading condition was assumed because of the lack of site-specific stress measurements.

- To optimize computer resources, a special composite material was developed, and mining of the seam was simulated by forcing the two layered nodes to displace uniformly toward each other. These innovative procedures have been useful in reducing computational resource requirements but may not accurately represent mining and caving of near-seam strata and thus could influence calculated deformation.

- The chain pillars were excluded from the model.

From this discussion, it becomes apparent that the escarpment stability analysis was data-limited and thus suffered from the shortcomings of applying numerical models in matching inelastic deformations. Excessive computational and manpower requirements have also been a limitation in applying more detailed two- and three-dimensional analyses. Nevertheless, the modeling exercise has been very useful for studying a mechanism that might play a role in escarpment stability. For the same reasons, the researchers envisioned the use of three-dimensional, finite-element studies to better understand the mechanism of failure as related to variations in topography (concave and convex geometries), a goal that will require the allocation of significantly greater engineering and computational resources. Alternatively, statistical and analytical approaches (such as three-dimensional influence function subsidence codes) may prove useful in evaluating the influence of topography on escarpment stability.

The technical challenges in using three-dimensional, finite-element analysis techniques may best be realized by reviewing USBM work (Shea-Albin 1992). This work consisted of generating two-dimensional slices 500 ft apart and then creating three-dimensional geometries by combining these slices using the ADINA code. The model is gravity loaded, and the coal seam is extracted in three steps.

Obviously, proper use of a three-dimensional analysis requires significantly more geologic and geotechnical data, including data from multiple coreholes, geologic mapping, tests for mechanical properties of rocks, and three-dimensional stress determinations (Maleki and Hollberg 1995, provide a discussion of measurements required for stability evaluation for much simpler mining geometry using 3-dimensional finite-difference methods (attachment A) . Calculated vertical surface deformation (subsidence) was 35 times less than measured values. More-detailed analyses were recommended in which slip lines and joints would be incorporated, which can easily exceed the capabilities of many mainframe computers. Note that grid spacings of 500 ft are too large to permit accurate modeling of surface topography, thus requiring finer meshes and even greater computer resources.

Other USBM researchers focused on the use of computationally more efficient two-dimensional codes, i.e., boundary element. These codes, however, were limited in the number of materials they could include, and the model was based upon generic rock property data (Ahola 1990). Additional discontinuum analyses incorporated joints in the model, but results were inconclusive because of the lack of information on rock and joint properties.

Statistical Approach

Multiple nonlinear regression analyses, as well as other statistical methods (such as discriminant analysis), can be used as tools to help predict escarpment stability. Such methods can use the wealth of information on actual escarpment behavior under a variety of geologic conditions and geometries. In this approach, a number of locations are selected along the escarpments at random, and all geometric and geologic factors that may contribute to escarpment stability are calculated (table 1). The statistical procedures can identify significant variables and result in a predictive tool for assessing the likelihood of failure in areas that might be of interest in the future. Attachment B presents technical papers that deal with the application of statistical and analytical techniques in studying rock mechanics problems.

We foresee the use of both statistical and analytical approaches to estimate the distances from the base of escarpment that rocks travel after failure. The statistical approach will depend upon actual survey (preferably, video records of escarpment failures) of travel distances for rock falls. This will allow in situ geologic and geometric conditions of the rock slopes near the Energy West longwall operations be taken into account. Using the travel distance as the dependent variable, one can then establish a relationship between the travel distance and site-specific geometric conditions (table 1). In addition, the analytical formulation developed by the Colorado Department of Transportation (Pfeiffer and others 1993) will be used. This technique is capable of simulating rock fall behavior and providing statistical analysis of rock fall using the slope geometry and frictional properties of rock-slope interfaces.

We are looking forward in working with your geological staff and will proceed with the statistical evaluations as soon as we receive the geologic and geometric data identified in table 1. Meanwhile, I have requested Mr. Richard Jones to provide periodic input to this study based on his extensive work in modeling escarpment stability near your operations (attachment C). We both concur that our technical approach is most suitable for developing predictive capabilities in the near term while encouraging the continuance of research in numerical modeling, which may lead to improved mechanical based models in the long-term.

Respectfully

Hamid Maleki P.E.
Principal

Table 1. Geologic, geometric, and response factors for location, .

Geologic Factor	Geometric Factor	Response Factor
Joint 1 orientation	Angle between joint 1 and face	Vertical displacement
Spacing	Angle between escarpment and joint 1	Horizontal displacement
Continuity		Volume of failure
Joint 2 orientation	Angle between joint 2 and face	Photograph
Spacing	Angle between escarpment and joint 2	Time of failure
Continuity		Face position
Bedding plane roughness (Cg shale)	Excavation width-to-depth ratio	Rock displacement after fail.
Hardness (Cg shale)	Thickness of Cg shale	
Hardness (Cg sandstone)	Thickness of Cg sandstone	
Bedding plane alteration	Erosion under escarpment	
	Talus volume	
	Canyon slope (%)	
	Escarpment slope (%)	
	Cg toe to seam distance and height	
	Angle between escarpment and mining limit	
	Concave, convex topographies	

References

Ahola M. 1990. Geomechanical Evaluation of Escarpments Subjected to Mining-Induced Subsidence. Rock Mechanics Challenges and Contributions. Balkema.

Jones R.E. 1994. Investigation of Sandstone Escarpment Stability in the Vicinity of Longwall Mining Operations. M.S. Thesis, Department of Mining Engineering, University of Utah.

Jones R.E., W.G. Pariseau, V. Payne and G. Takenaka. 1990. Sandstone Escarpment Stability in the Vicinity of Longwall Mining Operations. Proc., 31st. U.S. Symp. on Rock Mech. Golden, Colorado.

Maleki H. and K. Hollberg 1995. Structural Stability Assessment Through Measurements. Proc. ISRM Workshop on Rock Foundations, Tokyo, Japan, 1995.

Maleki H. and L. Chaturvedi 1997. Prediction of Room Closure and Stability of Panel 1 in the Waste Isolation Pilot Plant. Proc. ISRM and US 36th. Rock Mechanics Sympo. New York, NY. June 1997.

Maleki H. 1992. Significance of Bolt Tension in Ground Control. Intern. Symp. on Rock Support, Sudbury, ON, 1992.

Pells and others 1987. Cliff Line Collapse Associated with Mining Activities. Slope Stability and Stabilization. Balkema.

Shea-Albine 1992. Effects of Longwall Subsidence on Escarpment Stability. Proc., 3rd Workshop on Surface Subsidence Due To Underground Mining. WV Univ.

Starfield and Cundall 1988. Towards a Methodology for Rock Mechanics Modeling. Inter. J. Rock Mech. Min. Sci., vol 25, no.3, pp.99-106.

Pfeiffer T.J. , J.D. Higgins, R.D. Andrews , R.K. Barrett 1993- Colorado Rock Fall Simulation Program. CDOT-DTD-ED#_CSM-89-2B.

Terra-Tek 1987. Physical and Mechanical Propperties of Rock Core Samples. Deer Creek 14th Right Longwall.

ATTACHMENT A

ASSESSMENT OF STRUCTURAL STABILITY THROUGH MEASUREMENTS

ATTACHMENT B

APPLICATION OF STATISTICAL TECHNIQUES IN ROCK MECHANICS PROBLEMS- SELECTED TECHNICAL PAPERS

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON ROCK SUPPORT
SUDBURY / ONTARIO / CANADA / 16-19 JUNE 1992

Rock Support in Mining and Underground Construction

Edited by
PETER K. KAISER & DOUGAL R. McCREATH
Laurentian University, Sudbury, Ontario, Canada

OFFPRINT

A.A. BALKEMA / ROTTERDAM / BROOKFIELD / 1992

PROCEEDINGS OF THE INTERNATIONAL WORKSHOP ON ROCK FOUNDATION
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Rock Foundation

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R. YOSHINAKA
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Assessment of structural stability through measurements

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ABSTRACT: As part of its mission to improve mine safety, the U.S. Bureau of Mines implemented an extensive research program to characterize the sequence of damage to underground mine structures. Both static and geophysical measurements were obtained in the laboratory and in a western U.S. mine to study the in situ load-deformation behavior of floor material and to identify the location, timing, and growth of damage near mine excavations. This work was supplemented with three-dimensional numerical modeling to help explain the cause of damage.

It was shown that the stress field influenced the degree of damage to roof rock during excavation. Roof deformation and the extent of the damage zone grew rapidly as a result of failure in the mine floor. This failure was associated with pillar unloading and pillar shifting toward the abutment block, which increased compressive stresses in the mine roof near the pillar line. Laboratory and field measurements complemented each other, providing critical input for stability assessments and numerical models.

1 INTRODUCTION

As part of its mission to improve safety in U.S. mines, the U.S. Bureau of Mines (USBM) implemented an extensive measurement program to develop techniques for assessing changes in roof stability. Initial activities in a western U.S. trona mine utilized both static and tomographic techniques to develop a field method for assessing roof stability. These measurements (Maleki et al., 1993) also identified the interaction among roof, pillar, and floor structural elements and related the deterioration in roof conditions to premature failure of the mine foundation (floor).

To improve understanding of floor behavior, a laboratory and field measurement program was recently implemented at the same mine in an attempt to characterize in situ material behavior of the mine floor. These measurements were supplemented by both static and tomographic measurements in the mine roof and pillar and numerical modeling to better define the interaction among floor, pillar, and roof movements and the resultant stability problems.

In this paper, following a review of the mine's geological setting, foundation measurements (direct-shear tests, uniaxial compressive strength tests, in situ borehole shear tests, in situ plate-bearing tests, and tomographic imaging) and other measurements in the mine roof and pillar will be presented. Numerical modeling results will be used to verify the sequence and growth of damage in mine structures.

2 GEOLOGICAL SETTING AND MEASUREMENT PROGRAM

The field measurements were obtained in a western U.S. trona mine located in the Green River basin, Wyoming. The mine uses continuous miners and shuttle cars to develop a four-entry panel access with additional extraction on one side of the panel during retreat mining. Entries were 5 m wide, leaving 5-m-wide, 30-m-long pillars in place to support overburden.

The mineable seam is 3.3 m high and is located 426 m below the surface. The immediate roof consists of 1 m of trona and is overlain by a sequence of marlstone, trona, and shortite inclusions (fig. 1). Thin clay layers are present in both the seam and the roof. The immediate floor consists of marlstone with variable amounts of shortite crystalline inclusions.

Trona is the stiffest member of the strata. Young's modulus for trona is 17.24 GPa, six times higher than that of the marlstones in the mine floor. Specific gravity ranges from 2 to 2.4, and moisture content is 28 pct on the average.

The in situ stress field in the basin was measured using overcoring techniques and USBM deformation gauges in three boreholes. Measured stresses were as follows: east = 9.4 MPa, north = 15 MPa, vertical = 19 MPa, east-north shear = 2.8 MPa, north-vertical shear = 0.2 MPa, and east-vertical shear = 0.9 MPa. Both vertical and horizontal stresses were greater than expected from calculations of overburden weight. Similar measurements at the mine have confirmed the orientation of stresses, but magnitudes were 50 pct lower in the mine roof.

Earlier instrumentation projects in the mine (Maleki et al., 1993) identified large amounts of deformation that occurred first in the mine floor, possibly as a result of pillar penetration. However, there were not sufficient data to confirm the rock mass strength and the failure mechanism. In this investigation, an instrumentation program was designed to improve understanding of floor-rock behavior.

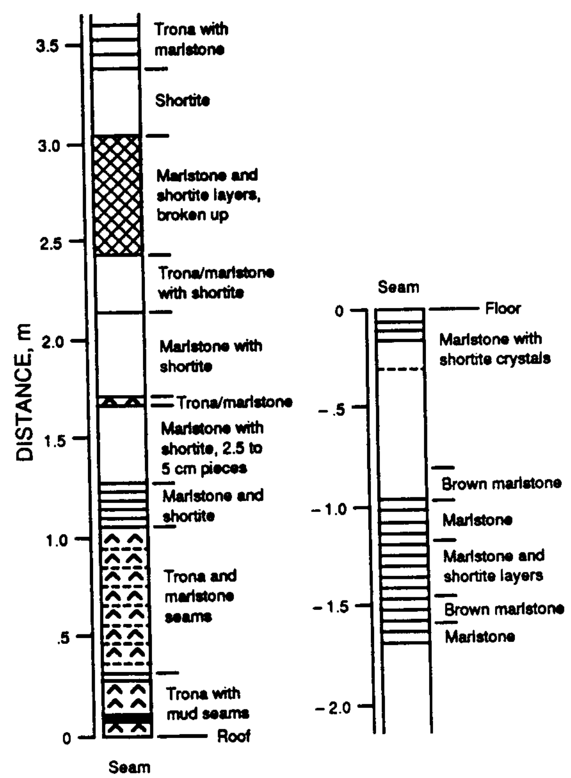

Figure 1. Corehole lithology.

Mining geometry and instrument layout is shown in figure 2. Most of the instruments were installed in room 1 and the adjacent pillar. However, the whole access panel was periodically mapped to record any obvious changes in strata fracturing, floor heave, rib falls, etc. At installation time, the face was 30 m from the cluster of instruments at mid-pillar. The development continued for 500 m before a 100-m-wide retreat face was set up and retreated toward the instruments. The following tasks were completed.

- o Tomographic surveys in the mine roof and floor at 45- to 60-day intervals.
- o Biweekly deformation measurements in the mine roof, pillar, and floor.
- o Mapping and borehole observations and core testing for the mine roof and floor at the beginning of the monitoring program and at other selected times.
- o Overcoring stress measurements within the pillar near completion of the monitoring program.
- o Borehole shear tests in the mine roof and floor at the beginning of the program.
- o Plate-bearing tests at the beginning of the program.

The tomographic layout is shown in figure 2. Accelerometers were attached to the mine roof and floor at 0.6-m spacings along the entry span. These accelerometers had flat frequency responses in the range of 1 to 6,000 Hz. Both an impact unit (Maleki et al., 1993) and blasting caps were used in boreholes as the energy source. They were energized in two source holes at 0.6 to 3.6 m into the roof and floor at 0.6-m spacings. The data acquisition system is described in a paper by Maleki et al. (1992).

Using seismic tomographic techniques (Schneider, 1990), one may construct a velocity or attenuation map of the zone of interest. In this study, a seismic travel-time tomographic survey of the mine roof and floor was implemented along the width of the entry to monitor changes in strata fracturing. Tomography is a mathematical inversion technique for imaging the areal distribution of a physical property of a solid object. Measurements of physical properties on the plane of interest can be solved for measurements obtained at the boundaries. A series expansion technique using an iterative, reweighted, least-squares method was used. Pixel dimension was approximately 50 cm in both the horizontal and vertical directions, which was compatible with the resolution for this study. For ray tracing, minimum time wave-front modeling was utilized (Schneider, 1990). A constant average velocity of the medium was used initially in the iterative process. First P-wave arrivals were picked for the tomographic calculations.

The resolution of the seismic method depends on the predominant wavelength in the signal. A frequency analysis of the recorded signal showed that the predominant frequency of the signal was 2 Hz. Since the seismic velocity of trona is about 4,200 m/s, the predominant wavelength was at best 2.1 m. A practical rule of thumb to determine resolution is that the seismic method should afford the resolution of features with a 1/4-wavelength dimension. The resolution of the system used in this study was at least 50 cm. The sampling frequency was 25 kHz, and the trace length was 40 milliseconds. The accuracy of triggering for this system was 40 microseconds. This time gave a 17-cm error in a medium of 4,200 m/s.

An array of extensometers was installed in the test area to measure relative roof movements. The extensometers were anchored from 1 to 5 m above the roof on 1-m spacings. Two cores were obtained from the roof and floor to measure physical properties. Roof appearance also was mapped to monitor development of fracture patterns.

Seam instruments consisted of vibrating wire stress meters placed in the pillars and abutment block and rib movement pins anchored 0.6, 1.5, 2.1, 2.7, and 3.3 m into the pillar. Relative lateral movements were measured using a tape extensometer attached to a 5-m-deep reference point in the abutment block. These stressmeters and floor movement pins were installed to monitor pillar response and roof-pillar-floor interactions. The pins were anchored diagonally below the pillars at depths of 0.9, 1.5, 2.1, and 3 m into the floor; tape extensometers and the same 5-m-deep reference point were used for these measurements.

USBM-developed deformation gauges and overcoring techniques were used in a horizontal hole to measure vertical stresses in the pillar at 0.5-m spacings; these measurements were critical for determination of residual strength of pillar-floor composite materials. Borehole observations and tomographic pillar surveys were carried out, but are not described in this paper.

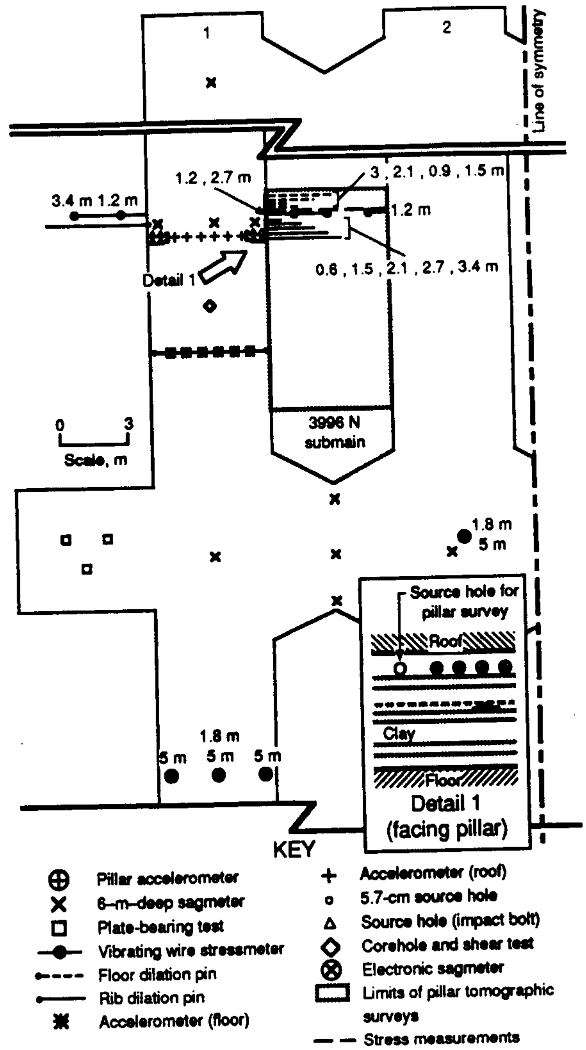

Figure 2. Instrument layout and mining geometry at time of installation.

3 FLOOR MEASUREMENTS

A number of laboratory and in situ measurements were obtained to characterize the load-deformation behavior of the floor strata. Laboratory tests consisted of direct-shear tests, uniaxial compressive strength tests, and sonic tests; these tests were completed on 50 mm in diameter samples obtained from the mine floor at the beginning of the field program. In situ measurements consisted of borehole shear tests, plate-bearing tests, tomographic measurements of velocity patterns, and lateral deformation measurements.

- o Laboratory direct-shear tests

These tests were performed on marlstones of the immediate floor, which contained various amounts of shortite crystals. To obtain shear strength parameters (cohesion, angle of friction, and dilation angle), normal load was changed from 0 to 400 kPa within the limitations of the laboratory testing machine. Samples were tested with a controlled shear velocity of 0.5 mm/min.

Most samples deformed 1 mm in shear (0.2 strain) before they reached their peak shear strength. A few samples that contained clay veins, however, yielded to a residual strength

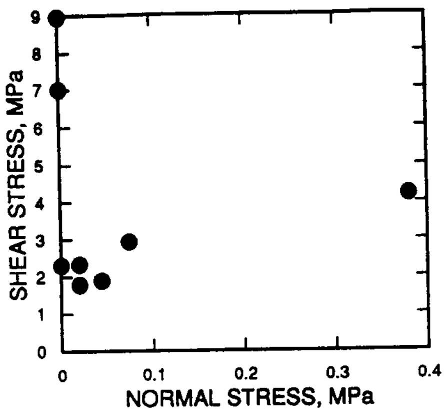

Figure 3. Direct-shear test results.

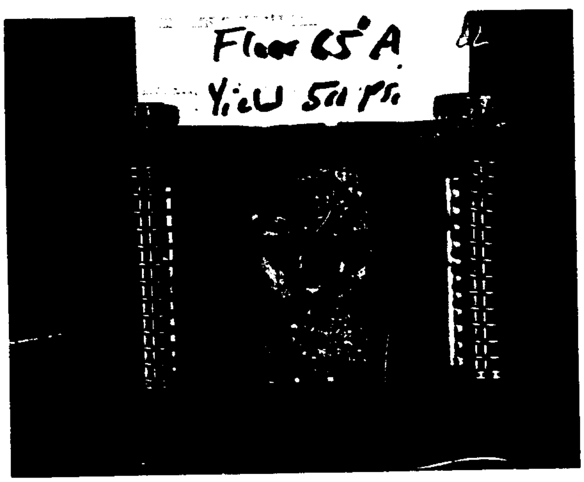

Figure 4. Typical condition of samples during unloading.

equal to 84 pct of the peak strength. Most vertical expansion (dilatancy) was reached just prior to peak strength, but dilatancy was reduced significantly during sliding. The dilation angle was influenced by the location of shortite inclusions, causing a significant uplift for some samples prior to failure. Dilation angles of 44° to 0° were calculated during loading and unloading of samples.

Figure 3 presents normal shear-stress relationships for these tests; shear strength is not strongly influenced by normal stress and thus the strength appears to be primarily influenced by cohesion. The cohesion was between 2 to 3 MPa for most tests at low normal stresses.

o Uniaxial compressive strength
Six intact 50- by 100-mm samples were tested in a stiff testing machine to determine full load-deformation behavior of the floor samples. Sample deformation was monitored by axial and lateral strain gauges and two axial linear transducers, which were used to monitor average strain in the post-failure regime when the strain gauges were not functional. Figure 4 shows the testing equipment and sample conditions during unloading.

Typical results (fig. 5) indicated a peak compressive strength of 13.8 MPa. Other tests show peak compressive strengths reaching 18 MPa. Samples rapidly unloaded to a residual strength of 1.5 MPa at 2 to 3 pct strain. Unloading was associated with near-vertical cracks, confirming that strength was controlled primarily by sample cohesion. Young's modulus and Poisson's ratio were ranged between 2.7 to 8 GPa and 0.1, respectively.

o Sonic measurements
The P-wave velocities of core samples were measured in the

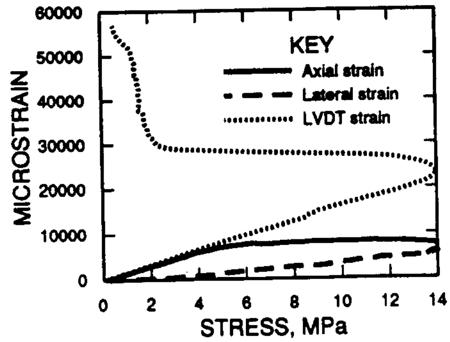

Figure 5. Typical stress-strain relationship for samples from mine floor.

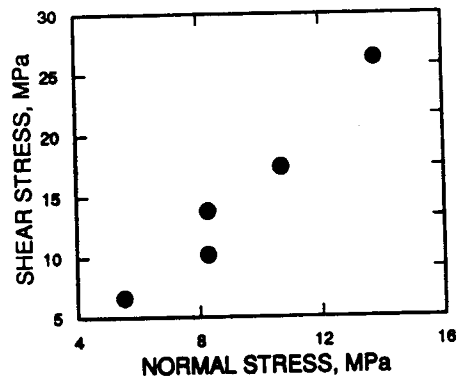

Figure 6. Normal shear stress relationship, borehole shear test.

laboratory prior to destructive tests and results were compared to in situ velocities obtained through tomographic calculations. There was a very good agreement between trona velocity (4,600 m/sec) calculated from the core and in situ. Floor rocks, however, exhibited 24 pct higher velocities in situ than in the laboratory; this result was attributed to one or any combination of the following: (1) stress-induced structural damage during excavation, (2) rock damage during sampling and preparation, and (3) higher confining stresses in situ.

o Borehole shear tests
The Iowa borehole shear test device was used to determine the shear strength parameters of floor rocks. The device consists of two grooved plates that are pushed into the borehole wall under a uniform normal load. Shear failure near the wall is induced by pulling the device out and recording the amount of deformation. The device was used in both intact and fractured zones that corresponded to core logs.

Typical results (fig. 6) for an intact zone provided an upper limit for the shear strength parameters that were in general agreement with laboratory results, i.e., a cohesion of 3.3 MPa and an angle of friction of 21°. Cohesion was significantly lower in the fractured zone.

o Plate-bearing tests
The plate-bearing device consisted of a 100-ton hydraulic jack installed between the roof and the floor, a 152-mm in diameter circular steel bearing plate, and a level for measuring the displacement of the hydraulic piston into the floor. A large plate was used at the roof contact to avoid any penetration into the roof. The tests were conducted in a fresh cut (fig. 2) after all debris was removed.

Two typical load-deformation behaviors were identified (fig. 7). The first was nonlinear behavior that changed into perfectly plastic behavior, and the second was linear behavior that reached peak bearing capacity and then dropped to a residual value at 16 mm of deformation. The peak stress range, for all tests, was from 7.5 to 20 MPa and the residual stress was 3 MPa.

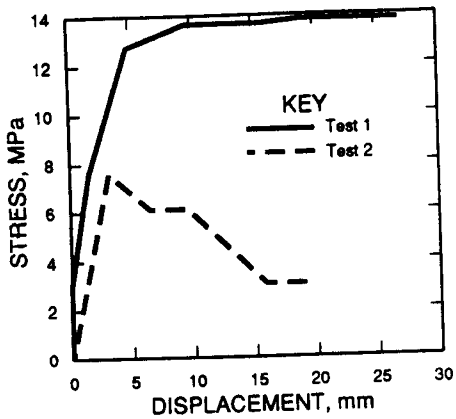

Figure 7. Typical load-deformation behavior, plate-bearing tests.

Figure 8. Failure pattern, plate-bearing tests.

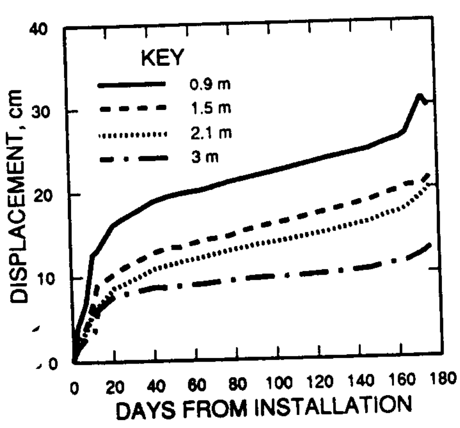

Figure 9. Lateral deformation history of mine floor.

The steel plate initially penetrated into the floor without any observed radial cracks (fig. 8); such behavior is common to porous, brittle material (Ladanyi, 1968) for which the mode of failure is structural collapse and little lateral strain at higher deformations exceeding 15 mm, however, in this test radial cracks appeared around the plate.

- o Lateral floor deformation
  Four deformation pins were anchored diagonally below the pillar at depths of 0.9, 1.5., 2.1, and 3 m into the floor to measure the amount of lateral movement of the floor rocks toward the excavation (fig. 2). The deepest anchor was approximately 2 m below the excavation horizon.

Three movement cycles were identified (fig. 9). (1) An accelerated cycle that occurred during the first 10 days after mining when pillar stress and penetration were maximum, (2) a steady deformation during which movement continued at a slower rate, and (3) another accelerated cycle beyond day 150 when secondary retreat mining resulted in load transfer to the pillar, which renewed penetration.

Lateral floor deformation exceeded elastic strains (1 pct) significantly, indicating that the failure process was initiated below the entire pillar width shortly after mining. The depth of the failure zone was at least 2 m because the amount of measured deformation significantly exceeded the amount of elastic deformation (1 pct strain) measured in the laboratory.

4 ROOF AND PILLAR MEASUREMENTS

An important part of this study was to assess the impact of floor failure on roof stability. This required obtaining detailed measurements of roof deformation history, changes in wave velocity in the roof, and periodic mapping. In addition, pillar stress and deformation profiles were measured to confirm inelastic deformation of the composite pillar and floor material.

- o Roof deformation
  Maximum roof relative deformation was measured between the collar of a hole and the deepest anchor (5 m into the roof). Roof movements were greatest in the No. 1 entry and least in the crosscuts.
  Relative roof deformation is presented in figure 10 along the span of the No. 1 entry. The movements were always higher near the pillar line than near the center of the entry, indicating rock damage at this location.

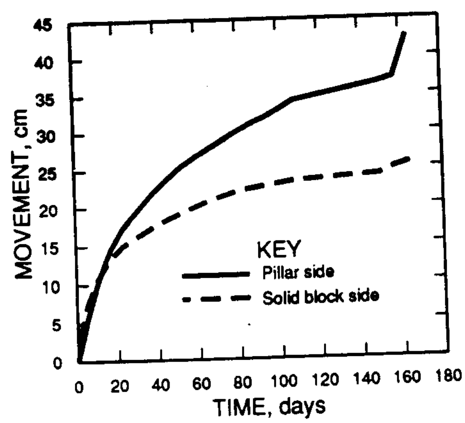

Figure 10. Relative deformation history of mine roof.

- o Wave velocity pattern
  Wave velocity images of the mine roof at the beginning and end of the monitoring program are presented to show the presence and growth of fracture zones (figs. 11 and 12). Although there was no visual sign of fracturing at the development stage (fig. 11*B*), wave velocities were lower near the pillar; this finding was in agreement with roof deformation measurements, indicating fracturing and structural damage near the pillar.
  Wave velocity in the mine roof changed significantly (25 pct) during this 6-month monitoring period as damage to the rock mass increased because of the growth of fractures and increases in bed separations. Figure 12 illustrates the velocity pattern and ground conditions when the retreating face approached within 15 m (50 ft) of the instruments. As rock fracturing developed toward the pillar side, the roof behaved as a cantilever beam. In time, other fractures formed in the upper portion of the roof (near the solid block), forming a block of rock that was suspended from the upper strata by roof bolts. The operator installed sets of secondary support (wire mesh and 2.4-m-long bolts) and tertiary support (3.6-m-long bolts) to control block movement.

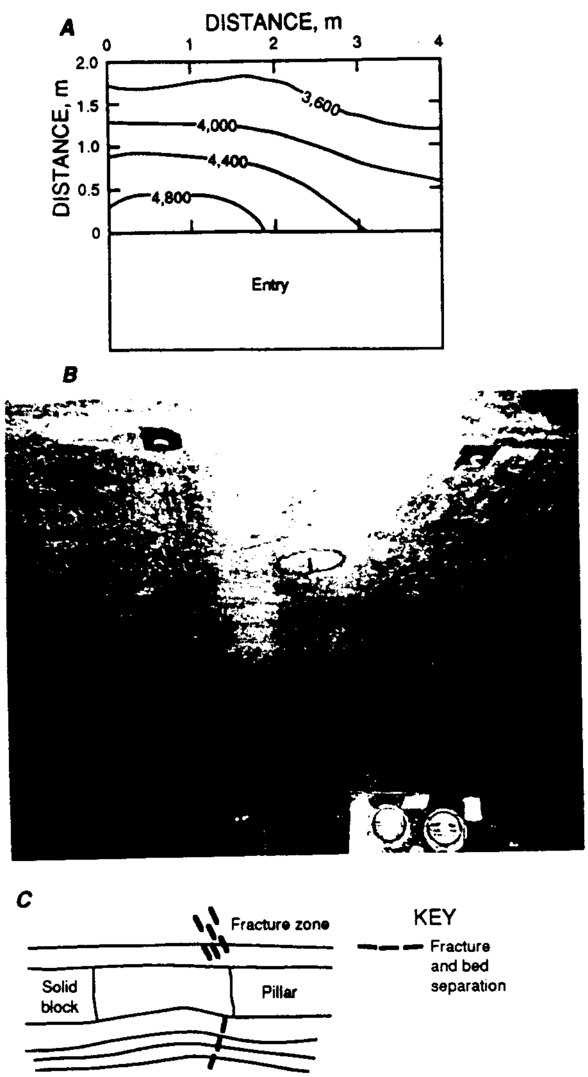

Figure 11. Velocity contours and ground conditions at development face positions. (*A*) Velocity image (M/A); (*B*) actual roof condition; (*C*) schematic of strata movements.

o Lateral pillar movement
The movement of the pillar with respect to the abutment block was measured with a tape extensometer attached between a reference point and anchors located 0.6, 1.5, 2.1, 2.7, and 3.4 m deep into the pillar. Note that the deepest anchor was set 0.5 m beyond the center (mid-width) of the pillar; this made it possible to determine whether the entire pillar was moving or just the ribs.

Although there was some differential movement between the anchors, the deformation pattern (fig. 13) indicated that the whole pillar shifted toward the abutment block by at least 50 mm. This behavior is not typical for an elastic pillar-floor system but can be represented with a Mohr-Columb strain-softening constitutive model for a mine floor, as described later.

o Pillar stress profile
A pillar stress profile was obtained using the overcoring stress measurement method when the retreating face was 50 m from the instrumented pillar. Ten overcores were obtained and tested in the biaxial chamber to obtain Young's modulus, which was used for calculation of the vertical and horizontal stresses.

Biaxial tests revealed a significantly lower Young's modulus for the first 1 m of the pillar than for the core of the pillar, indicating structural damage; this finding was in agree-

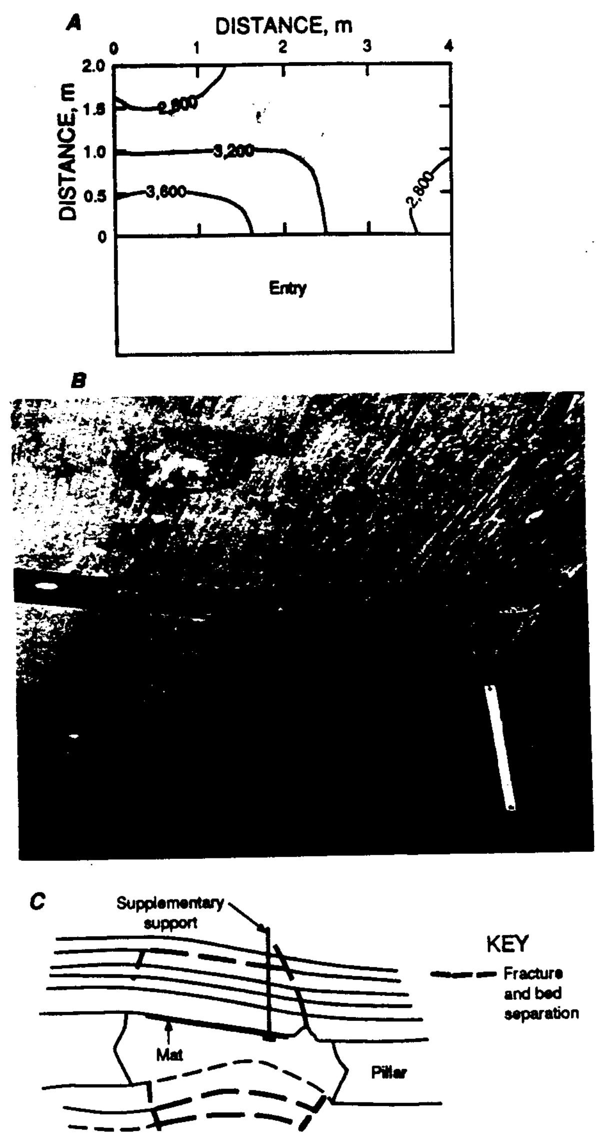

Figure 12. Velocity contours and ground conditions at retreating face position. (*A*) Velocity image (M/A); (*B*) actual roof condition; (*C*) schematic of strata movements.

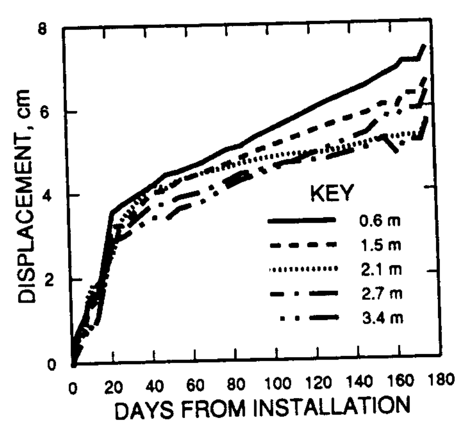

Figure 13. Lateral deformation history of mine pillar.

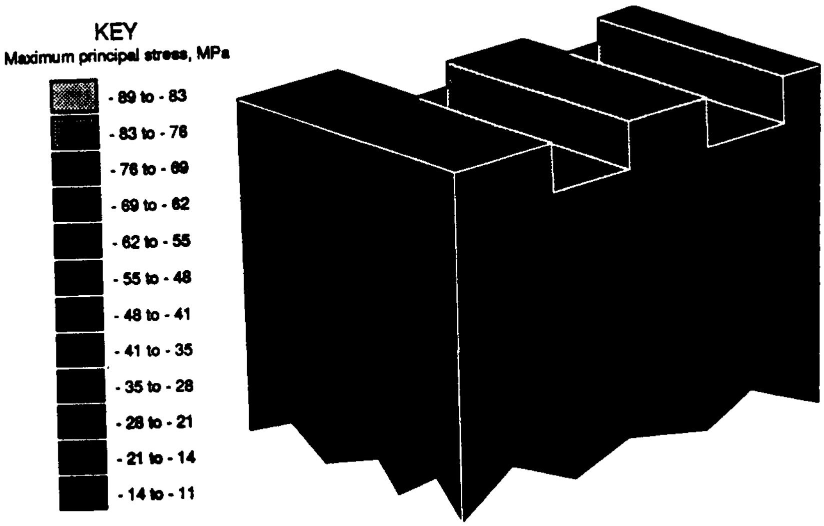

Figure 14. Model geometry and maximum principal stress contours, elastic analyses.

Table 1. Mechanical properties.

	Main roof	Seam and immediate roof	Floor
Shear modulus, GPa	2.1	6.4	0.8
Bulk modulus, GPa	3.2	19	1.7
Angle of friction	NA	NA	10°
Dilation angle	NA	NA	21° to 21.5°
Cohesion	NA	NA	7 MPa at $P_\epsilon = 0$ 1 MPa at $P_\epsilon = 0.008$

NA Not applicable.
P_ϵ = plastic strain.

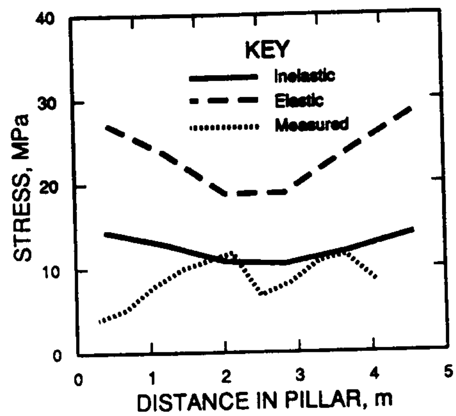

Figure 15. Comparison of measured and calculated vertical stresses on pillar.

ment with field observations of rib movements and slabbing.

The vertical stress for an average pillar was 7.3 MPa, significantly below the elastic pillar stresses of 24 MPa. This result confirmed that the composite pillar and the floor had yielded, reaching a residual strength of 7.3 MPa. Such a mechanism was further explored using three-dimensional numerical models.

5 NUMERICAL MODELING

Laboratory and field measurements provided valuable information regarding the load-deformation characteristics of floor rocks and the extent of failure zones in the mine floor and fracture zones in the mine roof. In particular, it was shown that the marlstones of the mine floor were soft and weak, reaching peak strength and then exhibiting strain-softening characteristics. Shear strength was controlled by cohesion while the angle of fricfion and dilatancy were generally small near the peak strength.

Although roof rocks were initially damaged under the influence of a rather high stress field, the damage and amount of deformation grew in time as a result of large amounts of inelastic deformation in the mine floor. Floor failure significantly influenced load transfer through the pillar and contributed to pillar shifting toward the solid block.

To help explain observed ground conditions and the failure mechanism, a series of two- and three-dimensional numerical models were set up. The modeling methodology (Maleki et al., 1993) consisted of a simple elastic analysis followed by inelastic modeling of the mine floor, pillar, and roof. An analysis using Mohr-Columb plasticity with strain softening for the floor rocks best agreed with observed deformation but required input regarding changes in cohesion, angle of friction, and dilation as a function of plastic strain (Itasca, 1994). These data were not available until recently. The modeling was completed for development mining (day 150), but excluded any load transfer resulting from retreat mining.

Material property inputs are presented in table 1. Elastic properties were obtained from laboratory measurements while variations in cohesion as a function of plastic strain were obtained from combining uniaxial and plate-bearing test results. Direct-shear tests were used for determination of dilation angles. A relatively low angle of friction of 10° was used based on laboratory and borehole shear tests (0° to 21° range).

The variations in cohesion with plastic strain were important in influencing calculated stresses and deformation. An upper and lower bound for cohesion was estimated using (1) one-half of uniaxial compressive strength (7 to 9.6 MPa range) and (2) bearing-capacity tests and Terzaghi's equation for general shear failure (1 to 2 MPa) (Das, 1994).

Initially, a three-dimensional elastic analysis was completed to study areas of high stress concentrations and failure zones; the latter was obtained through post-processing of results using a Mohr-Columb failure criterion. Figure 14 presents the analyzed geometry and the maximum principal stress contours. The front, right, and back sides of the model are lines of symmetry, effectively modeling an area eight times larger than shown. The top (roof) of the model is removed so stress distributions in the pillar floor, entries 1 and 2, the abutment block, and the crosscuts can be viewed.

Average elastic pillar stresses were 24 MPa, significantly higher than measured stresses. This result confirmed that the pillar-floor material yielded, transferring loads to the solid block. In addition, the maximum principal stress concentration was highest near the pillar rib and intersections (fig. 14), contributing to rock damage at an early stage of excavation at this location.

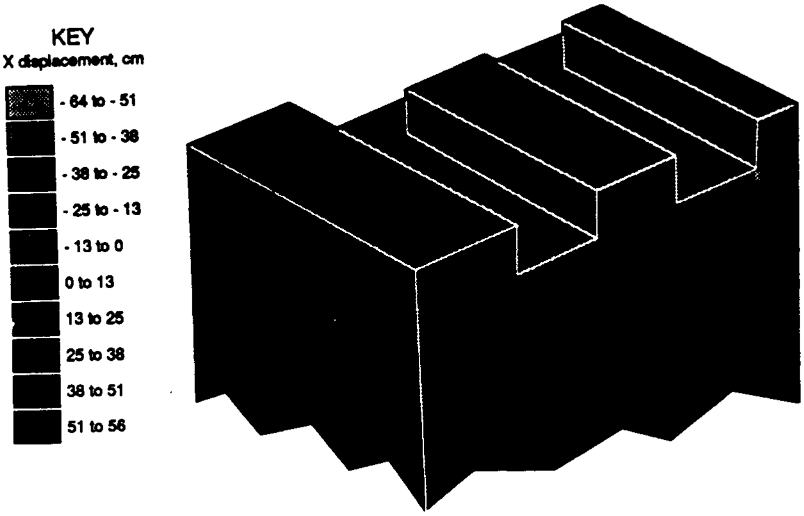

Figure 16. Lateral deformation contour, strain-softening model.

General calculated failure patterns and pillar stresses for the inelastic analysis were in good agreement with the measurements. In particular, the failure zone extended 2 to 3 m below the pillar, the pillar (fig. 15) transferred loads to the solid block, and lateral (x) the deformation of the whole pillar was toward the solid block (fig. 16).

Measured and calculated pillar vertical stresses are compared in figure 15 using the results from both elastic and inelastic modeling. Results confirm significant pillar unloading as a result of failure in the mine floor. Modeling predictions can be further improved by incorporating rib softening and including additional loads transferred because of retreat mining.

6 CONCLUSIONS

An assessment of the sources and the sequence of events leading to structural damage was identified using laboratory tests, field measurements, and numerical modeling techniques. Laboratory and field data were used to estimate in situ shear strength parameters for input to numerical models. Field measurements were also critical in identifying the initiation and growth of rock damage in the mine roof and floor.

It was shown that the roof was initially damaged under the influence of the stress field. The amount of roof deformation and the extent of the damage zone increased rapidly as a result of failure in the mine floor. This was associated with pillar unloading and shifting toward the solid block. This further compressed the roof along the pillar line (entry 1), increasing the extent of the damage zone. A three-dimensional Mohr-Columb plasticity model with strain softening agreed with the overall deformation and pillar stress patterns, providing a mechanism for explaining the cause of structural damage.

REFERENCES

Das, M.B. 1994. Principles of geotechnical engineering. 3rd ed., Boston: PWS Publishing, 672 pp.
Itasca 1994. Fast Lagrangian analysis of continua in three dimensions. Version 1.0, Minneapolis.
Ladanyi, B. 1968. Rock failure under concentrated loading. *10th Symp. on Rock Mech.*, SME.
Maleki, H., W. Ibrahim, Y. Jung & P.A. Edminster 1992. Development of in integrated monitoring system for evaluating roof stability. *Proc. 4th Conf. on Ground Control for Midwestern U.S. Coal Mines*, S. Illinois Univ., pp. 255-271.
Maleki, H., Y. Jung & K. Hollberg 1993. Case study of monitoring changes in roof stability. *Int. J. Rock Mech. Min. Sci. & Geomech. Abstr.*, Vol. 30, No. 7, pp. 1385-1401.
Schneider, W.A., Jr. 1990. A three-dimensional physical model applying tomographic inversion and seismic migration to the tunnel detection problem. Ph. D thesis, Colorado School of Mines.

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Significance of bolt tension in ground control

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ABSTRACT: Bolt installation tension is considered to be one of the most important factors contributing to rock reinforcement when mechanically anchored roof bolts are used. To evaluate the influence of uniform tensioning on roof stability, 13,000 mechanically anchored roof bolts were installed in an operating coal mine using both a conventional and a thrust-torque-controlled bolting machine. Geological and mine conditions were monitored when the bolts were installed and for 2 months afterward, and limited monitoring of roof sag, bolt tension, and changes in entry stability continued for another 4 years. Eleven of 24 variables were quantified and statistically analyzed for significance and correlations; the important bolting variables influencing roof sag were coefficient of variation of bolt tension and standard deviation of bolt tension. Long-term monitoring gave inconclusive results regarding bolt tension reinforcement mechanisms at this site. Other studies in highly stressed or weak ground have confirmed the importance of bolt tension in rock reinforcement. These studies are being integrated to develop criteria for primary support selection.

1 INTRODUCTION

The U.S. Bureau of Mines has supported several research projects to evaluate roof bolt reinforcement mechanisms and thus to increase bolt effectiveness for ground support. Two recent studies were directed to identifying optimum bolt tension for mechanically anchored bolts (Lang and Bichoff 1981) and evaluating the influence of uniform bolt tension on roof stability (Maleki et al. 1986). Through these and subsequent programs, the influence of torque and thrust on bolt installation tension was evaluated (Rosso 1977). One of the results of these programs was the development of a retrofitable control box that could monitor and control the torque and thrust of an existing bolting machine (Brest van Kempen and Sweet 1978; Mahyera et al. 1981; Mahyera and Jones 1984; and Brest van Kempen 1986).

To further evaluate the influence of uniform bolt tension on roof stability, a field project was initiated at a coal mine on the Wasatch Plateau of Utah (Maleki et al. 1986). During this project, 13,000 mechanically anchored bolts were installed in over 19 crosscuts in a four-entry system. Both a conventional bolter and a bolter equipped with torque and thrust control were used to place the bolts (the controlled bolter). Geologic, bolting, and geometric parameters were measured at the time of bolt installation and for 2 months after.

Statistical analyses of these data indicated that uniform bolt tension during installation was very important in limiting roof sag. However, nonbolting parameters, such as roof lithology and roof shape, were shown to have a significant influence on amount of roof sag as well. Furthermore, no significant stability problems (i.e., roof fall) occurred in areas where either mechanically anchored bolts or resin-grouted bolts had been used.

While searching for ways to select primary support systems for coal mine roof, the author has collected observations and measurements from 20 different strata in 12 U.S. coal mines and is incorporating this information into an expert system that relates bolt type to geology and stress conditions. Mechanically anchored bolts, fully resin-grouted bolts, and fully grouted tensioned bolts are considered. Other bolts, such as partially grouted combination bolts, are excluded from this study.

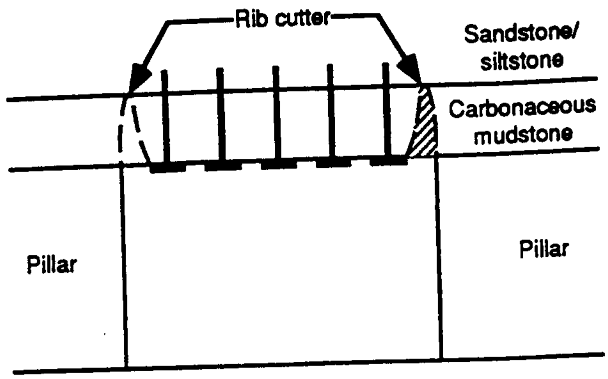

Figure 1. Schematic of bolt reinforcement by suspension.

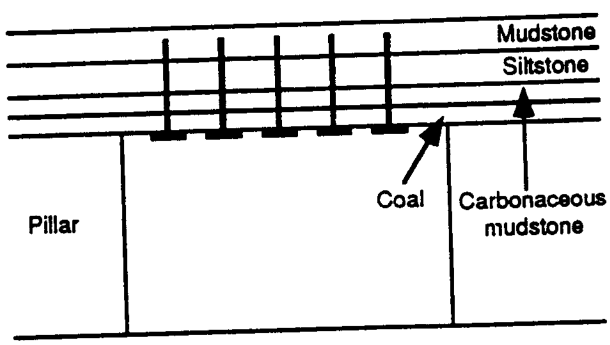

Figure 2. Schematic of bolt reinforcement by beam building.

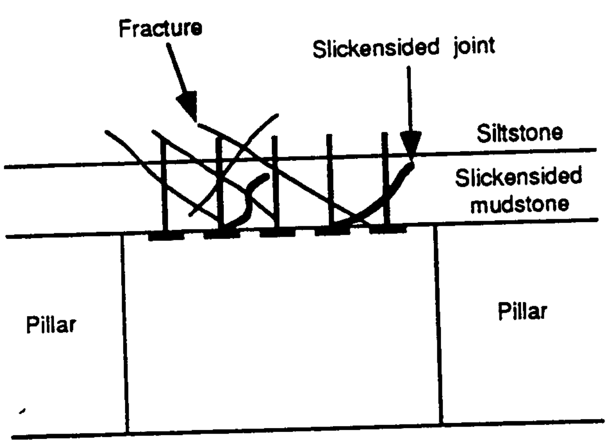

Figure 3. Schematic of bolt reinforcement by keying.

2 REINFORCEMENT MECHANISMS

Rock reinforcement prevents the detachment of thin beds from the rock mass surrounding an excavation by increasing the shear resistance of discontinuities and enhancing interlocking between rock blocks (Tadolini and Dyni 1991). These reinforcement mechanisms are commonly denoted as suspension (Figure 1), friction or beam-building (Figure 2), and keying effects (Figure 3). The type of rock support chosen should possess sufficient flexibility to allow stresses to be redistributed in plastic rock and should have enough stiffness to minimize sliding and bending between rock layers. In general, reinforcement should be installed as soon as possible after excavation to prevent rock strata from opening and sliding along discontinuities.

Table 1 compares the reinforcement mechanics of mechanically anchored, fully resin-grouted, and fully grouted tensioned (combination) bolts; Figure 4 (Stillborg 1986) presents stiffness characteristics of these bolts in dolomite. The stiffness of combination bolts may be estimated from the stiffness of the two curves for the other two bolt types and is believed to be higher than for the other two bolt types. From this figure, it is evident that resin and combination bolts provide much higher resistance to movement than do mechanically anchored bolts. On the other hand, mechanically anchored bolts are suitable for short-term reinforcement of uniform, thin-bedded or massive strata in mines with low tectonic stress fields. Fully resin-grouted bolts are suitable where a potential for sliding failure exists under low to moderate tectonic stress fields. Combination bolts, which combine the reinforcement characteristics of both resin-grouted and mechanically anchored bolts, are thus suitable for either weak or highly stressed rock masses.

3 SIGNIFICANCE OF BOLT TENSION

The importance of bolt tension in mine roof reinforcement was studied in a comprehensive field evaluation of mechanically anchored bolts. Results are summarized below.

3.1 Test site

A test site (Figure 5) was selected in a mine on the Wasatch Plateau where there was a large degree of variability in roof lithology, roof stability, and mining geometries. This variability was ideal for statistical evaluations. Roof lithologies at subsites A1, A2, and A3 were significantly different and consisted of a sandstone channel (A2) and mudstone (A1 and A3). Resin-grouted bolts and mats were used for primary roof support at the mine, but during the project, a switch was made to mechanically anchored bolts in the test section.

Table 1. Reinforcement mechanisms and factors influencing support effectiveness.

	Mechanically anchored	Fully resin-grouted	Combination
Reinforcement:			
Suspension....	Depends on anchorage capacity	Good	Best
Friction......	Depends on anchorage capacity and bolt installation tension	Good	Best
Keying........	Adequate	Good	Best
Suitability:			
Entry life....	Short-term	Long-term	Long-term
Stress field..	Low	Low to moderate	Low and high
Hydrologic....	Relieves hydrostatic pressure but may rust	Traps hydrostatic pressure	Traps hydrostatic pressure
Lithologic....	Massive...............	Laminated, cohesive	Laminated, noncohesive
	Laminated and uniform..	Massive	Massive

3.2 Roof bolting

A conventional bolter and a controlled bolter were used to compare tension uniformity as the bolts were placed. The controlled bolter was equipped with a retrofitable box for torque and thrust control; this retrofitable box was developed by Brest van Kempen and Associates under contract with the U.S Bureau of Mines. Hardened washers and lubrication at both the bolthead and the shell produced uniformly tensioned bolts. Two-thirds of the bolts were installed with the conventional bolter and one-third was installed with the controlled bolter.

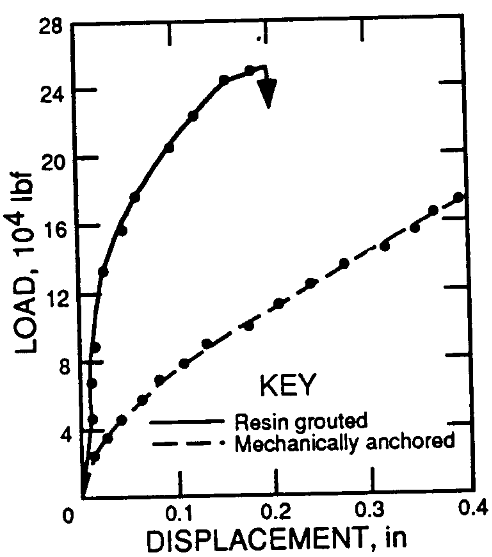

Figure 4. Typical pull test results from mechanically anchored and resin-grouted bolts (after Stillborg, 1986).

3.3 Characterization

Geologic characterization consisted of mapping the test site, logging the lithology of sagmeter hole cuttings and core holes (generally 10 ft deep), and plotting cross sections (Figure 6). Roof joints and other irregularities were recorded at the time of mining, while locations mined earlier were revisited to record roof flaking and falls, persistence of water, etc.

Bolting patterns changed from 3-ft spacings using 5-ft-long bolts in subsites A1 and A3 to 3-ft spacings using 4-ft-long bolts in the roof of a sandstone channel at subsite A2. Although mining heights were generally constant, there were some variations, from 7 ft at subsite A3 to 10 ft at subsite A2. A switch from mining

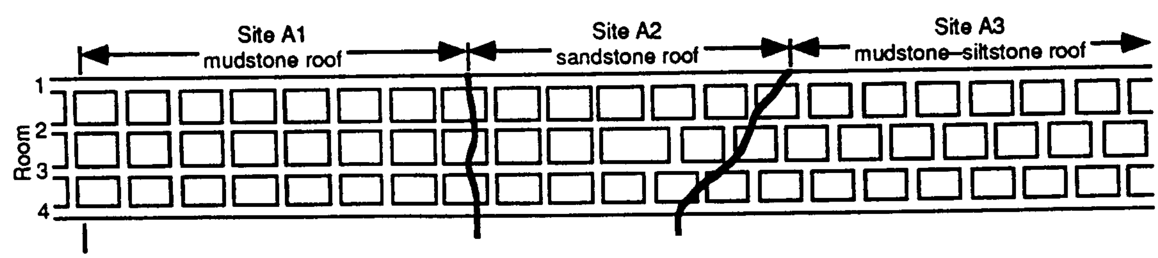

Figure 5. Plan view of test site.

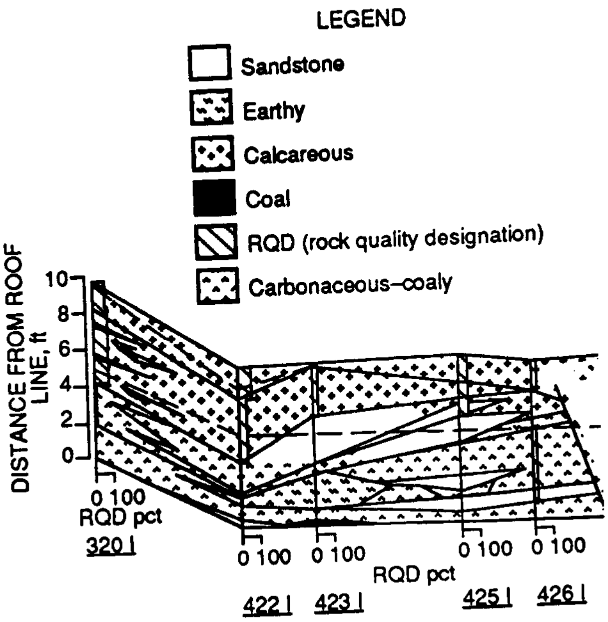

Figure 6. Lithologic cross section of roof at subsite A1.

four-way intersections to mining three-way intersections was made halfway through development at the test site. These data were recorded regularly on overlays of mine plans and used to derive numerical variables.

3.4 Instrumentation

Instruments consisted of 314 bolts for measuring bolt tension, 60 sagmeters, and several mechanical packers for measuring groundwater pressure. In addition, torque on all instrumented and standard bolts was measured immediately after the bolts were installed, and mine air conditions (temperature, humidity, and barometric pressure) were monitored continuously to determine if changes in these conditions caused any instability.

Proper measurements of bolt tension and bolt tension history were important to achieve the objectives of the project. Considerable research (Maleki et al. 1985a) was conducted to modify an existing bolt instrumented with an IRAD vibrating wire to measure bolt tension accurately. Some of the modifications were required so that the instrumentation did not affect bolt tension or the torque/tension relationship; this was important to prevent because the instrumented bolts were only a small portion of the total number of bolts installed. The instrumented bolts housed IRAD vibrating wire gauges in a central hole drilled in a larger diameter bolt. To prevent the bolt from bending and behaving nonlinearly at the instrumented location, roof facing was used (see Maleki et al. 1985b). The representativeness of the instrumented bolts was confirmed by comparing torque histories for these bolts with histories of bolts to the left and right.

Three to eight instrumented bolts were generally installed in clusters along with a sagmeter and, if there were indications of groundwater pressure, a mechanical packer. Average bolt tensions and standard deviations of bolt tension in relation to measured roof sag within 10 ft of the roof were then calculated at different times following installation.

These data, together with characterizations of the geologic, mining, and bolting variables for individual clusters (stations), were later used to determine the effects of geologic, mining, and bolting parameters on roof sag. The instruments were monitored frequently for 2 weeks after mining and then less frequently for up to 2 months.

3.5 Cluster data summaries

A data summary sheet was prepared for each of the 67 instrumented clusters. Each summary sheet (Figure 7) consisted of the histories of individual bolt tension, average bolt tension, bolt tension coefficient of variation, and roof sag, and a cluster map. The coefficient of variation for bolt tension is a convenient way of expressing variability in bolt tension (or bolt tension uniformity) as a ratio of average bolt tension. Cluster maps (Figure 7E) summarize characterization and mining data.

A logarithmic scale was used for the time axis of the plots because of the exponential nature of bolt tension decay. This transformation resulted in a linear decay line for bolt tension when no bed separations were present or when roof loads were applied. This idealized line is shown in Figure 7 as the tension decay line.

3.6 Numerical variables

Cluster data summaries and overlays were used to derive 37 variables: 10 geologic, 14 mining-bolting, and 11 response. Table 2 presents a summary of the algorithm. A few of the variables are described further below.

* Roof lithology variable--accounts for the thickness of major lithologic units within the first 10 ft of roof, their relative strengths (index), and their pos-

itions within the immediate roof. Position information was collected by using a multiplier (m) equal to 3 for the first 5 ft of rock and equal to 1 for the strata above. This resulted in higher values (indicating weaker roof) for roof lithology if weaker mudstones were within the first 5 ft of roof.

* Dip variable--accounts for changes in the slope of mudstone or other critical contacts, such as those that could occur in the vicinity of sandstone channels.

* Bolt tension decay slope--reflects rock properties at the bolt anchorage horizon and is calculated from measurements taken within 5 min of bolt installation.

* Roof shape variable--was assigned a value of 1 for a flat roof and 2 for a roof mined in stepwise form (with brows at midspan). Uneven roof shape leads to different depths of bolt anchor horizons and increases the potential for rock slabbing at midspan.

* Response variables--consisted of roof sag or other related variables (such as rate of sag, amount of bed separation above bolt anchorage horizons, roof safety index, and changes in roof span). The roof safety index (RSI) was derived from plots of average bolt tension (Figure 7) and reflected bolt loading after installation. An RSI of 0 reflected no bolt reloading with time, i.e., perfect bolt tension decay (linear tension decay versus log time).

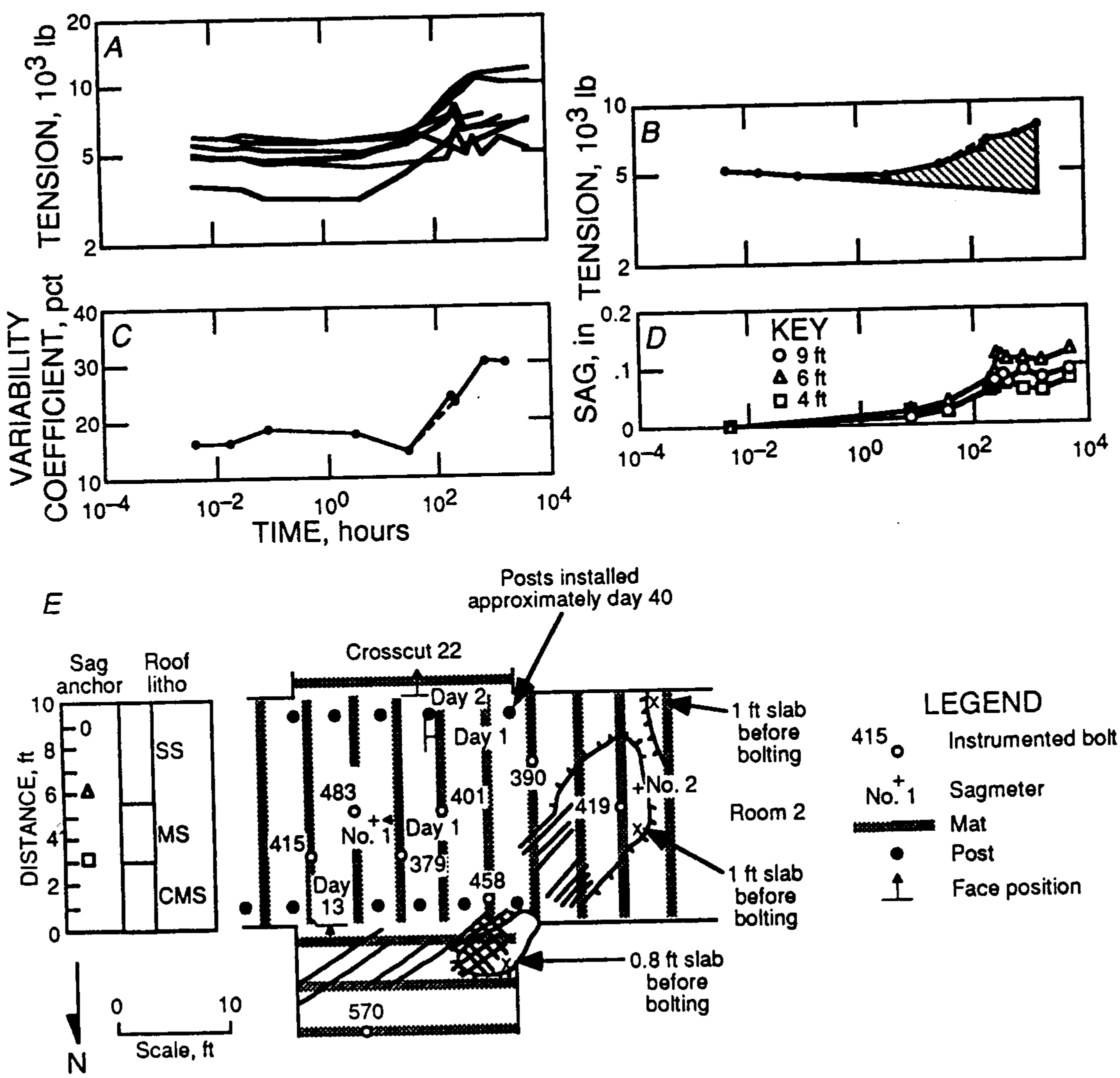

Figure 7. Summary sheet of cluster data for room 2, crosscut 22. A, Bolt tension histories; B, average bolt tension history of bolts in the cluster; C, coefficient of variation of bolt tension versus time; D, relative roof sag versus time; E, cluster map.

Table 2. Summary of algorithms used to derive numerical variables with values calculated for each data cluster set.

I. Geologic variables:	
A. Fracture density (eq. 1)	3.5
B. Roof lithology (eq. 2)	8.2
C. Dip = drop of over 20 ft of critical lithological contact	1.3
D. Bedding and anchor position = no. of beds anchorage position index with respect to major lithologic contact. If anchorage position = 0.5 to 1 ft, then index = 2; if anchorage position is greater than 1 ft, then index = 1	6
E. Anchorage lithology as related to bolt anchor capacity using weight as a factor: Carbonaceous mudstone = 16, Mudstone/siltstone = 4, Sandstone = 2	4
F. Average tension decay slope, lb/hr	1,049
G. Standard deviation of tension decay slope, lb/hr	438
H. Lost anchorage = percent of bolts lost over time	0
I. Presence of water: None = 0, Little = 3, Persistent = 6	0
J. Groundwater pressure, psi	0
II. Mining bolting variables:	
A. No. of instrumented bolts in cluster	7
B. Area of cluster, ft^2	513
C. Depth of cover, ft	1,537
D. Roof shape: Flat = 1, Stepwise = 2	2
E. Mining height, ft	8
F. Intersection type: Room/crosscut = 1, Three-way = 2, Four-way = 3	3
G. Time between mining and bolting: < 5 hr = 1, 5 - 16 hr = 2, > 16 hr = 3	2
H. Bolt length index: 4 ft = 1, 5 ft = 2	2
I. Bolt spacing index: 4 ft = 1, 3 ft = 2	2
J. Mat index: None = 1, Mesh = 2, Steel mesh = 3	3
K. Secondary support: None = 0, Post = 1, Posts plus cribs = 2, Posts plus bolts = 3	1
L. Timing of secondary support: 0 - 1 month = 1, 1 - 2 months = 2, Longer than 2 months = 3	3
M. Average bolt tension at installation, lb	5,113
N. Standard deviation of bolt tension at installation, lb	818

III.	Response variables:	
A.	Change in span at 2 months, pct	33
B.	Total roof sag at 2 weeks, in	0.110
C.	Total roof sag after 2 months, in	0.115
D.	Bed separation above anchor point, in	0.041
E.	Maximum rate of roof movement, in/yr	26.273
F.	Average bolt tension at 2 weeks, lb	7,226
G.	Standard deviation of bolt tension at 2 weeks, lb	2,117
H.	Average bolt tension at 2 months, lb	7,692
I.	RSI = area between decay curve and average bolt tension history:	
	At 2 weeks	1.15
	At 2 months	1.70
J.	Standard deviation of bolt tension at 2 months, lb	2,768
K.	Bolt energy = tension roof sag:	
	At 2 weeks	12.93
	At 2 months	2,879

Equation 1:

$$\text{Fracture density} = \sum_{i=1}^{n} = \left(\text{dip} + \frac{\text{no. of fractures}}{\text{spacing x } 10}\right),$$

where n = no. of fracture sets.

Equation 2:

$$\text{Roof lithology} = \sum_{i=1}^{n} m_i \frac{\text{Thickness}_i}{\text{Strength index}_i},$$

where m = 3 for beds in the first 5 ft of rock
or 1 for beds above 5 ft
and n = no. of beds within the first 10 ft.

	Thickness	Strength index
Carb. mudstone	3	1.5
Mudstone	2.5	4.5
Siltstone	0	5
Sandstone	4.5	6

3.7 Results

A matrix consisting of the 37 variables and 67 instrumented clusters was constructed. Frequency histograms for individual variables were also constructed to examine outlier values and thus correct any errors made in the derivation of the variables. In addition, the data were partitioned into different groups according to either geology (sites) or bolting techniques (conventional and controlled) to detect any bias (weighing) in data (Tables 3-4).

Bivariate correlations were formed between pairs of variables to identify any cause-and-effect structure in the data. For example, when roof lithology changed from the weak mudstones at subsite A1 to the competent sandstone channels at subsite A2, the anchorage properties (and thus bolt tension decay) improved simultaneously. As a result, the mining company switched to a pattern of different bolt spacings and mining heights at the same time. Thus, variations in one variable led to variations in others.

A statistical analysis was used to find which mathematical model best described the relationship between independent variables (geologic, mining, and bolting) and dependent (response) variables. Because there were 37 variables but only 67 data sets, considerable effort was given to identifying insignificant variables so that these could be eliminated from the

Table 3. Comparison of means of some geologic and bolting variables for different sites

Variable	Subsites			Remarks
	A1	A2	A3	
Index of roof lithology.....	6.68	2.90	5.68	A1 had weakest roof
Index of fracture density...	3.32	1.94	1.06	
Tension decay slope, lb/hr..	668	651	2,091	A3 had lowest bolt anchorage capacity

Table 4. Comparison of means of some variables of different bolting techniques

Variable	Bolting technique		Ratio
	Conventional	Controlled	
No. of instrumented clusters..........	47	20	2.30
Area of instrumented clusters, ft^2....	19,176	7,700	2.50
Index of roof lithology...............	5.85	4.83	1.21
Av. bolt tension at installation, lb..	4,000	9,400	.43
Roof sag at 2 months, in..............	.14	.08	1.75

analysis. An optimum response variable could then be determined, and variables that significantly influenced the response could be identified.

A standard multiple regression analysis with hierarchical, forward stepwise inclusion of independent variables was used (see Draper and Smith 1966) to identify the relative significance of the variables. Multiple regression analysis with hierarchical inclusion was used to identify and rank the variables of significance, taking into account the interrelationship of variables. In this technique, the variables are entered in a predetermined sequence, and regression solutions are performed at each step. Adjustments are made to remove any cause-and-effect relationship among independent variables before any additional variable is entered into the analysis. Inclusion of the variables into the mathematical model can be restricted further in a forward stepwise manner by some pre-established criteria related to the significance of any variable to the overall fit.

Finally, an analysis of residuals (Anscombe and Tukey 1963) was performed to check on the appropriateness of a regression analysis for the data and to check on the validity of a linear analysis. The results favored a linear multiple regression analysis, with no need for entering higher order terms.

Preliminary analyses identified the cause-and-effect structure for the independent variables and established the hierarchy of variable inclusion. From the preliminary analysis, it was shown that roof lithology had a significant influence on many of the variables, so the roof lithology variable was entered first. The influence of roof lithology on other variables was then removed.

Analyses were performed using different response variables to find the best regression equation. Roof sag at 2 months was the only logical indicator of short-term roof stability that correlated well with the independent variables and was thus selected as the response upon completion of the analysis. The rate of roof sag, on the contrary, resulted in a poor fit because these rates generally stabilized over time and thus were less sensitive to the bolt installation parameters.

At the conclusion of the preliminary analysis, 17 independent variables had been identified as being of significance to the response variable "roof sag at 2 months," which was then selected as the response representing "stability." Independent variables were thus reduced from 24 to 17, and response variables from 11 to 1.

Table 5 lists those independent variables selected from the 17 that had a significant influence on short-term roof stability as indexed by roof sag at 2 months. The table lists the level of significance and standardized regression coefficient (Nie 1975) for the final analyses.

Standardized regression coefficients are the number of standard deviation changes required for an independent variable to cause 1 standard deviation of change in the response, e.g., roof sag. Thus, these coefficients reflect the sensitivity of the response to individual mining, bolting, and geologic variables. Significance levels have similar functions, but they are related to probability for statistical

Table 5.--Summary of variables with significance levels less than 0.1[1]

Variable	Type	Significance level	Standardized regression coefficient
Coefficient of variation of bolt tension................	Bolting	0.023	0.33
Bolt anchorage capacity......	Geological	.020	.32
Roof lithology...............	Geological	.019	.31
Roof shape...................	Mining	.044	.26
Standard deviation of bolt tension................	Bolting	.087	-.24
Dip.........................	Geological	.098	-.22

[1]Or a significance level higher than 90 pct.

tests of significance; the smaller the probability, the better the linear correlation between the response and the individual variables. The overall correlation coefficient (R) was 0.62 for these analyses.

Among the 10 geologic variables, three were determined to be significant and sensitive to roof sag. Roof lithology and bolt tension decay had the most influence on roof sag, while dip had the least. Higher rates of roof sag were thus associated with weak mudstone roof and weak bolt anchorage. Gradual changes in the mudstone contact dip in the vicinity of the sandstone channels also increased the rate of roof sag.

Among the bolting parameters, the coefficient of variation of bolt tension and standard deviation of bolt tension were significant. The lower the coefficient of variation and the higher the standard deviation, the lower the rate of roof sag. Since coefficient of variation and standard deviation are related to each other by bolt tension, by implication bolt tension is an important bolting variable. However, in areas where both bolt tension and coefficient of variation were low, the rate of sag was low, indicating higher sensitivity to coefficient of variation than to bolt tension alone.

Among mining variables, roof shape was determined to be the only variable to affect roof sag. An uneven roof surface favors the formation of slabs at midspan, thus causing higher rates of sag. Other variables, such as the type of intersection (rooms or three- or four-way intersections) were not shown to be significant. This finding was confirmed by the low numbers of roof falls at the mine.

Several variables that could have affected roof sag could not be evaluated because they were not measured (horizontal stresses), they did not vary in the test section (cover depth and groundwater pressure), or they were highly correlated with other variables already identified as significant (bolt spacing). Fracture density did not affect roof sag because the roof joints were generally short and less than 2 ft deep.

The amount of time between mining and bolting did not significantly affect roof sag, but it did have a great influence on bed separation above bolt anchorage horizons, particularly after a longer time lapse (exceeding 8 hours), irrespective of bolt installation parameters.

Significant variables influencing short-term roof stability (roof sag at 2 months) may not have similar effects on long-term roof stability, measured as the occurrence of roof falls. This is because moderate roof movements can, for some lithologies and under some conditions of tectonic stress, stabilize the roof by developing arching action. Analysis of long-term data, including stress measurements, would be required to properly address the effects of mechanically anchored bolt installation on long-term roof stability.

3.8 Long-term results

Long-term observations and measurements in the test area (Maleki 1988) have not been conclusive in identifying the influence of bolt tension on roof stability. This is because roof falls occurred during retreat mining in both the conventional bolter and controlled bolter test sections, as well as in neighboring zones where fully resin-grouted bolts were used. One important conclusion was that bolt tension and the type of bolt used (i.e., mechanical versus resin) did not influence roof stability significantly under the geologic and stress conditions at this mine.

Stress measurements have now been obtained from a neighboring mine in the Wattis seam. The maximum principal stress is 1,050 psi oriented at N 25° E. For such moderate stresses, slippage along bedding planes has not been significant. This condition explains why studies have been inconclusive regarding bolt tension reinforcement mechanisms at this site. Stress measurements in other mines as well as experience have confirmed the importance of bolt tension for roof support in laminated, highly stressed roof rocks.

4 ANALYTICAL METHOD OF SUPPORT SELECTION

Long-term observations, stress measurements, and bolting practice in U.S. coal mines have been integrated to develop preliminary criteria for selecting primary support. Figure 8 presents results from studies of 20 different strata. This figure shows that support effectiveness and roof stability are related to stress and geologic conditions. Recent measurements (Maleki et al. 1991) have shown that fully grouted combination bolts spaced close together are effective in preventing slippage and roof falls under conditions of high geologic stress. Under such conditions, it is more important to install sufficient support as soon as possible than to let movement continue under the influence of far-field stresses.

In this preliminary effort, an average principal stress was calculated for the first 1 ft of roof rock using measured stresses and a rectangular geometry with a width-to-height ratio of 2:1. These stress concentrations can then be refined using numerical modeling techniques that incorporate geologic and geometric conditions such as roof, floor, and pillar interactions. Rock mass strength was calculated using the equation,

$$\text{Rock mass strength} = \frac{\text{uniaxial compressive strength}}{K},$$

where K = 1 for massive strata,
K = 2 for cohesive, medium-bedded strata,
and K = 3 for finely laminated, noncohesive strata.

Figure 8 presents the rock mass stress-strength relationship and a method for primary support selection for U.S. coal mines. Massive, competent strata with rock mass strengths exceeding 6,000 psi are self supportive at low stress levels. Mechanically anchored bolts are suitable for short-term roof support in medium-thick-bedded cohesive strata (two to three bedding planes per foot) where the tectonic stress field is low. Fully resin-grouted bolts are most suitable for long-term support of laminated material where the tectonic stress field is moderate. Fully grouted, tensioned bolts are most suitable for mines with high tectonic stress fields and low-to-medium rock mass strengths (less than 6,000 psi). Table 1 also presents other factors to be included in bolt selection.

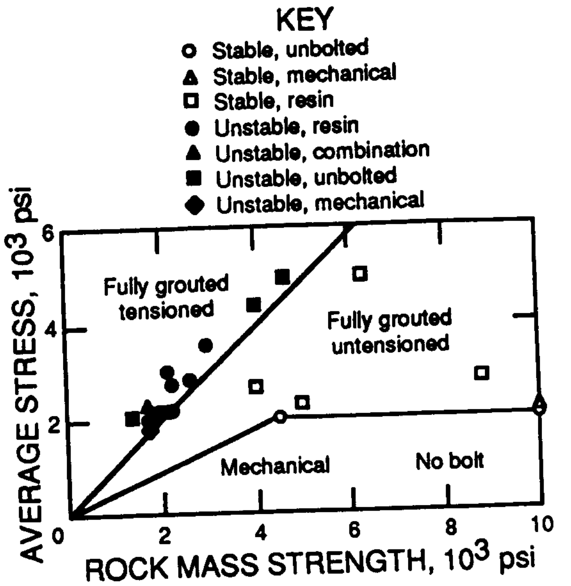

Figure 8. Average stress versus rock mass strength and support performance.

5 SUMMARY AND CONCLUSIONS

Short-term roof movement (sag) was shown to be lower in areas where uniformly high-tensioned roof bolts had been placed than other areas. This confirmed the importance of bolt tension in limiting roof movements when mechanically anchored roof bolts were used.

Long-term results were inconclusive regarding installed bolt tension reinforcement mechanisms under the geologic and stress conditions at the Wasatch Plateau site. No conclusion could be reached because there was no significant difference in roof fall frequency among the areas where bolts were installed under no tension (resin-grouted); low tension; and high, uniform tension. Subsequent stress measurements suggested that, because in situ stresses were moderate at this mine, there was no significant slippage along bedding planes. Thus, the primary support mechanism was suspension of the immediate roof from the upper strata. This condition held irrespective of bolt type or installation tension as long as there was adequate anchorage capacity for the mechanical bolts.

Recent observations and measurements (Maleki et al. 1991) confirmed the importance of both bolt installation tension and grout in preventing slippage along bedding planes in highly stressed or uncohesive, laminated rock masses. Under such geologic and stress conditions, it is important to install combination bolts spaced close enough together to prevent slippage, rather than allow movement under the influence of far-field stresses.

A preliminary criterion for the selection of primary support is proposed for U.S. coal mines on the basis of an analyses of average principal stresses and rock mass strengths under 20 strata conditions. Where stresses exceed strength, combination bolts spaced close together should be considered to minimize slippage and roof fall. Fully resin-grouted bolts are suitable for long-term support of roof where rock mass strength exceeds stresses. Mechanical bolts are suitable for short-term support of generally uniform, competent roof rock.

REFERENCES

Anscombe, F.J., and J.W. Tukey. 1963. The examination and analysis of residuals. Technometrics 5:141-160.

Brest van Kempen, H. 1986. How to design an efficient roof bolting plan based on simple in-mine measurements. Proceedings of the 5th Conference on Ground Control in Mining. West Virginia University, Morgantown, WV, pp. 15-28.

Brest van Kempen, H., and R. Sweet. 1978. Development and testing results of output torque indicator for underground mine roof bolting machine. Final report (contract HO 262006, Eimco Mining Machinery/Envirotech). BuMines OFR 131-82, 1982, 197 pp.

Draper, N.R., and H. Smith. 1966. Applied régression analysis. John Wiley and Sons, New York, NY, 201 pp.

Lang, T.A., and J.A. Bichoff. 1981. Research study of coal mine rock reinforcement. Leeds, Hill, and Jewett, Inc., San Francisco, CA, 255 pp.

Mahyera, A., H. Brest van Kempen, J. Conway, and A. Jones. 1981. Controlled thrust and torque placement of mechanical anchor bolts and their relationship to improved roof control. In Proceedings of the 1st Annual Conference on Ground Control in Mining, West Virginia Univ., Morgantown, WV, pp. 98-105.

Mahyera, A., and A.H. Jones. 1984. Roof bolt anchorage quality indicator tension decay equalizer. TerraTek, Salt Lake City, UT.

Maleki, H. 1988. Ground response to longwall mining. Colorado School of Mines Quarterly, Vol. 83, No. 3, 14 pp.

Maleki, H., M.P.H. Hardy, and H. Brest van Kempen. 1985a. Evaluation of roof bolt tension measuring techniques. In Proceedings of the 4th Conference on Ground Control in Mining, West Virginia Univ., Morgantown, WV, pp. 18-25.

Maleki, H., M.P.H. Hardy, and H. Brest van Kempen. 1985b. Tension-torque relationship for mechanically anchored roof bolts. In Research and Engineering Applications in Rock Masses, 26th U.S. Symposium on Rock Mechanics (So. Dakota School of Mines and Technology, Rapid City, SD, 1985). A.A. Balkema, Rotterdam, Netherlands, pp. 425-438.

Maleki, H., M.P.H. Hardy, and H. Brest van Kempen. 1986. Impact of mechanical bolt installation parameters on roof stability. In Rock Mechanics: Key to Energy Production, 27th U.S. Symposium on Rock Mechanics (Univ. of Alabama, Tuscaloosa, AL, 1986). SME, New York, NY, pp. 526-536.

Maleki, H., A. Weaver, and R. Acre. 1991. Stress-induced stability problems - A coal mine case study. In Rock Mechanics as a Multidisciplinary Science, Proceedings of the 32nd U.S. Symposium (University of Oklahoma, Norman, OK, July 10-12, 1991). A.A. Balkema, Rotterdam, Netherlands, pp. 1057-1064.

Nie, N.H. 1975. Statistical package for the social sciences, 2nd ed. McGraw-Hill, New York, NY.

Rosso, R. 1977. An investigation of the effects of hardened washers on the uniformity of roof bolt tension and resulting ground control in an underground mine. Final report (contract HO 262018, TerraTek). BuMines OFR 40-78, 1978, 201 pp.

Stillborg, B. 1986. Professional user's handbook for rock bolting. TransTech Pub., Clausthal-Zellerfeld, Federal Republic of Germany, 145 pp.

Tadolini, S.C., and R.C. Dyni. 1991. Transfer mechanics of full-column resin-grouted roof bolts. BuMines RI 9336, pp. 1-14.

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PREDICTION OF ROOM CLOSURE AND STABILITY OF PANEL 1 IN THE WASTE ISOLATION PILOT PLANT

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ABSTRACT

The Waste Isolation Pilot Plant (WIPP) is intended to be an underground repository for the permanent disposal of transuranic radioactive waste generated by defense activities. Both surface and underground facilities, including one waste panel, were excavated during the period from 1982 to 1988. The decision to use the repository for disposal has not yet been made.

The objective of this paper was to predict room closures and ground conditions for Panel 1 based on an analysis of extensive deformation data collected by Westinghouse Engineering from 119 instrumented locations throughout the WIPP facility. This study was important for both maintaining the safety of personnel and assuring the continuity of waste emplacement operations, given that the anticipated service life of the Panel 1 has nearly tripled from the original design life of 5 years.

The technical approach consisted of (1) characterization of 11 mining, bolting, and geologic variables at individual instrumented locations (119 clusters), (2) development of a mathematical model (multilinear regression analysis using stepwise inclusion of independent variables), (3) examination of the results, and (4) prediction of entry closures and ground conditions for the anticipated life of the facility given the specific geologic, mining, and support conditions at selected waste panels and access entries.

Based on an examination of standardized regression coefficients, several significant variables were identified that influence entry closure and long-term stability. These were excavation ratio, entry width, roof beam thickness, entry height, and age. Interestingly, bolting variables did not help explain variability in the data and thus were not included in the mathematical model. Considering the present roof conditions, anticipated future deformation, and mining experience with variety of proven roof support systems, it was concluded that only portions of Panel 1 may be used for waste emplacement with a reasonable degree of confidence.

KEYWORDS

Ground Control • Stability • Bolting • Regression • Prediction • Closure • Waste •

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Repository • Salt

INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) is located about 30 miles east of Carlsbad, New Mexico. The site was authorized by Congress in 1979 as a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from defense activities. The current mission is to receive, handle, and permanently dispose of transuranic mixed waste (both contact and remotely handled) in underground workings (panels), located 655 m below the surface within a nearly 610-m-thick sequence of evaporites called the Salado Formation (DOE 1995).

Development of underground workings has taken place in phases. Preceding each phase, there were engineering calculations by the project architect, followed by test mining and careful geotechnical evaluations having the purpose of characterizing the site and verifying the preliminary designs. The E140 drift, one of the main arteries of the facility for air supply and access, was mined during 1983, followed by mining and design verification in the SPDV area, which has geometric conditions similar to those in the waste panels, leading to development of Panel 1 during 1986–1988 (figure 1).

The mining schedule for Panel 1 was influenced by favorable short-term monitoring results in the SPDV area and initial schedule of waste arrival. Because of delays in receiving the waste, the average life of Panel 1 has been extended beyond the original functional life (5 years) to 17 years, based on current estimates of waste arrival in May 1998.

The objective of this study was to predict ground conditions during the first 7 years of waste emplacement operations in Panel 1 and to identify important geometric and bolting parameters that would influence these ground conditions. The latter objective was considered important for addressing necessary factors for "assuring" stability as well as to identify (1) geometric changes that could enhance the stability of future waste panels and/or (2) maintenance practices that might reduce the stability of existing entries. To "assure stability" in a repository within a geologic environment is very difficult because there are always variations in lithology, material properties, support characteristics, and the stress field, among other factors. This very high standard for nuclear waste disposal has been required at the WIPP site by public laws such as the WIPP Land Withdrawal Act (Public Law 102–579).

GEOLOGIC SETTING AND ROOF SUPPORT

The WIPP underground facility is located in the Salado Formation, a horizontally bedded formation consisting of halite, anhydrite, polyhalite, and clay layers. The stratigraphy in the immediate vicinity of the storage horizon consist of numerous layers of anhydrite, clay and halite containing various impurities such as clay (figure 2). The immediate roof is a 2-m-thick layer of relatively pure halite overlain by clay G and anhydrite layer b, which is 10 cm thick. There is a prominent 1-m-thick nonsalt bed below the storage level, referred as MB139. MB139 consists of anhydrite, polyanhydrite, halite, and polyhalite, and contains numerous partially infilled subhorizontal fractures (Stormont 1990). The immediate floor is a 1- to 1.5-m-thick salt layer.

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Prior to 1986, very few areas within the facility were roof bolted. At this time, SPDV Rooms 1 and 2 started to show signs of roof instability, leading into two monitored roof falls in 1991 and 1994. Between 1986 and 1988, more than 9,000 bolts were installed in the facility, particularly in the E140 drift, to control movement of roof. By 1990, most areas in the underground facilities had been systematically bolted using 1.8- to 3m-long, grade 75, mechanically anchored bolts (Peterson 1995). In 1991, a secondary support system, consisting of wire mesh, expanded metal, channel steel, and point-anchored, threaded rebar was installed in Room 1, Panel 1 (figure 3), to help extend the life of this room. Threaded rebar tension is manually adjusted on a periodic basis to reduce rebar load (DOE 1991). Other secondary support systems, including mechanical bolts, resin point-anchored threaded rebar (with and without slip nuts), cable bolts, and cable mesh, were installed in portions of Panel 1 and the E140 drift. Due to large amounts of convergence, roof fracturing, and lateral shifting (figure 4) along portions of the E140 drift, the immediate bolted salt roof was mined in 1996 (DOE 1994). In addition, a laboratory investigation was initiated to test and compare the load-carrying capacity of mechanical bolts and a variety of yielding cable bolts under the influence of combined tensile and lateral offset loading conditions.

To monitor ground conditions and study support performance, an intensive geotechnical monitoring program was implemented. This program consisted of monitoring strata deformation (figure 1), bolt loads, locations where bolts failed, strata fracturing, and lateral offsets at clay G and other horizons.

EVALUATION OF EXISTING GROUND CONDITIONS

Measurements of total roof deformation, deformation rate, convergence rate, and seismic wave velocity have been used in underground mines to assess roof stability (Maleki 1988; Maleki *et al.* 1993). These studies have identified site-specific deformation and velocity criteria to help assess roof stability and allocate supplementary support based on roof deformation and fracture patterns near roof fall locations.

In this study, the following criteria are used to assess present roof conditions for Panel 1.

- A roof deformation rate approaching 2.8 to 4.6 cm/yr. These values were reached in unsupported portions of barricaded SPDV rooms several years before an intentional roof collapse. Thus, they are indicative of the formation of roof slabs requiring supplementary support.
- A consistent increase in roof-floor convergence rate. Considering the age of the excavations, the convergence rate should decrease in time using the equations developed by Westinghouse Engineering (DOE 1995). A significant increase (15%) in the convergence rate indicates abnormal roof and/or floor movement.
- Excessive (5 cm) asymmetrical offsets at clay G or lower horizons and the presence of persistent shear and tensile fractures near the ribs are indicative of the formation of cantilevers in the mine roof (figure 4). Because of the limited ability of mechanical bolts and threaded rebar to accommodate both high tensile and offset (bending) moments (Peterson 1995; Maleki *et al.* 1985), this condition can be associated with a higher rate of bolt failure,

ISSN 0148-9062

leading to roof stability problems if adequate supplementary support is not installed in a timely fashion.

Tables 1 and 2 present the results and identify locations in Panel 1 where abnormal convergence rates and/or roof deformation rates have been measured. Factors known to influence the results are also noted in table 1.

Based on observations of roof appearance and lateral offset in boreholes (table 3), the authors suspect that the first roof beam (between clays G and F) has fractured, forming a cantilever beam in rooms of Panel 1. When a cantilever beam is formed, lateral movements may increase toward one side of an opening, inducing high bending moments along bolt shanks. A recent study (Peterson 1995) suggests that typical 1.9 cm in diameter, 3 m long, mechanically anchored, grade 75 bolts can stretch 20 cm longitudinally prior to failing, but could accommodate 3.8 cm of lateral offset loading.

This study also suggests that bolt life can be increased by reducing tension in the bolts to below 9090 jg. This is the logic for detensioning point-anchored, threaded rebar in Room 1.

In spite of detensioning, however, there have been four reported point-anchored, threaded rebar failures in Room 1. These failures have occurred near the middle (mid-pillar) of the room where the lateral offset rate is maximum (1.78 cm in 1 yr). Bolt failure not only depends on bolt load, lateral offset, and bolt grade, but also on installation practices, environmental factors, rates of ground movement, and fatigue; the latter is important where cyclic loading of bolts is involved (such as in Room 1, Panel 1). Overall the effectiveness of the special support system in Room 1, Panel 1, is reduced.

ANTICIPATED CONDITIONS

The technical approach for estimating ground conditions during the active life of Panel 1 consists of developing a mathematical relationship between the convergence rate and 11 mining, support, and time factors at 119 instrument clusters, and then using these relationships to calculate total expected convergence at these locations. After a brief review of the analysis technique, the authors identify important variables and estimate future deformation and ground conditions while examining some of the assumptions inherent in these analyses.

Analysis Technique

There are two methods used by engineers and researchers as tools to help predict conditions in the future: statistical and computational. Starfield , Cundall 1988 identify rock mechanics problems as "datalimited," that is, one seldom knows enough about a rock mass to use computational models unambiguously. Statistical methods, on the other hand, are uniquely capable of being applied where there are good data but a limited understanding of certain natural phenomena, such as the creep of rock salt. This is the case at the WIPP site, where there are sufficient data on convergence in excavations of different ages and geometries to allow a preliminary mathematical model to be built that can be used to identify significant variables and estimate future deformation. Examples of the use of both statistical and computational techniques

ISSN 0148-9062

to evaluate stability and performance is given by Maleki *et al.* 1985, Maleki 1992, Parson , Dahl 1971, and Munson *et al.* 1993.

Discussion of results and assumptions of analysis

Multilinear regression analysis techniques are used as tools to help predict ground movements during the active life of Panel 1 (until 2004). To assess both roof and floor conditions, the authors have used closure rate as the independent variable, utilizing rates from both 1993 and 1994 (DOE 1995; USBM 1994) and the latest available data (Maleki , Chaturvedi 1996). Dependant variables were selected on the basis of underground observations, data analysis, and bivariable correlations.

- *Roof span.* Measured roof-floor convergence depends on roof span, which varies between 3.35 and 10 m.
- *Roof beam thickness.* This variable measures the distance between the roof and clay G or H, depending on the relative position of the entry with respect to such clays (range 1.2 to 3.6 m).
- *Entry height.* Height generally varies between 2.5 and 4.6 m and reaches 5.5 to 6 m in room D and the salt handling shaft station.
- *Age.* Time from excavation year to present.
- *Excavation ratio.* This variable relates to higher vertical stresses, which are associated with higher overall extraction in any certain area.
- *Bolt length.* Roof bolts vary in length from .03 to 4 m.
- *Bolt spacing.* This variable relates to the density of roof bolts.

The multilinear regression procedure consisted of entering the dependant variables one at a time into the equation using a forward selection methodology (SPSS 1995). In this method, a variable is entered into the equation using the largest correlation with the dependant variable. If a variable fails to meet entry requirements, it is not included in the equation. If it does meet the criteria, the second variable with the highest partial correlation will be selected and tested for entering into the equation. This procedure is very desirable when there are hidden relationships among the variables. The multiple correlation coefficient (R) for the last step is 0.795; R is a measure of goodness-of-fit.

Important Variables

Based on an examination of standardized regression coefficients (table 4), the following variables best explain variations in the convergence rate.

- *Excavation ratio.* The convergence rate is higher as the excavation ratio (and the associated vertical stresses) increases.
- *Span.* Increasing the span results in an increase in convergence rate.
- *Beam thickness.* The thicker the roof beam, the lower the convergence rate.
- *Entry height.* Convergence rate is negatively related to entry height.
- *Age.* Convergence rate increases slightly as entries age.

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It is very interesting that bolting parameters (bolt density and bolt length) do not add significantly to the goodness-of-fit and thus are not included in the final equation, a conclusion that is in agreement with actual experience. That is, even the special support system in Room 1, Panel 1, is becoming ineffectual in controlling roof movements, as evidenced by the recent failure of the threaded rebar supports.

Expected Ground Conditions-Panel 1

Having developed a relationship among convergence rate, mining, and time variables, total roof-floor convergence can be calculated for both the E140 drift and Panel 1. For this, the authors have used average measured convergences with 1995 as the base and have added expected convergence for the anticipated life of the entries (figure 5). The calculated difference in movements for Rooms 1 and 7 is due solely to age differences, because other analyzed variables, such as bolting parameters, were found to be insignificant. In reality, the special support system in Room 1 provides some safety advantages in the short term, but these advantages can be expected to become ineffective before the turn of the century for the following reasons.

- Room 1 is closest to the main entries within its load transfer distance; it is experiencing the highest convergence rate at this time.
- The effectiveness of both mechanical bolts and threaded rebar is expected to deteriorate because of high lateral offset, potential for fatigue failure caused by frequent detensioning (3 to 12 times per year), and short, unused lengths of pigtail (<15 cm) for a number of rebar supports.

Total roof-floor convergence is expected to double in portions of Panel 1 during the active life of this panel. Assuming that the ratio of roof-to-floor movements will remain unchanged in the future, expected roof movements will also double during this period.

Considering the fractured nature of the mine roof and the expected additional deformation, there will be a need for additional, systematic internal and external support systems (such as cribs). The latter reduce storage capacity but will be very important for maintaining stability, particularly during the 1-year period of actual waste emplacement when it may not be possible to install additional support or to detension threaded rebar. The authors have more confidence on ability of cribs to accommodate the additional deformation than in the internal support systems based on their experience and measurements in underground mines (Maleki *et al.* 1986b). In particular, cribs can help reduce roof movements by transferring some load from heaving mine floor to the roof, and they can provide an open walkway even if the threaded rebar fails under axial and lateral offset loading conditions during waste emplacement operations.

Discussion of results and assumptions of analysis

Regression analysis is a powerful method for identifying important variables and for estimating conditions in the near future. Here are a few comments relating to the interpretation of results and improving future models.

- Several mining parameters are shown to have a significant impact upon the convergence rate,

ISSN 0148-9062

including span, extraction ratio, beam thickness, and height. Several other parameters, such as excavation sequence, load-transfer distances, and excavation orientation with respect to the stress field, are not included in the present analysis and can improve the goodness-of-fit.

- Although the existing database is generally broad (119 data points), data structure and missing variables at some locations influence the results.
- The assumption provided by the linear regression analysis is tested to be valid for the range of analyzed convergence rates (2 to 14 years after excavation). This is further supported with analyses of variance, F-statistics, and plots of standardized residuals (Maleki , Chaturvedi 1996; SPSS 1996).

CONCLUSIONS AND RECOMMENDATIONS

Based on an evaluation of present roof conditions, estimates of additional deformation, and experience in underground mines, the authors have come to the following conclusions regarding anticipated ground conditions during the waste emplacement operations, excluding any potential dynamic and/or thermal loading.

- There are two types of events that can contribute to stability-related safety concerns during the active life of Panel 1: free fall of failed roof bolts and localized roof falls.
- The potential for roof bolts to fail and fall is high, considering environmental conditions, installation practices, and expected future deformation. Safety problems associated with bolt falls, however, can be controlled by connecting the bolt assembly to the roof.
- The potential for the formation of roof slabs and localized cantilever beams in the mine roof is high, considering both the present condition of the roof and anticipated deformation. Roof fall potential is judged to be low as long as access is available, the extensive monitoring system is maintained, and supplementary support is installed in a timely fashion.
- The potential for localized roof beams to collapse and create safety hazards during waste emplacement operations can further be reduced by using external support systems, such as cribs, and/or abandoning some unstable rooms.

FIGURES

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Paper 186, Figure 1.

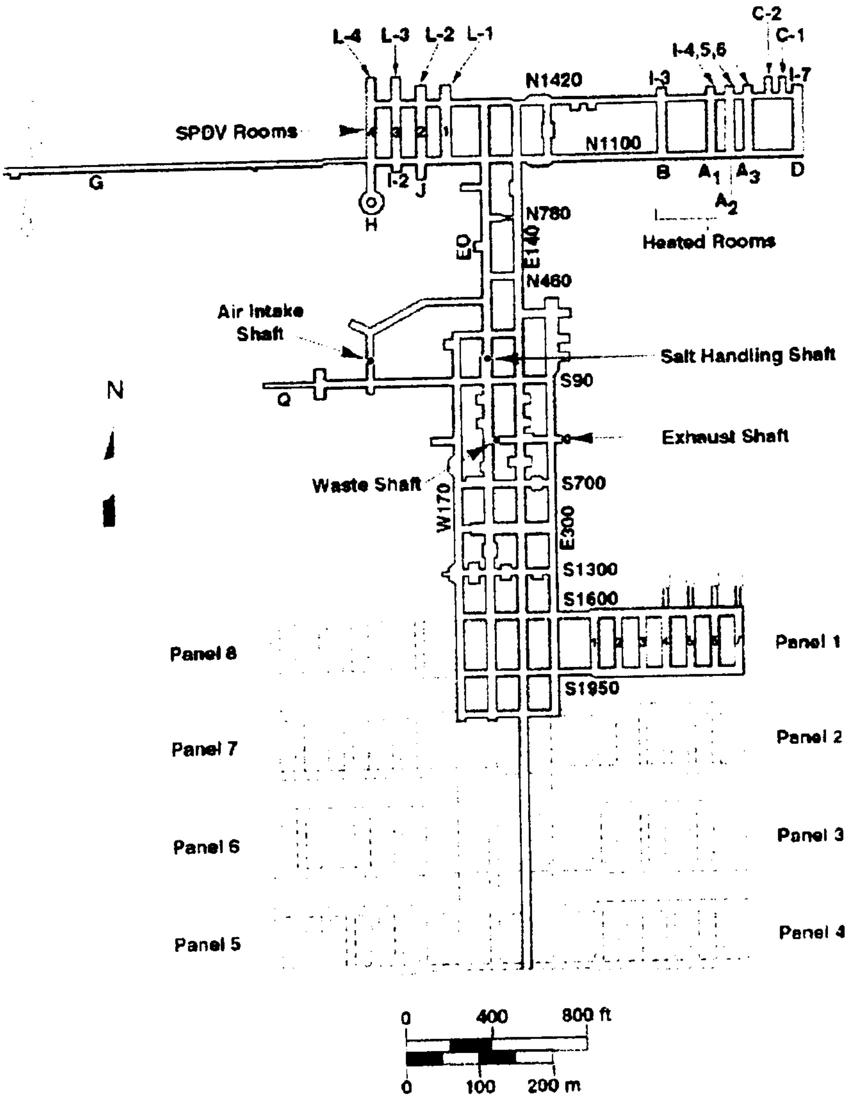

Figure 1. Underground layout of the WIPP repository

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Paper 186, Figure 2.

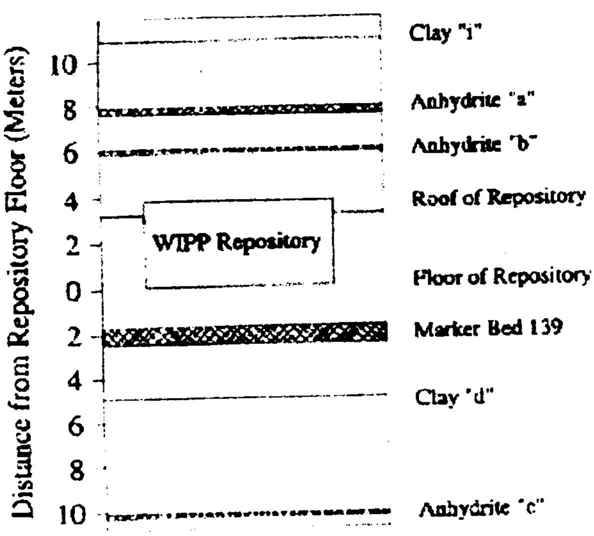

Figure 2. Interbeds near the WIPP repository.

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Paper 186, Figure 3.

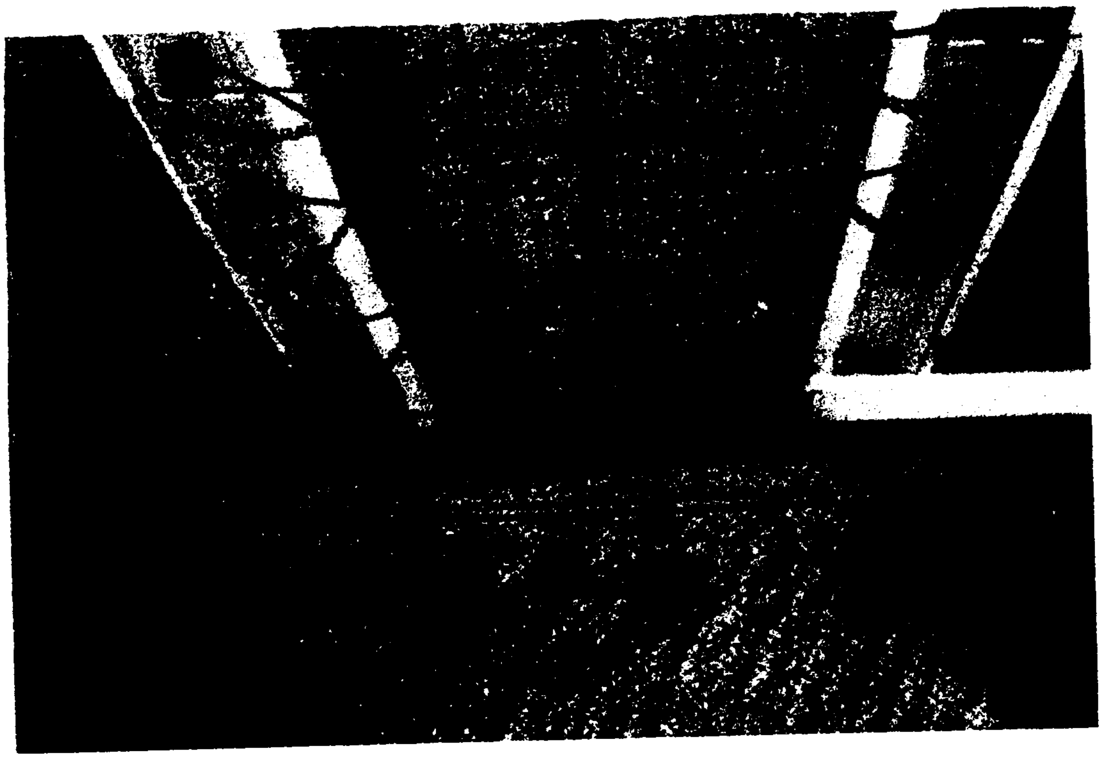

Figure 3. Room 1, Panel 1 support system. Steel chain is used to prevent the potential for free fall of threaded rebars

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Paper 186, Figure 4.

Figure 4. The immediate roof beam and the fracture pattern at one location along E 140 drift

Paper 186, Figure 5.

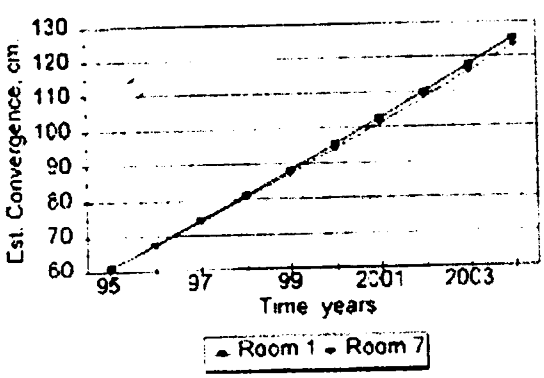

Figure 5. Estimated roof-floor convergence for two rooms of Panel 1, assuming a 7-year disposal rate.

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TABLES

Paper 186, Table 1.

Table 1.-Rate of roof deformation for selected areas

Location	Maximum yearly rate, cm/yr	Current rate, cm/yr	Comment
Room 1, Panel 1-center-north	2.92	3.3-3.81	Movements are influenced by detensioning procedures.
Room 4, Panel 1-north	3.81	2.79	Supplementary support has been installed, reducing rate.
Room 5, Panel 1-north	2.92	1.78	As above.
Room 6, Panel 1- center	2.69	2.54	

Paper 186, Table 2.

Table 2.-Roof-floor convergence rate for selected areas, cm per year

Location	Predicted*	Current	Percent difference
Room 1, Panel 1	5.21	4.83 to 12.19	-7 to 134
Room 3, Panel 1	5.33	6.86	28
Room 4, Panel 1	5.46	6.60	21
Room 5, Panel 1	5.46	6.35	16
Room 6, Panel 1	5.46	8.13	49
Room 7, Panel 1	5.46	5.33 to 7.62	0 to 39

* DOE/WIPP-95-2100- Equations are updated by the operator on a routine basis.

ISSN 0148-9062

Paper 186, Table 3.

Table 3.-Roof beam offset at or below clay G and observed roof fracturing.

Location	Offset, cm	Shear fracture	Tensile fracture	Comment
Room 1, center	6.35	Yes	No	Near threaded rebar failure locations.
Room 3	3.81	Yes	No	
Room 4, north	7.62	Yes	Yes	Cantilever forming.
Room 5, center-north	7.62	Yes	Yes	As above.
Room 6, center-north	7.62	Yes	Yes	As above.
Room 7, north	6.35	Yes	Yes	As above.
S1600, Room 2-6	NA	Yes	No	

Paper 186, Table 4.

Table 4.-Standardized regression coefficients and statistical significance

Variable	Standardized coefficient	T-significance
Span	0.388	0.0006
Excavation ratio	0.436	0.0000
Beam thickness	-0.380	0.0007
Entry height	-0.248	0.0288
Age	0.1724	0.0294
Constant		0.0707

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References

References

DOE (U. S. Dept. of Energy) 1991. Report of the Geotechnical Panel on the Effective Life of Rooms in Panel 1. DOE/WIPP 91–023, June.

DOE 1994. Investigation of the Advantages of Removing Highly Fractured Roof Beams. DOE/WIPP 94–025, Aug, 1994.

DOE 1995. Geotechnical Analysis Report for July 1993–June 1994, DOE/WIPP-95-2100.

Maleki H. 1988. Detection of Stability Problems by Monitoring the Rate of Movement. Coal Age, Dec.

Maleki H. 1992. Significance of Bolt Tension in Ground Control. *In* Intern. Symp. on Rock Support, Sudbury, ON.

Maleki H., L.Chaturvedi 1996. Stability Evaluation of Panel 1 Rooms and the E140 Drift at WIPP. Environmental Evaluation Group Report 63.

Maleki H. 1985. Evaluation of Rock Bolt Tension Measuring Techniques. 26th U.S. Symp. on Rock Mechanics, June 1985.

Maleki H. *et al.* 1986a. Impact of Mechanical Bolt Installation Parameters on Roof Stability. *In* 27th U.S. Symp. on Rock Mechanics.

Maleki H. *et al.* 1986b. Tailgate Support Evaluation at Plateau Mining Company. *In* 5th Conf. on Ground Control in Mining.

Maleki H. *et al.* 1993. A Case Study of Monitoring Changes in Roof Stability. Intern. J. of Rock Mech., vol. 30, no. 7.

Munson D. E. *et al.* 1993. Two- and Three-Dimensional Calculation of Scaled In Situ Test Using the M-D Model of Salt Creep. *In* Proc., 34th U.S. Rock Mechanics Symp., Madison, WI.

Parson , Dahl 1971. A Study of Causes for Roof Instability in the Pittsburgh Coal Seam. *In* Proc. 7th Canadian Rock Mechanics Symp.

Peterson G. 1995. Final Report on Rockbolt Testing for WIPP. Internal report prepared by Rock Mechanics Assist for Westinghouse Engineering, 11 pp.

USBM 1994. Annual Stability Evaluation of WIPP.

SPSS 1995. Statistical Packages for the Social Sciences, Chicago, IL.

Starfield , Cundall 1988. Towards a Methodology for Rock Mechanics Modeling. Inter. J. Rock Mech. Min. Sci. & Geomech. Abst., vol. 25, no.3, pp. 99–106.

Stormont 1990. Discontinuous Behavior Near Excavations in a Bedded Salt Formation. Sandia 89-2403.uc-721.

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ATTACHMENT C

LETTER REPORT

NorWest
Mine Services, Inc.

September 17, 1997

Dr. Hamid Maleki, P.E.
Principal
MALEKI TECHNOLOGIES INC.
5608 South Magnolia
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File No. 97-2087

Subject: Comments on Technical Approach for Escarpment Study

Dear Hamid:

I have reviewed your draft letter dated August 30, 1997 to Larry LaFrentz of Energy West regarding a technical approach for developing a predictive tool for the assessment of escarpment stability in the vicinity of Energy West's longwall operations. I would like to offer my comments on several of the topics addressed in this letter, which I hope will be useful in helping to define the direction of future investigations into this important subject area.

USE OF COMPUTER-BASED MECHANICAL MODELS

In your letter you have provided a clear picture of the situation that we currently face regarding the utility of computational models: if the appropriate type of computational model is selected to represent a particular mechanical system and the mechanical properties and boundary conditions are properly defined, then theoretically the model will provide us with a reasonably accurate estimate of the forces and strains in the system. The reality is, however, that in modeling large natural systems such as a longwall panel and its environs, we are, as you say, severely "data-limited". To eliminate or at least significantly minimize our "data-limited" condition, it would be necessary to have in hand the geometric and mechanical characteristics of virtually every joint, bedding plane, and material type in the system. For a system as large as a longwall panel and the surrounding terrain, this is a practical impossibility. Furthermore, the computational demands (core memory, calculation speed) of such a model would be far beyond the capabilities of even the most advanced super-computer currently in use.

During the University of Utah's escarpment investigations between 1990 and 1994, we optimistically (and perhaps naively) hoped that we could develop computer-based models with predictive capabilities, utilizing the software and hardware resources which were available to us at that time. We did not achieve this goal, but the models did help us gain a much better understanding of the mechanism(s) at work in the longwall mining/escarpment system.

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I would not, however, want to see the door closed on the effort to attain useful predictive capability by means of computer-based mechanical models. I will discuss this in a little more detail later in this letter.

STATISTICAL APPROACH

Given the practical barriers which we currently face with computer-based mechanical models, even with perhaps more sophisticated and powerful computational resources available to us now than in the early 1990's, I am in complete agreement with your recommendation that the substantial database of real-world subsidence and escarpment behavior be utilized to provide statistically-based prediction models for practical use by Energy West. There is rarely an instance where an abundance of real-world data would prove to be less useful for predictions of future behavior than some sort of abstract model of a complex, natural system. I must be frank and admit that I do not have an understanding of precisely how the available observational data would be used to develop statistically-based predictions of escarpment behavior, but based on your brief outline of a statistical approach given in your letter to Energy West, I feel that the concept has real merit.

ESTIMATION OF DEBRIS TRAVEL

In your letter of August 30th, you state that a secondary objective of your current studies is to estimate the extent of debris travel from portions of the escarpment which may be disturbed by mining. I just wanted to make you aware that the estimation of rolling rock momentum is a topic which is of importance in the design of safety berms for road construction, and that there is a body of literature available in the civil engineering realm which pertains to this issue. I wish that I could give you some specific recommendations on literature, but I can only recall that in an open-pit design report by Richard Call, there was a citation of one particular civil engineering study which provided specific recommendations for highway safety berm dimensions based on the height and inclination of the slope above the berm, and on the expected size and shape of the loose rock.

FUTURE CONSIDERATION OF COMPUTER-BASED MODELS

For the near-term, I believe that the utilization of real-world data within a statistical framework will provide the best opportunity to develop a usable predictive capability for the Castlegate Escarpment. For the long-term, my hope is that by searching out existing models, or possibly even developing new computer-based models which are more closely based on what really happens mechanically during longwall-induced subsidence, usable predictive models can be developed despite our continued "data-limited" condition. Specifically, I think of what really happens above a mined-out longwall panel: there is a Caved Zone which is composed of rubblized material that fills in the mined-out void and extends for some distance above the original seam elevation; next is the Fractured Zone which is composed of distinct, loose blocks of material, but probably retains most of the original stratigraphic ordering; finally, there is the Continuous Deformation Zone which is composed of generally continuous stratigraphic layers which have yielded in compliance with the deformations of the underlying layers.

I believe that application of a Discrete Element approach using something like the recently developed Particle Flow Code (PFC) to modeling of the Caved and Fractured Zones would give us a much more realistic representation of what happens mechanically in these portions of the general subsidence zone. Modeling of the Continuous Deformation Zone could be handled by either a Finite Element (or Boundary Element) approach, or possibly by an extension of the PFC model by modifying the normal and shear stiffness and bond strengths between particles. If a continuum model like Finite Element is used to represent the Continuous Deformation Zone, then some way of coupling the PFC and FE models would need to be devised.

Interestingly, what I am suggesting here is the reverse of what was done in our studies through the University of Utah: Discrete Element modeling of the area immediately surrounding the excavation, possibly coupled with Finite Element modeling of the more distant areas. I have attached a copy of a brief article by Charles Fairhurst which discusses recent developments in Discrete Element modeling (specifically, the PFC model). I have also attached a copy of a paper which describes some Finite Element subsidence modeling of a coal mining operation in Yugoslavia; what interests me about this paper is the very large subsidence displacements that the model was able to show at the surface, which indicates to me that this model is capable of handling very large strains—much larger than anything that we could show with the UTAH2 or UTAH3 Finite Element codes.

I appreciate the opportunity you have given me to review this draft letter, and I hope to be able to remain involved in subsidence and escarpment-related work in the future. Do not hesitate to contact me if you have any questions regarding these comments.

Sincerely,

NORWEST MINE SERVICES, INC.

Richard Jones

Richard Jones, P.E.

REJ/sk

Corncob Wash Joint Measurements and Surface Observations 1997

On October 16, 1997, a field reconnaissance was made of the Corncob Wash area to observe the effects of subsidence over 9th and 10th East longwall panels of Cottonwood Mine. This study consisted of observing and measuring as many joint sets and tension cracks as could be found along the top of the Castlegate Sandstone, surveying with GPS those locations, and taking photographs of the Castlegate escarpment failures associated with the subsidence. A tabulation of these observations and a map are included with this report.

Jointing in the Castlegate sandstone and overlying Upper Price River formation is not abundant in this area. The escarpment itself does not appear to be strongly joint controlled, consisting of a series of gently curving coves and convex "points."

The Castlegate escarpment in the study area consists of a vertical cliff approximately 200-300 feet high, unbroken from the point on the east end to a large overhanging cove on the west end. This portion of the Castlegate escarpment is entirely underlain by the 10th East longwall panel. Nearly all of the escarpment in this area shows evidence of subsidence - related failure. The large cove at the western end of the observation area shows extensive spalling. Old photographs show that this cove had an overhanging rim extending almost all the way around the cove, which collapsed. Survey prism #PR13 fell with the rim. Other portions of the cliff face show extensive spalling also, with blocks either collapsing due to foundation failure, or rotating outward from the cliff face. Some partially collapsed blocks are still present, leaning back against the cliff face, moved downward, but not having rotated far enough to fail.

Along the length of the escarpment, 12 joint sets and 3 tension cracks were observed and measured. About 1/2 of the joint sets observed were roughly parallel to the escarpment face. Along the east-west trending cliff, the average orientation of these joints is approximately N 85° W, one of the well known subsidiary joint sets of the area. The remainder of the joints along this portion of the cliff range from N50°E to N20°W. In the cove area, the joint sets observed ranged from N60°E to N10°W. These are sub-parallel to the cliff face. The cliff face in the cove area is a smooth curve from an east-west orientation to a north-south orientation, with little evidence of joint control.

Three tension cracks were observed on the ground above the escarpment. These ranged from N25°E to N5°E, roughly parallel to the longwall face (and roughly perpendicular to the cliff face) in this area.

Subsidence measuring prisms **PR10, PR11,** PR12, PR13, and PR14 are (or were) all in the study area. These prisms showed as much as 4.8 vertical feet of movement and as much as 4 feet of horizontal movement. PR13 was mounted on the overhanging rim of the cove, and fell with the rim before any significant movement was shown. PR14 is on the southern edge of the mining area above the cliff and showed little movement.

From the ground, it appears as though the Castlegate sandstone and surrounding formations dip into the mountain toward the northwest. The regional dip in this area is slightly to the west-northwest but the dip of the beds on the Mountainside in this area may have been increased by the subsidence zone to the north and west. This could explain why some of the failed blocks did not rotate outward from the cliff face, but moved downward, leaning against the cliff and not breaking up.

East Mountain Joint Studies	Ken Fleck, Chuck Semborski, Tom Lloyd											
Corncob Wash Study Area												
	Joint Measurement Locations:											
Geologic Factors:	Loc. #1	Loc. #2	Loc. #3	Loc. #4	Loc. #5	Loc. #6	Loc. #7	Loc. #8	Loc. #9	Loc. #10	Loc. #11	Loc. #12
Joint Set #1 Strike	N. 45 E.	N. 50 E.	N. 70 E.	E.-W.	N. 80 E.	N. 80 W.	N. 55 E.	N. 80 W.	N. 80 W.	N. 5 E.	N. 40 E.	N. 60 E.
Joint Set #1 Spacing	10	10	8		10	12.5	5			5		5
Joint Set #1 Continuity - Hor.	10	15	80	8	15	30	7	10	15	2	50	8
Joint Set #1 Continuity - Vert.	40	6	10	8	30	5	7	1	10	5	10	6
Joint Set #2 Strike		N. 20 W.				N. 10 W.	N. 35 E.					N. 10 W.
Joint Set #2 Spacing		10				10						5
Joint Set #2 Continuity - Hor.		7				50	50					5
Joint Set #2 Continuity - Vert.		6				10	10					5
Bed. Plane Roughness - Cg. Shale												
Hardness - Cg. Shale												
Hardness - Cg Sandstone												
Bedding Plane Alteration												
Geometric Factors:												
Angle Between Joint Set #1 and Face	45	50	70	90	80	80	55	80	80	5	40	60
Angle Between Escarpment and Joint Set #1	45	40	0	20	20	20	60	0	0	0	0	50
Angle Between Joint Set #2 and Face		20				10	35					10
Angle Between Escarpment and Joint Set #2		70				50	80					30
Excavation Width-to-Depth Ratio												
Thickness (ft) of Castlegate Shale												
Thickness (ft) of Castlegate Sandstone												
Erosion Under Escarpment												
Talus Volume												
Canyon Slope (%)												
Escarpment Slope (%)												
Castlegate Toe to Seam Distance												
Angle Between Escarpment and Mining Limit												
Response Factors:												
Vertical Displacement, Feet												
Horizontal Displacement, Feet												
Volume of Failure (Cubic Feet)												
Photograph		L. West	2, S & E							3, W & E		
Time of Failure												
Face Position												
Rock Displacement (Feet) after Failure												
Tension Crack Strike			N 20 E	N 5 E						N 25 E		
Tension Crack Horizontal Continuity				40						30		
Tension Crack Strike												
Tension Crack Horizontal Continuity												
Tension Crack Strike												
Tension Crack Horizontal Continuity												

East Mountain Jo tudies	Ken Fleck, Chuck Semborski, Tom Llo									
Corncob Wash Study Area - Cell Data	PAGE 1									
Escarpment Cell Number										
Geologic Factors:	1	2	3	4	5	6	7	8	9	10
Joint Set #1 Strike	N45E	N50E			N70E	N90E		N80E		
Joint Set #1 Spacing	10	10			8	10		10		
Joint Set #1 Continuity - Hor.	10	15			80	15		15		
Joint Set #1 Continuity - Vert.	40	6			10	30		30		
Joint Set #2 Strike		N20W								
Joint Set #2 Spacing		10								
Joint Set #2 Continuity - Hor.		7								
Joint Set #2 Continuity - Vert.		6								
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	45	50			70	90		80		
Angle Between Escarpment and Joint Set #1	45	40			10	45		10		
Angle Between Joint Set #2 and Face		20								
Angle Between Escarpment and Joint Set #2		70								
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	240	240	200	220	220	230	240	250	240	240
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	75	85	77	76	78	81	86	85	88	87
Escarpment Slope (%)	313	140	183	176	147	144	150	156	156	209
Castlegate Toe to Seam Distance	730	780	780	780	780	780	780	780	780	790
Angle Between Escarpment and Mining Limit	82	82	78	78	77	83	89	90	90	83
Response Factors:	(PR10)						(PR11)			
Vertical Displacement, Feet	-4.7						-2.6			
Horizontal Displacement, Feet	3.2 E						1.2 S			
Volume of Failure (Cubic Feet)	200,000	200,000	200,000	200,000	100,000				100,000	200,000
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike	N20E		N5E							
Tension Crack Horizontal Continuity	50		40							
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain Jc tudies	Ken Fleck, Chuck Semborski, Tom Ll									
Corncob Wash Study Area - Cell Data	PAGE 2									
	Escarpment Cell Number									
Geologic Factors:	11	12	13	14	15	16	17	18	19	20
Joint Set #1 Strike			N80W		N55E		N80W	N80W		N5E
Joint Set #1 Spacing			12.5		5					5
Joint Set #1 Continuity - Hor.			30		7		10	15		2
Joint Set #1 Continuity - Vert.			5		7		1	10		5
Joint Set #2 Strike			N10W		N35E					
Joint Set #2 Spacing			10							
Joint Set #2 Continuity - Hor.			50		50					
Joint Set #2 Continuity - Vert.			10		10					
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face			80		55		80	80		5
Angle Between Escarpment and Joint Set #1			10		25		5	0		90
Angle Between Joint Set #2 and Face			10		35					
Angle Between Escarpment and Joint Set #2			50		85					
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	250	250	260	250	300	260	260	240	240	240
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	81	87	85	87	93	91	91	94	86	80
Escarpment Slope (%)	185	185	216	250	227	227	250	240	240	250
Castlegate Toe to Seam Distance	790	790	790	790	790	790	790	795	795	795
Angle Between Escarpment and Mining Limit	79	75	71	68	68	63	57	56	56	52
Response Factors:							(PR12)			
Vertical Displacement, Feet							-4.8			
Horizontal Displacement, Feet							3.9 S			
Volume of Failure (Cubic Feet)	200,000	200,000	100,000		100,000	200,000	200,000	200,000	200,000	200,000
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain Jo[illegible]tudies	Ken Fleck, Chuck Semborski, Tom Llo[illegible]								
Corncob Wash Stu[illegible] Area - Cell Data	PAGE 3								
	Escarpment Cell Number								
Geologic Factors:	21	22	23	24	25	26	27	28	29
Joint Set #1 Strike				N40E				N60E	
Joint Set #1 Spacing								5	
Joint Set #1 Continuity - Hor.				50				8	
Joint Set #1 Continuity - Vert.				10				6	
Joint Set #2 Strike								N10W	
Joint Set #2 Spacing								5	
Joint Set #2 Continuity - Hor.								5	
Joint Set #2 Continuity - Vert.								5	
Bed. Plane Roughness - Cg. Shale									
Hardness - Cg. Shale									
Hardness - Cg Sandstone									
Bedding Plane Alteration									
Geometric Factors:									
Angle Between Joint Set #1 and Face				40				60	
Angle Between Escarpment and Joint Set #1				0				50	
Angle Between Joint Set #2 and Face								10	
Angle Between Escarpment and Joint Set #2								25	
Excavation Width-to-Depth Ratio									
Thickness (ft) of Castlegate Shale									
Thickness (ft) of Castlegate Sandstone	250	250	290	300	270	270	250	250	250
Erosion Under Escarpment	N	N	N	Y	Y	Y	N	N	N
Talus Volume									
Canyon Slope (%)	80	75	72	75	65	65	65	65	65
Escarpment Slope (%)	260	250	250	272	245	250	250	250	250
Castlegate Toe to Seam Distance	795	800	800	800	800	750	750	750	750
Angle Between Escarpment and Mining Limit	52	48	49	52	57	59	68	71	79
Response Factors:			(PR 13)						(PR 14)
Vertical Displacement, Feet			FELL						
Horizontal Displacement, Feet			FELL						0.5 E
Volume of Failure (Cubic Feet)	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	100,000
Photograph									
Time of Failure									
Face Position									
Rock Displacement (Feet) after Failure									
Tension Crack Strike	N25E								
Tension Crack Horizontal Continuity	30								
Tension Crack Strike									
Tension Crack Horizontal Continuity									
Tension Crack Strike									
Tension Crack Horizontal Continuity									

East Mountain [illegible] Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 1									
	Escarpment Cell Number									
Geologic Factors:	1	2	3	4	5	6	7	8	9	10
Joint Set #1 Strike	N70W			N90E		N5E				
Joint Set #1 Spacing										
Joint Set #1 Continuity - Hor.	80			100		100				
Joint Set #1 Continuity - Vert.	80			100		100				
Joint Set #2 Strike										
Joint Set #2 Spacing										
Joint Set #2 Continuity - Hor.										
Joint Set #2 Continuity - Vert.										
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	70			90		5				
Angle Between Escarpment and Joint Set #1	50			10		60				
Angle Between Joint Set #2 and Face										
Angle Between Escarpment and Joint Set #2										
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	200	150	150	150	200	200	200	150	200	150
Erosion Under Escarpment	Y	Y	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	75	77	71	75	69	80	80	90	90	75
Escarpment Slope (%)	100	107	125	125	200	167	118	100	90	71
Castlegate Toe to Seam Distance	880	880	880	880	880	880	870	870	870	860
Angle Between Escarpment and Mining Limit	30	32	34	36	39	41	44	47	50	53
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain [illegible] Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 2									
	Escarpment Cell Number									
Geologic Factors:	11	12	13	14	15	16	17	18	19	20
Joint Set #1 Strike				N5E	N5E	N5E				
Joint Set #1 Spacing				30	50					
Joint Set #1 Continuity - Hor.				70	60	50				
Joint Set #1 Continuity - Vert.				70	60	50				
Joint Set #2 Strike										
Joint Set #2 Spacing										
Joint Set #2 Continuity - Hor.										
Joint Set #2 Continuity - Vert.										
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face				5	5	5				
Angle Between Escarpment and Joint Set #1				5	45	80				
Angle Between Joint Set #2 and Face										
Angle Between Escarpment and Joint Set #2										
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	150	170	200	250	250	200	150	150	150
Erosion Under Escarpment	N	N	N	N	N	Y	N	N	N	N
Talus Volume										
Canyon Slope (%)	75	91	86	81	75	77	81	70	68	78
Escarpment Slope (%)	94	78	77	100	125	166	160	113	107	150
Castlegate Toe to Seam Distance	850	850	850	850	850	850	850	850	850	850
Angle Between Escarpment and Mining Limit	57	63	68	68	68	71	75	90	83	78
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain t Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 3									
	Escarpment Cell Number									
Geologic Factors:	21	22	23	24	25	26	27	28	29	30
Joint Set #1 Strike	N10E	N80W		N10E	N10E	N10E	N10E		N10E	N5E
Joint Set #1 Spacing	30	40			40		50		30	20
Joint Set #1 Continuity - Hor.	80	50		60	60	50	50		50	50
Joint Set #1 Continuity - Vert.	80	50		60	60	50	50		50	50
Joint Set #2 Strike	N80W									N90E
Joint Set #2 Spacing	40									
Joint Set #2 Continuity - Hor.	50									50
Joint Set #2 Continuity - Vert.	50									50
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	10	80		10	10	10	10		10	5
Angle Between Escarpment and Joint Set #1	60	40		80	80	60	60		45	90
Angle Between Joint Set #2 and Face	80						90			90
Angle Between Escarpment and Joint Set #2	30						40			0
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	200	200	240	250	250	250	250	250	240
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	71	68	65	58	58	57	57	63	68	75
Escarpment Slope (%)	136	154	105	133	156	131	131	125	167	160
Castlegate Toe to Seam Distance	850	850	840	830	820	810	800	800	800	800
Angle Between Escarpment and Mining Limit	74	68	68	61	65	67	71	76	83	86
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain t Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 4									
	Escarpment Cell Number									
Geologic Factors:	31	32	33	34	35	36	37	38	39	40
Joint Set #1 Strike	N5E	N5E	N5E	N5E	N5E			N5E	N5E	N90E
Joint Set #1 Spacing	30	30			30			50	50	30
Joint Set #1 Continuity - Hor.	60	50	50	50	50			50	50	50
Joint Set #1 Continuity - Vert.	60	50	50	50	50			50	50	40
Joint Set #2 Strike		N90E			N80E					
Joint Set #2 Spacing										
Joint Set #2 Continuity - Hor.		50			60					
Joint Set #2 Continuity - Vert.		50			60					
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	5	5	5	5	5			5	5	90
Angle Between Escarpment and Joint Set #1	70	90	85	70	70			5	5	60
Angle Between Joint Set #2 and Face		90			80					
Angle Between Escarpment and Joint Set #2		0			70					
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	200	200	200	200	200	200	200	200	200	200
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	77	78	75	73	70	69	67	80	77	80
Escarpment Slope (%)	133	118	133	125	114	136	150	115	115	120
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	83	83	83	83	83	83	83	81	80	79
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain [illegible]t Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 5									
Escarpment Cell Number										
Geologic Factors:	41	42	43	44	45	46	47	48	49	50
Joint Set #1 Strike	N90E	N5E		N20E	N90E	N5E	N90E	N90E	N90E	
Joint Set #1 Spacing	40	40				20	30	30		
Joint Set #1 Continuity - Hor.	40	40		110	70	70	100	70	110	
Joint Set #1 Continuity - Vert.	40	40		110	70	70	100	70	110	
Joint Set #2 Strike		N90E					N5E			
Joint Set #2 Spacing							30			
Joint Set #2 Continuity - Hor.		60					70			
Joint Set #2 Continuity - Vert.		60					70			
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	90	5		20	90	5	90	90	90	
Angle Between Escarpment and Joint Set #1	30	60		90	30	10	50	0	0	
Angle Between Joint Set #2 and Face		90					5			
Angle Between Escarpment and Joint Set #2		40					10			
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	200	200	200	200	200	200	150	150	150
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	73	75	70	73	69	78	75	78	73	73
Escarpment Slope (%)	125	243	200	167	142	182	223	136	136	136
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	73	68	74	76	80	85	78	85	85	85
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain t Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 6									
	Escarpment Cell Number									
Geologic Factors:	51	52	53	54	55	56	57	58	59	60
Joint Set #1 Strike					N5E	N5E	N90E	N90E		
Joint Set #1 Spacing					40	40	50	50		
Joint Set #1 Continuity - Hor.					50	50	100	100		
Joint Set #1 Continuity - Vert.					50	50	100	100		
Joint Set #2 Strike					N90E	N90E				
Joint Set #2 Spacing					60	60				
Joint Set #2 Continuity - Hor.					90	90				
Joint Set #2 Continuity - Vert.					90	90				
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face					5	5	90	90		
Angle Between Escarpment and Joint Set #1					30	30	60	70		
Angle Between Joint Set #2 and Face					90	90				
Angle Between Escarpment and Joint Set #2					60	60				
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	150	150	150	150	150	150	150	200	200
Erosion Under Escarpment	N	N	N	N	N	N	N	Y	Y	Y
Talus Volume										
Canyon Slope (%)	73	77	77	77	75	77	75	75	58	60
Escarpment Slope (%)	375	125	125	136	136	136	130	133	200	222
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	78	82	75	69	65	60	55	52	49	49
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountair [illegible]nt Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 7									
	Escarpment Cell Number									
Geologic Factors:	61	62	63	64	65	66	67	68	69	70
Joint Set #1 Strike			N90E		N10E		N10E	N10E	N10E	N5E
Joint Set #1 Spacing			30		50		50		50	30
Joint Set #1 Continuity - Hor.			50		70		70	60	50	50
Joint Set #1 Continuity - Vert.			50		70		70	60	50	50
Joint Set #2 Strike										
Joint Set #2 Spacing										
Joint Set #2 Continuity - Hor.										
Joint Set #2 Continuity - Vert.										
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face			90		10		10	10	10	5
Angle Between Escarpment and Joint Set #1			30		60		60	60	60	40
Angle Between Joint Set #2 and Face										
Angle Between Escarpment and Joint Set #2										
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	200	200	200	200	200	200	250	250	250
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	75	88	81	77	75	75	71	71	72	72
Escarpment Slope (%)	182	133	133	133	182	182	182	179	179	156
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	49	52	54	57	60	63	67	71	76	75
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain : Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 8									
	Escarpment Cell Number									
Geologic Factors:	71	72	73	74	75	76	77	78	79	80
Joint Set #1 Strike	N5E	N5E	N5E	N5E	N5E				N5E	N5E
Joint Set #1 Spacing	30	30	30	30	30				40	40
Joint Set #1 Continuity - Hor.	50	50	60	60	60				50	50
Joint Set #1 Continuity - Vert.	50	50	60	60	60				50	50
Joint Set #2 Strike	N90E	N90E								N90E
Joint Set #2 Spacing	50	50								
Joint Set #2 Continuity - Hor.	50	50								50
Joint Set #2 Continuity - Vert.	50	50								50
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	5	5	5	5	5				5	5
Angle Between Escarpment and Joint Set #1	40	40	40	40	40				70	70
Angle Between Joint Set #2 and Face	90	90								90
Angle Between Escarpment and Joint Set #2	50	50								20
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	200	200	200	200	200	150	150	150	250	250
Erosion Under Escarpment	N	N	N	N	N	N	N	Y	Y	Y
Talus Volume										
Canyon Slope (%)	62	63	70	75	80	80	57	57	75	78
Escarpment Slope (%)	167	142	125	125	133	111	100	80	125	130
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	69	65	59	54	51	47	43	41	41	42
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain [illegible] Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 9									
	Escarpment Cell Number									
Geologic Factors:	81	82	83	84	85	86	87	88	89	90
Joint Set #1 Strike	N5E	N5E	N5E	N5E		N5E	N5E	N5E	N5E	N5E
Joint Set #1 Spacing	20	20	20			20	20		20	
Joint Set #1 Continuity - Hor.	50	50	50	80		80	80	70	50	60
Joint Set #1 Continuity - Vert.	50	50	50	80		80	80	70	50	60
Joint Set #2 Strike	N90E	N90E				N90E				
Joint Set #2 Spacing	20									
Joint Set #2 Continuity - Hor.	50	50				100				
Joint Set #2 Continuity - Vert.	50	50				100				
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	5	5	5	5		5	5	5	5	5
Angle Between Escarpment and Joint Set #1	70	70	70	70		80	70	70	45	45
Angle Between Joint Set #2 and Face	90	90				90				
Angle Between Escarpment and Joint Set #2	20	20				10				
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	250	200	200	200	200	200	150	150	150	150
Erosion Under Escarpment	Y	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	80	63	68	74	71	71	77	45	61	61
Escarpment Slope (%)	104	173	125	133	214	214	182	150	150	107
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	42	42	42	45	46	52	51	46	43	41
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain [illegible] Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 10									
	Escarpment Cell Number									
Geologic Factors:	91	92	93	94	95	96	97	98	99	100
Joint Set #1 Strike	N5E	N5E	N5E	N90E	N90E	N90E	N5E	N5E	N5E	N90E
Joint Set #1 Spacing	30	30		50	50	50	30	30	20	
Joint Set #1 Continuity - Hor.	50	70	60	100	100	60	70	60	70	60
Joint Set #1 Continuity - Vert.	50	70	60	100	100	60	70	60	70	60
Joint Set #2 Strike				N5E	N5E	N5E				
Joint Set #2 Spacing				100	50	100				
Joint Set #2 Continuity - Hor.				70	60	60				
Joint Set #2 Continuity - Vert.				70	60	60				
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	5	5	5	90	90	90	5	5	5	90
Angle Between Escarpment and Joint Set #1	45	60	60	30	30	20	90	90	90	0
Angle Between Joint Set #2 and Face				5	5	5				
Angle Between Escarpment and Joint Set #2				60	60	70				
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	150	150	150	150	150	150	150	150	150
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	75	79	79	79	73	71	71	77	75	75
Escarpment Slope (%)	100	107	115	100	100	100	115	150	136	136
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	40	39	36	35	35	35	58	62	69	71
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain Jc[illegible]tudies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 11									
	Escarpment Cell Number									
Geologic Factors:	101	102	103	104	105	106	107	108	109	110
Joint Set #1 Strike	N10E									
Joint Set #1 Spacing	70									
Joint Set #1 Continuity - Hor.	80									
Joint Set #1 Continuity - Vert.	80									
Joint Set #2 Strike										
Joint Set #2 Spacing										
Joint Set #2 Continuity - Hor.										
Joint Set #2 Continuity - Vert.										
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	10									
Angle Between Escarpment and Joint Set #1	90									
Angle Between Joint Set #2 and Face										
Angle Between Escarpment and Joint Set #2										
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	150	150	200	150	150	150	150	150	150
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	76	83	81	81	81	79	75	77	75	71
Escarpment Slope (%)	136	136	150	222	200	167	136	187	187	200
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	68	74	77	78	75	68	61	61	68	71
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain . Studies	Ken Fleck									
Rilda Canyon Stu.y Area - Cell Data	PAGE 1									
	Escarpment Cell Number									
Geologic Factors:	1	2	3	4	5	6	7	8	9	10
Joint Set #1 Strike	N70W			N90E		N5E				
Joint Set #1 Spacing										
Joint Set #1 Continuity - Hor.	80			100		100				
Joint Set #1 Continuity - Vert.	80			100		100				
Joint Set #2 Strike										
Joint Set #2 Spacing										
Joint Set #2 Continuity - Hor.										
Joint Set #2 Continuity - Vert.										
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	70			90		5				
Angle Between Escarpment and Joint Set #1	50			10		60				
Angle Between Joint Set #2 and Face										
Angle Between Escarpment and Joint Set #2										
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	200	150	150	150	200	200	200	150	200	150
Erosion Under Escarpment	Y	Y	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	75	77	71	75	69	80	80	90	90	75
Escarpment Slope (%)	100	107	125	125	200	167	118	100	90	71
Castlegate Toe to Seam Distance	880	880	880	880	880	880	870	870	870	860
Angle Between Escarpment and Mining Limit	30	32	34	36	39	41	44	47	50	53
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain . Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 2									
Escarpment Cell Number										
Geologic Factors:	11	12	13	14	15	16	17	18	19	20
Joint Set #1 Strike				N5E	N5E	N5E				
Joint Set #1 Spacing				30	50					
Joint Set #1 Continuity - Hor.				70	60	50				
Joint Set #1 Continuity - Vert.				70	60	50				
Joint Set #2 Strike										
Joint Set #2 Spacing										
Joint Set #2 Continuity - Hor.										
Joint Set #2 Continuity - Vert.										
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face				5	5	5				
Angle Between Escarpment and Joint Set #1				5	45	80				
Angle Between Joint Set #2 and Face										
Angle Between Escarpment and Joint Set #2										
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	150	170	200	250	250	200	150	150	150
Erosion Under Escarpment	N	N	N	N	N	Y	N	N	N	N
Talus Volume										
Canyon Slope (%)	75	91	86	81	75	77	81	70	68	78
Escarpment Slope (%)	94	78	77	100	125	166	160	113	107	150
Castlegate Toe to Seam Distance	850	850	850	850	850	850	850	850	850	850
Angle Between Escarpment and Mining Limit	57	63	68	68	68	71	75	90	83	78
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain t Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 3									
	Escarpment Cell Number									
Geologic Factors:	21	22	23	24	25	26	27	28	29	30
Joint Set #1 Strike	N10E	N80W		N10E	N10E	N10E	N10E		N10E	N5E
Joint Set #1 Spacing	30	40			40		50		30	20
Joint Set #1 Continuity - Hor.	80	50		60	60	50	50		50	50
Joint Set #1 Continuity - Vert.	80	50		60	60	50	50		50	50
Joint Set #2 Strike	N80W									N90E
Joint Set #2 Spacing	40									
Joint Set #2 Continuity - Hor.	50									50
Joint Set #2 Continuity - Vert.	50									50
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	10	80		10	10	10	10		10	5
Angle Between Escarpment and Joint Set #1	60	40		80	80	60	60		45	90
Angle Between Joint Set #2 and Face	80						90			90
Angle Between Escarpment and Joint Set #2	30						40			0
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	200	200	240	250	250	250	250	250	240
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	71	68	65	58	58	57	57	63	68	75
Escarpment Slope (%)	136	154	105	133	156	131	131	125	167	160
Castlegate Toe to Seam Distance	850	850	840	830	820	810	800	800	800	800
Angle Between Escarpment and Mining Limit	74	68	68	61	65	67	71	76	83	86
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain t Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 4									
	Escarpment Cell Number									
Geologic Factors:	31	32	33	34	35	36	37	38	39	40
Joint Set #1 Strike	N5E	N5E	N5E	N5E	N5E			N5E	N5E	N90E
Joint Set #1 Spacing	30	30			30			50	50	30
Joint Set #1 Continuity - Hor.	60	50	50	50	50			50	50	50
Joint Set #1 Continuity - Vert.	60	50	50	50	50			50	50	40
Joint Set #2 Strike		N90E			N80E					
Joint Set #2 Spacing										
Joint Set #2 Continuity - Hor.		50			60					
Joint Set #2 Continuity - Vert.		50			60					
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	5	5	5	5	5			5	5	90
Angle Between Escarpment and Joint Set #1	70	90	85	70	70			5	5	60
Angle Between Joint Set #2 and Face		90			80					
Angle Between Escarpment and Joint Set #2		0			70					
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	200	200	200	200	200	200	200	200	200	200
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	77	78	75	73	70	69	67	80	77	80
Escarpment Slope (%)	133	118	133	125	114	136	150	115	115	120
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	83	83	83	83	83	83	83	81	80	79
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain [illegible]t Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 5									
Escarpment Cell Number										
Geologic Factors:	41	42	43	44	45	46	47	48	49	50
Joint Set #1 Strike	N90E	N5E		N20E	N90E	N5E	N90E	N90E	N90E	
Joint Set #1 Spacing	40	40				20	30	30		
Joint Set #1 Continuity - Hor.	40	40		110	70	70	100	70	110	
Joint Set #1 Continuity - Vert.	40	40		110	70	70	100	70	110	
Joint Set #2 Strike		N90E					N5E			
Joint Set #2 Spacing							30			
Joint Set #2 Continuity - Hor.		60					70			
Joint Set #2 Continuity - Vert.		60					70			
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	90	5		20	90	5	90	90	90	
Angle Between Escarpment and Joint Set #1	30	60		90	30	10	50	0	0	
Angle Between Joint Set #2 and Face		90					5			
Angle Between Escarpment and Joint Set #2		40					10			
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	200	200	200	200	200	200	150	150	150
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	73	75	70	73	69	78	75	78	73	73
Escarpment Slope (%)	125	243	200	167	142	182	223	136	136	136
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	73	68	74	76	80	85	78	85	85	85
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain t Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 6									
	Escarpment Cell Number									
Geologic Factors:	51	52	53	54	55	56	57	58	59	60
Joint Set #1 Strike					N5E	N5E	N90E	N90E		
Joint Set #1 Spacing					40	40	50	50		
Joint Set #1 Continuity - Hor.					50	50	100	100		
Joint Set #1 Continuity - Vert.					50	50	100	100		
Joint Set #2 Strike					N90E	N90E				
Joint Set #2 Spacing					60	60				
Joint Set #2 Continuity - Hor.					90	90				
Joint Set #2 Continuity - Vert.					90	90				
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face					5	5	90	90		
Angle Between Escarpment and Joint Set #1					30	30	60	70		
Angle Between Joint Set #2 and Face					90	90				
Angle Between Escarpment and Joint Set #2					60	60				
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	150	150	150	150	150	150	150	200	200
Erosion Under Escarpment	N	N	N	N	N	N	N	Y	Y	Y
Talus Volume										
Canyon Slope (%)	73	77	77	77	75	77	75	75	58	60
Escarpment Slope (%)	375	125	125	136	136	136	130	133	200	222
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	78	82	75	69	65	60	55	52	49	49
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountair [illegible]nt Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 7									
	Escarpment Cell Number									
Geologic Factors:	61	62	63	64	65	66	67	68	69	70
Joint Set #1 Strike			N90E		N10E		N10E	N10E	N10E	N5E
Joint Set #1 Spacing			30		50		50		50	30
Joint Set #1 Continuity - Hor.			50		70		70	60	50	50
Joint Set #1 Continuity - Vert.			50		70		70	60	50	50
Joint Set #2 Strike										
Joint Set #2 Spacing										
Joint Set #2 Continuity - Hor.										
Joint Set #2 Continuity - Vert.										
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face			90		10		10	10	10	5
Angle Between Escarpment and Joint Set #1			30		60		60	60	60	40
Angle Between Joint Set #2 and Face										
Angle Between Escarpment and Joint Set #2										
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	200	200	200	200	200	200	250	250	250
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	75	88	81	77	75	75	71	71	72	72
Escarpment Slope (%)	182	133	133	133	182	182	182	179	179	156
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	49	52	54	57	60	63	67	71	76	75
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain : Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 8									
	Escarpment Cell Number									
Geologic Factors:	71	72	73	74	75	76	77	78	79	80
Joint Set #1 Strike	N5E	N5E	N5E	N5E	N5E				N5E	N5E
Joint Set #1 Spacing	30	30	30	30	30				40	40
Joint Set #1 Continuity - Hor.	50	50	60	60	60				50	50
Joint Set #1 Continuity - Vert.	50	50	60	60	60				50	50
Joint Set #2 Strike	N90E	N90E								N90E
Joint Set #2 Spacing	50	50								
Joint Set #2 Continuity - Hor.	50	50								50
Joint Set #2 Continuity - Vert.	50	50								50
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	5	5	5	5	5				5	5
Angle Between Escarpment and Joint Set #1	40	40	40	40	40				70	70
Angle Between Joint Set #2 and Face	90	90								90
Angle Between Escarpment and Joint Set #2	50	50								20
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	200	200	200	200	200	150	150	150	250	250
Erosion Under Escarpment	N	N	N	N	N	N	N	Y	Y	Y
Talus Volume										
Canyon Slope (%)	62	63	70	75	80	80	57	57	75	78
Escarpment Slope (%)	167	142	125	125	133	111	100	80	125	130
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	69	65	59	54	51	47	43	41	41	42
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain ` Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 9									
	Escarpment Cell Number									
Geologic Factors:	81	82	83	84	85	86	87	88	89	90
Joint Set #1 Strike	N5E	N5E	N5E	N5E		N5E	N5E	N5E	N5E	N5E
Joint Set #1 Spacing	20	20	20			20	20		20	
Joint Set #1 Continuity - Hor.	50	50	50	80		80	80	70	50	60
Joint Set #1 Continuity - Vert.	50	50	50	80		80	80	70	50	60
Joint Set #2 Strike	N90E	N90E				N90E				
Joint Set #2 Spacing	20									
Joint Set #2 Continuity - Hor.	50	50				100				
Joint Set #2 Continuity - Vert.	50	50				100				
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	5	5	5	5		5	5	5	5	5
Angle Between Escarpment and Joint Set #1	70	70	70	70		80	70	70	45	45
Angle Between Joint Set #2 and Face	90	90				90				
Angle Between Escarpment and Joint Set #2	20	20				10				
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	250	200	200	200	200	200	150	150	150	150
Erosion Under Escarpment	Y	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	80	63	68	74	71	71	77	45	61	61
Escarpment Slope (%)	104	173	125	133	214	214	182	150	150	107
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	42	42	42	45	46	52	51	46	43	41
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain … Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 10									
Escarpment Cell Number										
Geologic Factors:	91	92	93	94	95	96	97	98	99	100
Joint Set #1 Strike	N5E	N5E	N5E	N90E	N90E	N90E	N5E	N5E	N5E	N90E
Joint Set #1 Spacing	30	30		50	50	50	30	30	20	
Joint Set #1 Continuity - Hor.	50	70	60	100	100	60	70	60	70	60
Joint Set #1 Continuity - Vert.	50	70	60	100	100	60	70	60	70	60
Joint Set #2 Strike				N5E	N5E	N5E				
Joint Set #2 Spacing				100	50	100				
Joint Set #2 Continuity - Hor.				70	60	60				
Joint Set #2 Continuity - Vert.				70	60	60				
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	5	5	5	90	90	90	5	5	5	90
Angle Between Escarpment and Joint Set #1	45	60	60	30	30	20	90	90	90	0
Angle Between Joint Set #2 and Face				5	5	5				
Angle Between Escarpment and Joint Set #2				60	60	70				
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	150	150	150	150	150	150	150	150	150
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	75	79	79	79	73	71	71	77	75	75
Escarpment Slope (%)	100	107	115	100	100	100	115	150	136	136
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	40	39	36	35	35	35	58	62	69	71
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

East Mountain Jc[illegible]Studies	Ken Fleck									
Rilda Canyon Study Area - Cell Data	PAGE 11									
	Escarpment Cell Number									
Geologic Factors:	101	102	103	104	105	106	107	108	109	110
Joint Set #1 Strike	N10E									
Joint Set #1 Spacing	70									
Joint Set #1 Continuity - Hor.	80									
Joint Set #1 Continuity - Vert.	80									
Joint Set #2 Strike										
Joint Set #2 Spacing										
Joint Set #2 Continuity - Hor.										
Joint Set #2 Continuity - Vert.										
Bed. Plane Roughness - Cg. Shale										
Hardness - Cg. Shale										
Hardness - Cg Sandstone										
Bedding Plane Alteration										
Geometric Factors:										
Angle Between Joint Set #1 and Face	10									
Angle Between Escarpment and Joint Set #1	90									
Angle Between Joint Set #2 and Face										
Angle Between Escarpment and Joint Set #2										
Excavation Width-to-Depth Ratio										
Thickness (ft) of Castlegate Shale										
Thickness (ft) of Castlegate Sandstone	150	150	150	200	150	150	150	150	150	150
Erosion Under Escarpment	N	N	N	N	N	N	N	N	N	N
Talus Volume										
Canyon Slope (%)	76	83	81	81	81	79	75	77	75	71
Escarpment Slope (%)	136	136	150	222	200	167	136	187	187	200
Castlegate Toe to Seam Distance	800	800	800	800	800	800	800	800	800	800
Angle Between Escarpment and Mining Limit	68	74	77	78	75	68	61	61	68	71
Response Factors:										
Vertical Displacement, Feet										
Horizontal Displacement, Feet										
Volume of Failure (Cubic Feet)										
Photograph										
Time of Failure										
Face Position										
Rock Displacement (Feet) after Failure										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										
Tension Crack Strike										
Tension Crack Horizontal Continuity										

ENERGY WEST MINING COMPANY

North Rilda Lease Area
Vegetation Survey and Evaluation
September, 1997

Submitted to:

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Energy West Mining Company, North Rilda Lease Area
Vegetation Survey and Evaluation
September, 1997

1.0 Introduction

Energy West Mining Company, a wholly-owned subsidiary of PacifiCorp, an Oregon corporation, submitted an application to the U.S. Forest Service to permit the North Rilda Lease Area adjacent to the Deer Creek Mine. Based on the current mine layout, the two southern panels of each seam are projected to extend below the Castlegate Sandstone escarpment. As specified in the lease stipulations, "except at specifically approved locations, the Castlegate escarpment must be protected from mining induced failure." Where escarpment failure is proposed or anticipated, an environmental analysis will be needed to assess the impacts.

The scope of this report is for a vegetation survey to address vegetation resources that would be affected by escarpment failure. This vegetation survey addresses the following areas:

1. Threatened, Endangered and Sensitive Plants
   a. Identify plant species occurrence in the survey area.
   b. Depict plant species occurrence.
   c. Relative abundance.

2. Vegetation
   a. Delineate and describe vegetation communities and relative abundance of each community in the survey area.
   b. Map vegetation communities based on the two dominant species (dominant overstory/dominant understory) in the survey area.

The vegetation survey at the North Rilda Canyon Lease Area was conducted by privately contracted environmental consultant, Patricia K. Johnston, Wildlife/Vegetation Specialist, September, 1997.

2.0 Methodology

Vegetation Community Mapping

Initial research included coordination with Robert Thompson, Range Conservationist of the U.S. Forest Service (USFS), Leland Sasser, Soil Scientist and George Cook, Range Conservationist of the Natural Resource Conservation Service (NRCS).

Aerial photos provided by Energy West of the North Rilda Canyon Lease taken in 9/94, USGS topographic maps, and field review (including extensive hiking) were used to map vegetation communities within the 1,960 acre lease area.

Initially, the scope of work was to map vegetation communities below the escarpment area, those communities that had the potential to be impacted by an escarpment failure. However, it was requested by Thompson, USFS to expand the scope of work to map all vegetation communities within the 1,960 acre lease area.

Threatened, Endangered and Sensitive Plants

Only one species, Hedysarum occidentale var. canone Canyon sweetvetch or Coal sweetvetch, was identified by the USFS, Thompson, that would require attention. As per phone conversation with Larry England, U.S. Fish & Wildlife Service, November 17, 1997, H.occidentale var. canone is listed as a Forest Service sensitive species and has no special listing with the USF&W. It is not protected or given special consideration with any T&E designation.

It was addressed with Thompson, USFS, the lateness of the growing season and that the flowering season for H. occidentale var. canone, would have been past by at least 6-8 weeks. However, due to the distinctive vegetative characteristics of this plant, Thompson was satisfied with the survey time of year. Further, the possible occurrence of H. occidentale var. canone within the potential escarpment failure area was remote.

3.0 Results

Vegetation Mapping

Four major vegetation communities and one major vegetation community complex were described upon field review; Upland Very Steep Shallow Loam (Pinyon-Juniper)-578 acres, Mountain Complex-556 acres, Mountain Stony Loam (Browse)-68 acres, Mountain Very Steep Stony Loam (Douglas Fir)-705 acres, and Loamy Bottom-53 acres. After careful review of the soil and vegetative information provided by both the U.S. Forest Service and the Natural Resource Conservation Service, it was determined that the mapping units as described by the NRCS were more closely associated with the vegetative communities in the North Rilda Canyon Lease Area. The preliminary NRCS Emery County Soil Survey meets and slightly overlaps the east boundary of the lease area. The following vegetation communities were mapped on behalf of Energy West by Johnston, vegetation consultant, September - October, 1997.

Vegetation Community (Ecological Site)

Upland Very Steep Shallow Loam - Pinyon-Utah Juniper:

Overstory: Pinyon - Utah Juniper (scattered Douglas fir)
Understory: Sagebrush and salina wildrye

The upland very steep shallow loam occurs on the south facing slopes of the North Rilda Canyon Lease area. It occurs between 7400-8600'. At the lower reaches it occurs on the toe slopes, 0-15% slope, that rapidly rise into slopes of 50-70%. This area is bound at its upper reaches by the Castlegate escarpment. This vegetation boundary is marked more significantly by an elevation change, at which point the Utah Juniper drops out of the plant community and production of the vegetation community increases, at which point the Mountain Complex becomes the vegetation community.

Mountain Complex:

Mountain Stony Loam (Browse)
Overstory: Pinyon-Utah juniper
Understory: Salina wildrye and mountain sagebrush
Mountain Shallow Loam (Salina Wildrye)

Overstory: Curlleaf mountain mahogany, serviceberry, pinyon and Utah juniper

Understory: Salina wildrye, sagebrush and snowberry

Mountain Loam

Overstory: none

Understory: Salina wildrye, mountain sagebrush and snowberry

Mountain Stony Loam (Browse) 60%, Mountain Shallow Loam (Salina Wildrye) 25%, Mountain Loam (Salina Wildrye) 15%, vegetation community components are so intricately intermingled that it was not practical to map them separately.

The Mountain Shallow and Stony sites are on the south and east facing slopes. Slopes range from 30-50% and between 8600-9400'. the Mountain Loam (Salina Wildrye) site is predominately on the mountain ridgetop, but does occur in patches on the side slopes. Slopes are fairly flat on the ridgetops 3-15%, however, can be as high as 50% on the side slopes.

The north facing slopes both north and south of the Rilda Canyon road are dominated by the Mountain Very Steep Stony Loam-Douglas fir vegetation community.

The slopes range from 40-60% and occur between 8000-9600 feet.

Overstory: Douglas fir

Understory: Elk sedge, salina wildrye, snowberry, Oregon grape

The last vegetation community that is present within the North Rilda Canyon lease area is the Loamy Bottom site. It is the area affected by the presence of the perennial stream and high water table in the canyon bottom.

Overstory: Aspen, blue spruce, douglas fir

Understory: (highly diverse with grasses, forbs and shrubs) snowberry, mountain sagebrush, needlegrass (Stipa spp.) and wildrye (Elymus spp.)

Threatened, Endangered and Sensitive Plants

H. occidentale var. canone, is typically distributed Pinyon-juniper, sagebrush, and wash communities between 5,000 and 8,000 feet elevation. The Castlegate Escarpment occurs at approximately 8800 feet within the Mountain Stony Loam, Mountain Shallow Loam, Mountain Loam and Mountain Very Steep Stony Loam - Douglas Fir vegetation communities.

H.occidentale var.canone was not found after a field survey was conducted to determine the its presence in Rilda Canyon and within the lease area.

Assessment of Spotted Bat (Euderma maculatum) and Townsend's Big-eared Bat (Corynorhinus townsendii) in the Proposed North Rilda Lease Area. Manti La Sal National Forest, Emery County, Utah.

Conducted for Energy West Mining Co.

Submitted by:

Richard E. Sherwin

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Contents

Assessment of the Spotted Bat (Euderma maculatum) and Townsend's Big-eared Bat (Corynorhinus townsendii) in the Proposed North Rilda Lease Area. Manti La Sal National Forest, Emery County, Utah

Conducted for Energy West Mining Co.

The purpose of this report is to provide an assessment of the distribution, relative abundance, and habitat requirements of the Spotted bat (Euderma maculatum) and Townsend's big-eared bat (Corynorhinus townsendii) in the North Rilda area. These parameters were investigated for the following: **1)** areas under consideration as potential lease sites for mining; **2)** sites where subsurface coal mining is ongoing, and; **3)** sites (both on and off the Manti La Sal National Forest) that served as controls (no mining activities).

Background

Townsend's big-eared bat is a mid-sized insectivorous bat that is believed to be strongly associated with the availability of caves and abandoned mines. It is distributed throughout Utah, and is the most species of bat observed within caves and abandoned mines. During summer months the males remain solitary while females congregate into maternity colonies numbering between a dozen to several hundred individuals. Mixed colonies are formed in the winter (primarily in caves and abandoned mines) where the animals mate and hibernate. Winter and summer sites are generally within a few miles of each other. This species is associated with a broad suite of vegetation types, but local populations appear to be strongly influenced by the presence of rock outcrops and a juniper (Juniperus) vegetative component (Sherwin, in prep.). Although C. townsendii is broadly distributed and is commonly observed in caves and abandoned mines, it is never observed in large numbers in the west (ie. the largest known maternity roost in Utah (Logan Cave) numbers only approx. 350 individuals (Sherwin et al., 1996).

The Spotted bat is the only member of the genus Euderma and is distinguished easily from all other North American species of bats by its huge pinkish-red ears and distinctive coloration and patterning (O'Farrell 1981). E. maculatum are black dorsally with three large circular white spots, two on each shoulder and the third above the base of the tail. White patches also are found at the posterior base of the ears. Ventrally, spotted bats have hair that is black at the base but white distally (O'Farrell 1981). Spotted bats utilize a variety of habitats from Idaho and Montana south to Queretaro, Mexico (Watkins, 1977). They have been collected at sites ranging from ponderosa pine and spruce-fir associations (Hoffmeister, 1986; Reynolds 1981; Vorhies, 1935) to deserts and caves or cave-like associations (Easterla, 1973; Hardy, 1941; Parker, 1952; Ruffner, et al., 1979). Several authors have suggested that Spotted bats may be migratory (Barbour and Davis, 1969; Berna, 1990; Ruffner et al., 1979).

Use of "bat detectors", which record the species-specific "call signature" of Spotted bats has made it possible to determine whether or not Spotted bats occur in a given area. Recent studies in Colorado and Utah (Navo et al., 1992; Rogers, 1997; Storz, 1995) indicate that it may be common locally or even abundant (Easterla, 1973). For example, in a study to document the presence of Spotted bats in Washington Co., Utah Rogers, (1997), detected this species at 39% of the sites surveyed. Those results indicated that the Spotted bat was more common that was previously thought. In previous natural history studies of the Spotted bat (Easterla, 1970, 1973; O'Farrell, 1981; Rogers, 1997; Wai-Ping and Fenton, 1989), sites for roosting in cliffs (availability of cracks and crevices of the proper size in limestone or sandstone rock formations) and the presence of drinking water were hypothesized to be factors important in limiting its distribution.

Moreover, in Washington Co., Utah, Spotted bats were observed foraging near roads with moderate vehicular traffic (Rogers, 1997). This indicates that at least some environmental perturbations resulting from human activity are not a hindrance to the activity patterns of Spotted bats.

Methodology

The project was divided into two phases. The objective of Phase I was to determine if either the Spotted or Townsend's big-eared bat was located within the proposed Lease Area. Four survey sites were selected within the proposed Lease Area which appeared to represent the "best" habitat for each species. The proposed Lease Area was surveyed for suitable habitat by air (fixed wing) and ground surveys combined with viewing aerial photos and examining topographical and vegetation maps. Each survey site was monitored for four nights.

Because Spotted bats were detected at multiple sites (see Results), Phase II was initiated. Phase II consisted of determining habitat utilization, relative abundance, and distribution of Spotted bats within the Lease Area (as well as the control sites located off of the proposed Lease Area). Phase II concentrated on the subset of localities at which Spotted bats were detected as part of Phase I. In so far as possible, habitat utilization was determined. This included observations of movement patterns of Spotted bats as well as information on possible day and night roost locations. Relative abundance was judged by the number of calls detected over time. Because it was not possible to differentiate individuals by their calls, absolute abundance (number of individuals per unit area) could not be determined.

Spotted bats have a relatively low frequency echolocation call (15-9 kHz; Leonard and Fenton, 1984; Navo et al., 1992) and are discernable to the human ear without recording or listening devices (Woodsworth et al., 1981). However, Spotted bat calls are similar to audible calls produced by the Big free-tailed bat and therefore, detection based entirely on auditory cues is unsatisfactory. Fortunately there are several types of bat detectors available on the market that can be used to enhance the acoustic abilities of researchers. The Anabat II bat detector presents a visual representation (ie. a sonogram) of each call recorded, thus making it possible to visually distinguish individual species. Spotted bat calls recorded with an Anabat II bat detector or a similar device are species specific (Leonard and Fenton, 1984 - ie. the acoustic signature of Spotted bats relative to the Big free-tailed bat is diagnostic, making it possible to unambiguously identify this species electronically).

Townsend's big-eared bats produce calls that are generally "ultrasonic" or beyond the range of hearing for investigators (Kunz and Martin, 1982). In addition, their calls are relatively "soft" and therefore has a shorter range of detectibility than other species of bats that occur in the survey areas. However, this species is routinely taken in mist nets (pers. obsv.), especially over water. In addition, potential night roost sites (highway bridges, other bridge-like structures, caves, rock shelters, etc.) were surveyed within lease areas, active mine areas and control sites.

Electronic surveys were conducted using the Anabat II bat detector (Titley Electronics) using several modifications of the standard procedures for detecting most species of bats (O'Farrell and Gannon, pers. comm). Listening posts were established and monitored throughout the times when bats were active (sunset to ca. 03:00 hrs.). Presence of Spotted bats at a particular site was determined by detection of their calls--for example, see Fenton et al.,1987).

Mist netting was conducted to augment electronic bat detection. Mist nets were placed over open water (beaver ponds, stock ponds, wetlands) where bats likely would come to forage or drink. A minimum of 20 meters of net was used to survey each site, with the number of nets used depended on the amount of open water judged to be accessible to bats. Nets were set up before sunset and monitored until ca. 03:00 hrs. Although the Spotted bat is considered a late flier with a highly variable foraging time (Easterla, 1973), Storz (1995:81) observed that spotted bats began foraging "always after dark, and remained active throughout the night...". Therefore, mist nets were monitored until all bat activity ceased (in some cases activity continued from sunset to sunrise).

Results

Use assessment for Townsend's big-eared bats in specified areas

No Townsend's big-eared bats were located within the proposed Lease Area during this project.

Use assessment for Spotted bats in specified areas

Table 1 summarizes results of Spotted bat surveys conducted on the proposed Lease Area during this project. The Anabat II bat detector is the primary source of these data. To complete surveys of all available sites, Phase II was initiated once a positive identification of a Spotted bat was made within the Lease area.

Spotted bats were detected by their species-specific echolocation calls at two of the four localities (50.0%) sampled during Phase 1. No Spotted bats were mist netted during this study. However, Spotted bat vocalizations were recorded at sites: Eclifl (Rilda Canyon); Ewnet1 (Rilda Canyon). Both of these locations are at relatively low elevations (in relation to the rest of the lease area)(Figure 1).

A typical echolocation recording would occur as follows. Usually ca. 1 hr after sunset, one or more investigators would begin to hear audible calls likely produced by Spotted bats. The Anabat II microphone would then be pointed in the direction of the call to record the call digitally. A spotlight would be used to observe the direction and movements of that particular individual.

In every instance, only a single Spotted bat was detected at one time. However, during the course of an evening, multiple recordings/sightings of spotted bats occurred at several sites when surveys were maintained at one locality throughout the night. The time intervals between individual recordings were fairly uniform at each site, but varied from site to site. Intervals were as short as ca. 5 min. to as long as ca. 1 hr. 30 min. between recordings.

One of the sites within the proposed Lease Area Eclifl represents a foraging area for at least one individual. At this site recordings were being made of single individuals following a regular search pattern or "beat" to forage. Spotted bats at Ewnet 1 appeared to be only flying through the area on the way from the roost site(s) to lower elevation foraging areas. Both of these locations were relatively low elevation sites associated with riparian vegetation. None of the higher elevation non riparian sites produced call patterns indicative of this species. These observations are consistent with those made by Storz (1995) in similar habitat. Based on these data, it appears that Spotted bats are solitary while foraging and are rather evenly spaced over suitable foraging habitat. It appears that most individuals are foraging at lower elevation sites located off of the proposed Lease Area.

While specific individual roost sites were not located, general roosting areas were identified on cliff faces/rock outcrops in Rilda Canyon within the proposed Lease Area. Additional roosting areas were identified throughout the Huntington Canyon drainage (Figure 3), outside of the Lease Area. Additional roosting sites are located off site within suitable cliffs throughout the Huntington Canyon drainage.

Discussion and Management Implications

Townsend's big-eared bat was not identified within the North Rilda Area during this study. Townsend's big-eared bat is believed to be limited primarily by the availability of suitable roost sites, particularly caves and abandoned mine resources. The abandoned mines within the proposed North Rilda Lease Area were recently (ca. 1985-1990) reclaimed by the Utah Division of Oil, Gas & Mining (UDOGM). Pre-closure surveys conducted by this agency did not identify Townsend's big-eared bats utilizing these sites prior to closure (Amodt, pers. Comm). However, the habitat and local relief represents excellent Townsend's habitat (Sherwin et. al, in prep.) and it is possible that the difficulties associated with sampling for this species outside of the roost site are preventing its detection.

No Spotted bats were mist netted during this study. There is some indication that water source(s) may not be as critical for the Spotted bat as for other species of bats with which it co-occurs. In a study of urine concentrating ability among selected species of bats, the spotted bat could concentrate its urine more effectively than any species of bat evaluated, with the exception of two typically "desert species", the pallid bat (Antrozous pallidus) and the Western pipistrelle (Pipistrellus hesperus - Geluso, 1978). It is likely that Spotted bats were using water sites specifically to forage rather than drink, making netting extremely difficult.

Spotted bats were observed throughout the eastern (lower elevation) portions of the proposed Lease Area particularly in Rilda Canyon The highest concentration of calls were recorded in Rilda and Huntington Canyons. These canyons seem to best represent "classic" Spotted bat habitat with an abundance of fractured sandstone cliffs, and large areas of suitable foraging habitat.

Spotted bats were observed foraging at one area within the North Rilda Lease Area. This site (Eclifl) seems to represent a minor foraging site (minor in relation to the larger foraging areas located off site in Huntington Canyon). It appears that they are using the proposed Lease Area primarily as a roosting area, and are using the canyons as flyways to reach lower elevation foraging areas. The principal Spotted bat foraging areas are located over the lower elevation riparian habitat located near the mouth of Huntington Canyon. Spotted bats concentrated foraging efforts above the upper canopy of intact riparian vegetation, particularly cottonwood trees (Populus ssp).

Although absolute densities are not available it is possible to make some inferences regarding the minimum size of the population resident within the proposed Lease Area. Based on the number of calls reported at each site and the times of recording, it appears that the Lease Area supports no fewer than 3 individuals.

Spotted bats are not restricted to the Lease Area, but rather are widely distributed in low densities throughout the entire area. In fact, Spotted bats were detected in suitable habitat throughout the area (including utilizing the parking lots of the Village Inn Motels in Huntington and Castledale).

There also is evidence that Spotted bats tolerate at least moderate human disturbance while foraging. Surveys were conducted at several sites near roads with light to moderate vehicular traffic (Crandall Canyon, Huntington Canyon), including tandem trucks used for hauling coal from the GENWAL mine portal located in Crandall Canyon . Spotted bats were observed foraging at low elevation sites off the lease areas, sometimes within 30 m of the right of way.

Spotted bats are common throughout the Huntington Canyon area. They were identified utilizing the proposed Lease Area, the active mine permit area and the control sites (Table 2). Based on the number of individuals observed and their habitat use patterns, it does not appear that current mining practices represent a long term threat to the viability of this population. However, future additional survey work regarding habitat use and population trends would be valuable in confirming this hypothesis. However, the homogeneity of chiropteran communities between all sample sites (Table 3)(see also reports regarding the proposed Southern Lease Area (LBA 11) and proposed Cottonwood Canyon Lease Areas), indicates that no species is being threatened by the mining practices currently in use within study areas. The bat communities in all areas sampled consist of the same suite of species among all areas of similar habitat and complexity (this includes sites in actively mined areas, control sites, and proposed lease areas).

The fact that Spotted bats are relatively common in active and previously mined areas implies that past cliff failures have not dramatically impacted resident populations. As a cliff roosting species, it is likely that they have adapted to tolerate natural rock fall and subsidence. Mine related cliff failures do not generally result in a net loss of habitat (ie. cliffs), but rather provide replacement habitat which may later be colonized by members of the local population. The results of this study indicate that Spotted bats are "common" enough throughout the area that the localized failure of cliffs (as a result of coal mining within the proposed Lease Area) does not pose a serious threat to the population as a whole. Assuming that current mining practices remain in place, we do not foresee that underground coal mining represents a serious threat to the sustainability of viable populations of Spotted bats or any bat species within the project area.

LITERATURE CITED

Baillie, J., and B. Groombridge (eds.). 1996. 1996 IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland, 368 pp.

Barbour, R. W., and W. H. Davis. 1969. Bats of America. University of Kentucky Press, Lexington, 286 pp.

Berna, H. J. 1990. Seven bat species from the Kaibab Plateau, Arizona, with a new record of Euderma maculatum. Southwestern Naturalist, 35:354-356.

Easterla, D. A. 1965. The spotted bat in Utah. Journal of Mammalogy, 46:665-668.

Easterla, D. A. 1966. Yuma myotis and fringed myotis in southwestern Utah. Journal of Mammalogy, 47:350-351.

Easterla, D. A. 1970. First records of the spotted bat in Texas and notes on its natural history. American Midland Naturalist, 83:306-308.

Easterla, D. A. 1973. Ecology of the 18 species of Chiroptera at Big Bend National Park, Texas. Northwest Missouri State University Studies, 349:1-165.

Fenton, M. B., and G. P. Bell. 1981. Recognition of species of insectivorous bats by their echolocation calls. Journal of Mammalogy, 62:233-243.

Fenton, M. B., D. C. Tennant, and J. Wyszecki. 1987. Using echolocation calls to measure the distribution of bats: the case of Euderma maculatum. Journal of Mammalogy, 68:142-148.

Geluso, K. N. 1978. Urine concentrating ability and renal structure of insectivorous bats. Journal of Mammalogy, 59:312-323.

Handley, C. O., Jr. 1959. A revision of American bats of the genera Euderma and Plecotus. Proceedings of the United States National Museum, 110::95-246.

Hardy, R. 1941. Some notes on Utah bats. Journal of Mammalogy, 22:289-295.

Hoffmeister, D. F. 1986. Mammals of Arizona. University of Arizona Press, Tucson, 602 pp.

Kunz, T. H., and R. A. Martin. 1982. Plecotus townsendii. Mammalian Species no. 175, Special Publication, American Society of Mammalogists, 6 pp.

Leonard, M. L., and M. B. Fenton. 1983. Habitat use by spotted bats (Euderma maculatum, Chiroptera: Vespertilionidae): roosting and foraging behavior. Canadian Journal of Zoology, 61:1487-1491.

O'Farrell, M. J. 1981. Spotted Bat. Euderma maculatum. J. .A. Allen. Bulletin of the American Museum of Natural History, 29 pp.

Navo, K. W., J. A. Gore, and G. T. Skiba. 1992. Observations on the spotted bat, Euderma maculatum, in northwest Colorado. Journal of Mammalogy, 73:547-551.

Parker, H. C. 1952. Two new records of the spotted bat in California. Journal of Mammalogy, 33:480-482.

Poche, R. M., and G. L. Baillie. 1974. Notes on the spotted bat (Euderma maculatum) from southwest Utah. Great Basin Naturalist, 34:254-256.

Reynolds, R. P. 1981. Elevational record for Euderma maculatum (Chiroptera: Vespertilionidae). The Southwest Naturalist, 26::91-92.

Rogers, D. S. 1997. Habitat assessment of the Spotted bat (Euderma maculatum) and other former C2 species of bats in Washington Co., Utah. Unpublished report, Bureau of Land Management, 32 pp.

Rufner, G. A., R. M. Poche, M. Meierkord, and J. A. Neal. 1979. Winter bat activity over a desert wash in southwestern Utah. Southwestern Naturalist, 24:447-453.

Sherwin, R. E., D. Stricklan, and D. S. Rogers. Macrohabitat affinities of Townsend's big-eared bat in northern Utah. Journal of Mammalogy. In prep.

Sherwin, R. E., S. Haymond, D. Stricklan, and D. Arling. 1996. The gating and management of Logan Cave Utah: a cooperative effort. Bat Research News: Winter, 1996.

Storz, J. F. 1995. Local distribution and foraging behavior of the spotted bat (Euderma maculatum) in northwestern Colorado and adjacent Utah. Great Basin Naturalist, 55:78-83.

Vorhies, C. T. 1935. The Arizona specimen of Euderma maculatum. Journal of Mammalogy, 16:224-226.

Wai-Ping, V., and M. B. Fenton. 1989. Ecology of spotted bat (Euderma maculatum) roosting and foraging behavior. Journal of Mammalogy, 70:617-622.

Watkins, L. C. 1977. Euderma maculatum, Mammalian Species no. 77, Special Publications, American Society of Mammalogists, 4 pp.

Williams, D. F., J. O. Druecker and H. L. Black. 1970. The karyotype of Euderma maculatum and comments on the evolution of the Plecotine bats. Journal of Mammalogy, 51:602-606.

Woodsworth, G. C., G. P. Bell, and M. B. Fenton. 1981. Observations on the echolocation, feeding behavior, and habitat use of Euderma maculatum (Chiroptera: Vespertilionidae) in south-central British Columbia. Canadian Journal of Zoology, 59:1099-1102.

Table 1: Relative abundance of Spotted bats at four sites in Rilda Canyon. See map (Figure 1) for location of sites.

LOCATION	SITE	ABUNDANCE INDEX (# CALLS / # HOURS)
Rilda Canyon	Eclif1	0.375
Rilda Canyon	Ewnet 1	0.175
Rilda Canyon	Eclif2	0.000
Rilda Canyon	Erilmd	0.000

Table 2: Relative abundance of Spotted bats at various control sites (sites sampled off of the proposed Lease Area). See map (Figure 2) for locations.

LOCATION	SITE	ABUNDANCE INDEX (# CALLS / # HOURS)
Bear Creek	Co-op	0.000
Biddlecome Hollow	Gclif	0.308
Huntington Creek	Ghunmd	0.250
Huntington Creek	Htnet 1	2.077
Huntington Creek	Gbat01	4.000
Mill Fork	Mlfrk	5.000
Tie Fork Canyon	Gpool6	0.500
Cottonwood Creek	Orngl	0.500
Straight Canyon	Coxswl	0.000
Cottonwood Creek	Ovilmn	6.000
Joes V. Reservoir	Joevrv	0.500
Huntington Creek	Ghunm2	0.000

Table 3. Results of bat surveys in areas selected as control and or foraging sites in the Huntington Canyon Area. See map (Figure 1) for locations. Sites where Spotted Bats were detected are indicated by **boldfaced print.**

Lat./Long. locations are single fix G.P.S. using Garmin 45 XL© hand-held unit. WGS 84 Map Datum. Elevations are interpolated from 7.5 min quad maps, with 40 foot contour intervals.

LOCATION	SITE (Lat. Long.)	HABITAT DESCRIPTION	BAT SPECIES FOUND	A = AUDIO DETECTION N = NETTED
Crandall Canyon	**Gpool2** (N 39 27.81' W 111 08.91')	Elevation: 7425 ft. Nets set over small beaver pond. Series of cliffs in immediate area. Roosting area(s) adjacent to site.	**Spotted bat** Big brown bat Long-eared myotis Silver-haired bat Yuma myotis Hoary bat Long-legged myotis	A A,N A,N A,N N N N
Biddlecome Hollow	**Gcliff** (N 39 27.91' W 111 08.76')	Elevation: 7440 ft. Listening post set on cliff face, approx. 75' above road surface. Roosting area(s) adjacent to site	**Spotted bat** Big brown bat Long-eared myotis Silver-haired bat Myotis ssp.	A A A A A
Tie Fork Canyon	**Gpool6** (N 39 27.33' W 111 08.58')	Elevation: 7430 ft. Listening post set at small marsh area adjacent to road. Roosting area(s) adjacent to site.	**Spotted bat** Big brown bat Silver-haired bat Long-eared myotis	A A A A
Huntington Canyon	**Ghunmd** (N 39 27.02' W 111 08.37')	Elevation 7270 ft. Listening post set on small sagebrush covered rise. Roosting area(s) adjacent to site.	**Spotted bat** Big brown bat Myotis ssp.	A A A

Huntington Canyon (Cont'd)	Ghunm2 (N 39 26.80' W 111 08.30')	Elevation 7210 ft. Listening post set among cottonwoods adjacent to Huntington creek.	Big brown bat Myotis ssp. Silver-haired bat	A A A
	Mlfrk (N 39 26.66' W 111 08.18')	Elevation 7180 ft. Listening post set at base of large cliff face. Roosting area(s) adjacent to site. Active foraging area.	**Spotted bat** Big brown bat Yuma myotis Silver-haired bat	A A A A
	Gbat01 (N 39 24.33' W 111 06.64')	Elevation: 6785 ft. Listening post set among large stand of cottonwood trees. Major foraging area.	**Spotted Bat** Big brown bat Long-legged myotis	A A A
	Htnet1 (N 39 24.05' W 111 06.57')	Elevation: 6765 ft. Listening post and nets set in large marsh area. Major foraging area. Roost site(s) located in cliffs above site.	**Spotted Bat** Big brown bat Hoary bat Yuma Myotis	A A,N A,N A,N
Bear Creek Canyon	Co-op (N 39 23.96' W 111 06.01')	Elevation: 6850 ft. Listening post set in open meadow.	Big brown bat Myotis ssp. Silver-haired bat Long-eared myotis	A A A A

Table 3 (Continued). Results of bat surveys in areas selected as control and or foraging sites in the Huntington Canyon Area. See map (Figure 1) for locations. Sites where Spotted Bats were detected are indicated by **boldfaced print.**

Lat./Long. locations are single fix G.P.S. using Garmin 45 XL© hand-held unit. WGS 84 Map Datum. Elevations are interpolated from 7.5 min quad maps, with 40 foot contour intervals.

Assessment of Spotted Bat (Euderma maculatum)
and Townsend's Big-eared Bat (Corynorhinus townsendii)
in the Proposed Lease Areas. Manti La Sal
National Forest, Emery County, Utah.

APPENDICES

APPENDIX 1

Cottonwood Canyon Sites Omitted From Table 3

Cottonwood canyon sites omitted from table 3.

Cottonwood Canyon	**CTNWD1** (N 39 19.89' W 111 11.80')	Elevation: 7655' Listening post set adjacent to stream at mouth of Roans Canyon. Nets set across stream.	**Spotted bat** Long-legged myotis Long-eared myotis Silver-haired bat	A N,A N,A N,A
	CTNWD2 (N 39 22.26' W 111 13.37')	Elevation: 8480' Listening post set at mouth of Dairy Canyon. Net set over small creek. No bats netted	Silver-haired bat Long-eared myotis	A A
	CTNWD3 (N 39 21.60' W 111 14.33')	Elevation: 9730' Listening post set in open meadow at fairly high elevation.	Long-eared myotis Silver-haired bat long-legged myotis	A A A
	CTNWD4 (N 39 19.52' W 111 13.94')	Elevation: 9200' Listening post set adjacent to small spring. Nets set over pond.	**Spotted bat** Silver-haired bat Long-eared myotis	A A,N A,N

Table 3 (Continued). Results of bat surveys in areas selected as control and or foraging sites in the Huntington Canyon Area. See map (Figure 1) for locations. Sites where Spotted Bats were detected are indicated by **boldfaced print.**

Lat./Long. locations are single fix G.P.S. using Garmin 45 XL© hand-held unit. WGS 84 Map Datum. Elevations are interpolated from 7.5 min quad maps, with 80 foot contour intervals.

Assessment of Spotted Bat (Euderma maculatum) and Townsend's Big-eared Bat (Corynorhinus townsendii) in the Proposed North Rilda Lease Area. Manti La Sal National Forest, Emery County, Utah.

Conducted for Energy West Mining Co.

Submitted by:

Richard E. Sherwin

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Carl A. Johansson

Chapter

Contents

APPENDIX 2

Figures

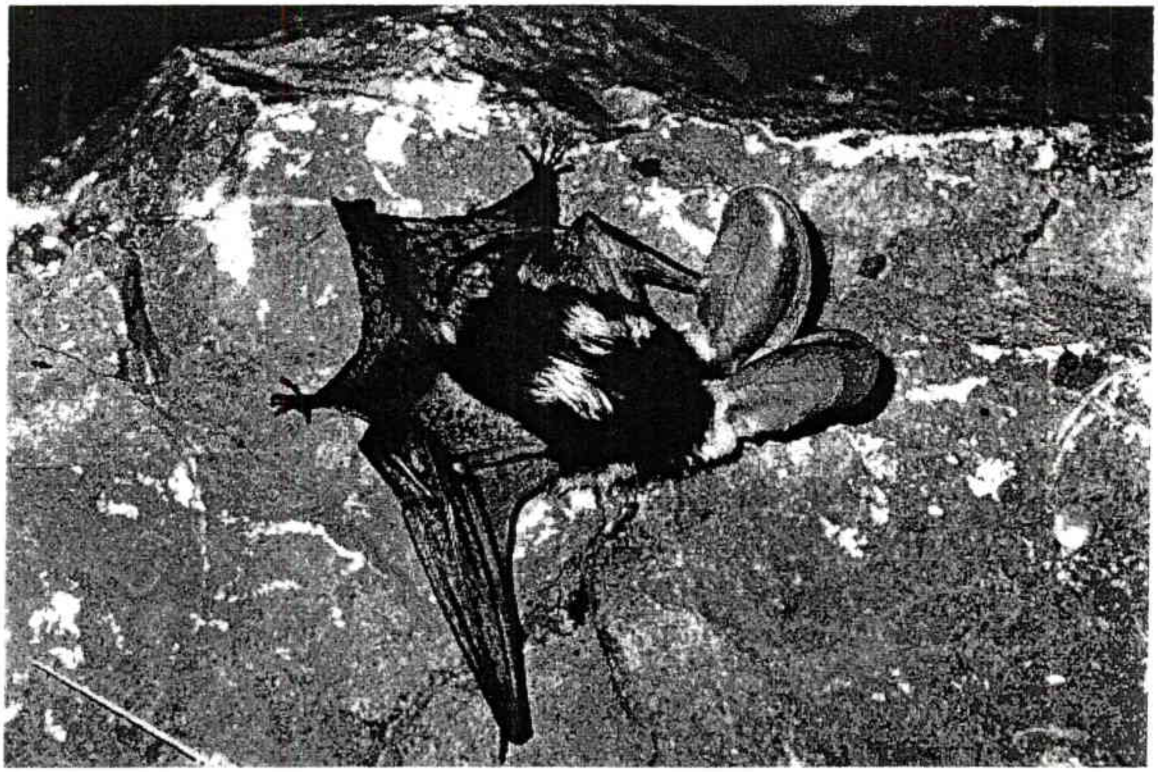

Figure 1. Spotted bat (Euderma maculatum).

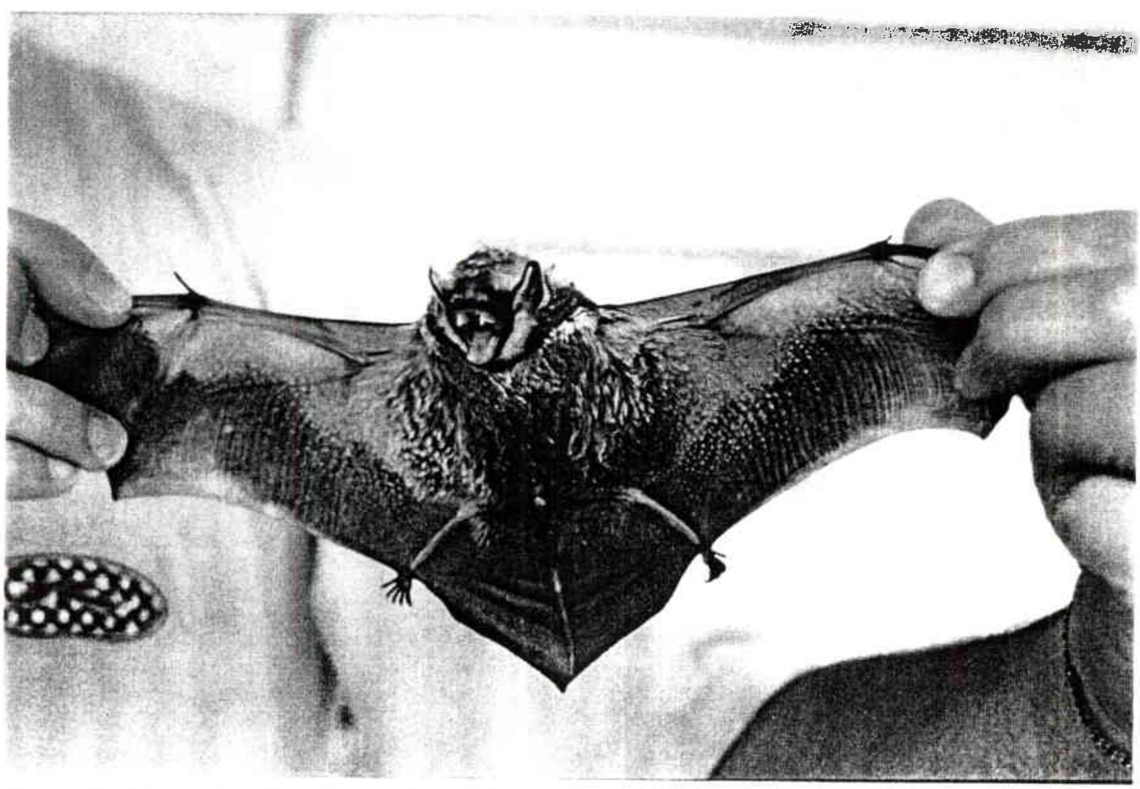

Figure 2. Hoary bat (Lasiurus cinereus).

Figure 3. Yuma Myotis (Myotis yumanensis).

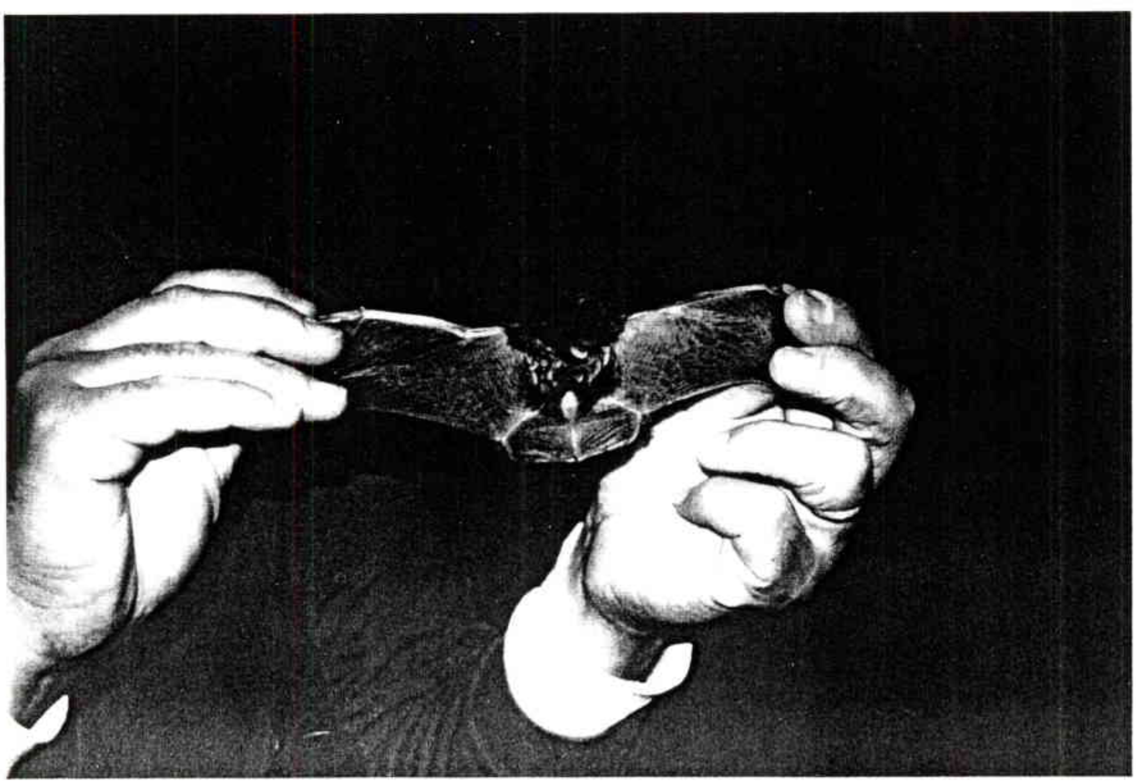

Figure 4. Silver-haired bat (Lasionycteris noctivigans).