OPEN-FILE REPORT 99-18

History, Geology, and Environmental Setting of Selected Mines near Creede, Rio Grande National Forest, Mineral County, Colorado

By John Neubert and Robert H. Wood II

Colorado Geological Survey
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FOREWORD

Open-File Report 99-18 describes the history, geology, and environmental setting of nine mine sites in the Creede area. All of the sites lie at least partly on U.S. Forest Service-administered land. Seven of the sites are in the East and West Willow Creek drainage basins, and two sites are in the Miners Creek drainage basin. The sites were selected by the U.S. Forest Service based on the results of an abandoned mine inventory recently completed by the Colorado Geological Survey. This information will be used to develop reclamation plans in conjunction with the Willow Creek Reclamation Committee efforts to remediate the entire Willow Creek watershed.

Funding for this project was provided mostly by the U.S. Forest Service (Agreement No. 1102-0007-98-035). Partial funding came through the Water Quality Data program of the Colorado Geological Survey from the Colorado Department of Natural Resources Severance Tax Operational Fund. Severance taxes are derived from the production of gas, oil, coal, and minerals.

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ABBREVIATIONS AND SYMBOLS

AMLIP	Abandoned Mine Land Inventory Project
CDPHE	Colorado Department of Public Health and Environment
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
cps	counts per second
CR	County Road
cfs	cubic feet per second
°	degree
EE/CA	Engineering Evaluation/Cost Analysis
EDR	Environmental Degradation Rating
EPA	United States Environmental Protection Agency
=	equals
FR	Forest Road
4WD	four-wheel drive
gpm	gallons per minute
<	less than
≤	less than or equal to
µg/L	micrograms per liter
µ	microns
µS	microSiemens
mg/L	milligrams per liter
>	more than
NPL	National Priorities List
n/a	not applicable
no.	number
#	number
oz	troy ounces
p.	page(s)
ppm	parts per million
PMDT	passive mine drainage treatment
/	per
%	percent
PHR	Physical Hazard Rating
PBS	Primary Base Series
quad	quadrangle (7.5-minute)
x	times (when factoring ion concentrations or radioactivity)
trec	total recoverable
U.S.	United States
USFS	United States Department of Agriculture—Forest Service
BLM	United States Department of Interior—Bureau of Land Management
v.	volume

INTRODUCTION

During the summer of 1998, the U.S. Forest Service (USFS) requested the Colorado Geological Survey (CGS) to research the history and describe in detail the environmental setting of several mines in the Creede area. These mine sites exhibited extreme, significant, or potentially significant environmental degradation (ratings = 1, 2, 3) during the course of a forest-wide inventory of abandoned mines conducted by the Colorado Geological Survey. The inventory numbers assigned to the sites in this report refer to this Abandoned Mined Land Inventory Project, completed in the Creede area in 1992. The inventory number is unique for each site and is keyed to Universal Transverse Mercator (UTM) coordinates. For example: inventory area number "09-04-330/4192-1" indicates "Forest No.–Ranger District No.–XUTM/YUTM–Area No." Sites described in this report include the Amethyst Mine and Chance dump along West Willow Creek; the Midwest Mine along Nelson Creek; the Phoenix Park Millsite, Outlet Tunnel, Solomon Mine, and Mammoth Tunnel along East Willow Creek; and the Ace Mine and Big Six Mine (Silver Horde) along Miners Creek (Figure 1).

Many of the mines along East and West Willow Creeks and Nelson Creek were included in Preliminary Assessments and a Site Investigation completed by the Colorado Department of Public Health and Environment in 1995 and 1997, respectively (O'Grady, 1995a, 1995b, 1997).

Areas of concern at the Ace, Big Six, Midwest, Phoenix Park mill, Outlet Tunnel, and Mammoth Tunnel sites are wholly on USFS-administered land. The Amethyst, Chance, and Solomon sites are mostly private land, but include small portions of USFS-administered land within or immediately downstream of the disturbed area.

METHOD OF INVESTIGATION

Colorado Geological Survey personnel conducted a thorough search of published and unpublished literature describing the mines and mining history of the Creede area. The Mineral County courthouse records, and USFS and Bureau of Land Management files were examined for mining claim and ownership information. In some instances, historical information from various sources is contradictory, and Colorado Geological Survey personnel attempted to determine which sources were most accurate. However, some contradictions remain in the historical data reported in the following sections.

An excellent source of mining history information is the Colorado Division of Minerals and Geology (which incorporates the former Colorado Bureau of Mines). Mine inspector reports, information reports, operator reports, and mine manager reports describe in varying detail the mine operations. Many of the accounts by authors of the Mineral Resources serial publication by the U.S. Geological Survey probably originated with information from these files or from the inspectors themselves.

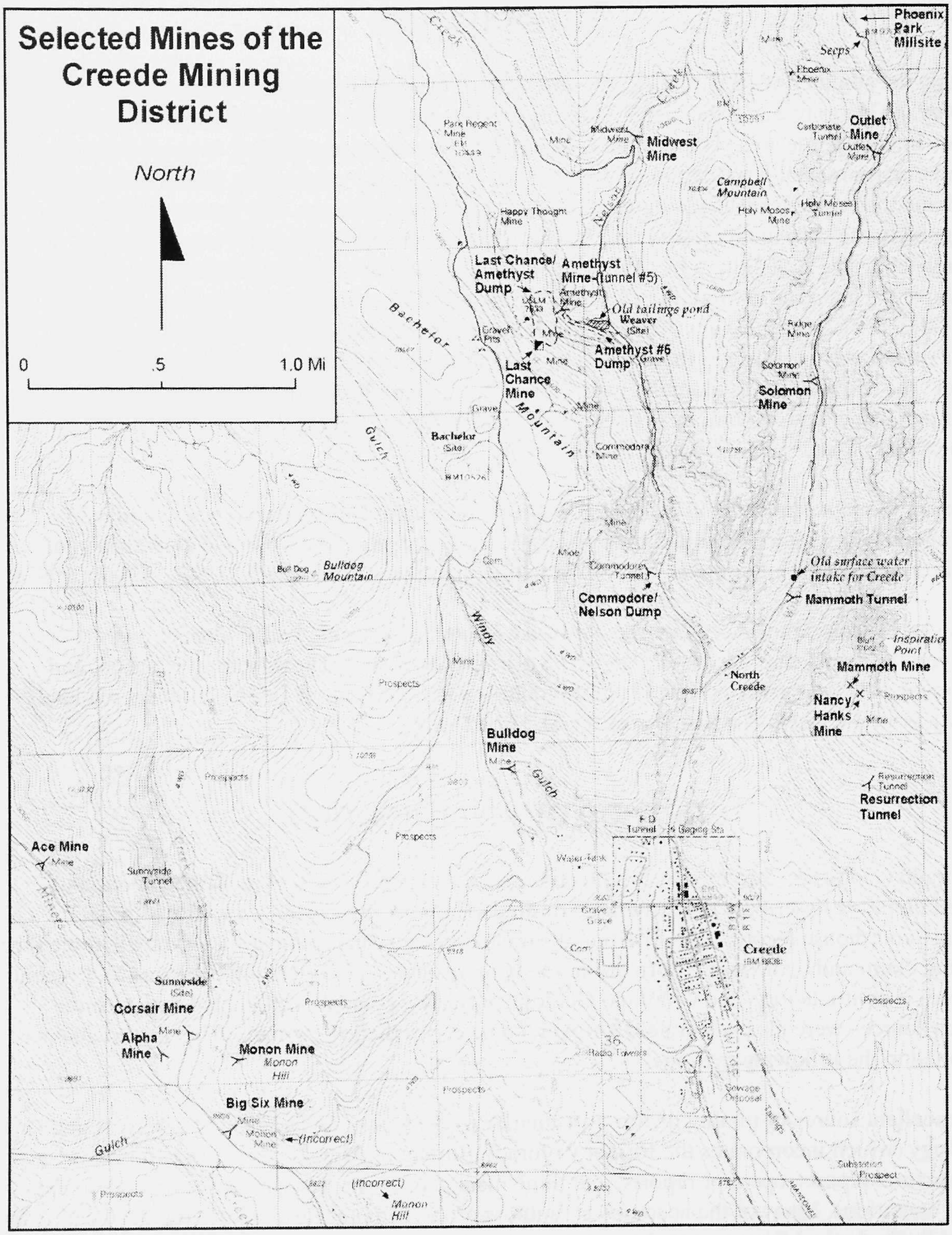


Figure 1. Location map showing Creede and some important mine features.

Often, mine developments reported by the Colorado Bureau of Mines and U.S. Geological Survey are identical. In this report, unpublished reports referenced to the Colorado Bureau of Mines are available at the Colorado Division of Minerals and Geology, a division of the Colorado Department of Natural Resources. All mine sites were examined in the field. At some sites, additional field work was required. Surface mapping, water testing, and sampling of waste-rock piles and water were done at some locations. Surface maps at the Midwest Mine, Phoenix Park Millsite, Ace Mine, and Big Six Mine were done with a tape and compass. The surface map at the Outlet Tunnel was done using the Mineral Survey sheet as a base, then pace and compass survey to add details.

LOCATION AND GEOGRAPHIC SETTING

Creede is the county seat and the largest town in Mineral County, Colorado. Mine sites described in this report lie within about 3 miles north and west of Creede, along East and West Willow Creeks, Nelson Creek, and Miners Creek (Figure 1). These creeks all drain into the Rio Grande, which is about 2 miles south of Creede. Elevation of the sites ranges from about 8,800 feet at the Big Six Mine to about 10,200 feet at the Midwest Mine.

HISTORICAL OVERVIEW

Significant mining activities did not occur near Creede until relatively late compared to most of Colorado. Claim staking in the early to mid-1880s led to little, if any, production. Discovery and development of the rich Solomon-Holy Moses vein in 1889, and the much richer Amethyst vein in 1891, led to a boom at Creede. After the initial boom subsided, the Creede mining district continued producing through the mid-1980s, with the exception of a 3-year hiatus in the early 1930s (Table 1). Silver was the major commodity produced, although lead and zinc were also important, especially near the turn of the century and after about 1949. Gold was a minor byproduct. (See Steven and Ratté, 1965, p. 6-7.) No mines were producing in the Creede district in 1998.

Nearly all of the recorded production of Mineral County until about 1965 was from three major vein systems in the Creede area, discussed in the Geologic Setting section below. Through 1966, production from the Creede district was about 58 million ounces of silver; 150,000 ounces of gold; 2,300 tons of copper; 125,000 tons of lead; and 40,000 tons of zinc from 2 million tons of ore (Meeves and Darnell, 1968, p. 6).

After 1969 nearly all production was from the Bulldog Mine. From 1969 to 1985, the Bulldog deposit was a substantial producer. Any production from the Creede district since 1985 has been minor. Total production from the Creede district through 1999 is estimated at about 85 million ounces of silver; 155,000 ounces of gold; 5,480 tons of copper; 160,000 tons of lead; and 50,000 tons of zinc from 4 million tons of ore (Nelson, 1989, p. 18).

Table 1. Metal production in Mineral County. {Blank spaces indicate no data available).

YEAR	MINES	TONNAGE Short Tons	GOLD		SILVER		COPPER		LEAD		ZINC	
			Ounce	Value	Ounce	Value	Pound	Value	Short Tons	Value	Short Tons	Value
1891	1			$3,429		$178,360						
1892				$25,932		$3,500,000						
1893				$52,970		$5,582,765						
1894				$45,116		$2,362,176						
1895				$129,181		$1,849,924				$196,621		
1896				$52,934		$1,896,384				$42,796		
1897				$40,380		$3,854,593		$154		$203,476		
1898				$46,370		$5,388,657		$1,659		$197,878		
1899	3	11,600	962,020		3,065				3,419		650	
1900				$201,471		$2,918,590		$2		$618,393		
1901				$102,813		$2,342,670		$150		$455,846		
1902		1,024		$113,913		$2,486,008		$23		$378,692		$37,955
1903				$175,860		$2,075,272		$18		$368,624		$143,026
1904	10	124,278	10,909	$225,487	1,666,309	$953,961		$161	4,652	$407,088	930	$93,007
1905	10	91,338	8,812	$182,162	814,189	$491,770			5,288	$497,079	1,257	$148,294
1906	13	126,164	7,713	$159,445	1,150,318	$770,713			6,519	$743,185	1,781	$217,327
1907	10	104,977	5,706	$117,946	870,456	$574,501			5,328	$564,819	919	$108,450
1908	7	61,131	5,760	$119,063	725,602	$384,569			866	$72,743	550	$51,705
1909	7	64,941	5,264	$108,825	891,185	$463,416	17,401	$2,262	4,518	$388,583	909	$98,134
1910	9	62,956	5,862	$121,181	773,722	$417,810	29,031	$3,687	4,123	$362,824	1,211	$130,784
1911	9	65,932	8,669	$179,196	545,319	$289,019	33,384	$4,173	3,837	$345,355	629	$71,738
1912	10	66,488	4,160	$86,002	714,909	$439,669	23,885	$3,941	2,865	$257,860	154	$21,299
1913	12	56,763	2,432	$50,282	805,343	$486,427	31,647	$4,905	1,699	$149,528	227	$25,473
1914	9	27,952	934	$19,304	615,734	$340,501	32,586	$4,334	701	$54,670		
1915	9	28,071	1,598	$33,039	291,807	$147,946	8,943	$1,565	1,191	$111,960	43	$10,662
1916	9	38,103	1,506	$31,124	373,956	$246,063	13,138	$3,232	1,148	$158,361	120	$32,237
1917	12	32,755	489	$10,101	361,517	$297,890	19,297	$5,268	653	$112,294	27	$5,607
1918	11	28,372	674	$13,943	640,959	$640,959	3,490	$862	495	$70,263		
1919	13	16,718	439	$9,083	369,575	$413,924	355	$66	467	$49,508	48	$7,028

Table 1. Continued.

YEAR	MINES	TONNAGE Short Tons	GOLD		SILVER		COPPER		LEAD		ZINC	
			Ounce	Value	Ounce	Value	Pound	Value	Short Tons	Value	Short Tons	Value
1920	12	12,597	276	$5,710	272,322	$296,831	1,120	$206	266	$42,523		
1921	8	7,076	185	$3,816	192,468	$192,468	1,899	$245	78	$7,055		
1922	9	3,978	80	$1,654	106,903	$106,903	3,422	$462	77	$8,440		
1923	8	6,462	116	$2,394	228,867	$187,671	1,088	$160	119	$16,629	21	$2,788
1924	7	4,647	72	$1,494	239,149	$160,230			96	$15,325	21	$2,665
1925	5	8,047	43	$885	738,735	$512,682			251	$43,587	4	$608
1926	5	8,855	33	$672	551,468	$344,116			1,774	$28,376		
1927	4	3,592	12	$246	214,580	$121,820			38	$4,743		
1928	6	4,021	24	$490	210,159	$122,943			12	$1,334		
1929	7	5,436	122	$2,517	612,497	$326,461			136	$17,073		
1930	5	4,576	114	$2,364	396,044	$152,477			74	$7,430		
1931	No mining											
1932	No mining											
1933	No mining											
1934	7	5,907	55	$1,922	479,890	$310,232			88	$6,545		
1935	7	9,312	22	$753	499,684	$359,145			176	$14,072		
1936	8	10,738			422,071				185			
1937	9	12,734	4	$154	321,546	$248,716			139	$16,402		
1938	7	35,656	187	$6,552	457,595	$295,819			121	$11,086		
1939	10	37,083	709	$24,815	596,858	$405,140	1,300	$135	359	$33,746		
1940	8	41,113	893	$31,255	866,402	$616,108	10,200	$1,153	650	$64,950		
1941	6	41,560	904	$31,640	906,712	$644,773	32,000	$3,776	570	$64,980		
1942	6	39,243	644	$22,540	805,202	$572,588	77,600	$9,390	526	$70,457		
1943	7	30,290	465	$16,275	630,952	$448,677	101,000	$13,130	578	$86,625	7	$1,404
1944	9	27,883	444	$15,540	518,161	$368,470	75,000	$10,125	479	$76,560	8	$1,710
1945	6	18,354	238	$8,330	433,177	$308,037	69,400	$9,369	303	$52,030	5	$1,035
1946	7	15,552	175	$6,125	355,110	$286,929	61,000	$9,882	246	$53,628	3	$732
1947	6	24,760	245	$8,575	317,712	$287,529	46,600	$9,786	329	$94,810	7	$1,694

Table 1. Continued.

YEAR	MINES	TONNAGE Short Tons	GOLD		SILVER		COPPER		LEAD		ZINC	
			Ounce	Value	Ounce	Value	Pound	Value	Short Tons	Value	Short Tons	Value
1948	9	28,614	247	$8,645	297,926	$269,638	36,000	$7,812	451	$161,458	88	$23,408
1949	6	37,944	779	$27,265	263,867	$238,813	74,000	$14,578	1,162	$367,192	671	$166,408
1950	2	47,072	803	$28,105	345,247	$312,466	68,000	$14,144	1,422	$383,940	837	$247,932
1951	3	45,422	804	$28,140	236,652	$214,182	50,000	$12,100	1,167	$403,782	892	$324,688
1952	3	41,685	1,122	$39,270	174,219	$157,677	48,000	$11,616	1,513	$487,186	1,024	$339,968
1953	2	37,372	1,257	$43,995	173,966	$157,448	24,000	$6,888	1,696	$444,352	858	$197,340
1954	7	45,399	1,964	$68,740	238,685	$216,022	50,000	$14,750	2,178	$596,772	1,111	$239,976
1955	7	28,596	1,025	$35,875	135,640	$122,761	36,000	$13,428	1,192	$355,216	745	$183,270
1956	2	29,432	802	$28,070	111,731	$101,122	47,200	$20,060	1,266	$397,383	927	$253,616
1957	4	50,010	1,622	$58,170	279,249	$252,734	136,200	$40,996	2,231	$638,095	1,819	$422,101
1958	3	26,988	785	$27,475	92,841	$84,026	80,000	$20,882	1,233	$288,569	1,019	$207,896
1959	2	29,394	800	$28,000	131,433	$118,954	126,000	$38,651	1,615	$37,335	1,275	$293,204
1960	3	38,541	833	$29,155	237,364	$214,826	316,000	$101,308	2,177	$509,336	1,918	$494,908
1961	1	41,657	624	$21,840	303,995	$281,040	550,000	$164,850	1,884	$338,083	2,371	$545,353
1962	1	44,382	570	$19,950	276,356	$299,846	434,000	$133,949	1,967	$361,965	2,324	$534,416
1963	1	26,039	440	$15,400	252,555	$232,048	282,000	$86,794	1,205	$260,258	1,644	$378,074
1964	1	41,993	495	$17,325	284,716	$368,138	530,000	$172,910	1,542	$403,873	2,438	$663,163
1965	2	43,182	547	$19,145	185,449	$239,785	478,000	$169,035	1,549	$483,319	2,286	$667,395
1966	2	44,895	618	$21,630	143,034	$184,943	464,000	$167,829	1,539	$465,089	1,988	$576,390
1967	2	44,135	446	$15,610	111,365	$172,616	482,000	$184,326	1,451	$406,378	2,148	$594,820
1968	2	41,004	516	$20,258	96,740	$207,469	182,000	$75,743	1,593	$420,948	1,529	$412,911
1969-1985	1				25,300,000				24,300			

Data from Reports of the Director of the Mint, 1880–1908.
U.S. Geological Survey—Mineral Resources of the United States, 1892–1923.
U.S. Bureau of Mines—Mineral Resources of the United States, 1924–1933.
U.S. Bureau of Mines—Minerals Yearbook, 1935–1985.

GEOLOGIC SETTING

Creede is located in the San Juan Mountains of southwestern Colorado in the midst of several Tertiary-age calderas, some which overlap one another topographically and in age. Mineralization in the Creede mining district is related to the Creede caldera, the youngest of the calderas. The Creede caldera lies immediately south of Creede, and the northern boundary of the caldera roughly coincides with the Rio Grande. (See Steven and Ratté, 1965, plate 1.)

Mineralization in the Creede mining district occurred during the latter stages of the formation of the Creede graben, a post-caldera structural feature that extends north from the Creede caldera. The Creede graben extends from about the Solomon-Holy Moses fault along East Willow Creek on the east to the Alpha-Corsair fault near Miners Creek on the west. Major faults of the graben trend nearly north and were mineralized after most of the displacement was complete. (See Steven and Ratté, 1965, p. 60, 63, 68-69, plate 2.)

Through 1956, more than 98% of the production value of the Creede district originated from three vein systems: the Amethyst and related hanging-wall veins, the Solomon-Holy Moses vein, and the Alpha-Corsair vein (Steven and Ratté, 1965, p. 6). About 93% was from the Amethyst vein and its associated hanging-wall veins.

The Amethyst and Last Chance Mines are two of the several mines driven on the Amethyst vein system, the largest and most persistent of the mineralized fault zones. Smaller mineralized faults related to the Amethyst lie in the hanging wall of the vein, west of the main fault. (See Steven and Ratté, 1965, p. 65-66.)

The Solomon, Outlet, and Phoenix Mines were all driven in the Solomon-Holy Moses fault zone. This fault does not exhibit a large displacement and is not as richly mineralized. (See Steven and Ratté, 1965, p. 67-68, 85-86.)

The Ace Mine was probably driven to intersect the Alpha-Corsair vein, but mineralization along this vein apparently decreases northward (Steven and Ratté, 1965, p. 85, plate 2).

The Big Six Mine exposes mineralized and replaced travertine and tuffs of the Tertiary-age Creede Formation. The Creede Formation is a post-caldera sedimentary unit consisting of reworked volcanic rocks and hot-springs deposits. (See Steven and Ratté, 1965, p. 84-85, plate 1.)

The Midwest Mine explores a minor fault zone that hosts a northwest-trending vein within the Creede graben (Steven and Ratté, 1965, p. 86).

The Mammoth Tunnel was a crosscut adit that apparently never intersected any significant volume of mineralized material or any large structural features.

AMETHYST MINE

The Amethyst Mine (inventory area #09-04-330/4192-1) was one of the largest producers in the Creede mining district. It lies about 2 miles north of Creede, along West Willow Creek near its confluence with Nelson Creek (Figure 1). Most of this area is privately owned, but part of the dump may lie on USFS-administered land, and environmental effects of the mine extend onto USFS-administered land adjacent to and downstream of the mine site. This area should be surveyed to accurately determine ownership.

Mining History

History and production of the numerous mines driven in the Amethyst vein system intermingle and overlap, and the accuracy of the reports referenced below cannot be verified. Every effort was made to separate the data according to mines, if possible. Some of the reports by the mine inspectors, operators, and U.S. Geological Survey authors are contradictory. In those instances, the inspector report may be the most accurate.

The Amethyst Mine was originally developed by two shafts sunk on the vein. Later it was operated through an adit driven from the surface near the banks of West Willow Creek (Amethyst No. 5 Tunnel). Eventually it was connected through several stopes to the Commodore (Emperius) Mine. (See Information report-Amethyst 5 Level (Emperius), Colorado Bureau of Mines, May 24, 1984.)

The Amethyst lode claim was initially located in 1891 by N.C. Creede (Henderson, 1926, p. 56). In 1892, when Mineral Survey No. 7333 (Amethyst Lode) was conducted, David H. Moffat, Lafayette E. Campbell, and Nicholas C. Creede owned the claims. (See Mineral Survey No. 7333, available at the Bureau of Land Management, Colorado State Office.)

In 1891 the first reported production from the Amethyst was valued at $3,429 in gold and had a coinage value of $178,360 in silver (Smith, 1892, p. 184).

In 1892 production from the Amethyst was valued at $25,932 in gold with a coinage value of $713,193 in silver (Smith, 1893, p. 126). When Mineral Survey No. 7333 was conducted on the Amethyst Lode on February 3, 1892, a short incline and an inclined shaft were surveyed on the claim (Mineral Survey No. 7333, available at the Bureau of Land Management, Colorado State Office). By the end of 1892, the Amethyst had produced about 20,000 tons of ore worth $2,000,000 (Emmons and Larsen, 1923, p. 3-4).

By 1899 the Nelson Tunnel, about 1,600 feet below the Amethyst, had been driven more than 8,000 feet and was draining the Amethyst Mine and others. Reported production from the Amethyst Mine in 1899 was 7,480 tons, containing 187,000 oz of silver; 1,122 oz of gold; and 1,047 tons of lead. (See Hodges, 1900, p. 112.) In 1899, S.W. Martin leased the Amethyst waste-rock pile and made several shipments (Denver Times, October 3, 1899, p. 6).

In 1901 the Amethyst Mine was tied up by legal controversies (Hodges, 1902, p. 123-127).

By 1902 the workings were extensive and 10 men were working. Amethyst Mining Co. (D.H. Moffat, President; Cyrus Miller, Manager; L.E. Campbell, Superintendent) operated the mine. (See Colorado mining directory and buyer's guide, June 1902, p. 99.) Another account reports 250 employees (Dunbar's western mining directory, 1901-1902, p. 161).

In 1904, three miners employed by Amethyst Mining Company ran drifts, sank winzes, and mined sulfide ore averaging \$19/ton gross. By 1904, the No. 3 Shaft was 1,000 feet deep on a 56° incline with drifts every 100 feet, except between the 7th and 9th levels. The drifts averaged 650 feet long on each side of the shaft. The Amethyst Mine was connected with the Last Chance Mine (levels 4, 5, 9, and 10), the Happy Thought or United Mines (level 9), and the Nelson Tunnel (level 9). The Nelson Tunnel was 400 feet below the bottom of the main Amethyst shaft. (See Managers report for 1904-Amethyst Mine, to Colorado Bureau of Mines, October 22 and 28, 1904, p. 258-259.)

By 1906 the inclined shaft that accessed the working levels at the Amethyst was 1,060 feet deep. The mine was equipped with a 100-ton/day concentrating mill. (See Naramore, 1907, p. 225.)

In 1907 more tonnage was mined than in 1906, however, because of lower silver and base-metal prices, the value was less. Mine workings were accessed through a 1,400-foot inclined shaft, and the sulfide ore was treated in the 100-ton/day concentrating mill. Electric power was installed. (See Naramore, 1908, p. 263.)

During 1909, 66 employees, including 15 miners, mined sulfide ore averaging \$10/ton and operated the 100-ton/day Amethyst concentrating mill 24-hours/day. Developments on the property included:

No.1 Shaft, 30 feet north of south end line; caved and abandoned.

No.2 Shaft, 200 feet north of south end line; caved near the surface and connected with 7th level south, which was connected with No.3 Shaft.

No.3 Shaft, 400 feet north of south end line. Depth of this 6-foot by 10-foot, two-compartment shaft was 1,283 feet, and the bottom of this shaft connected to the Nelson Tunnel through a 110-foot crosscut.

No.1-4 levels, all were caved and abandoned at 100 feet.

No.5 level, 200 feet north of Shaft No.3, 900-foot-long drainage tunnel to the surface.

No.6 level, 250 feet north of Shaft No.3, 350 feet south.

No.7 level, 265 feet north of Shaft No.3, south to south end line.

No.9 level, 350 feet north of Shaft No.3, south to south end line.

No.10 level, 800 feet north of Shaft No.3, south to south end line.

No.11 level, 30 feet south of Shaft No.3, north to north end line.

No.12 level, 680 feet north of Shaft No.3, 50 feet south.

(See Managers report for 1909-Amethyst Mine, to Colorado Bureau of Mines, December. 1, 1909, p. 95.) The Amethyst was the chief producing mine in the Creede mining district. Concentrates were shipped from the mill situated on the property. (See Henderson, 1911a, p. 320.)

During 1910, 69 employees mined sulfide ore averaging $10/ton and operated the 100-ton/day Amethyst Mill (Managers report for 1910-Amethyst Mine, to Colorado Bureau of Mines, December 8, 1910, p. 132). Of the nine mines reporting production in the Creede mining district, the largest tonnage was mined at the Amethyst Mine. Ore averaged 5% zinc and 10% lead, with some silver and free gold. Abundant silver was lost in the tailings because some of the silver minerals were associated with siliceous gangue. Gold occurred in the fine fractions on the tables. Lead and zinc minerals required coarse concentration with jigs, followed by an intermediate treatment on tables, then finished with slime. (See Henderson, 1911b, p. 425.)

In 1911, 22 employees mined sulfide ore averaging $10/ton and operated the 100-ton/day Amethyst Mill until June 30, when all work stopped (Managers report for 1911-Amethyst Mine, to Colorado Bureau of Mines, November 27, 1911, p. 182.) The mine was one of the largest producers of the district (Henderson, 1912, p. 552).

The work done from 1909 to 1911 was apparently done by Cyrus Miller Leasing and Milling Company. They were leasing from Amethyst Mining Company, owner of the Amethyst Mine (Amethyst, Hidden Treasure, Snowstorm, Albion, and Smuggler claims). (See Managers reports for 1909, 1910, 1911-Amethyst Mine, to Colorado Bureau of Mines, December 1, 1909, December 8, 1910, November 27, 1911.)

On March 1, 1912, mining resumed with 99 employees, including 43 miners. Lead-sulfide ore averaging $10/ton was processed at a concentrating mill. (See Managers report for 1912-Amethyst Mine, to Colorado Bureau of Mines, March 7, 1913, p. 170-171.)

Through 1912 the Amethyst Mine had produced about $4,000,000, mostly in silver. The shaft was about 1,300 feet deep, with 12 levels and about 2.5 miles of workings. Early operators (dates not specified) trammed their ore to North Creede where it was loaded on railroad cars and shipped to a smelter. By 1912, the tram to North Creede was ruined, and the ore was trammed about 800 feet to a nearby mill on West Willow Creek. The mill was equipped with crushers, rolls, trommels, jigs, tables, and a canvas plant. (See Emmons and Larsen, 1923, p. 159.) This mill is probably the same one that began operating in about 1906. The tailings impoundment shown on Emmons and Larsen (1923, plate 1) and discussed in the Waste and Hazard Characteristics section of this report is probably associated with this mill.

During 1913, 85 employees (30 miners) produced lead- and zinc-sulfide ore averaging $10/ton in value, and processed the ore at the 100-ton/day concentrating mill (Managers report for 1913-Amethyst Mine, to Colorado Bureau of Mines, November 11, 1913, p. 340).

In 1914, 20 employees operated the 100-ton/day concentrating mill, and three miners produced sulfide ore containing lead, zinc, gold, and silver averaging $10/ton. By 1914 the mine had three shafts of 100 feet, 700, feet and 1,280 feet; winzes of 35 feet and 420 feet; about 15,000 feet of drifts; and crosscuts of 25 feet, 480 feet, and 1,000 feet. (See Managers report for 1914-Amethyst Mine, to Colorado Bureau of Mines, January 10, 1915, p. 295.)

No production was reported in 1916, however, a gravity tramway, shaft house, engine and boiler houses, blacksmith shop, and ore bins were constructed at the surface (Operators Annual Report for 1916-Emperius Mine and Mill/Amethyst Mine, to Colorado Bureau of Mines, February 8, 1917). The Amethyst Mine produced an unspecified amount in 1916 according to Henderson (1917, p. 459-460). These reports are contradictory, but any production from the Amethyst Mine during 1916 was probably small.

From 1912 to 1916, the Amethyst Mining Company (L.E. Campbell, President) leased the Amethyst Mine (Amethyst, Hidden Treasure, Snowstorm, Albion, and Smuggler claims) and the 100-ton/day concentrating mill to Creede Triune Mining Company (John H. Berkshire, President). (See Managers reports for 1912, 1913, 1914-Amethyst Mine, to Colorado Bureau of Mines, March 7, 1913, November 11, 1913, January 10, 1915; and Operators Annual Report for 1916-Emperius Mine and Mill/Amethyst Mine, to Colorado Bureau of Mines, February 8, 1917.)

In 1917 work in the Commodore and Amethyst Mines included 90 feet of drifts and 87 feet of raises. Production was 5,333 tons averaging 11.6 oz/ton of silver and 3.5% lead. (See Operators Annual Report for 1917-Creede Exploration Company, to Colorado Bureau of Mines, January 28, 1918.) Probably all of the production listed came from the Commodore, because the Amethyst Mine is not listed as a producer by Henderson (1920, p. 833). Apparently sometime in 1917, Creede Exploration Company (a subsidiary of American Smelting and Refining Company) became the operator under a 20-year lease for all of the holdings below the Nelson Tunnel level of the Bachelor Mining Company, Commodore Mining Company, Last Chance Mining Company, Amethyst Mining Company, and Creede Mines Company. The lease also included the Commodore and Creede power plants and all of the Commodore and Amethyst workings above the Nelson Tunnel except an area above the No. 3 level, operated by the Commodore Mining Company. (See Operators Annual Report for 1917-Creede Exploration Company, to Colorado Bureau of Mines, January 28, 1918; Mine Inspector report-Creede Exploration Company, May 3, 1918, Colorado Bureau of Mines; Larsen, 1930, p. 93.)

During 1918 work included retimbering and repairing of the mine. The 450-foot-deep Commodore Shaft was deepened 35 feet after dewatering. The 100-foot-deep shaft at the Amethyst Mine was dewatered, allowing 300 feet of drifting along the vein. Crosscuts were driven from the Nelson Tunnel to the 3-foot-wide New York vein and the Commodore Shaft. Ore was mined from old workings in the Amethyst and Commodore Mines. (See Mine Inspector report-Creede Exploration Company, May 3, 1918, Colorado Bureau of Mines.) Development work in the Commodore and Amethyst Mines included 3,040 feet of drifts, 178 feet of crosscuts, and 550 feet of raises. (See Operators Annual Report for 1918-Creede Exploration Company, to Colorado Bureau of Mines, February 3, 1919; and Mine Inspector report-Creede Exploration Company, April 28, 1919, Colorado Bureau of Mines.)

In April 1919 Creede Exploration Company suspended operations after extensive exploration and development work failed to reveal commercial-grade ore below the Nelson Tunnel. The operators had drifted for 1,913 feet along the vein from the Commodore shaft, 350 feet below the collar; and for 359 feet from the Bachelor Shaft, 122 feet below the Nelson Tunnel. (See Mine Inspector report-Creede Exploration Company, April 28, 1919, Colorado Bureau of Mines.) The Amethyst Mine is listed as a producer in 1919 by Henderson (1922a, p. 778).

During 1920, five workers mined 2,854 tons of ore averaging 0.05 oz/ton of gold, 15 oz/ton of silver, and 3% lead. Amethyst Leasing Company leased the mine from Amethyst Mining Company. (See Operators Annual Report for 1920, to Colorado Bureau of Mines, January 16, 1921.)

The Amethyst was apparently not a major producer in 1921, but from 1922 to 1925 it was one of the "principal producing mines" of the district (Henderson, 1924, p. 500; Henderson, 1925, p. 541; Henderson, 1927a, p. 634; Henderson, 1927b, p. 634; Henderson, 1928, p. 719).

In 1928 a 160-foot-long tunnel that was intended to access the Pittsburgh vein intersected five unknown veins that averaged from 20 to 840 oz/ton of silver (R.J. Murray, Mine Inspector report-Amethyst Mine, June 21, 1928, Colorado Bureau of Mines). Production from the Amethyst Mine was 633 tons valued at \$72/ton and averaging 131 oz/ton of silver and 3.05% lead (Operators Annual Report for 1928, to Colorado Bureau of Mines, February 9, 1929). In 1928, 200 feet of drifts were driven in the Amethyst Mine (Henderson, 1931, p. 850).

Development work on the five newly discovered veins continued throughout 1929. A 50-foot-deep winze developed the largest of the veins, which ranged from 2 to 4 feet wide and averaged 150 to 400 oz/carload of silver. Production was about 300 tons/month. (See R.J. Murray, Mine Inspector report-Amethyst Mine, April 5, 1929, Colorado Bureau of Mines.) Ten workers excavated 102 feet of winzes, 160 feet of drifts, and 230 feet of raises. In 1929 production from the Amethyst Mine was 2,580 tons valued at \$78.73/ton (\$203,136 total) that contained about 4 oz of gold; 382,782 oz of silver; and 176,240 pounds of lead. (See Operators Annual Report for 1929, to Colorado Bureau of Mines, February 12, 1930; Henderson, 1932, p. 947.)

Amethyst Leasing Company probably operated the mine from 1921 to 1927, but reports confirming that were not located. Amethyst Leasing Company, with William Sloan as manager, operated the mine from 1928 to 1930 (R.J. Murray, Mine Inspector reports-Amethyst Mine, June 21, 1928, and April 5, 1929 Colorado Bureau of Mines). Herman Emperius had a sublease on the Amethyst in 1927 or 1928 (Larsen, 1930, p. 97).

During 1930, ten workers excavated 100 feet of winze, 190 feet of drifts, and 80 feet of crosscuts. Production from the Amethyst Mine was 1,174 tons valued at \$28.08/ton (\$31,283 total) that contained 9.87 oz of gold, 79,417 oz of silver, and 68,632 pounds of lead. (See Operators Annual Report for 1930, to Colorado Bureau of Mines, January 9, 1931; Henderson, 1933, p. 1067.)

Because of low silver prices, all of the mines in the Creede district closed June 1, 1930 (Henderson, 1933, p. 1067). The U.S. Treasury raised the silver price in late 1933, and production from the Amethyst Mine by Amethyst Leasing Company resumed in 1934 and continued until 1936 (Henderson, 1935, p. 224; Operators Annual Reports for 1935 and 1936, to Colorado Bureau of Mines, February 8, 1936, and January 7, 1937).

In 1934 the Amethyst Mine was worked through a short tunnel and a 100-foot winze. Ore was produced from the tunnel and from the 50-foot level in the shaft. Production was about 125 tons/month. (See R.J. Murray, Mine Inspector report-Amethyst Mine, July 19, 1934, Colorado Bureau of Mines.) Seven workers mined 1,046 tons of ore valued at \$40,874 that contained

66,223 oz of silver and 52,373 pounds of lead (Operators Annual Report for 1934, to Colorado Bureau of Mines, January 29, 1935).

During 1935 the operators developed 166 feet of drifts and raises, and 312 feet of crosscuts. Production from the Amethyst Mine was 1,542 tons valued at $65,495, with 90,870 oz of silver and 5,483 pounds of lead. (See Operators Annual Report for 1935, to Colorado Bureau of Mines, February 8, 1936.)

In 1936 production from the Amethyst Mine was 1,481 tons valued at $52,031, with 70,001 oz of silver and 28,151 pounds of lead (Operators Annual Report for 1936, to Colorado Bureau of Mines, January 7, 1937).

During 1937, four workers mined 510 feet of drifts, crosscuts, and raises. Production was 1,098 tons valued at $12,098 ($11/ton), averaging 18 oz/ton of silver and 1.7% lead. (See Operators Annual Report for 1937, to Colorado Bureau of Mines, February 10, 1938.) After an ore-purchase agreement was completed with the Amethyst group and other large mines in the area, Creede Mills, Incorporated constructed a 100-ton/day flotation mill 1 mile south of Creede (Henderson and Martin, 1938, p. 271).

In 1938, 388 feet of drifts and crosscuts, and 135 feet of raises were developed, probably in the Sloan Tunnel. Production was 7,671 tons valued at $70,054 ($9.13/ton), averaging 0.026 oz/ton of gold, 15.7 oz/ton of silver, 1.5% lead, 0.5% zinc, 3% iron, and 1% sulfur. (See Operators Annual Report for 1938, to Colorado Bureau of Mines, January 28, 1939.) The new mill concentrated ore at a ratio of about 38:1, and produced concentrates averaging 0.20 oz/ton gold, 471 oz/ton silver, and 13.6% lead. About 30% of the treated material came from dumps. (See Henderson and Martin, 1939, p. 289.)

During 1937 and 1938, the Nelson Lease Partnership subleased part of the Amethyst Mine (Sloan Tunnel) from the Amethyst Mining Company (Operators Annual Reports for 1937 and 1938, to Colorado Bureau of Mines, February 10, 1938, and January 28, 1939).

Creede Mills, Incorporated (Thomas P. Campbell, President) reopened the Amethyst No. 5 Tunnel in February 1939, after 40 years of inactivity. More than 2,000 feet of tunnel was repaired and rerailed in an effort to access a large "cave" of silver-lead ore on the Happy Thought and Park Regent properties. Thirty to 40 tons of ore were shipped daily to the mill from the No. 5 Tunnel. In addition, about 50 tons/day of the finer dump material from the Amethyst Mine was trucked to the mill for processing. (See R.J. Murray, Mine Inspector report-Amethyst No. 5 Tunnel and Amethyst dump, April 8 and June 30, 1939, Colorado Bureau of Mines.) Creede Mills was leasing from Creede Mines, Incorporated (Operators Annual Report for 1939, to Colorado Bureau of Mines, January 29, 1940).

In early 1940, Creede Mills, Incorporated (leasing from Amethyst Mining Company) drove four headings from the 2,400-foot-long Amethyst No. 5 Tunnel into ore zones in the hanging wall. Daily production was 50 tons of mill-grade ore. (See R.J. Murray, Mine Inspector report-Amethyst No. 5 Tunnel, March 21, 1940, Colorado Bureau of Mines.) In September, Emperius Mining Company acquired all of the leases and assumed management of the mines and the 100-

ton/day flotation mill. Development work included 300 feet of crosscuts, 500 feet of drifts, and 170 feet of raises in the Amethyst Mine; and 600 feet of drifts and 150 feet of crosscuts in the Happy Thought Mine. Mine production was 11,874 tons valued at $166,862 ($14.05/ton) and averaging 0.057 oz/ton of gold, 8.92 oz/ton of silver, and 3.25% lead. The mill processed 25,477 tons producing 1,359 tons of concentrate valued at $312,200 and averaging 0.39 oz/ton of gold, 267 oz/ton of silver, and 26.5% lead. Forty workers were employed at the mine and 15 in the mill. (See Operators Annual Report for 1940, to Colorado Bureau of Mines, January 30, 1941.) Emperius Mining Company was owned by Ben Poxson in 1940 (John Jackson, personal communication with Les Dobson, USFS, March 1999).

During 1941 Emperius Mining Company drove exploratory drifts at greater depths than the old mine workings from the 3,000-foot-long tunnel under the Happy Thought and several other properties. Daily production was 50 tons of mill-grade ore and 15 tons of direct-shipping ore. Ore was hauled by horse trains on 12- and 16-pound rail from the mine, then trucked to the railroad at Creede. The shipping ore was sent by rail directly to Leadville for smelting. Five workers were employed in the mill and 40 underground. (See R.J. Murray, Mine Inspector report-Amethyst No. 5 Tunnel, March 25, 1941, Colorado Bureau of Mines.)

By 1942 Emperius Mining Company controlled most of the mines in the Creede mining district (Henderson, 1943, p. 336). The majority of their 85 underground employees worked in the Amethyst No. 5 Tunnel. Between 60 and 70 tons of ore were shipped daily from the No. 5 Tunnel and about 30 tons/day from the other mines. (See R.J. Murray, Mine Inspector report-Emperius Mining Company properties, February 24, 1942, Colorado Bureau of Mines.) Ore was shipped to a 100-ton/day flotation mill at Creede. Production was 2,402 tons of direct-shipping ore valued at $40,250 (averaging $33.50/ton) and containing 42 oz/ton of silver and 3% lead. In addition, 34,119 tons were milled (averaging $13/ton) containing 0.01 oz/ton of gold, 18 oz/ton of silver, 3% lead, and 0.05% copper. The mill produced 2,305 tons of concentrates valued at $400,447 (averaging $178.50/ton) and containing 0.2 oz/ton of gold, 265 oz/ton of silver, 21% lead, 8% zinc, and 2.5% copper. Ninety people worked in the mine and 17 at the mill. (See Operators Annual Report for 1942-Emperius Mining Company, February 8, 1943, to Colorado Bureau of Mines.)

Emperius Mining Company (B.T. Poxson, President) continued to operate the Amethyst and nearby properties until 1972 (Operator Annual reports, to Colorado Bureau of Mines; Mine Inspector reports, Colorado Bureau of Mines; Information reports, Colorado Bureau of Mines; various authors, U.S. Bureau of Mines Minerals Yearbooks). For a few years, the Amethyst Mine was idle or was subleased from the Emperius Mining Company, as described in the following paragraphs. Although all of the dates are not clear, Emperius Mining became an owner or part-owner of at least some of the properties. According to John Jackson (personal communication with Les Dobson, USFS, March 1999), about 50% of the production from the Amethyst was done under the ownership of Emperius Mining Company (Ben and Ty Poxson, owners).

During 1943 the Amethyst group and several nearby mines were operated through the Amethyst No. 5 Tunnel. About 100 tons/day of oxide ore were mined through three winzes below and two raises above the No. 5 Tunnel. Gas pockets were encountered, temporarily closing parts of the mine. (See R.J. Murray, Mine Inspector report-Creede Group, March 24, 1943, Colorado Bureau of Mines.) Ore was milled at the Emperius Mining Company's 100-ton/day flotation mill at Creede. About 3,400 feet of drifts, 200 feet of raises, and 250 feet of winzes were driven during the year. Production was 2,597 tons of direct shipping ore valued at $77,910 (averaging $30/ton) containing 0.04 oz/ton of gold, 35 oz/ton of silver, and 7% lead. In addition, 27,683 tons were milled (averaging $21.96/ton) containing 0.01 oz/ton of gold, 25 oz/ton of silver, 3% lead, and 0.05% copper. The mill produced 2,645 tons of concentrates (averaging $141.54/ton) containing 0.1 oz/ton of gold, 211 oz/ton of silver, 21% lead, and 2.8% copper. Sixty four people worked in the mine and 15 at the mill. (See Operators Annual Report for 1943-Emperius Mining Company, January 19, 1944, to Colorado Bureau of Mines.)

Also in 1943, Emperius Mining Company began an intense effort on the Commodore No. 5 Tunnel, designed as a haulageway for producing base-metal-rich sulfide ore from the Amethyst vein system (Brief History of Emperius Mining Company, unpublished report provided by Hecla Mining Company to USFS).

In 1944 the Amethyst and several other mines, including the Commodore, operated through the Amethyst No. 5 Tunnel. Between 75 and 90 tons/day of silver-lead ore were mined and shipped. The 4,300-foot-long Commodore No. 5 Tunnel was extended to a point 500 feet below the deepest workings of the Amethyst No. 5 Tunnel. (See R.J. Murray, Mine Inspector report-Amethyst No. 5 Tunnel and Commodore No. 5 Tunnel, May 26, 1944, Colorado Bureau of Mines.) Production from the group of mines was 1,729 tons of direct-shipping ore valued at $30,269 (averaging $17.51/ton) containing 0.092 oz/ton of gold, 15.39 oz/ton of silver, 5.87% lead, 0.008% zinc, and 0.001% copper. About 5,450 tons were milled (averaging $17.75/ton) containing 0.027 oz/ton of gold, 26.5 oz/ton of silver, and 3.84% lead. (See Operators Annual Report for 1944-Emperius Mining Company, February 20, 1945, to Colorado Bureau of Mines.)

In 1945 and 1946 most of the workings were still accessed through the Amethyst No. 5 Tunnel. Daily production was between 60 and 65 tons of oxide silver ore, mostly mined 75 to 200 feet below the tunnel. Work continued on the Commodore No. 5 Tunnel, the lowest tunnel in the area. (See R.J. Murray, Mine Inspector report-Emperius Operations, April 10, 1945, and August 14, 1946, Colorado Bureau of Mines.) Creede Mills, Incorporated sold the Missing Link Lode, which includes the Amethyst No. 5 Tunnel, to Emperius Mining Company (Denver County courthouse records). As of 1945, many owners were associated with the large group of properties leased by Emperius Mining Company (R.J. Murray, Mine Inspector report-Emperius operations, August 14, 1946, Colorado Bureau of Mines). This was probably true throughout the history of the Amethyst and related mines. It seems that many corporate entities and individuals held ownership in these rich mines.

During 1947, 60 tons/day of ore were shipped to the Emperius Mill from the Amethyst No. 5 (45 tons) and Commodore No. 5 (15 tons) Tunnels. Work continued on the Commodore No. 5 Tunnel, designed to intersect deeper ore zones and as a haulage tunnel for ore from the Amethyst No. 5 Tunnel. (See R.J. Murray, Mine Inspector report-Amethyst-Volunteer-New York-Commodore No. 5 and others, April 22, 1947, Colorado Bureau of Mines.)

Seven men were working on a lease from Emperius Mining in the Amethyst Tunnel in 1948. Most of the 1948 production from the Amethyst vein system was by Emperius Mining through the Commodore No. 5 Tunnel, where mining was conducted on three stopes, four raises, and four headings. An average of 1,300 tons/month of ore was mined from the Amethyst and Commodore No. 5. Dump material (1,800 tons in August) from the Commodore was also trucked to the mill. Thirteen men worked at the surface, 27 mined underground, and 12 men were employed in the mill. (See John Doyle, Mine Inspector report-Emperius Mine and Mill, September 10 and 11, 1948, Colorado Bureau of Mines.)

In early 1949 Emperius Mining Company was mining 100 tons/day of ore from the Amethyst and Commodore Mines, and shipping six railroad cars/month of lead concentrates to Leadville. Zinc concentrates were shipped to Amarillo. Ore was mined at a higher rate than the mill's 100-ton/day capacity. (See John Doyle, Mine Inspector report-Emperius Mine and Mill, February 15 and 16, 1949, Colorado Bureau of Mines.) Emperius Mining Company employed 48 workers underground and 12 in the mill. In June, 3,800 tons of ore were mined from 3- to 8-foot-wide veins. The Commodore level connected to the Amethyst No. 11 level by mid-1949. (See John Doyle, Mine Inspector report-Emperius Mine and Mill, July 12 and 13, 1949; and Amethyst-Commodore No. 5 and others, April 22, 1947, Colorado Bureau of Mines.)

During 1950 Emperius Mining Company operations were confined to the Commodore Tunnel. Eight lessees worked the Amethyst Mine on a split-check leasing system. Production was one car/week. (See John Doyle, Mine Inspector report-Amethyst Mine, October 6, 1950, Colorado Bureau of Mines.)

Two lessees were mining an old stope in a sublevel 170 feet above the main tunnel in the Amethyst Mine in 1951. Two 50-ton carloads of silver-lead ore had been shipped recently. (See John Doyle, Mine Inspector report-Amethyst Mine, October 2, 1951, Colorado Bureau of Mines.)

The Amethyst Mine produced an unspecified quantity in 1952 and 1953 (Martin, 1955, p. 253; Martin and Kelly, 1956, p. 267-268).

In 1954 Emperius Mining Company employed 83 workers; 10 in the Amethyst Mine and 47 in the Commodore Tunnel. Production was 41,000 dry tons of zinc concentrates and 577 dry tons of lead concentrates. (See John Doyle, Mine Inspector, Information report-Commodore Tunnel-Amethyst Mine-Emperius Mill, Colorado Bureau of Mines, January 3, 1955.)

Unquantified production came from the Amethyst in 1955 and probably 1956. The mill burned in August 1955, and a new 150-ton/day flotation mill opened in June 1956. (See Kelly and others, 1958, p. 279; Kelly and others, 1958, p. 293-294.)
Production decreased after the first half of 1957 because of lower metal prices. In April, Emperius Mining Company produced 5,000 tons; June production was 3,000 tons. Zinc concentrates were stockpiled, and enough silver and lead ores were shipped to keep operating. (See Joe Keating, Mine Inspector, Information report-Amethyst and Commodore Mines and Creede Mill, December, 1957, Colorado Bureau of Mines.)
Continued low metal prices caused operations to cease July 1, 1958. All 56 employees were laid off by Emperius Mining until October, when 14 employees reopened the Amethyst Mine. Ore

was stockpiled for the mill, scheduled to reopen in November. (See Joe Keating, Mine Inspector, Information report-Amethyst Mine, September 29, 1958, Colorado Bureau of Mines.)

The Emperius Mine, which includes the Commodore, Amethyst, and others, operated in 1959 and 1960 (Ransome and others, 1960, p. 234; Howes, 1961, p. 241). It is not clear if any production came from the Amethyst Mine.

Electricity was provided to the mine in 1961, and in 1962 a fan was installed for ventilation purposes. A sublevel was driven 35 feet above the Amethyst No. 5 level (the main haulageway). About 1,200 feet of stopes, from 100 to 200 feet in length and 5 to 14 feet in width, were developed above the sublevel. Fifteen employees were shipping 1,500 tons/month of ore. By 1962 the Commodore Tunnel connected with the Amethyst Mine through a series of raises. Raises No. 17 and No. 20 connected the Commodore No. 5 level with the Amethyst No. 5 level, a distance of at least 680 vertical feet. The mine inspector report implies that the raises were not direct connections. (See John Doyle, Mine Inspector, Information reports-Amethyst Mine-Commodore Mine, July 1, 1962, Colorado Bureau of Mines.)

A management-employee disagreement closed the mines from January to July, 1963. Later in the year the Amethyst and Commodore Mines produced 3,000 tons/month. (See Information Report-Amethyst Mine-Commodore Mine, December 10, 1963, Colorado Bureau of Mines.)

During 1964 and 1965, 13 employees worked in the Amethyst Mine (John Doyle, Mine Inspector, Information reports-Amethyst Mine, December 31, 1964 and December 16, 1965, Colorado Bureau of Mines). Emperius Mining Company gained control of Commodore Mining Company in 1961 and Amethyst Mining Company in 1964 (Brief History of Emperius Mining Company, unpublished report provided by Hecla Mining Company to USFS).

From 1966 to 1968, the Emperius Mine was a producer, but it is not reported if any production originated in the Amethyst Mine (Bieniewski and Henkes, 1967b, p. 203; Bieniewski and Henkes, 1968, p. 210-213; Bieniewski and Henkes, 1970, p. 169). Throughout the 1960s, most of the production was from the Commodore (Brief History of Emperius Mining Company, unpublished report provided by Hecla Mining Company to USFS).

In 1969 the mining method at the Amethyst and Commodore was changed from shrinkage stoping to sublevel caving. Development in the Amethyst and Commodore mines included 3,853 feet of drifts, 980 feet of crosscuts, and 795 feet of raises. Twelve stopes, averaging 200 feet long, 5 feet wide, and 100 feet high, were completed during the year. (See Joe Keating, Mine Inspector, Information reports-Amethyst and Commodore, November 30, 1969, Colorado Bureau of Mines.)

Pillars were extracted above the Amethyst level during 1970 (Bernard Javernick, Mine Inspector, Information reports-Amethyst and Commodore, December 24, 1970, Colorado Bureau of Mines). **Significant production from the Amethyst Mine probably ceased in 1970**. Any production after 1970 is not separable from production from other mines of the Emperius group, and is probably minor.

Production from the Creede mining district was about $42,000,000 before the Emperius operations began. Emperius Mining Company produced about $32,000,000 during its operations from the mid-1930s to 1972. (See Brief History of Emperius Mining Company, unpublished report provided by Hecla Mining Company to USFS.)

As of 1971, the upper and lower waste-rock piles for the Amethyst covered about 27.5 acres. These mine dumps had not been used since 1969. (See a letter from the Emperius Mining Company to Bernie Javernick, mine inspector, November 15, 1971, Colorado Bureau of Mines.)

During 1972 Emperius Mining Company reported work only on the Commodore No. 4 and No. 5 levels; no work was reported at the Amethyst Mine. Production rate was 4,500 tons/month until May 6, when mining was stopped because of the lack of a zinc contract. (See Bernard Javernick, Mine Inspector, Information report- Emperius Mine, December 28, 1972, Colorado Bureau of Mines.)

In early 1973 Minerals Engineering Company (C.E. Melbye, President) leased the Emperius Mine from Emperius Mining Company with a 3-year option to buy the property and also had a lease on the Creede Mines, Incorporated property. Ben and Tyrus Poxson controlled Emperius Mining, and Humphreys Engineering Company controlled Creede Mines. (See Information report- Emperius Mine, December 27, 1973, Colorado Bureau of Mines; Kuklis, 1974, p. 155; Denver Post, January 13, 1973, p. 8.) Clean-up and installation of track on the Amethyst level was done for exploration and sampling purposes. No ore was produced. (See Bernard Javernick, Mine Inspector, Information report- Emperius Mine, December 27, 1973, Colorado Bureau of Mines.) Later in 1973, Minerals Engineering Company formed a partnership with Statesman Mining, Incorporated, of Aspen (Kuklis, 1976, p. 142). The partnership was called Creede Associates, Ltd. (Nelson, 1989, p. 23). In 1974, Minerals Engineering acquired Statesman Mining Company's interest in the Emperius Mine (Smith, 1977, p. 151).

From 1974 to 1976, Minerals Engineering produced lead-zinc ore with silver and gold byproducts (Nelson, 1989, p. 19). The ore included about 41,000 tons of material from the Chance, Del Monte, and Amethyst dumps and 84,000 tons of new production (unpublished documents provided by Hecla Mining Company to USFS).

During 1976 some improvements were made on the Amethyst level (Bernard Javernick, Mine Inspector, Information report- Emperius Mine, December 30, 1976, Colorado Bureau of Mines). Houston Oil and Minerals subleased from Minerals Engineering and conducted exploration work during 1976 and 1977 (Operators Annual Report for 1977-Emperius Mine and Mill, to Colorado Bureau of Mines, March 2, 1978; Nelson, 1989, p. 19).

In 1978 Minerals Engineering Company operated the mines owned by Emperius Mining Company (Operators Annual Report for 1978-Emperius Mine and Mill, to Colorado Bureau of Mines). Through a joint venture with Minerals Engineering, Chevron Resources did most of the work, which included rehabilitation of some underground workings and exploration drilling (unpublished report by CoCa Mines provided to USFS).

In 1979 Chevron drilled and conducted geochemical surveys. Chevron also cut trenches for bulk samples in the Chance dump. (See Operators Annual Report for 1979-Emperius Mine and Mill, to Colorado Bureau of Mines; unpublished report by CoCa Mines provided to USFS.)

Chevron drove new drifts of 1,700 feet and 1,200 feet on the Chance No. 2 and Amethyst No. 5 levels, respectively, in 1980. The drifting produced about 12,500 tons of material used for bulk testing. (See unpublished report by CoCa Mines provided to USFS.)

Exploration drilling was the major activity during 1981 (unpublished report by CoCa Mines provided to USFS).

The extensive exploration program conducted by Chevron from 1978 to 1981 revealed about 20 million tons of low-grade, subeconomic resources (Nelson, 1989, p. 19; unpublished report by CoCa Mines provided to USFS).

In 1982 Pioneer Nuclear, Incorporated entered into an option agreement with Minerals Engineering regarding mines near Creede (documents provided by Hecla Mining Company to USFS). Pioneer Nuclear continued exploration and shipped 500 tons of ore to an ASARCO smelter (unpublished report by CoCa Mines provided to USFS; unpublished documents provided by Hecla Mining Company to USFS).

In 1984 the Amethyst No. 5 level was owned and operated by Minerals Engineering Company. Four employees conducted exploration and developed one stope/raise and a test drift on the vein. (See Information report-Amethyst 5 Level, May 24, 1984, Colorado Bureau of Mines.)

Six workers were core drilling in the Commodore No. 5 level, and drifting and developing a stope on the Amethyst No. 5 level in early 1985 (Information report-Commodore and Amethyst Levels, March 24, 1985, Colorado Bureau of Mines).

In 1986, six employees of Minerals Engineering Company were enlarging the main drift of the Amethyst level, sampling underground ore zones, and core drilling from the surface (Information report-Emperius, Amethyst Level, December 5, 1986, Colorado Bureau of Mines).

Any work after 1986 was probably limited to additional exploration activities.

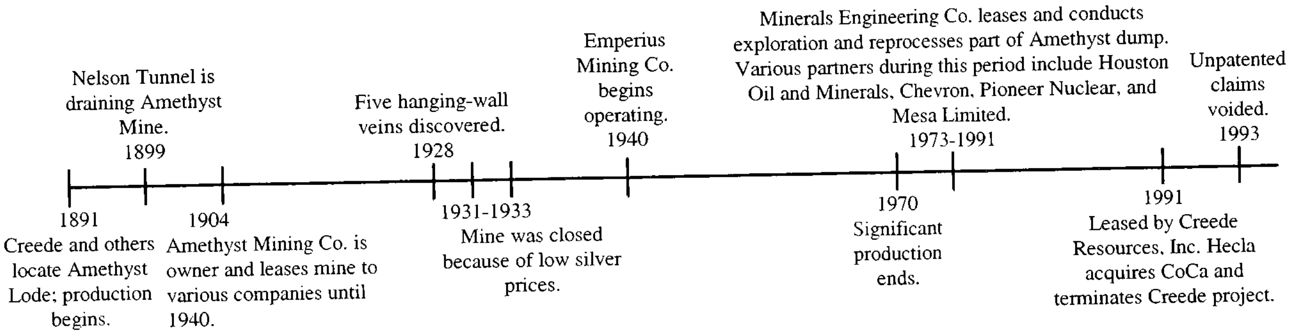
Mesa Limited Partnership acquired Pioneer Nuclear, and Minerals Engineering changed its name to CoCa Mines, Incorporated in 1986 (Denver County courthouse records). Minerals Engineering/CoCa and Pioneer Nuclear/Mesa Limited Partnership controlled the property from 1982 until about 1988 (Nelson, 1989, p. 11, 19).

In 1988 Mesa Limited Partnership opted out of the joint venture with CoCa Mines (unpublished report from CoCa Mines provided by Hecla Mining Company to USFS).
In 1991 Creede Resources, Incorporated (a Colorado corporation) acquired CoCa's interest in mines near Creede. Hecla Mining Company bought CoCa Mines in 1991 and terminated the Creede project. (See documents provided by Hecla Mining Company to USFS.)

As of September 1998, several companies and individuals owned the patented claims that include the Amethyst and Last Chance Mines and the vicinity. Owners include Commodore Mining Company, Creede Mines, Last Chance Mining and Milling Company, Fairview Land Corporation, Martha Johnson, Mary Patrick, and Debra Stevens. (See Mineral County courthouse records.)

Kanawha Mines, Limited, (owned by the Poxson's) and Creede Mines owned some unpatented claims near the Amethyst and Last Chance patented claims as recently as 1992, but the claims were voided in 1993. Before abandonment, the claims were evidently leased to Creede Resources Incorporated, a subsidiary of Hecla Mining Company. (See BLM files; John Jackson, personal communication with Les Dobson, USFS, March 1999.)

Timeline summarizing highlights in the mining history of the Amethyst Mine



Geology

The Amethyst Mine developed the Amethyst vein and related hanging-wall veins that were emplaced along fault zones related to the Creede graben. Various members of the Bachelor Mountain Rhyolite are the host rocks. The Willow Creek Member forms the entire footwall and the hanging wall in the lower levels. The younger Campbell Mountain and Windy Gulch Members are the hanging wall rocks in the upper levels. (See Steven and Ratté, 1965, plate 1, p. 65-67.)

At the Amethyst Mine, the fault and associated veins strike north-northwest and dip 50° to 70° west. The main vein varies from 1 to 12 feet wide, but is typically 3 to 6 feet wide. The fault is downthrown to the west, and displacement is at least 600 vertical feet. This fault was active before, during, and after mineralization. At the Amethyst Mine, numerous near-vertical, subparallel fractures in the hanging wall form a 100-foot-wide shear zone near the surface. Deeper in the system, these vertical fractures are fewer but larger, and get closer to the main fault. (See Steven and Ratté, 1965, plate 1, p. 65-67; Emmons and Larsen, 1923, p. 162.)

The Amethyst and Last Chance Mines developed the Amethyst vein system in its most continuously mineralized segment, both laterally and vertically. In addition, the mineralized hanging-wall fractures are closely spaced. The more persistent and richer mineralization in this part of the vein system may be related to a double bend in the fault that occurs in this vicinity. (See Steven and Ratté, 1965, p. 71-72.)

At the Amethyst Mine, oxidized ore predominates to a depth of level 6, about 600 feet below the surface. Below this, only small seams and fractures that cut the primary ore are oxidized. Vein minerals in the oxidized and/or unoxidized part of the vein include quartz, chlorite, barite, galena, sphalerite, pyrite, chalcopyrite, cerussite, anglesite, limonite, goslarite, manganese oxides, barite, jarosite, silver, gold, and cerargyrite. (See Emmons and Larsen, 1923, p. 161-162.)

Where unoxidized, the main Amethyst vein comprises fragments of silicified country rock in a matrix of varying amounts of clay, chlorite, amethystine quartz, white quartz, and sulfides. Galena, sphalerite, and pyrite are the major sulfides. Fluorite and rhodochrosite are minor accessory minerals. (See Steven and Ratté, 1965, p. 69.)

Textures of the vein vary considerably, from layered ribbons of quartz that were successively deposited in open fissures with little post-mineral disturbance, to segments where post-mineralization fault movement has sheared and/or brecciated the vein (Steven and Ratté, 1965, p. 69).

In the upper levels of the Amethyst Mine, generally above the Amethyst No. 5 Tunnel, wall rocks of the vein are intensely argillized to soft, light-colored clay. The appearance of this argillized wall rock roughly coincides with the upper limit of ore-grade material in the vein. The richest vein material is often just below the zone of argillized wall rock. (See Steven and Ratté, 1965, p. 70.)

Site Description

Because most of this site is privately owned, very little "on-the-ground" examination was done during this study. The mining legacy of this area is obvious even to the casual observer. Large dumps, equipment sheds, mill ruins and foundations, etc., are common sights along West Willow Creek. Within inventory area #09-04-330/4192-1, two waste-rock piles (#201 and #202) are the primary features of environmental concern to the USFS.

The southeastern end of mining feature #201 may extend onto USFS-administered land. This waste-rock pile is associated with the adit labeled Amethyst Mine on the PBS and U.S. Geological Survey topographic maps. This adit is probably the Amethyst No. 5 (Figure 1). A structure believed to be a breached wooden tailings dam is below the Amethyst Mine in West Willow Creek, near the boundary of private land and USFS-administered land (USFS-AMLIP inventory form #09-04-330/4192-1).

Mining feature #202, from the Commodore and Nelson Tunnels, is a large waste-rock pile that fills the valley floor of West Willow Creek (Figure 1). Feature #202 appears to be entirely privately owned.

Waste and Hazard Characteristics

Dump #201 from the Amethyst No. 5 Mine is estimated at 20,000 cubic yards, but only a fraction of that volume is resting on USFS-administered land. The dump is barren of vegetation and is cut by gullies that connect directly with West Willow Creek. The toe of the dump extends to and is eroded by West Willow Creek. (See USFS-AMLIP inventory form #09-04-330/4192-1; Kirkham, 1993, p. 14-15.)

A structure believed to be a breached wooden tailings dam is in West Willow Creek near the boundary of private land and USFS-administered land (USFS-AMLIP inventory form #09-04-330/4192-1). Plate 1 in Emmons and Larsen (1923) shows a pond or impoundment in this area, just upstream of the confluence with Nelson Creek (Figure 1). If, as historical and physical evidence suggests, a tailings pond existed here and was breached, the tailings were dispersed downstream in West Willow Creek onto USFS-administered and private land.

Dump #202 is from the Commodore and Nelson Tunnels (Figure 1). The estimated 20,000 cubic yards of waste rock fills the valley floor, and West Willow Creek is conveyed through the pile via culvert. All of feature #202 appears to be privately owned, but material eroding from this waste-rock pile affects West Willow Creek on a small tract of USFS-administered land immediately downstream of the dump. (See USFS-AMLIP inventory form #09-04-330/4192-1; Kirkham, 1993, p. 14.)

Because most of the underground mine workings at the Commodore and Amethyst Mines drifted and stoped on the Amethyst and related hanging-wall veins, the waste rock associated with dumps #201 and #202 is probably mostly low-grade vein material and wallrock. A smaller percentage is probably composed of barren volcanic rock excavated when crosscuts and haulageways were constructed. Some of the dump material from the Amethyst Mine was rich enough to process at various times, suggesting that parts of the waste-rock pile contain mineralized material.

Mineralogy of the dump probably closely reflects that of the vein, which includes quartz, chlorite, barite, galena, sphalerite, pyrite, chalcopyrite, cerussite, anglesite, limonite, goslarite, manganese oxides, barite, jarosite, silver, gold, and cerargyrite (Emmons and Larsen, 1923, p. 161-162). Fluorite and rhodochrosite are minor accessory minerals (Steven and Ratté, 1965, p. 69).

Numerous water tests and samples were collected during previous investigations of the Willow Creek watershed. Tests performed during the mine inventory in June of 1992 show pH of the creek water dropping from 7.2 just below the Amethyst Mine, to 7.1 below the Commodore Mine. Conductivity rises from 69 to 131 μS in the same reach (Kirkham, 1993, p. 14-15).

Samples collected by the Water Quality Control Division of CDPHE in 1990 suggest that West Willow Creek is degraded with respect to cadmium, copper, lead, and zinc below the Amethyst Mine compared to water above this mine (Table 2). A sample from West Willow Creek immediately below the Commodore Mine contained even higher concentrations of these same elements, suggesting that waste rock from the Commodore Mine and the small discharge from the Nelson Tunnel may be significant sources of metal contamination in West Willow Creek (O'Grady, 1995a, Table 2).

A comprehensive sampling program was done in 1995 as part of a Site Investigation of East and West Willow Creeks (O'Grady, 1997). Stream water and sediments were sampled at several locations in the stream reach near the Amethyst-Commodore Mines. The only mine water within this area that was sampled was the Nelson Tunnel on private land. Two waste-rock samples were collected from both the Amethyst and Commodore-Nelson Tunnel mine dumps (Table 3).

Water samples collected for the Site Investigation show that cadmium and zinc concentrations increase significantly in West Willow Creek immediately below the Amethyst Mine. In general, concentrations of cadmium, copper, lead, and zinc gradually increase downstream from the Amethyst Mine to the Commodore Mine. Downstream of the Commodore Mine, the pH drops about 0.7 units, and cadmium, manganese, and zinc increase dramatically (Table 2).

Compared to samples collected from above the Amethyst and Last Chance Mines, stream sediments show a significant increase in cadmium, copper, mercury, silver, and zinc immediately below the Amethyst Mine (Table 3). With the exception of zinc, metal concentrations in the sediment appear to be diluted by the influx of sediment from Nelson Creek at the next sample site downstream. In the stream reach between Nelson Creek and the Commodore Mine, concentrations of antimony and arsenic in the sediments more than double. These increases may be attributable to waste rock eroded from the Amethyst and Last Chance Mine dumps and the breached tailings pond described previously. Concentrations of cadmium, copper, lead, manganese, mercury, and zinc in the sediments increase dramatically below the Commodore Mine, almost certainly because of material eroded from the Commodore/Nelson Tunnel waste-rock pile.

Both waste-rock samples from the Amethyst Mine were high in lead, silver, and zinc (Table 3). One of the samples also contained high concentrations of antimony, arsenic, and mercury. At the Commodore Mine, one of the waste-rock samples contained abundant cadmium, copper, lead, manganese, silver, and lead; and the other sample was relatively unmineralized.

Table 2. Water sample analyses results for areas near the Amethyst and Commodore Mines. [Results are shown in dissolved concentrations and µg/L unless noted. Blank columns indicate the parameter was not analyzed or the results are not known. The 1990 samples are reported in O'Grady (1995a). The remaining samples were collected in late May or early June, 1995, and are reported in O'Grady (1997). As recorded by CDPHE, the total recoverable metals are considerably different than the dissolved metals for the sample collected below the Commodore Tunnel, but they are nearly identical to the total recoverable metals for the Nelson Tunnel sample. Because of a probable lab error, the total recoverable metals for the sample collected below the Commodore Tunnel are not listed here.]

Analyzed or tested parameter	W. Willow below Equity Mine, 4/12/90	W. Willow below Equity Mine, 9/10/90	W. Willow below Amethyst Mine and confluence of Nelson Creek, 4/12/90	W. Willow below Amethyst Mine and confluence of Nelson Creek, 9/10/90	Nelson Tunnel, 4/12/90	Nelson Tunnel, 9/10/90	W. Willow below Commodore Tunnel, 4/12/90
Flow (cfs)	0.76	2.73	1.96	3.48	0.026	0.044	0.76
pH	8.17	6.19	7.17	6.15	6.5	7.9	6.76
Cadmium			11	7	55	74	48
Copper			8		14	22	20
Iron	110 (trec)						
Lead			50	20			75
Manganese					4,100	5,500	630
Silver					0.27		0.26
Zinc			580	290	15,000	17,000	7,300

Analyzed or tested parameter	W. Willow above Amethyst Mine	W. Willow above Nelson Creek and below Amethyst Mine	W. Willow below Nelson Creek and Amethyst Mine	W. Willow above Commodore Tunnel	W. Willow below Commodore Tunnel and above E. Willow	Nelson Tunnel
Flow (cfs)	23.31	23.31	25.36	24.34	21.91	0.07
pH	7.46	7.23	7.57	7.48	6.77	5.30
Conductivity	45 µS	50 µS	55 µS	60 µS	49 µS	375 µS
Total suspended solids	5.00 mg/L	7.00 mg/L	10.00 mg/L	4.00 mg/L	<4.00 mg/L	
Hardness	26.54 mg/L	25.60 mg/L	25.41 mg/L	25.15 mg/L	125.52 mg/L	283.93 mg/L
Alkalinity	24.40 mg/L	20.40 mg/L	21.00 mg/L	19.80 mg/L	21.20 mg/L	
Aluminum	212 461 (trec)	164 414 (trec)	171 523 (trec)	218 468 (trec)	171	1,050 1,080 (trec)
Antimony	<1.90 (both)	<1.90 (both)	<1.90 2.30 (trec)	<1.90 (both)	<1.90	<1.90 (both)
Arsenic	<3.20	<3.20	<3.20	<3.20	<3.20	4.60 4.00 (trec)
Barium	13.30 13.90 (trec)	12.70 13.70 (trec)	13.50 18.30 (trec)	17.20 17.00 (trec)	17.10	40.30 39.80 (trec)
Beryllium	<0.30 (both)	<0.31 (both)	<0.22 (both)	<0.39 (both)	<0.33	2.20 2.10 (trec)
Cadmium	1.20	3.40	4.90	5.80	12.70	301

Analyzed or tested parameter	W. Willow above Amethyst Mine	W. Willow above Nelson Creek and below Amethyst Mine	W. Willow below Nelson Creek and Amethyst Mine	W. Willow above Commodore Tunnel	W. Willow below Commodore Tunnel and above E. Willow	Nelson Tunnel
	<1.00 (trec)	3.50 (trec)	5.10 (trec)	5.50 (trec)		293 (trec)
Calcium	8,440 9,030 (trec)	8,550 8,670 (trec)	8,460 8,580 (trec)	8,500 (both)	8,760	43,200 42,500 (trec)
Chromium	<0.90 (both)	<0.90 (both)	<0.90 (both)	<0.90 (both)	<0.90	<0.90 (both)
Cobalt	<0.60 (both)	<0.60 (both)	0.71 0.93 (trec)	<0.60 (both)	<0.60	15.90 15.50 (trec)
Copper	1.60 2.00 (trec)	2.90 4.20 (trec)	5.20 6.60 (trec)	5.00 5.40 (trec)	6.30	285 287
Fluoride	<0.10 mg/L	<0.10 mg/L	<0.10 mg/L	<0.10 mg/L	<0.10 mg/L	
Iron	118 297 (trec)	59.50 245 (trec)	75.30 343 (trec)	118 289 (trec)	48	10.60 214 (trec)
Lead	2.70 3.10 (trec)	3.50 7.50 (trec)	4.70 11.00 (trec)	11.20 13.50 (trec)	9.00	451 464 (trec)
Magnesium	936 969 (trec)	936 959 (trec)	939 967 (trec)	940 953 (trec)	979	4,700 4,600 (trec)
Manganese	8.10 11.60 (trec)	11.40 17.30 (trec)	15.40 21.30 (trec)	15.60 18.50 (trec)	236	15,900 16,300 (trec)
Mercury	<0.20 (both)	<0.20 (both)	<0.20 (both)	<0.20 (both)	<0.20	<0.20 (both)
Nickel	<1.40 (both)	8.40 <1.40 (trec)	<1.40 (both)	5.50 <1.40 (trec)	<1.40	<1.40 (both)
Potassium	669 694 (trec)	666 661 (trec)	679 700 (trec)	702 681 (trec)	744	4,770 4,360 (trec)
Selenium	<4.40 (both)	<4.40 (both)	<4.40 (both)	<4.40 (both)	<4.40	5.10 7.10 (trec)
Silver	<0.50 (both)	<0.50 (both)	<0.50 (both)	<0.50 (both)	<0.50	5.30 5.60 (trec)
Sodium	2,640 2,990 (trec)	2,680 2,930 (trec)	2,590 2,880 (trec)	2,700 2,760 (trec)	2,960	22,200 21,200 (trec)
Sulfate	8.33 mg/L	12.60 mg/L	9.53 mg/L	9.84 mg/L	12.10 mg/L	
Thallium	<4.50 (both)	<4.50 (both)	<4.50 (both)	<4.50 (both)	<4.50	4.60 4.90 (trec)
Vanadium	<0.94 0.82 (trec)	<0.70 (both)	<1.10 1.20 (trec)	0.88 <0.40 (trec)	0.64	<0.40 (both)
Zinc	85.30 92.00 (trec)	219 223 (trec)	288 293 (trec)	355 348 (trec)	1,570	20,500 19,800 (trec)

Table 3. Stream-sediment and waste-rock sample analyses results for areas near the Amethyst and Commodore Mines. [Results are shown in ppm unless noted. The samples were collected in late May or early June, 1995, and the results are reported in O'Grady (1997).]

Analyzed parameter	Sediment – W. Willow above Amethyst Mine	Sediment - W. Willow above Nelson Creek and below Amethyst Mine	Sediment - W. Willow below Nelson Creek and Amethyst Mine	Sediment - W. Willow above Commodore Tunnel	Sediment - W. Willow below Commodore Tunnel and above E. Willow	Waste rock Amethyst Mine	Waste rock - Amethyst Mine	Waste rock Commodore Mine	Waste rock Commodore Mine
Aluminum	5,460	6,370	4,080	2,810	5,500	1,220	1,780	3,160	10,100
Antimony	1.20	2.10	2.30	6.50	4.40	32.40	111.00	26.70	2.10
Arsenic	32.10	44.30	47.40	104	96.90	551	628	446	64.30
Barium	108	154	76.30	165	327	70.80	38.50	1,390	205
Beryllium	0.37	0.43	<0.30	0.42	0.79	<0.14	<0.60	<0.47	0.37
Cadmium	4.60	11.20	8.40	9.10	28.40	8.70	8.80	38.00	8.10
Calcium	2,820	3,140	1,620	2,360	3,310	<28.10	<23.00	376	2,990
Chromium	2.00	2.60	1.00	<1.90	<2.70	0.50	0.61	3.20	5.80
Cobalt	4.80	6.40	3.30	3.50	5.10	0.45	<0.22	<3.00	6.60
Copper	16.00	90.50	20.50	29.20	101	100	361	1,880	86.40
Iron	12,600	14,600	7,410	9,750	12,200	12,900	20,500	24,400	26,700
Lead	658	984	571	982	1,440	4,770	12,900	21,000	877
Magnesium	2,170	2,550	1,100	1,170	1,790	52.60	19.80	920	4,170
Manganese	580	678	530	468	1,300	751	11.50	2,390	754
Mercury	<0.14	0.19	<0.13	<0.12	0.22	0.10	1.10	0.31	<0.11
Nickel	<0.43	<0.45	<0.36	<0.39	<0.40	<0.29	<0.29	<0.29	<0.31
Potassium	1,580	1,630	947	814	1,210	1,430	962	634	2,040
Selenium	1.50	1.60	<1.10	<1.20	<1.20	1.10	1.40	3.10	2.50
Silver	0.58	16.80	2.90	6.60	5.30	39.00	85.10	96.60	5.20
Sodium	393	339	490	309	710	487	467	1,130	510
Thallium	<1.40	<1.40	<1.20	<1.30	1.50	7.80	5.80	5.10	1.40
Vanadium	22.40	25.20	10.20	14.10	17.40	5.80	4.90	9.00	33.60
Zinc	404	807	942	848	2,420	1,280	1,470	3,550	832

The privately owned Nelson Tunnel had a small discharge of less than 0.1 cfs during some of the previous investigations. This feature was not examined during the present investigation. Samples collected in 1990 and 1995 contained high concentrations of cadmium, manganese, and zinc. In the 1995 samples, aluminum, cobalt, copper, lead, silver, and thallium concentrations were also elevated (Table 2). Because of the low flow from Nelson Tunnel, metal loading from this source is relatively minor (O'Grady, 1997, p. 9).

Migration Pathways

Groundwater Pathway

On the walls of recently abandoned drifts in the Amethyst Mine, sulfate-rich waters percolating through the vein deposited goslarite (zinc sulfate) and iron sulfates (Emmons and Larsen, 1923, p. 161). This phenomenon indicates the abundance of sulfate and zinc in the water associated with this vein system. Oxidation of the upper levels of the Amethyst vein is nearly complete, and the acid-generating potential of the oxidized portions of the vein is low. Sulfides with significant acid-generating potential are abundant lower in the vein system.

Groundwater flow has been completely altered by the numerous interconnected mines in this area. Many of the lower adits were driven both as drainage tunnels and as haulageways for the upper levels of the mines. The Nelson Tunnel was driven for these purposes and drained about 3,000 gpm (~6.5 cfs) of water from the Amethyst, Chance, and Commodore Mines in 1901 (Hodges, 1902, p. 123-127). As of 1965, the Nelson Tunnel drained a "moderate" flow of water (Meeves and Darnell, 1968, p. 30). Now it drains less than 0.1 cfs, perhaps as a result of the development of the Bulldog Mine in Windy Gulch. According to the Colorado Mined Land Reclamation Division (1982, p. 25-13), as of 1982 the Bulldog Mine was dewatering many of the interconnected mines of the West Willow Creek drainage basin, and many mines that once discharged into West Willow Creek were now relatively dry.

The closest registered well for household or domestic use is about ¾ mile northwest of the Amethyst Mine on the slope above the Happy Thought Mine. The well was sunk at an elevation of about 10,500 feet and is less than 90 feet deep (Colorado Division of Water Resources records, 1999). The well is upgradient and is probably not affected by the Amethyst Mine.

Another registered well is about 1 mile to the south-southwest at an elevation of about 10,300 feet in Windy Gulch (Colorado Division of Water Resources records, 1999). This well is more than 1,300 feet deep and penetrates to depths that could theoretically intersect water affected by the Amethyst workings, which lie at elevations roughly between 8,800 and 10,600 feet. The Bulldog vein lies between this well and the Amethyst vein. The complicated subsurface mining geology in this area, which is honeycombed with workings related to the Amethyst-Commodore Mine and the Bulldog Mine, would make any effects from these mines virtually impossible to separate. The quality of this well water is not known.

Two wells for household use are registered in North Creede, but they are shallow and lie in the East Willow Creek valley, and are not affected by water from the Amethyst Mine. Another registered well, about 450 feet deep, lies on the slopes southeast of North Creede at an elevation of about 9,700 feet (Colorado Division of Water Resources records, 1999). Willow Creek Canyon hydrologically separates the Amethyst Mine from this well.

Because small-yield wells, typical of household use, had no requirements for registration prior to 1972, some unregistered wells probably exist in the town of Creede. These wells likely draw from the surficial aquifer of Willow Creek. Surface water in Willow Creek is highly degraded with metals related to past mining activities, and the surficial aquifer is probably degraded to some extent. Because the Amethyst Mine impacts the surface water of West Willow Creek (see discussion below), it may have a similar effect on the surficial aquifer of Willow Creek.

Near the confluence with the Rio Grande, four wells for domestic and household use lie on the east side of Willow Creek, and two wells on the west side of Willow Creek provide water for the town of Creede (Colorado Division of Water Resources records, 1999). The surficial aquifer of the Rio Grande is the most common source for well water in this area. This aquifer is in hydrologic communication with the Rio Grande and is probably not significantly affected by metals contamination. (See O'Grady, 1995b, p. 10-11.)

Surface Water Pathway

Surface water in West Willow Creek is slightly degraded with metals downstream of the Amethyst Mine. This degradation is probably a result of the stream water in contact with dumps of the Amethyst and Last Chance Mines. Metal content in stream sediments also increases below the Amethyst and Last Chance Mines. Metal concentrations in surface water and stream sediments are considerably higher further downstream, below the Commodore Mine.

Fish do not live in West Willow Creek below the Amethyst and Last Chance Mines because of dissolved metals in the stream and habitat destruction associated with past mining activities (O'Grady, 1997, p. 6). Downstream targets within 15 miles of this inventory area include excellent trout fisheries on the Rio Grande River, extensive wetlands, and habitats for Threatened and Endangered Species. Habitats suitable for peregrine falcons, bald eagles, wolverines, and Mexican spotted owls are present in this area. (See O'Grady, 1997, p. 6.)

Soil Exposure Pathway

No one lives within a mile of the waste-rock pile (dump #201) of the Amethyst Mine that lies on USFS-administered land. Tourists frequently drive by the site, but "No Trespassing" signs discourage foot traffic onto the waste-rock piles of the Amethyst and Commodore Mines. Metal concentrations in the dumps are not high enough to pose a risk for such brief exposures.

Air Exposure Pathway

The waste-rock piles are generally composed of sand-size or larger fragments and are moderately cemented (USFS-AMLIP inventory form #09-04-330/4192-1). No residences are nearby and exposure to tourists is limited to brief episodes. For these reasons, the air exposure pathway is considered a minimal risk.

CHANCE DUMP

The Chance dump (inventory area #09-04-329/4194-1) may be a misnomer for this site. The waste-rock pile (dump #200) that apparently extends onto USFS-administered land within this inventory area is probably a mixture of material from the Last Chance Mine and the upper levels of the Amethyst Mine (Figure 1). The Last Chance Lode is on the hill above and south of the Amethyst Lode claim. It is possible that waste rock from the Last Chance was hauled along contour to the north and dumped down the hill to the northeast. Whether this waste-rock pile originated from the Amethyst or Last Chance Mine, or both, the mine opening from which the waste rock was produced is privately owned and was not examined during this investigation. An accurate survey would be necessary to determine property boundaries.

Throughout its history, this mine is usually referred to as the Last Chance Mine. The mining and operational history of the Last Chance closely parallels that of the Amethyst Mine. From about the 1970s and later, operations at the Last Chance are not distinguishable from operations at the Amethyst/Commodore Mine, which were controlled by the same group. It is believed that underground production at the Last Chance probably ended in the mid-1940s, but dump material was processed later, as described below.

Mining History

The Last Chance Lode was originally located in August 1891 by T. Reininger (Henderson, 1926, p. 56). Mineral Survey No. 7263A was conducted on the Last Chance Lode on November 10, 1891. At the time of the survey, four short adits were surveyed on the claim, which was owned by Ralph Granger, Erick Von Buddenbrock, and Theodore Reininger. (See Mineral Survey No. 7263A, available at the Bureau of Land Management, Colorado State Office.)

In 1891 the first recorded production from the Last Chance Mine was valued at $5,553 in gold and had a coinage value of $287,677 in silver (Smith, 1892, p. 184).

Production in 1892 had a coinage value of $2,343,122 in silver (Smith, 1893, p. 126). By the end of 1892, the Last Chance had produced about 15,000 tons of ore worth about $1,500,000 (Emmons and Larsen, 1923, p. 5).

Many of the large mines closed in 1894 because of large amounts of water (Hodges, 1900, p. 110-112). It is not clear if the Last Chance remained open.

In 1896 Last Chance Mining and Milling Company (J. Saunders, President; H. Wolcott, Secretary) and New York and Chance Mining Company (H. Wolcott, President; S. Dickson, Secretary) owned parts of the Last Chance Mine (Bartow and Simmons, 1896, p. 89).

During 1898 workings were accessed from a 1,400-foot, inclined (58°), 3-compartment (4.5 feet by 15 feet) shaft located near the south end of the claim. Water filled the 12-level shaft up to the 6th level, but the Nelson Tunnel, scheduled for completion in March 1899, would drain the shaft from 50 feet below its present bottom. All drifts from the No.6 level up to the No.1 level connect with the Amethyst Mine to the north and New York Mines to the south. An average of 12 employees mined 1,150 tons/month using back stoping and drifting methods. Assay value averaged \$30/ton. Last Chance Mining and Milling Company leased the mine to Harrington Leasing Company. (See Mine Inspector report and Mine report-Last Chance Mine v. 3, p. 142 and 220, November 17, 1898, Colorado Bureau of Mines.)

By 1899 the Nelson Tunnel was more than 8,000 feet long and was connected to the Last Chance and other mines, draining them to a depth of 1,600 feet. At the Last Chance Mine, 18 employees mined about 1,000 tons/month of ore worth about \$20/ton, mostly in silver. Twelve levels, 80 feet to 100 feet apart, with 10,000 feet of drifts and raises, were accessed through a 3-compartment, 1,400-foot-deep shaft. Reported production from the Last Chance Mine by the Last Chance Mining and Milling Company was 16,000 tons containing 768,000 oz of silver; 1,600 oz of gold; and 1,280 tons of lead. (See Mine Inspector report and Mine report-Last Chance Mine, v. 4, p. 76 and 154, October 18, 1899, Colorado Bureau of Mines; Hodges, 1900, p. 110-112.)

In 1901 the Last Chance Mine was embroiled in legal controversies (Hodges, 1902, p. 123-127).

Twenty men were employed by Last Chance Mining and Milling Company (H.R. Wolcott, Secretary; J.W. Westlake, Manager) at the Last Chance in 1902 (Colorado mining directory and buyer's guide, June 1902, p. 99). Another account reports a crew of 50 workers, and that Westlake was leasing part of the mine from the New York and Chance Mining Company. (Dunbar's western mining directory, 1901-1902, p. 161).

The Last Chance was worked under a leasing system in 1904 (Downer, 1905, p. 118).

In 1905 Creede United Mines Company, which owned the Del Monte, Last Chance, and New York Mines, was the largest producer in Mineral County. Zinc was a byproduct for Creede United Mines Company. (See Waldemeyer, 1906, p. 205.)

In 1906 the "Del Monte Leasing Company shipped silver-lead ores carrying some gold from the properties of the New York and Chance Mining Company, the Volunteer Mining Company, and the Last Chance Mining and Milling Company. The New York and Chance Leasing Company also produced from the New York and Chance mines." (See Naramore, 1907, p. 224.)

In 1909 and 1910, a large tonnage of lead-silver ore was shipped from the Last Chance Mine (Henderson, 1911a, p. 320; Henderson, 1911b, p. 425).

An increased tonnage of lead-silver, smelting-grade ore with minor gold was shipped from the Last Chance-New York-Volunteer group in 1911 (Henderson, 1912, p. 552).

Through about 1912, the Last Chance-New York-Volunteer group had produced about \$19,000,000 from a 1,400-foot-deep shaft and 2 miles of underground workings. Volunteer Mining Company (a holding company) was a significant stockholder in Last Chance Mining and Milling Company. Del Monte Leasing Company leased the mine, and it was operated by A.E. Humphreys of Denver and A. Collings of Creede. (See Emmons and Larsen, 1923, p. 152-153.) The Last Chance-New York-Volunteer group reported production from 1912 to 1915 (Henderson, 1913, p. 688; Henderson, 1914, p. 263; Henderson, 1916, p. 293; Henderson, 1917, p. 459-460). Production figures were not listed.

Ten employees mined 400 tons/month averaging $18/ton in 1916. The Last Chance Mine was owned by Last Chance, Del Monte and New York Company and was operated by the D.M. and Chance Mining Company (A.M. Collins, Manager) under a lease. (See Mine Inspector report, March 17, 1916, Colorado Bureau of Mines.)

During 1916 and 1917, ore from the New York-Last Chance-Volunteer group was concentrated at the Humphrey flotation mill (Henderson, 1918, p. 367; Henderson, 1920, p. 833). This mill was located just below the confluence of East and West Willow Creeks.

In 1918 Last Chance Mining Company's property was leased to Delmonte Leasing Company. The following list of sublessees mined on various levels: Pollock and Miller-3rd level, Corlette and Stone-4th level, Bennett-5th level, McLaughlin brothers-6th level, Carpenter-7th level, and Cunningham and Welle-8th and 9th levels. (See Mine Inspector report, May 6, 1918, Colorado Bureau of Mines.)

In 1919 lessees (McLaughlin, Cunningham, and Bennett) again operated the New York, Del Monte, and Chance group. Production averaged 80 tons/month, and a total of 600 tons was shipped, averaging 0.04 oz/ton of gold, 25 oz/ton of silver, and 3% lead. (See Operators Annual Report for 1919-Last Chance Mine; and Mine Inspector report, April 30, 1919, Colorado Bureau of Mines.)

Eight sublessees worked the Del Monte, New York, and Chance group through the 1,450-foot-deep Last Chance Shaft during 1920 (Mine Inspector report, May 11, 1920, Colorado Bureau of Mines).

In 1921 Morgan and Sloan leased from the D.M. Chance Mining Company and sold 320 tons of ore, averaging 20 oz/ton of silver and 3% lead from the Last Chance Mine (Operators Annual Report for 1921-Last Chance Mine, to Colorado Bureau of Mines, April 8, 1922).

The New York-Last Chance-Volunteer group was among the principal producers of the district in 1922 (Henderson, 1925, p. 541).

In 1923 Morgan and Sloan (leasing from D.M. Chance Mining Company) sold 751 tons of ore ($18,025 in silver, $532 in gold, and $974 in lead) from the Last Chance Mine (Operators Annual Report for 1923-Last Chance Mine, to Colorado Bureau of Mines, January 21, 1924). Ore from the Last Chance Mine was dropped to the Wooster Tunnel, where the ore was hauled to the D.&R.G.W. loading bins. The 1,500-foot-deep shaft had 12 levels. (See R.J. Murray, Mine Inspector report, September 14, 1923, Colorado Bureau of Mines.)

The New York-Last Chance-Volunteer group remained among the principal producers of the district throughout 1924 and 1925 (Henderson, 1927b, p. 634; Henderson, 1928, p. 719).

Sublessees (Eric Nelson and Associates) worked the Last Chance Mine again in 1926. Exploration was the primary activity, although a small tonnage of ore was shipped to the smelter. All the ore was trammed through the Commodore Tunnel by horse and mule, and transported by an aerial bucket tram to railroad cars. (See R.J. Murray, Mine Inspector report, May 13, 1926, Colorado Bureau of Mines.)

In 1927 the Morgan and Sloan Leasing Company drove 300 feet of drifts and raises on the New York-Last Chance-Volunteer group, and the group was among the principal producers of the district (Henderson, 1930, p. 556).

During 1928 ore was mined on various levels, dropped through the Last Chance Shaft to the Nelson Tunnel, where it was transported by jig-back tram to railroad cars. (See R.J. Murray, Mine Inspector report, January 30, 1928, Colorado Bureau of Mines.) About 110 feet of crosscuts, 70 feet of raises, and 240 feet of drifts were driven in the New York-Last Chance-Volunteer group (Henderson, 1931, p. 850).

In 1929 the P. and E. Lease Company (Herman Emperius, Manager) abandoned work in the P. and E. Tunnel and began work in the Last Chance No. 2 Tunnel on the Pittsburgh vein. P. and E. subleased from Morgan and Sloan. (See R.J. Murray, Mine Inspector report, May 17, 1929, Colorado Bureau of Mines.) About 720 feet of drifts, 90 feet of raises, and 70 feet of winze were driven in the New York-Last Chance-Del Monte group (Henderson, 1932, p. 947).

In 1930, 180 feet of drifts were driven in the New York-Last Chance-Del Monte group. All of the mines in the district closed on June 1 because of low silver prices. (See Henderson, 1933, p. 1067.)

During 1934, the Last Chance Mine was reopened after a 3-year closure. Ore was mined through a series of tunnels, dropped through the Last Chance Shaft to the Nelson Tunnel, hauled by mule to surface bins, and transported over a 600-foot aerial bucket tram to railroad cars. The ore averaged 100 oz/ton silver. Eight employees shipped about 150 tons/month of ore. New development during 1934 included about 400 feet of tunnel and 50 feet of raise. Last Chance Mining and Milling Company owned the mine, which was operated by Emperius Mining Company under sublease from William Sloan and Company (William Sloan, Manager). (See R.J. Murray, Mine Inspector reports, February 26, 1934, and July 19, 1934, Colorado Bureau of Mines; Operators Annual Report for 1934-Last Chance Mine, to Colorado Bureau of Mines, January 16, 1935.)

The Del Monte-Last Chance-New York-Pittsburgh group recorded production in 1935 and 1936 (Henderson, 1936, p. 263; Henderson and Martin, 1937, p. 328).

About 250 tons/month were shipped in 1937 (R.J. Murray, Mine Inspector report, June 9, 1937, Colorado Bureau of Mines). About 513 feet of drifts and crosscuts were developed. Total production for 1937 was 1,938 dry tons averaging $29.23/ton ($56,661 total value) containing 39 oz/ton silver and 2.44% lead. (See Operators Annual Report for 1937-Last Chance Mine, to Colorado Bureau of Mines, February 10, 1938.) The New York-Last Chance-Del Monte-Pittsburgh group was part of a larger group of mines that completed an ore-purchase agreement with Creede Mills, Incorporated. Creede Mills built a 100-ton/day flotation mill 1 mile south of Creede. (See Henderson and Martin, 1938, p. 271.) Last Chance Mining Company owned the mine, which was operated under lease by Emperius Mining Company (R.J. Murray, Mine Inspector report, June 9, 1937, Colorado Bureau of Mines). Presumably, Emperius Mining Company operated the mine in 1935 and 1936, too, but no verifying records were located.

About 125 tons/month were shipped to the Creede Mill from the 1,500-foot-long Last Chance No. 2 Tunnel in 1938. Last Chance Mining and Milling Company leased the mine to the operators, G.K. and R.G. Munsell. (See R.J. Murray, Mine Inspector report, June 26, 1938, Colorado Bureau of Mines.)

In 1939 the Del Monte-New York-Last Chance-Pittsburgh group reported production. Emperius Mining Company operated the mines under a sublease from Morgan and Sloan. (See Henderson and Martin, 1940, p. 273.)

From 1941 to 1944, Emperius Mining Company produced from the Last Chance Mine (Henderson and Martin, 1943, p. 307; Henderson, 1943, p. 336; Henderson, Mote, and Cushman, 1945, p. 332; Mote, 1946, p. 318).

It appears that significant underground production at the Last Chance Mine ended in 1944. After 1944 any minor production from the mine would probably have been lumped into the Emperius Mine reports.

In 1972 Minerals Engineering Company leased Emperius Mining Company's properties near Creede Mine (Kuklis, 1974, p. 155). The lease probably included the Last Chance Mine.

In 1973 Minerals Engineering, apparently in partnership with Statesman Mining Incorporated, improved the roads to the Commodore and Chance Mines in order to ship 400,000 tons of stockpiled ore (Kuklis, 1976, p. 142). The "stockpiled ore" was probably waste rock from previous generations of mining. Minerals Engineering was the operator when about 41,000 tons of the 400,000 tons of dump of the Last Chance/Amethyst Mine were processed, ending in October 1976. (See Information report-Emperius Mine and Mill, December 30, 1976, Colorado Bureau of Mines; unpublished documents provided by Hecla Mining Company to USFS.)

In 1974 Minerals Engineering Company acquired Statesman Mining's interest in the Emperius Mine, which probably included the Last Chance Mine (Smith, 1977, p. 151). From the early 1970s until at least 1991, the leases, subleases, etc., regarding the Last Chance Mine apparently are identical to those discussed previously involving the Amethyst Mine.

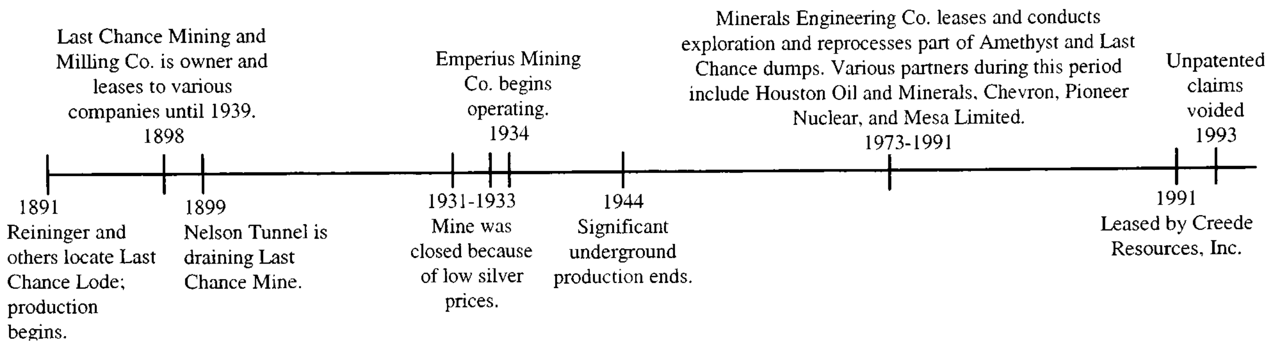
In 1979, Chevron excavated some trenches on the dump of the Last Chance for bulk sampling (unpublished documents provided by Hecla Mining Company to USFS).

About 1,700 feet of new exploration drifts were driven on the Last Chance No. 2 level in 1980, and some of the material was shipped for bulk sampling and processing (unpublished documents provided by Hecla Mining Company to USFS).

As of September 1998, several companies and individuals owned the patented claims that include the Amethyst and Last Chance Mines and the vicinity. Owners included Commodore Mining Company, Creede Mines, Last Chance Mining and Milling Company, Fairview Land Corporation, Martha Johnson, Mary Patrick, and Debra Stevens. (See Mineral County courthouse records.)

Kanawha Mines, Limited, (a company owned by Ben and Ty Poxson according to John Jackson, personal communication with Les Dobson, USFS, March 1999) and Creede Mines owned some unpatented claims near the Amethyst and Last Chance patented claims as recently as 1992. These claims were voided in 1993. Before abandonment, the claims were evidently leased to Creede Resources Incorporated, a subsidiary of Hecla Mining Company. (See BLM files.)

Timeline summarizing highlights in the mining history of the Last Chance Mine



Geology

The Last Chance Mine was driven on the Amethyst vein and associated hanging-wall veins and is adjacent to the south side of the Amethyst Mine (Figure 1). The geology at the Last Chance Mine is similar to that of the Amethyst Mine. A few noteworthy exceptions are described below.

At the Nelson Tunnel level (level 13) a hornblende quartz latite porphyry dike is exposed in the hanging wall of the Amethyst vein (Emmons and Larsen, 1923, p. 154).

As noted in the geology description of the Amethyst Mine, the mineralized hanging wall fractures are closely spaced. At the Last Chance Mine, a zone about 100 feet wide and extending from level 2 to level 6 was mined as a unit called the "Big Cave". The zone included six closely spaced hanging-wall veins and highly silicified and sericitized rocks between them. This rich ore was so soft and decomposed that it was mined without blasting. (See Emmons and Larsen, 1923, p. 155; Steven and Ratté, 1965, p. 71-72.)

Site Description

This site was not accessed during the present investigation. A cursory visual examination revealed that much of dump #200 lies on private land, although a considerable volume rests on a "peninsula" of USFS-administered land between U.S.L.M. 7333 and West Willow Creek. The toe of the dump extends to West Willow Creek (USFS-AMLIP inventory form #09-04-329/4194-1).

Waste and Hazard Characteristics

During the inventory, dump #200 was estimated to be about 3,000 feet long, 1,000 feet wide, and contain 50,000 cubic yards of waste rock. The volume of waste rock may be underestimated because other estimates of the combined volumes of the Amethyst and Last Chance Mine dumps are about 400,000 tons (which is about 250,000 cubic yards), as discussed in the Mining History sections regarding these mines. The face of the dump is extremely steep and potentially unstable. The toe of the dump extends into West Willow Creek, and fragments of mineralized rock containing galena, pyrite, and sphalerite lie in the creek adjacent to this feature. (See Kirkham, 1993, p. 9.) Efforts as late as the 1970s to process this dump indicate that it contains significant volumes of mineralized rock.

Kirkham (1993, p. 9) tested the water in West Willow Creek above and below this feature. Upstream of dump #200, pH was 7.71 and conductivity was 92 μS. Downstream of the dump, but above the Amethyst No. 5 waste-rock pile described in the previous section (dump #201, inventory area #09-04-330/4192-1), pH was 7.83 and conductivity was 85 μS. Test results suggest that despite the presence of mineralized rock in the active stream channel of West Willow Creek, degradation is not significant.

No water samples are known to have been collected between this feature and the Amethyst No. 5 dump. Any degradation resulting from this site would be difficult to screen out from degradation associated with the Amethyst No. 5 (dump #201) described previously. The area disturbed by mining is virtually continuous between these sites.

Migration Pathways

Because of their proximity and similarity in mineralogy and placement adjacent to the creek, the pathways for this waste-rock pile are the same as for the Amethyst Mine waste-rock pile, discussed in the previous section. These pathways are not repeated here.

MIDWEST MINE

The Midwest Mine (inventory area #09-04-330/4195-2) is located along Nelson Creek, about ¾ mile above its confluence with West Willow Creek (Figure 1). This property has also been called the Gateway Mine and Colewood Mine. The area of environmental concern at this site lies entirely on USFS-administered land.

Mining History

The Midwest Mine has no recorded production despite considerable underground development.

No records describing this property prior to 1923 were located, but an adit symbol is on the map published in 1923 by Emmons and Larsen (1923, plate 1). Because most of the Emmons and Larsen field work was done in 1911 and 1912, it is likely that the adit was at least started by 1911.

An adit at this property was driven about 60 to 90 feet from 1920 to 1926. The portal was near the site of the present-day ventilation shaft, and the mine was called the Colewood Tunnel. (John Jackson, personal communication with Les Dobson, USFS, March 1999.) In the early and middle 1920s the Colewood Tunnel was owned by Elwood Neff and Pearl Neff (Larsen, 1930, p. 98).

In 1923 two men worked the Midwest Mine (Resurrection Tunnel?). The 4-foot by 6-foot tunnel was about 1,600 feet long. (See R.J. Murray, Mine Inspector report, August 14, 1923, Colorado Bureau of Mines.) In 1925, five men worked the Midwest Mine (Resurrection Tunnel?), which was 2,000 feet long (R.J. Murray, Mine Inspector report, February 7, 1925, Colorado Bureau of Mines). These reports from 1923 and 1925 probably refer to the Resurrection Tunnel (Figure 1), east of Creede and also owned by Midwest Mining Company. (John Jackson, personal communication with Les Dobson, USFS, March 1999.)

Midwest Mining Company, an Illinois company, operated the mine from 1926 to 1929 and drove more than 1,000 feet of workings. This company went out of business in 1929. About 5,000 tons of material were placed on the dump during the late 1920s. Because much of this drifting was along the vein, this material is more mineralized than the surrounding country rock, but is subeconomic in grade. (John Jackson, personal communication with Les Dobson, USFS, March 1999.)

By 1929 the Midwest Mine was about 1,100 feet long according to maps provided to Larsen (1930, p. 98-99).

In 1941 the Gateway claims, which include the Midwest Mine, were staked by E.J. Dabney and John Van Buskirk (BLM files).

From 1945 to 1958, the Gateway Mine (formerly known as the Midwest Mine) was owned and operated by John Van Buskirk, Verne Miller, and Emmett Dabney. In the summer of 1950 an ore zone 60 feet above the tunnel on a 70° incline, and 700 feet from the portal, was stoped. This ore was not mined, so much as caved. This part of the vein is soft gouge that continually caved and was removed. About 50 tons of this material, which was the most mineralized rock ever extracted from the mine, was buried in the dump between the ventilation shaft and the outhouse. (See J. Dole, Mine Inspector report, October 5, 1950, Colorado Bureau of Mines; John Jackson, personal communication with Les Dobson, USFS, March 1999.)

From 1958 to 1968, John Jackson was the owner/operator (John Jackson, personal communication with Les Dobson, USFS, March 1999).

In 1968, two employees were staking claims and attempting to reopen the mine. New Midwest Mining Company (R.L. Wahl, Jr., President; A.R. Phillips, Vice President; C. Kirk, Secretary; A.N. Hawa, Treasurer; J.R. Jackson, Manager), also known as Gateway Access Corporation, operated the mine. (See Operators Annual Report for 1968-Midwest Mining Ltd., to Colorado Bureau of Mines, January 28, 1969.) CF&I Steel Corporation directed and funded the operation (John Jackson, personal communication with Les Dobson, USFS, March 1999).

During 1969 four employees conducted exploration work and drove a 176-foot crosscut from the main 1,750-foot tunnel. The mine was owned by New Midwest Mining Ltd. and operated by Gateway Access Corporation, John R. Jackson, Manager. (See Mine Inspector report, November 11, 1969, Colorado Bureau of Mines.) The New Midwest Mining Corporation owned eight patented claims (Mineral Survey No.'s 7386, 16300, and 16305) and 24 unpatented claims (Gateway and Gateway No. 1-32). C. Kirk, Secretary of New Midwest Mining, was listed as representing CF&I Steel Corporation, a partner in this project. (See Operators Annual Report for 1969-Midwest Mining Ltd., to Colorado Bureau of Mines, January 30, 1970.)

In 1970 exploration and development continued at the Midwest Mine. Drifting was continued for 1,000 feet. At the time of the inspection, a drill rig was setting up to drill a 750-foot-long angled hole from the surface in an effort to test the vein about 300 feet below the surface. (See Mine Inspector report, October 16, 1970, Colorado Bureau of Mines.) The drilling revealed soft vein material that was difficult to recover in cores. Another drill hole, 1,000 feet deep, encountered a breccia zone cemented with galena and sphalerite. Core presently stored at the Midwest Mine were extracted by Houston Oil and Minerals, CF&I, and Minerals Engineering Company during various exploration efforts. (John Jackson, personal communication with Les Dobson, USFS, March 1999.) In 1970 Gateway Access Corporation was listed as the operator, and New Midwest Mining Ltd. was listed as owner. (See Mine Inspector report, October 16, 1970, Colorado Bureau of Mines; Operators Annual Report for 1970-Midwest Mining Ltd., to Colorado Bureau of Mines, January 5, 1971.)

From 1968 to 1972, Gateway Access Corporation drove a 2,500-foot-long adit at the site of the present portal. This newer adit has rails and paralleled the vein and the old adit for about 1,200 feet, with two crosscuts driven to intersect and test the vein. Because most of this adit was driven in relatively barren country rock, the county used much of the material removed during this phase of mining as road fill material. (John Jackson, personal communication with Les Dobson, USFS, March 1999.)

In the late 1970s, Houston Oil and Minerals did some drilling at the property, mostly about ½ mile north of the portal (John Jackson, personal communication with Les Dobson, USFS, March 1999).

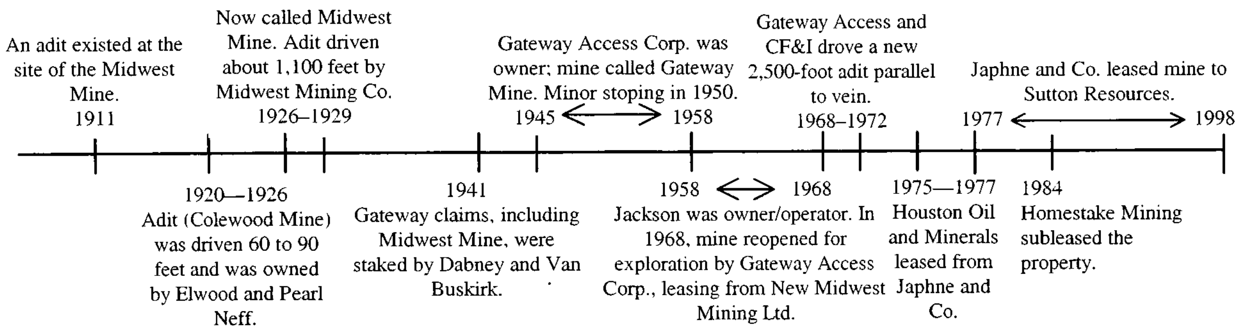
As of 1982, rehabilitation of the mine workings was complete, and geophysics and drilling confirmed vein extensions and discovered additional, previously unknown veins (Metals Economics Group, 1984, p. 47).

From the late 1970s until 1998, Sutton Resources and Homestake Mining apparently only did assessment work at the site (John Jackson, personal communication with Les Dobson, USFS, March 1999).

From sometime in the 1970s until 1998, Japhne and Company of Denver (a general partnership owned by John and Inez Jackson, Allan and Clara Phipps, and Cole Neff) owned the Gateway claims, including the Midwest Mine. Houston Oil and Minerals Corporation of Denver leased the property from 1975 to 1977. Sutton Resources Limited, possibly a subsidiary of Crown Resources Corporation, leased the property from 1977 to 1998. (See BLM files; John Jackson, personal communication with Les Dobson, USFS, March 1999; (Metals Economics Group, 1984, p. 46.)

In 1998, Japhne and Company was dissolved, and John Jackson transferred his interest to Clara Phipps. (John Jackson, personal communication with Les Dobson, USFS, March 1999; BLM files.)

Timeline summarizing highlights in the mining history of the Midwest Mine



Geology

The vein explored by the Midwest Mine strikes N.46°W., dips 70°NE., and is hosted in Campbell Mountain rhyolite. The vein lies within a zone of gouge and fractured, altered host rock. Near the portal, the vein comprises white gouge with limonite stains. Deeper underground, the fracture zone includes dark streaks of sulfide-rich breccia that occasionally extend into the hanging wall. One of these breccia zones is nearly continuous for the length of the adit, varying from a few inches to a foot in width. This dark breccia zone contains brecciated and altered rhyolite fragments cemented with galena, sphalerite, chalcopyrite, pyrite, and anglesite. (See Larsen, 1930, p. 99.)

Site Description

The most important feature of environmental concern at this site is a large waste-rock pile that covers much of the valley floor of Nelson Creek. At this location, the Nelson Creek stream valley is relatively wide. In June and September of 1998, Nelson Creek had no surface flow above the dump, but a pond adjacent to the dump on the east was filled with water, and a seep emerged from near the toe of the dump (Figure 2). None of the water showed visible evidence of degradation. The dry streambed of Nelson Creek and erosional features such as rills suggest that surface water intermittently flows over the waste-rock pile.

The waste-rock pile (dump #202) has two tiers, is about 300 feet long by 100 feet wide, and contains about 4,000 cubic yards of material (USFS-AMLIP inventory form #09-04-330/4195-2). Much of the dump is composed of bleached light gray, argillic- and phyllic-altered volcanic rock with moderate amounts of finely disseminated pyrite. Relatively fresh, unaltered volcanic rocks also occur.

Buildings on the site appear to be relatively modern compared to most buildings in the Creede mining district. Tracks coming from the portal split. The eastern branch leads to a maintenance building, and the longer western branch extends onto the dump. A ventilation pipe for the adit and a core shack lie west of the portal.

Waste and Hazard Characteristics

According to John Jackson (personal communication with Les Dobson, USFS, March 1999), acidic water is pooled underground in the caved workings of the Midwest Mine, but the adit does not discharge, and the volume of water must be small. Also, Mr. Jackson reports that the most mineralized dump material comprises 50 tons of gouge and vein material that was removed in about 1950 and buried in the dump between the ventilation shaft and the outhouse. Trenching would be required to locate and characterize this mineralized rock. Because the most recent drifting paralleled the vein, material removed during the mining in the late 1960s and early 1970s is considerably less mineralized than the material removed in the 1920s. The county used much of the most recent generation of waste rock as fill material on roads (John Jackson, personal communication with Les Dobson, USFS, March 1999).

During the present investigation, a composite sample was collected from about 600 feet of the road on the eastern side of the mine. This part of the road is apparently constructed of dump material. The sampled area extends from the culvert north of the mine to the pond east of the

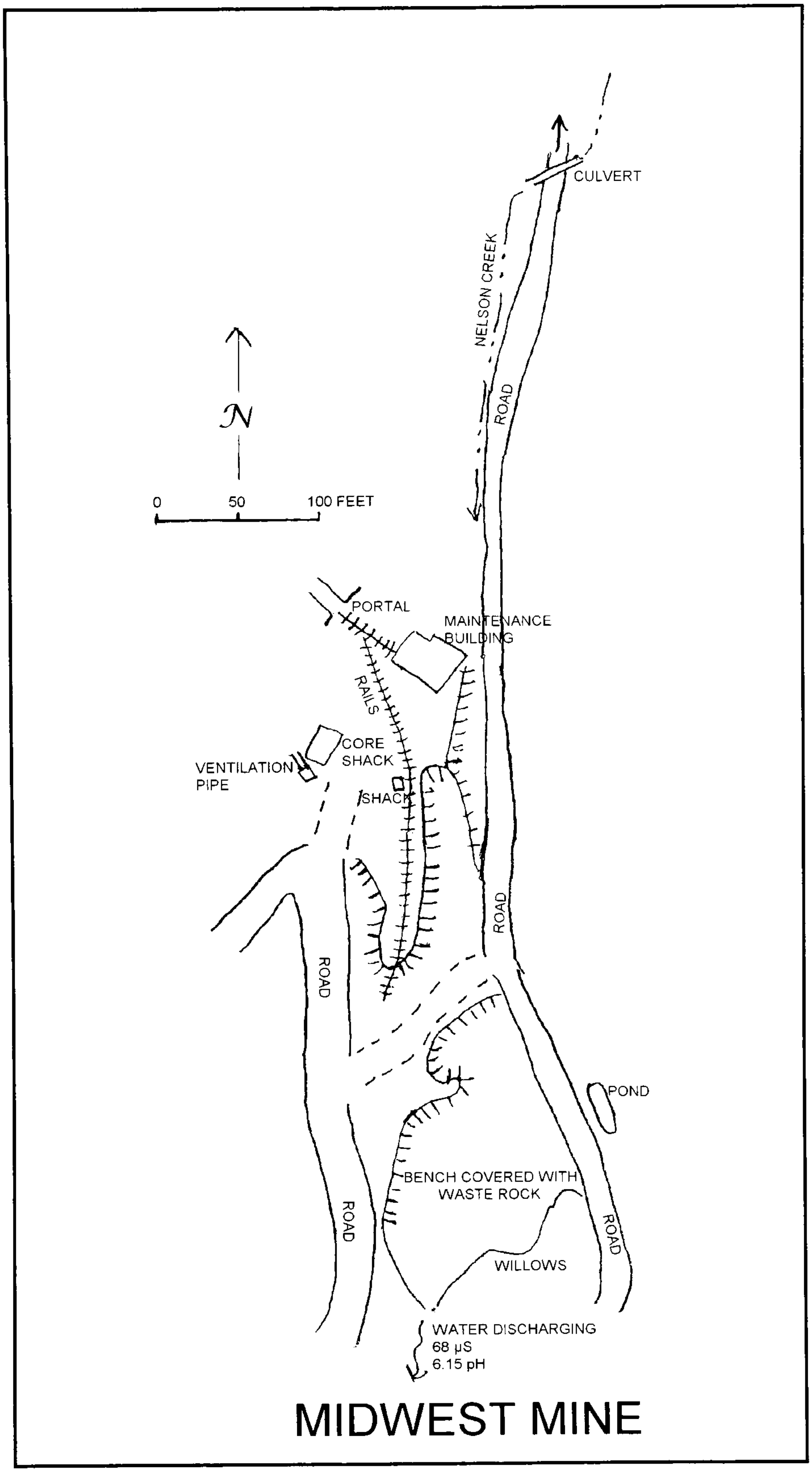


Figure 2. Surface map of the Midwest Mine.

road adjacent to the lower tier of the dump (Figure 1). Previously, CDPHE had collected two samples from the dump and three stream-sediment samples from Nelson Creek (O'Grady, 1997). Sample results indicate that the material on the road is similar in composition to the waste rock (Table 4). Both are slightly mineralized. The road material, and probably the waste rock too, have acidic compositions that may increase acidity in Nelson Creek, especially during snowmelt and precipitation events. In the sediments, arsenic shows a dramatic increase, and copper and lead concentrations increase significantly immediately below the mine. Some of these effects are diluted prior to Nelson Creek joining West Willow Creek (Table 4).

Surface water at and near this site has been tested and sampled several times. Kirkham (1993, p. 9) tested the water of Nelson Creek. His tests showed pH of 6.4 above the mine and 3.6 below the dump. Conductivity rises from 39 μS above the mine to 133 μS below the dump. Water in the ponds east of the Nelson Creek Road and southeast of the mine yielded similar test results as Nelson Creek above the mine. During the present investigation in September 1998, water emerging into the willows just below and south of the toe of the dump had pH of 6.15 and conductivity of 68 μS (Figure 2).

Water sample results suggest that the water of Nelson Creek immediately below the Midwest Mine is significantly degraded compared to water above the mine with respect to pH, arsenic, cadmium, cobalt, copper, iron, lead, manganese, and zinc (Table 5). The sample from below the mine may be from standing water because no flow was recorded. A long residence time and evaporation may account for the high metal content and low pH in the sample. By the time Nelson Creek reaches West Willow Creek about 0.75 mile downstream, most of these effects have been diluted and/or some of the metals have precipitated. Because of the moderate metal concentrations and the low flow, metal loads at the mouth of Nelson Creek are minor compared to West Willow Creek.

Migration Pathways

Groundwater Pathway

Although the older and caved adit reportedly contains acidic water, this water does not discharge, and the volume must be small. The Midwest vein probably crosses the valley of Nelson Creek at about the location of the dump. Although this vein may be a conduit for groundwater to discharge into the alluvium of the valley, the vein consists of abundant gouge, which is often impermeable. The small amount of water reported in the underground workings is supporting evidence that this vein system is not a major influence in the groundwater system. (John Jackson, personal communication with Les Dobson, USFS, March 1999.)

The closest registered well for household use is about 0.75 mile southwest of the Midwest Mine on the slope above the Happy Thought Mine. The well was sunk at an elevation of about 10,500 feet and is less than 90 feet deep (Colorado Division of Water Resources records, 1999). The well is not in hydrologic communication with the Midwest Mine.

Table 4. Analytical results for stream-sediment samples from Nelson Creek, waste-rock samples from the Midwest Mine dump, and the sample from the Nelson Creek Road. [Results are in ppm unless noted; blank spaces indicate the parameter was not analyzed. Sediment and dump samples are reported in O'Grady (1997).]

Parameter	Sediment above Midwest Mine	Sediment below Midwest Mine	Sediment just above West Willow Creek	Road on east side of Midwest Mine (composite)	Midwest Mine dump - north	Midwest Mine dump - south
pH				4.23		
Neutralization potential				<0.1 tons $CaCO_3$/1,000 tons		
Potential acidity				3.0 tons $CaCO_3$/1,000 tons		
Net acid-base potential				-3.0 tons $CaCO_3$/1,000 tons		
Al_2O_3				0.27%		
CaO				0.03%		
Fe_2O_3				0.85%		
K_2O				0.18%		
MgO				0.02%		
Na_2O				<0.01%		
Sulfur				0.17%		
Aluminum	2,420	1,170	2,780		981	978
Antimony	1.50	8.20	1.40	23	10.40	12.10
Arsenic	12.80	165.00	82.40	185	222	222
Barium	86.70	34.30	52.90	88	16.40	14.10
Beryllium	0.45	<0.20	<0.35	<1	<0.11	<0.04
Bismuth				<50		
Boron				<5		
Cadmium	0.08	<0.08	0.13	<5	<0.19	<0.51
Calcium	1,680	288	1,140		<26.00	<18.40
Chromium	<0.86	<0.48	<1.00		0.45	0.33
Cobalt	2.50	0.43	1.90	<10	<0.37	<0.66
Copper	2.30	18.90	11.60	11	4.60	6.50
Gold				0.004		
Iron	3,860	5,670	5,260		6,110	8,480
Lead	13.00	310.00	88.50	365	121	169
Lithium				<1		
Magnesium	508	102	477		24.50	21.10
Manganese	441	59.90	285	46	2.20	2.20
Mercury	<0.11	<0.12	<0.12	0.54	<1.20	1.60
Molybdenum				18		
Nickel	0.70	<0.37	0.54	3	<0.30	<0.29
Phosphorus				150		
Potassium	862	519	675		1,210	1,300
Selenium	<1.10	<1.20	<1.30	<50	<0.95	1.10
Silver	<0.12	0.25	1.80	2.0	5.50	8.90
Sodium	177	229	252		232	218
Strontium				7		
Thallium	<1.10	1.90	<1.40	<100	15.20	23.70
Tellurium				<50		
Tin				<50		
Titanium				18		
Tungsten				<20		
Vanadium	6.90	3.60	4.60	4	1.60	0.97
Zinc	22.40	28.50	36.80	156	47	128

Table 5. Water sample results for Nelson Creek near the Midwest Mine. [Results are shown in dissolved concentrations and µg/L unless noted. Blank columns indicate the parameter was not analyzed or the results are not known. The 1990 samples are reported in O'Grady (1995a), and the remaining samples were collected in late May or early June, 1995, and are reported in O'Grady (1997).]

Analyzed or tested parameter	Nelson Creek below Midwest Mine, 4/12/90	Nelson Creek above W. Willow, 4/12/90	Nelson Creek above Midwest Mine, 1995	Nelson Creek below Midwest Mine, 1995	Nelson Creek above W. Willow, 1995
Flow (cfs)		0.03	0.48		0.86
pH			6.98	3.99	7.25
Conductivity			48 µS	100 µS	32 µS
Total suspended solids			7 mg/L	40 mg/L	6 mg/L
Hardness			15.81 mg/L	18.22 mg/L	16.18 mg/L
Alkalinity			18.20 mg/L	<10.00 mg/L	<10.00 mg/L
Aluminum	2,500		248 2,260 (trec)	1,580 2,630 (trec)	<136 1,280 (trec)
Antimony			<1.90 (both)	<1.90 (both)	<1.90 (both)
Arsenic			<3.20 (both)	8.20 61.20 (trec)	<3.20 10.10 (trec)
Barium			21.60 36.20 (trec)	20.80 25.20 (trec)	22.10 28.30 (trec)
Beryllium			<0.27 (both)	<0.76 (both)	<0.461 (both)
Cadmium	2.9	1.8	<0.30 (both)	2.00 (both)	0.58 <0.40 (trec)
Calcium			5,040 5,230 (trec)	5,840 6,080 (trec)	5,070 5,460 (trec)
Chloride			<3.00 mg/L	<3.00 mg/L	<3.00 mg/L
Chromium			<0.90 2.10 (trec)	<0.90 0.91 (trec)	<0.90 (both)
Cobalt			<0.60 (both)	2.30 (both)	<0.60 0.61 (trec)
Copper	40	19	<0.70 0.82 (trec)	34.80 38.70 (trec)	3.00 5.80 (trec)
Fluoride			<0.10 mg/L	<0.10 mg/L	<0.10 mg/L
Iron	3,500	370	73.40 783 (trec)	2,890 4,420 (trec)	33.20 809 (trec)
Lead	16	7	<1.90 2.50 (trec)	10.70 19.70 (trec)	<1.90 4.50 (trec)
Magnesium			467 668 (trec)	617 739 (trec)	505 619 (trec)
Manganese	130	510	1.50 20.70 (trec)	68 77.50 (trec)	38.60 46.30 (trec)
Mercury			<0.20 (both)	<0.20 (both)	<0.20 (both)
Nickel			<1.40 (both)	<1.40 1.50 (trec)	<1.40 (both)
Potassium			903 1,250 (trec)	905 1,080 (trec)	861 986 (trec)
Selenium			<4.40 (both)	<4.40 (both)	<4.40 (both)
Silver	0.2		<0.50 (both)	<0.50 (both)	<0.50 (both)
Sodium			1,580 1,880 (trec)	1,600 1,880 (trec)	1,760 2,010 (trec)
Sulfate			3.80 mg/L	3.80 mg/L	4.54 mg/L
Thallium			<4.50 (both)	6.50 <4.50 (trec)	<4.50 (both)
Vanadium			0.99 1.90 (trec)	0.54 1.50 (trec)	0.82 0.60 (trec)
Zinc	320	220	<3.20 <10.00 (trec)	149 157 (trec)	32.50 42.10 (trec)

Similarly, registered wells in Windy Gulch about 2 miles south-southwest, and three wells in and near North Creede about 2.5 miles south-southeast, are not hydrologically connected to the Midwest Mine.

Because small-yield wells, typical of household use, had no requirements for registration prior to 1972, some unregistered wells probably exist in the town of Creede. These wells likely draw from the surficial aquifer of Willow Creek. Surface water in Willow Creek is highly degraded with metals related to past mining activities, and the surficial aquifer may be degraded to a similar extent. The Midwest Mine contributes only small amounts of metals into the surface water of West Willow Creek (see discussion below) and probably has no measurable effect on the Willow Creek surficial aquifer nearly 4 miles downstream in Creede.

Surface Water Pathway

Surface water in Nelson Creek is moderately degraded downstream of the waste-rock pile at the Midwest Mine. Most of the year, surface flow of Nelson Creek near the Midwest Mine is small, probably less than 50 gpm. However, during thunderstorms and the peak of snowmelt, surface flow is higher. During this investigation in September 1998, Nelson Creek had no surface flow immediately above the mine, but water apparently flowing beneath the alluvium at a small rate emerged below the dump of the Midwest Mine. Kirkham (1993, p. 9) estimated the surface flow of Nelson Creek above the mine at about 10 gpm in late May of 1992. In June of 1995, during a period of significant snowmelt, Nelson Creek just above the Midwest Mine had a measured flow of about 200 gpm or less than 0.5 cfs (Table 5). Because of the low flows and moderate metal concentrations in Nelson Creek most of the year, loading into West Willow Creek is minor. During precipitation events and snowmelt, loading to West Willow Creek probably increases, but is still insignificant compared to the loads carried in West Willow Creek.

Fish do not live in West Willow Creek below the Amethyst Mine because of dissolved metals in the water and habitat destruction associated with past mining activities (O'Grady, 1997, p. 6). Although this area includes the confluence of Nelson Creek with West Willow, metals from Nelson Creek are only small contributors to stream toxicity.

Soil Exposure Pathway

No one lives within about 2 miles of this site, and no one is currently working there. This mine is easily accessed by roads and is part of a self-guided 4WD tour of the mountains north of Creede. Although numerous people drive by this feature during the summer, few get out of their vehicles and walk around the site. In any event, exposure times are short, and metal concentrations on the dump are low. The soil exposure pathway is not considered a significant risk.

Air Exposure Pathway

Because of short exposure times and low metal concentrations, this pathway is considered a minimal risk.

SOLOMON MINE

The Solomon Mine (inventory area #09-04-331/4194-2) is about 2 miles north of Creede along East Willow Creek (Figure 1). This site is almost entirely on private land, but water draining from the Solomon Mine enters East Willow Creek, which flows onto USFS-administered land about 600 feet downstream. The Solomon is one of the oldest mines in the Creede area, but it was not a major producer compared to the Commodore/Amethyst Mines or Bulldog Mine. The portal of the Solomon Mine is probably on the Ethel Mill-Site patented claim, Mineral Survey No. 13049.

Mining History

The Solomon-Holy Moses vein was discovered by N.C. Creede in 1889 (Emmons and Larsen, 1923, p. 175). C.F. Nelson located the Solomon lode claim in 1890 (Henderson, 1926, p. 56). When Mineral Survey No. 6837 was conducted on the Solomon, Mexico, Hiram, Senator Farwell, and General Mahone lodes on January 27, 1891, the claims were owned by Thomas M. Bowen (Mineral Survey No. 6837, available at the Bureau of Land Management, Colorado State Office).

The Solomon Mine was a major producer throughout the 1890s (Steven and Ratté, 1965. p. 8). In 1898, H.C. Rowley of Creede was a partner (Mining Reporter, v. 38, September 1, 1898, p. 18).

In 1899 the concentrating mill on the Solomon and Ethel properties had a 60-ton/day capacity and employed jigs and Wilfley tables for separation of the lead and zinc. Their zinc product was consigned to the smelters of Kansas, Missouri, and Illinois. Reported production from the Solomon and Ethel properties was 2,600 tons containing 7,020 oz of silver; 342.5 oz of gold; 1,092 tons of lead; and 650 tons of zinc. (See Hodges, 1900, p. 110-112.)

In 1901 the Solomon and two other lead-zinc mills in the area commanded the best prices in Colorado for their concentrates (Hodges, 1902, p. 123-127).

From about 1899 to 1901, C.S. Abbott owned the Solomon Mine and mill. In two years he made enough profit to pay for the mine and adjacent mill. (See Denver Times, December 4, 1901, p. 11.)

In 1902 East Willow Mining Company developed the mines on Campbell Mountain. Large quantities of ore were blocked out on the Solomon, Ethel, and Moses claims along the Solomon-Holy Moses vein system. A 50-ton/day concentrating mill worked 24-hours/day and produced about 7 tons of zinc and 8 tons of lead, both of excellent grade. The company planned on doubling the capacity of the mill. (See Downer, 1903, p. 108-110.)

During 1904 the Solomon Mill operated at a 60-ton/day capacity (Downer, 1905, p. 118).

In 1905 working levels at the King Solomon Mine were accessed through a 300-foot-deep inclined winze, 400 feet from the portal (Lindgren, 1906, p. 205). This winze eventually reached a depth of more than 400 feet with four levels and exposed the most productive part of the Solomon vein (Emmons and Larsen, 1923, p. 177). The King Solomon Mine was listed as an important producer, and the King Solomon Mill was recovering zinc, lead, silver, and gold (Waldemeyer, 1906, p. 205).

During 1906 the 75-ton/day Solomon Mill recovered rich lead-zinc concentrates from sulfide ores. The ore also contained some gold and silver. (See Naramore, 1907, p. 225.)

The last major production was 1907, when $150,000 worth of ore was produced from the vein system, mostly from the Solomon Mine (Steven and Ratté, 1965. p. 9).

Through about 1912, the Solomon-Holy Moses vein system had produced about $1,000,000 of ore, mostly through the Solomon Mine. The adit was a 400-foot-long crosscut to the vein system. Drifts extended north for about 3,000 feet along two veins. Three levels were extensively developed. The most productive part of the Solomon Mine was a 420-foot-deep, 4-level winze that was flooded by 1912. Although exact dates are not given, about 1912 the Solomon claim was owned by the King Solomon Mining Company (Emmons and Larsen, 1923, p. 175-177.)

The Solomon-Holy Moses Mine produced in 1913, and the ore was concentrated prior to shipping (Henderson, 1914, p. 263).

The Solomon Mine reported production in 1916 (Henderson, 1918, p. 367).

The Solomon Mine did not produce in 1917. Development work included 75 feet of shaft. (See Operators Annual Report-Solomon Mine, to Colorado Bureau of Mines, January 28, 1918.) Henderson (1920, p. 833) reports the Solomon as a producer, contradicting the Operator's report.

No production was reported in early 1918. Development work included 40 feet of shaft and 317 feet of drift. (See Operators Annual Report-Solomon Mine, to Colorado Bureau of Mines, February 3, 1919.) Work was in the Solomon or Lockridge winze, 420 feet below the tunnel level and 4,000 (400?) feet from the portal. Miners were repairing timbers and pumping water from the winze. (See Mine Inspector report-Solomon Mine, July 26, 1918, Colorado Bureau of Mines.) In June 1918, lessees intended to remove the pillar around the shaft. The mine was dewatered to the 3rd level, and 35 feet of drift was driven on the 2nd level. Later in 1918 or early in 1919, several cars of ore were shipped after treatment in the mill located on the property. (See Mine Inspector report-Solomon Mine, May 1, 1919, Colorado Bureau of Mines.)

From sometime in 1917 to April 1918, the American Smelting and Refining Company (Daniel Guggenheim, President, and J. Gordon Hardy, Manager) leased the Solomon, Ethel, Holy Moses, Cliff, and Ethel Mill Site. C.M.S. Mines Company (Consolidated Moses Solomon) owned these claims. (See Operators Annual Reports for 1917 and 1918-Solomon Mine, to Colorado Bureau of Mines, January 28, 1918, and February 3, 1919.) Later in 1918, C.M.S. Mines Company leased all of the ground on the Solomon vein below the Ethel Tunnel level to the Solomon Leasing Company (Frank Ullman, President and Manager) (Mine Inspector report-Solomon Mine, July 26, 1918, Colorado Bureau of Mines).

In early 1919 lead-zinc ore from the Solomon-Ethel claims was milled at the Solomon 25-ton/day concentration mill (Henderson, 1922a, p. 778). Mill capacity differs from previous descriptions, but perhaps the mill only operated part time, rather than 24-hours/day as mentioned for 1902.

C.M.S. Mines Company leased the Solomon, Ethel, Holy Moses, Cliff, and Ethel Mill Site to H.D. Barnhart (Operators Annual Report for 1919-Solomon Mine, to Colorado Bureau of Mines, April 20, 1920).

By 1922 the mine was a 4.5 foot by 6 foot by 1.25 mile tunnel. A small fissure vein was mined about 200 feet from the portal. The 100-ton/day mill on the property had been idle for 2 or 3 years. (See Mine Inspector report-Solomon Mine, August 27, 1922, Colorado Bureau of Mines.) Work by Ethel Leasing Company (H.D. Barnhart, Manager) included 60 feet of drifts resulting in production of 90 tons of ore averaging 0.20 oz/ton of gold, 2 oz/ton of silver, 25% lead, 12% zinc, and 7% sulfur (Operators Annual Report for 1922-Solomon Mine, to Colorado Bureau of Mines, March 15, 1923). The production may have been from the Ethel Mine; the Operators Report is not clear. C.M.S. Mines Company still owned the property (Mine Inspector report-Solomon Mine, August 27, 1922, Colorado Bureau of Mines).

From 1904 to 1923, when production ceased, the mine produced about $1,000,000 worth of ore (Steven and Ratté, 1965. p. 9).

In 1934 the Consolidated Moses Solomon Mines Company group reported production (Henderson, 1935, p. 224). It is not clear if any of the production originated from the Solomon Mine.

After several years of inactivity, the Solomon Mine was reopened in 1945. It was owned by Solomon Mining Company (Ralph Ellithorpe, agent) and leased to the New Ridge Mining Company (O. B. Helmick, Manager). The adit was getting cleaned up, and a new drift was to be driven around an area of caved stopes. (See R.J. Murray, Mine Inspector report-Solomon Tunnel, April 10, 1945, Colorado Bureau of Mines.) A shipment of 130 tons of sulfide ore came from the Solomon Tunnel. The ore was mined from fissures 30 and 40 feet above the tunnel on the Solomon and Mexico claims and was transported through the Solomon Tunnel. Seven underground and one surface worker were employed. (See R.J. Murray, Mine Inspector report-Solomon Tunnel, July 21, 1945, Colorado Bureau of Mines.)

During 1946 a small fissure of sulfide ore was mined in two stopes above the Solomon Tunnel. Three to eight underground and one or two surface workers were employed. Ore was trucked to the Creede Mill for shipment. The New Ridge Mining Company (O. B. Helmick, Manager) was listed as the operator, but no owner was listed (See R.J. Murray, Mine Inspector reports-Solomon Tunnel, May 7, 1946, and January 8, 1947, Colorado Bureau of Mines.)

In 1947 development work included sinking a 30-foot-deep shaft and completion of the mill house. About 200 tons of ore were shipped, worth $25/ton and averaging 0.08 oz/ton of gold, 3 oz/ton of silver, and 10% lead. Twenty tons were milled, worth $35/ton, containing 0.15 oz/ton of gold, 10 oz/ton of silver, and 19% lead. (See Operators Annual Report for 1947-Solomon Mine, to Colorado Bureau of Mines, January 10, 1948.) By early 1947, New Ridge Mining Company (O. B. Helmick, Manager) was listed as owner and operator of the Solomon Tunnel (Mine Inspector report-Solomon Tunnel, January 8, 1947, Colorado Bureau of Mines).

In 1948 and most of 1949, Paul Davis of Del Norte and Wintz were listed as shippers of ore. In late 1949 and 1951, Wintz, Lehman, and Hosselkus were listed as shippers. (See Salsbury, 1952, Table 1; John Jackson, personal communication with Les Dobson, USFS, March 1999.)

Production figures for 1951 conflict somewhat. Martin (1954, p. 1468) reported that 94 tons of silver-lead ore were mined from the Solomon group in 1951. TOC Development Company (J.M. French, President) produced 214 tons of ore, valued at $2,635.23, from the Mexico, Solomon, and Ethel Mines. The property was worked by lease part of the year and subleased to TOC Development the remainder of the year. C.W. Withrow owned the Mexico Mine, and R.C. Ellithorpe owned the Solomon and Ethel Mines. (See Operators Annual Report for 1951-Solomon Mine, to Colorado Bureau of Mines, February 15, 1952.)

In addition to minor production from the Solomon, during 1950 and 1951, the Rio Grande Mining Company worked the Rio Grande, Maggie, and Wandering Jew (leased from Gerald Hughes) through the Solomon Tunnel (Operators Annual Reports for 1950 and 1951-Rio Grande Mining Company, to Colorado Bureau of Mines, January 18, 1951, and January 29, 1952). No production was reported.

In 1952, TOC Development Company shipped 308 tons of lead-silver-gold ore from the Holy Moses-Solomon-Ethel group (Martin, 1955, p. 235). The ore was trucked to Creede, then sent by rail to the American Smelting and Refining Company smelter in Leadville (MacLaren and Salsbury, 1952, p. 1). The Mexico patented claim was owned by C.O. Withrow of Denver and leased to Allen Hosselkus, Alvin Wintz, and R.R. Lehman of Creede. The Ethel Lode and Mill-site and Solomon Lode patented claims were owned by Alice Hosselkus, Allen Hosselkus, Mrs. T.W. Rafter, Mrs. Pearl Moody, Alex Duncan, R.C. Ellithorpe, J.J. Williams, and Wallace Wright. All of these claims are part of the Solomon Mine and were leased to TOC Development Company, apparently owned by Allen Hosselkus, Wintz, and Lehman. (See Salsbury, 1952, p. 6-7.)

Despite the heightened activities and interest in the site, the Solomon Mine produced less than $20,000 worth of ore from 1950 through 1952 (Steven and Ratté, 1965. p. 11).

A production record for the Solomon group is shown in Salsbury (1952, Table 2). Some years the production is lumped with that of the Holy Moses, however. Not including the years that the Holy Moses is listed, the Solomon group produced a total of about 31,000 tons of ore containing 3,500 oz gold; 296,000 oz silver; 3,500 tons lead; and 1,200 tons zinc. The listed years of production were 1904-1907, and 1950. It is not known how much production came from the Solomon Mine when the figures are lumped together with the Holy Moses. Salsbury (1952, Table 1) shows smelter returns from the Solomon-Mexico group in 1945, 1948-1950, and 1951-1952, even though Table 2 lists "no production" for the Solomon group from 1935-1949. The amount shipped was about 800 tons and the net return to the shippers totaled about $12,000.

During 1966 work started on a 4-foot by 8-foot winze, 2,900 feet from the portal. Planned depth of the winze was 120 feet, with stations cut at 50 feet and 100 feet. Five underground and five surface workers were employed. (See Joe Keating, Mine Inspector report-King Solomon, July 15, 1966, Colorado Bureau of Mines.)

In 1967 water encountered at 20 feet stopped work on the winze started in 1966. Low-grade ore was blocked out, and construction began on a 150-ton/day washing plant (crusher, trommel screen, two jigs, and two shaker tables). This washing plant is probably the Phoenix Park mill described in the following section of this report. One surface and three underground workers were employed. (See Joe Keating, Mine Inspector report-King Solomon, October 27, 1967, Colorado Bureau of Mines.) Construction continued on a 400-ton/day mill scheduled for completion in February, 1968 (Operators Annual Report for 1967-Solomon Mine, to Colorado Bureau of Mines, January 5, 1968). Mill capacity reported by the mine inspector and the operator were vastly different.

In 1968 construction was completed on a 150-ton/day washing plant designed to remove the abundant clay associated with the ore of the Solomon Mine. About 52 tons/day of ore was removed from stockpiles stored in the underground stoped areas. Two underground and two surface workers were employed. (See Joe Keating, Mine Inspector report-King Solomon, June 21, 1968, Colorado Bureau of Mines.) About 1,000 tons of ore were shipped from the King Solomon Mine, worth $545 in gold, $402 in silver, $3,586 in zinc, $6,259 in lead, and $170 in cadmium (Operators Annual Report for 1967-King Solomon Mine, to Colorado Bureau of Mines, March 20, 1969).

Development and exploration continued until March 1969, when the King Solomon Mine was closed (Joe Keating, Mine Inspector report-King Solomon, November 11, 1969, Colorado Bureau of Mines).

In 1970 work in the King Solomon Mine consisted of cleaning up caved areas, widening and straightening the main drift, and sampling the veins at the extremities of the workings (Bernard Javernick, Mine Inspector report-King Solomon, October 16, 1970, Colorado Bureau of Mines).

As of 1971, King Solomon Mining Corporation had operated their mill (probably the Phoenix Park Mill) intermittently for the previous 5 years. Dump rock was processed until September. Clean up operations, retimbering, and geochemical and geophysical exploration were the main underground activities in the King Solomon Mine. Five acres of tailings were on the property, probably in Phoenix Park. (See Bernard Javernick, Mine Inspector reports-King Solomon Mill, November 16 and November 23, 1971, Colorado Bureau of Mines.)

In September 1971, Eagle-Picher Industries, Incorporated took an option on the King Solomon properties, but King Solomon Mining Company was listed as owner (Bernard J. Javernick, Mine Inspector report-King Solomon Mine, November 23, 1971, Colorado Bureau of Mines). Eagle Picher Industries Incorporated processed 500 tons of dump material in September and October before closing the mill. About 250 tons of caved material were removed from the mine and placed on the dump where the 500 tons was removed. (See Operators Annual Report for 1971-King Solomon Mine, to Colorado Bureau of Mines, January 24, 1972.)

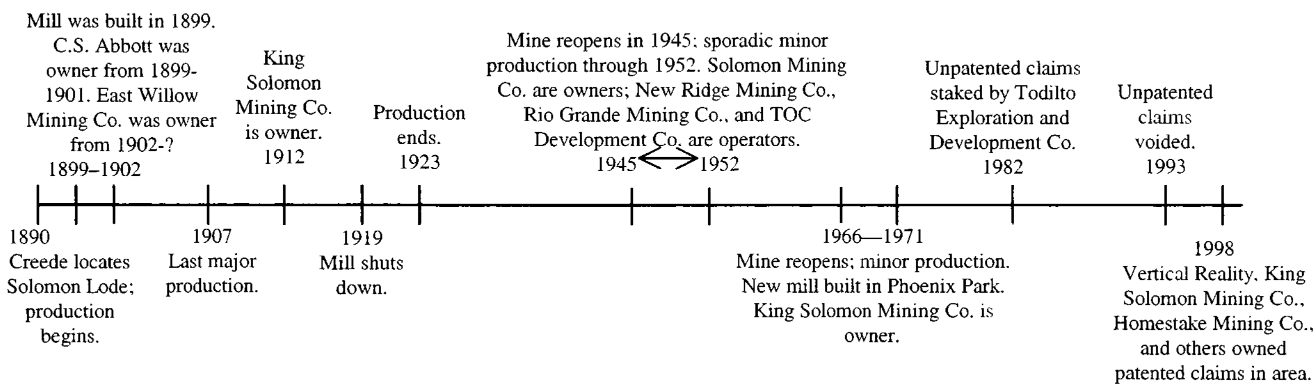
From 1963 to mid 1971, King Solomon Mining Company, with J.M. Muir, Jr. as President and various managers, was listed as operator of the King Solomon Mine. Some of these years this company was listed as owner, and other years it was listed as a lessee. (See Mine Inspector reports-King Solomon, July 15, 1966, October 27, 1967, June 21, 1968, November 11, 1969, October 16, 1970, Colorado Bureau of Mines; Operators Annual Reports for 1963, 1964, 1965, 1966, 1967, 1968-Solomon Mine, to Colorado Bureau of Mines, January 15, 1964, July 15, 1965, February 9, 1966, January 6, 1967, January 5, 1968, March 20, 1969.) This is not the same King Solomon Mining Company listed as the owner in 1912 (John Jackson, personal communication with Les Dobson, March 1999).

Production and milling operations ceased in 1971. In 1974 Tom Clark of Arvada, Colorado, was listed as the operator. The King Solomon (Phoenix Park) Mill was dismantled, and the machinery was removed, possibly for use in the Leadville area. (See Bernard Javernick, Mine Inspector report-King Solomon Mill, December 10, 1974, Colorado Bureau of Mines.)

A large area that includes the USFS-administered land near the Solomon Mine was staked by Todilto Exploration and Development Corporation (311 Washington SE, Albuquerque, NM 87108) as part of the Rat unpatented claim group in 1982. The claims were voided in 1993. (See BLM files.)

As of September 1998, Vertical Reality of Creede owned the patented land that includes the Solomon Mine. Nearby patented claims were owned by King Solomon Mining Company and Homestake Mining Company. (See Mineral County courthouse records.)

Timeline summarizing highlights in the mining history of the Solomon Mine



Geology

The Solomon Mine was driven as a crosscut to intersect the Solomon-Holy Moses vein system. This vein system lies within a fault zone that probably reflects a minor sag adjacent to the eastern side of the Creede graben. The fault strikes nearly north and dips about 60° west. The western side of the fault has dropped about 300 to 400 feet relative to the eastern side. The vein pinches to the south. (See Steven and Ratté, 1965, p. 67-68, plate 1; Emmons and Larsen, 1923, p. 94.)

About 75 feet north of where the Solomon crosscut intersects the Solomon-Holy Moses fault zone, the fault splits into two segments, each with a mineralized vein. The eastern vein is the Ethel and the western is the Solomon. The two veins gradually separate to a maximum of about 300 feet, then rejoin about 2,000 feet north of the divergence. (See Emmons and Larsen, 1923, p. 177.)

Host rock at the Solomon Mine is the Willow Creek Member of the Bachelor Mountain Rhyolite. Further north, the Solomon-Holy Moses fault has dropped the Campbell Mountain Member on the western side of the fault so that it contacts the Willow Creek Member on the eastern side of the fault. (See Steven and Ratté, 1965, plate 1.)

The vein within the fault zone is similar to the Amethyst vein, both in mineralogy and texture. Brecciation and crushing of the minerals within the vein is common. (See Steven and Ratté, 1965, p. 67, 79.) Metallic minerals in the unoxidized portion of the Solomon and Ethel veins are galena, sphalerite, pyrite, and minor chalcopyrite. Gangue minerals include green chlorite, talc, quartz, and minor fluorite. Minor amounts of gold and silver occur. Oxidized portions of the vein extend to about 80 feet above the adit level, which is 1,000 feet below the ground surface. Cerussite, limonite, manganese oxides, pyrite, and minor galena and sphalerite occur in the oxidized ore. Locally, the vein contained up to 35% lead. Similar to the Amethyst vein, oxidized ore extends deeply along fractures and is often mixed with the primary ore. (See Emmons and Larsen, 1923, p. 177-179.)

Site Description

The portal of the Solomon Mine drains a moderate flow of degraded water and is quite close to East Willow Creek. In efforts to safeguard the public and remediate the metal-laden effluent, in 1991 Colorado Division of Minerals and Geology installed a locked bulkhead door with a drain, and placed about 1 foot of fine- and medium-sized crushed limestone on the adit floor for 40 feet immediately inside the portal. Mine water flows across and through the limestone, out a buried drain pipe in the bulkhead door, and into three passive-mine-drainage-treatment ponds. During this construction the East Willow Creek Road was rerouted to act as a buffer between the Solomon waste-rock pile and East Willow Creek. In 1993 the discharge pipe from the lowest (northernmost) pond was cut, and the pond discharge was routed into a french drain that drains southward, parallel to the East Willow Creek Road and between the road and the pond. The drain passes beneath the road, eventually leading to East Willow Creek. During this phase of construction, a second drain pipe was installed in the bulkhead door that would allow the effluent to bypass the treatment ponds, should that become necessary in the future. (See Kirkham, 1993. p. 10; Kirkham, personal communication, June 1999.)

Mine effluent enters the upper, or southernmost pond via an underground pipe through the bulkhead door, and was not accessible for sampling in 1998. The water flows into the next two ponds, working its way northward before entering the discharge pipe that leads to the french drain. The french drain was apparently clogged during site visits in June and September of 1998, and the effluent emerged at the surface in the ditch between the East Willow Creek Road and the waste-rock pile, near the toe of the northernmost pond. Effluent was flowing down the road ditch for a short distance, then crossing the road and draining into East Willow Creek. Some of the effluent seeps into the ground before reaching East Willow Creek at the surface.

Waste and Hazard Characteristics

Since installation of the bulkhead, emplacement of the limestone on the adit floor, and construction of the treatment ponds in 1991, the treatment ponds have been modified, tested, and sampled on numerous occasions. Some of the post-construction reports and sample results are included in O'Grady (1995a, appendix F). Removing partly caved portions of the adit during construction of the bulkhead door and placement of the limestone lowered the water level underground, and zinc concentration in the effluent fell about 90% to about 1,000 to 2,000 μg/L.

In April 1994, the treatment ponds were removing 60% to 98% of most of the dissolved metals, with the exception of manganese. The discharge from the lowest treatment pond was murky, however, and contained 20% to 100% more metals in raw samples compared to filtered samples.

Kirkham (USFS-AMLIP form #09-04-331/4194-2) tested the effluent at the portal and at the discharge from the lowest of the treatment ponds in late May of 1992. Flow was about 12 gpm at both test sites, conductivity was 157 µS and 180 µS, and pH was 4.7 and 6.8, respectively. Kirkham also tested East Willow Creek below the Solomon Mine dump, and conductivity was 42 µS and pH was 7.8 on a flow of more that 7,000 gpm.

Despite construction of the treatment ponds in 1991, samples collected from East Willow Creek in 1990 and 1995 yield fairly similar results, especially in regard to total recoverable metals (Table 6). Lead and zinc concentrations in East Willow Creek are considerably elevated below the Solomon Mine, probably in large part because of the influx of highly degraded effluent from the Solomon Mine. Samples collected by CDPHE in 1995 suggest the ponds were still slightly effective for cadmium, copper, iron, and lead, but ineffective for aluminum, manganese, thallium, and zinc (Table 6). Even in 1995, the effluent in the lowest pond was still highly degraded, despite a 50% reduction in a few of the metal concentrations.

During the present investigation in June 1998, mine effluent was tested and sampled in the uppermost treatment pond and at the seep below the lowest pond, presumably the treatment pond discharge point because the french drain was clogged. At the uppermost pond, pH was 4.03, conductivity was 793 µS, and red precipitate was accumulating on the bottom. Water emerging in the ditch had a measured flow of 15.8 gpm and had pH 4.28 and conductivity of 828 µS, with no red precipitate. Analytical results suggest that the treatment ponds are no longer functioning as designed. Metal concentrations and pH are similar in the upper pond and in the water emerging in the ditch below the lowest pond. Aluminum, cadmium, lead, manganese, thallium, and zinc greatly exceed state standards in both samples (Tables 7, 8). Copper, iron, and sulfate also exceed standards.

Table 6. Water sample results for East Willow Creek and the Solomon Mine. [Results are shown in dissolved concentrations and µg/L unless noted. Blank columns indicate the parameter was not analyzed or the results are not known. The 1990 samples are reported in O'Grady (1995a). The remaining samples were collected in late May or early June 1995 and are reported in O'Grady (1997).]

Analyzed or tested parameter	E. Willow Cr. above Solomon Mine, 4/12/90	Solomon Mine effluent, 4/12/90	Solomon Mine effluent, 9/10/90	E. Willow Creek below Solomon Mine, 4/12/90	E. Willow Creek below Solomon Mine, 9/10/90	E. Willow above Solomon Mine, 1995	Solomon Mine effluent, 1995	Lowest treatment pond, Solomon Mine, 1995	E. Willow below Solomon Mine, 1995
Flow (cfs)	3.68	0.009		2.91	9.22	27.39	0.10		22.17
pH	8.03	4.88		6.98	6.5	6.95	4.33		7.59
Conductivity						39 µS	495 µS		38 µS
Total suspended solids						<4.00 mg/L	4.00 mg/L		<4.00 mg/L
Hardness						19.46 mg/L			19.33 mg/L
Alkalinity						23.20 mg/L	<10.00 mg/L		23.60 mg/L
Aluminum						226 581 (trec)	1,860 1,880 (trec)	1,680 (trec)	<188 565 (trec)
Antimony						<1.90 (both)	<1.90 (both)	<1.90 (trec)	<1.90 (both)
Arsenic						<3.20 (both)	7.20 8.40 (trec)	3.50 (trec)	<3.20 (both)
Barium						7.00 (both)	14.60 15.00 (trec)	15.10 (trec)	6.50 7.10 (trec)
Beryllium						<0.41 (both)	2.40 2.20 (trec)	2.20 (trec)	<0.35 (both)
Cadmium	0.32	77	180	1.3	0.9	0.34 <0.30 (trec)	203 198 (trec)	157 (trec)	0.69 <0.30 (trec)
Calcium						6,020 6,660 (trec)	85,500 (both)	87,700 (trec)	6,140 6,550 (trec)
Chloride						<3.00 mg/L	<3.00 mg/L		<3.00 mg/L
Chromium						<0.90 (both)	<0.90 (both)	<0.90 (trec)	<0.90 (both)
Cobalt						<0.60 (both)	93.60 93.40 (trec)	89.90 (trec)	<0.60 (both)
Copper		34	30			<0.70 1.20 (trec)	21.90 21.60 (trec)	10.80 (trec)	<0.70 2.00 (trec)
Fluoride						<0.10 mg/L	<0.34 mg/L		<0.10 mg/L
Iron		700	1,200			142 256 (trec)	1,460 1,610 (trec)	807 (trec)	46.80 247 (trec)
Lead	25	770	1,000	59	71	4.20 6.00 (trec)	1,780 1,760 (trec)	1,350 (trec)	6.60 59.70 (trec)
Magnesium						611 687 (trec)	21,700 21,100 (trec)	21,800 (trec)	647 723 (trec)
Manganese		4,000	7,800			8.60 9.80 (trec)	8,040 8,020 (trec)	8,100 (trec)	18.70 25.00 (trec)
Mercury						<0.20 (both)	<0.20 (both)	<0.20 (trec)	<0.20 (both)
Nickel						<1.40 (both)	<1.40 (both)	<1.40 (trec)	<1.40 (both)
Potassium						708 663 (trec)	5,560 5,060 (trec)	5,200 (trec)	695 801 (trec)
Selenium						<4.40 (both)	<4.40 (both)	<4.40 (trec)	<4.40 (both)
Silver						<0.50 (both)	<0.50 0.78 (trec)	0.98 (trec)	<0.50 (both)
Sodium						2,900 2,860 (trec)	14,700 14,100 (trec)	13,900 (trec)	2,910 3,030 (trec)
Sulfate						4.07 mg/L	439 mg/L		4.54 mg/L
Thallium						<4.50 (both)	19.50 14.60 (trec)	13.90 (trec)	<4.50 (both)
Vanadium						<1.40 (both)	<0.40 (both)	<0.40 (trec)	<1.30 (both)
Zinc	20	20,000	28,000	180	130	27.50 24.90 (trec)	18,600 18,300 (trec)	17,500 (trec)	116.00 142 (trec)

Table 7. Solomon Mine upper pond water sample results, 1998.

Hardness = 288 mg/L

Analyzed parameter	Mine effluent*	State water standard*	Factor above standard
Aluminum	2,330 µg/L (trec) 2,160 µg/L	n/a 87 µg/L	n/a 24.8 x standard
Arsenic	2.6 µg/L (trec)	50 µg/L (trec)	Below standard
Cadmium	190 µg/L	2.6 µg/L	73 x standard
Calcium	79 mg/L	no standard	n/a
Chloride	0.50 mg/L	250 mg/L	Below standard
Copper	42 µg/L	29 µg/L	1.4 x standard
Fluoride	1.0 mg/L	2 mg/L	Below standard
Iron	780 µg/L (trec) 860 µg/L	1,000 µg/L (trec) 300 µg/L	Below standard 2.9 x standard
Lead	1,360 µg/L	17.4 µg/L	78 x standard
Magnesium	22 mg/L	no standard	n/a
Manganese	8,830 µg/L (trec) 8,250 µg/L	n/a 50 µg/L	n/a 165 x standard
Potassium	5.2 mg/L	no standard	n/a
Silver	0.11 µg/L	0.46 µg/L	Below standard
Sodium	8.1 mg/L	no standard	n/a
Sulfate	450 mg/L	250 mg/L	1.8 x standard
Thallium	17 µg/L (trec)	0.5 µg/L (trec)	34 x standard
Zinc	39,900 µg/L (trec) 37,700 µg/L	2,000 µg/L (trec) 260 µg/L	20 x standard 145 x standard

* dissolved concentration unless noted.

Table 8. Solomon Mine pond discharge water sample results, 1998.

Hardness = 316 mg/L

Analyzed parameter	Mine effluent*	State water standard*	Factor above standard
Aluminum	2,230 µg/L (trec) 2,260 µg/L	n/a 87 µg/L	n/a 26 x standard
Arsenic	2.7 µg/L (trec)	50 µg/L (trec)	Below standard
Cadmium	180 µg/L	2.8 µg/L	64 x standard
Calcium	87 mg/L	no standard	n/a
Chloride	2.2 mg/L	250 mg/L	Below standard
Copper	33 µg/L	32 µg/L	1 x standard
Fluoride	1.5 mg/L	2 mg/L	Below standard
Iron	610 µg/L (trec) 580 µg/L	1,000 µg/L (trec) 300 µg/L	Below standard 1.9 x standard
Lead	1,320 µg/L	19.9 µg/L	66 x standard
Magnesium	24 mg/L	no standard	n/a
Manganese	8,710 µg/L (trec) 8,840 µg/L	n/a 50 µg/L	n/a 177 x standard
Potassium	6.0 mg/L	no standard	n/a
Silver	0.08 µg/L	0.54 µg/L	Below standard
Sodium	8.9 mg/L	no standard	n/a
Sulfate	440 mg/L	250 mg/L	1.8 x standard
Thallium	16 µg/L (trec)	0.5 µg/L (trec)	32 x standard
Zinc	37,500 µg/L (trec) 38,100 µg/L	2,000 µg/L (trec) 281 µg/L	18.8 x standard 136 x standard

* dissolved concentration unless noted.

Sediment samples collected in 1995 by O'Grady (1997) are inconclusive at this specific site (Table 9), but in general, concentrations of arsenic, cadmium, copper, manganese, and especially lead and zinc, increase in the sediments of East Willow Creek from above Phoenix Park to the mouth (Tables 10-12). The sample from the Solomon Mine dump is highly mineralized, especially with respect to iron, lead, and zinc.

Kirkham (1993, p. 10) reports that waste-rock samples from the Solomon, Ridge, and Outlet Mines, and a trenched sediment sample from below the Solomon Mine, all collected by Colorado Division of Minerals and Geology, contained similar amounts of soluble metals. He suggests that constant water flow through the mineralized stream sediments probably degrades the stream water more than the normally dry waste-rock piles. This mineralized sediment probably originated from erosion and redeposition of mine dumps and mill tailings placed in and near East Willow Creek during the early years of mining. Kirkham (personal communication, June 1999) reports that a stockpile rich in zinc at the Ridge Mine was removed during a catastrophic flood event several years ago. Erosion of some of these mine dumps continues to the present. Erosion of the Solomon dump has been slowed by rerouting the creek and the East Willow Creek Road, so that now the road provides a narrow buffer zone between the creek and the toe of the dump.

Table 9. Analytical results for stream-sediment samples from East Willow Creek near the Solomon Mine, and waste rock from the Solomon Mine dump. [Results are in ppm unless noted; all samples were collected in 1995 and reported by O'Grady (1997).]

Parameter	Sediment above Solomon Mine	Sediment below Solomon Mine	Solomon Mine dump
Aluminum	4,520	4,940	11,800
Antimony	1.90	<1.20	1.40
Arsenic	16.70	3.30	327
Barium	90.60	55.20	10.70
Beryllium	<0.35	<0.57	0.31
Cadmium	12.80	4.50	71.50
Calcium	2,090	3,170	291
Chromium	1.70	2.60	0.20
Cobalt	3.60	3.10	4.10
Copper	124	10.70	51.20
Iron	8,240	5,630	26,900
Lead	451	737	17,900
Magnesium	1,670	1,320	10,400
Manganese	336	361	2,770
Mercury	<0.12	<0.33	0.67
Nickel	<0.41	<0.91	<0.30
Potassium	953	705	776
Selenium	<1.30	<2.90	4.20
Silver	0.22	<0.33	6.60
Sodium	490	499	2,240
Thallium	<1.30	<2.90	6.70
Vanadium	19.10	13.10	13.60
Zinc	1,820	485	4,010

Migration Pathways

Groundwater Pathway

The Solomon Mine drains about 10 to 20 gpm of groundwater from the portal. These workings have probably drained water for most of the history of the mine. The winze that developed the most productive part of the Solomon vein flooded shortly after work stopped (Emmons and Larsen, 1923, p. 177). That winze probably required constant pumping during mining.

Most likely, the vast majority of the acidified, metal-rich water of the Solomon-Holy Moses vein system that lies above the elevation of the haulageway is released to the surface at the Solomon portal. However, the flooded portions of the mine may contribute significant metal loads to the local groundwater supply.

The closest registered wells for household use are two shallow wells about 1 mile downstream in North Creede. These wells presumably draw from the surficial aquifer of East Willow Creek. Mine effluent from the Solomon Mine that degrades surface water in East Willow Creek probably affects the surficial aquifer to some extent. Most likely, these wells produce degraded water.

Another registered well, about 450 feet deep, lies on the slopes southeast of North Creede at an elevation of about 9,700 feet (Colorado Division of Water Resources records, 1999). This well is topographically above and would not be affected by the Solomon Mine or its effluent.

Some unregistered wells for household use probably exist in the town of Creede. These wells likely draw from the surficial aquifer of Willow Creek. Surface water in Willow Creek is highly degraded with metals related to past mining activities, and the surficial aquifer is probably degraded to some extent. Some of this degradation is attributable to metal loading from the Solomon Mine (see following discussion).

Surface Water Pathway

Surface water in East Willow Creek is significantly degraded downstream of the Solomon Mine. In addition to the metal-rich effluent from the Solomon Mine, metals may be leached from the eroded waste rock and mill tailings that have been transported and redeposited into the stream channel of East Willow Creek. Inflows of degraded groundwater related to the Solomon Mine may also contribute to surface-water metal loads downstream of the mine. Although brook trout and a healthy benthic community thrive further upstream, fish do not live in East Willow Creek below the Solomon Mine because of high metal concentrations and habitat destruction associated with past mining activities (O'Grady, 1995a, p. 4, 12).

Until at least 1995, the town of Creede obtained drinking water from an intake on East Willow Creek about 1 mile downstream of the Solomon Mine. This intake was closed in about 1995 after the town converted to a groundwater source from south of Creede. The switch to groundwater was predicated on a requirement to have filtration systems for all surface-water sources for drinking water. The town decided that converting to a groundwater source would be less expensive than installing and maintaining a filtration system. (See O'Grady, 1997, p. 6.)

Prior to abandonment of the surface water intake, a routine test of the water after chlorination showed a lead concentration of 25 µg/L, above the recommended level of 15 µg/L for drinking-water supply. No other metals occurred in concentrations above the recommended levels, however, zinc was not tested. (See O'Grady, 1995a, p. 11-12.)

Downstream targets within 15 miles downstream of this inventory area include excellent trout fisheries on the Rio Grande, extensive wetlands, and habitat for Threatened and Endangered Species. Habitats suitable for peregrine falcons, bald eagles, wolverines, and Mexican spotted owls are present in this area. (See O'Grady, 1997, p. 6.)

Soil Exposure Pathway

No one lives within a mile of the Solomon Mine, however, tourists frequently drive by this site. Few get out of their vehicles, however. Although the Solomon Mine dump is moderately mineralized, the metal concentrations are not high enough to pose a risk for brief exposures.

Air Exposure Pathway

Most of the 20,000-cubic-yard dump is composed of moderately well cemented, sand-size and smaller particles (USFS-AMLIP inventory form #09-04-331/4194-2). No residences are nearby, and exposures to tourists are brief. The air exposure pathway poses little risk to the public.

PHOENIX PARK MILLSITE

The Phoenix Park Millsite (inventory area #09-04-331/4196-1) is about 3½ miles north of Creede along East Willow Creek (Figure 1). This is a fairly recent mill site that presumably processed ore and/or dump material hauled up from the Solomon Mine. The mill building was visible on a 1973 air photo, but only a foundation remains now. (See Kirkham, 1993, p. 12.) The lack of equipment and the small amount of tailings suggest that this was probably the mill operated intermittently during the late 1960s and early 1970s, discussed in the Solomon Mine section above. The USFS PBS map indicates that the tailings ponds are probably on USFS-administered land, and that most of the rest of the site, including the mill foundation, is on private land.

Mining History

The only mention of this site in the literature was in regard to the Solomon Mine. It is believed that this mill was associated with the Solomon Mine and was constructed in the late 1960s. The small amount of tailings suggests that the mill processed very little material during its brief history.

Patented claims (Washington, Jim Blaine, Lincoln, and Ben Harrison Lodes) adjacent to and including part of the Phoenix Park Millsite were surveyed September 10, 1892 and were owned by Hiram P. Bennett (Mineral Survey No. 7732, available at the Bureau of Land Management, Colorado State Office).

In 1967 construction began on a 150-ton/day washing plant that included a crusher, trommel screen, two jigs, and two shaker tables (Joe Keating, Mine Inspector report-King Solomon, October 27, 1967, Colorado Bureau of Mines). Construction proceeded on a 400-ton/day mill scheduled for completion in February 1968 (Operators Annual Report for 1967-Solomon Mine, to Colorado Bureau of Mines, January 5, 1968.) Mill capacity reported by the mine inspector and the operator are vastly different, but they are probably referring to the same site.

At the Mineral County courthouse, KSMC Millsite No. 11-26 (Book 7-D, p. 69-88) are most likely the claims associated with this millsite. This mill was built in anticipation of large production from the Phoenix Mine and Outlet Tunnel (John Jackson, personal communication with Les Dobson, USFS, March 1999).

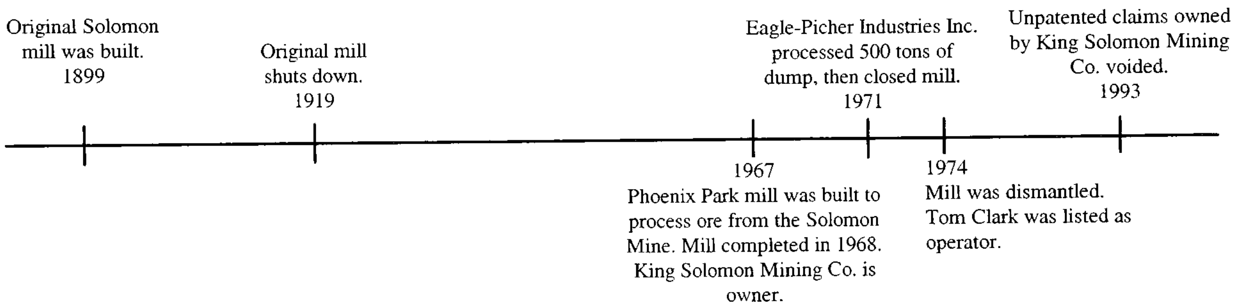
In 1968 construction was completed on the 150-ton/day washing plant designed to remove the abundant clay associated with ore from the Solomon Mine. The plant was similar to that used at a sand and gravel operation. About 50 tons/day of ore were removed from stockpiles stored in underground stoped areas of the Solomon Mine. King Solomon Mining Company (James Muir and Associates) was owner. (See Joe Keating, Mine Inspector reports-King Solomon, June 21, 1968, Colorado Bureau of Mines.) About 1,000 tons of ore were shipped from the King Solomon Mine, worth $545 in gold, $402 in silver, $3,586 in zinc, $6,259 in lead, and $170 in cadmium (Operators Annual Report for 1967-King Solomon Mine, to Colorado Bureau of Mines, March 20, 1969). Even after milling, the metal concentration and value of the final product were low.

In May of 1971, King Solomon Mining Company was cleaning up and repairing the mill. Dump rock from the King Solomon Mine was processed from June until September. Five acres of tailings were on the property. (See Bernard Javernick, Mine Inspector reports-King Solomon Mill, November 16 and November 23, 1971, Colorado Bureau of Mines.) Eagle-Picher Industries, Incorporated optioned the property from King Solomon Mining Company and processed 500 tons of dump material in September and October before closing the mill (Operators Annual Report for 1971-King Solomon Mine, to Colorado Bureau of Mines, January 24, 1972).

Milling operations ceased in 1971. In 1974 Tom Clark of Arvada, Colorado, was the operator when the King Solomon Mill was dismantled. The machinery was removed, possibly to be used in the Leadville area (Bernard Javernick, Mine Inspector report-King Solomon Mill, December 10, 1974, Colorado Bureau of Mines).

King Solomon Mining Company was listed as the claimant until the unpatented millsite claims were voided in 1993 (BLM files).

Timeline summarizing the operational history of the Phoenix Park Millsite



Geology

The Phoenix Park Millsite is built in an area mapped as unconsolidated glacial deposits. Willow Creek and Campbell Mountain Members of the Bachelor Mountain Rhyolite form the bedrock surrounding the site. No faults are mapped in this immediate vicinity. (See Steven and Ratté, 1965, plate 1.) Unconsolidated rocks and soil were exposed at the tailings ponds.

Site Description

Features of concern on USFS-administered land at the Phoenix Park Millsite are two small tailings ponds about 200 feet west of East Willow Creek. In June and September, 1998, the upper, or northernmost pond was dry and had very few tailings. The lower, or southernmost pond had shallow water covering part of the bottom and a small amount of damp tailings (Figure 3). Because these ponds were built in the 1960s, it is doubtful they have any kind of liner to prevent seepage.

In general, this site appears relatively benign. Both ponds have gullies revealing where surface water collected in road ditches drain into them. Neither pond shows evidence of surface discharge, indicating that water draining into them evaporates and/or seeps into the ground.

The concrete mill foundation lies on private land immediately to the northwest of the ponds. About 150 feet north of the northernmost pond, on private land, a large volume of broken, relatively fresh rock is piled. Seemingly, this rock is barren country rock, showing minor or negligible evidence of mineralization, however, the rock pile was not examined closely because it lies on private land.

Waste and Hazard Characteristics

Combined, the tailings ponds cover about 2 acres. The depth of the tailings is unknown, but is believed to be less than 5 feet and probably less than 2 feet. During the inventory done in late May 1992, some water was in both tailings ponds. The northern pond had brown water with pH of 6.5 and conductivity of 475 μS. The southern pond had blue-green water and sediment and had pH of 7.4 and conductivity of 285 μS. East Willow Creek was tested above and below this site; pH was 7.7 and 7.6, and conductivity was 22 μS and 38 μS, respectively. (See USFS-AMLIP inventory form #09-04-331/4196-1.)

O'Grady (1997) collected water, stream-sediment, and tailings samples in 1995 during a Site Investigation. Sample results suggest the tailings are slightly mineralized (Table 10). Lead is elevated in both tailings deposits. Apparently, tailings in the southern pond are more mineralized than those of the northern pond. Arsenic, cadmium, and zinc show the largest differences.

Water samples from upstream and downstream of the tailings ponds contained similar metal concentrations (Table 10), suggesting little, if any, effect to surface water by the millsite.

In the stream sediments, iron and manganese concentrations increased at the downstream site (Table 10). It is unknown if the slightly elevated concentrations result from the location of the sample within the streambed, or if the results reflect an influence from the millsite.

Migration Pathways

Groundwater Pathway

No surface discharge is evident at the Phoenix Park Millsite. Surface water that drains from the road and surrounding area into the ponds either evaporates or seeps into the unconsolidated glacial deposits that underlie the ponds. If the water in the ponds seeps into the ground, it probably discharges into flow was about 10 to 15 gpm, pH was 6.30, and conductivity was 70 μS. Surface water samples from East Willow Creek collected by O'Grady (1997) provide no evidence of an influx of degraded water near this site.

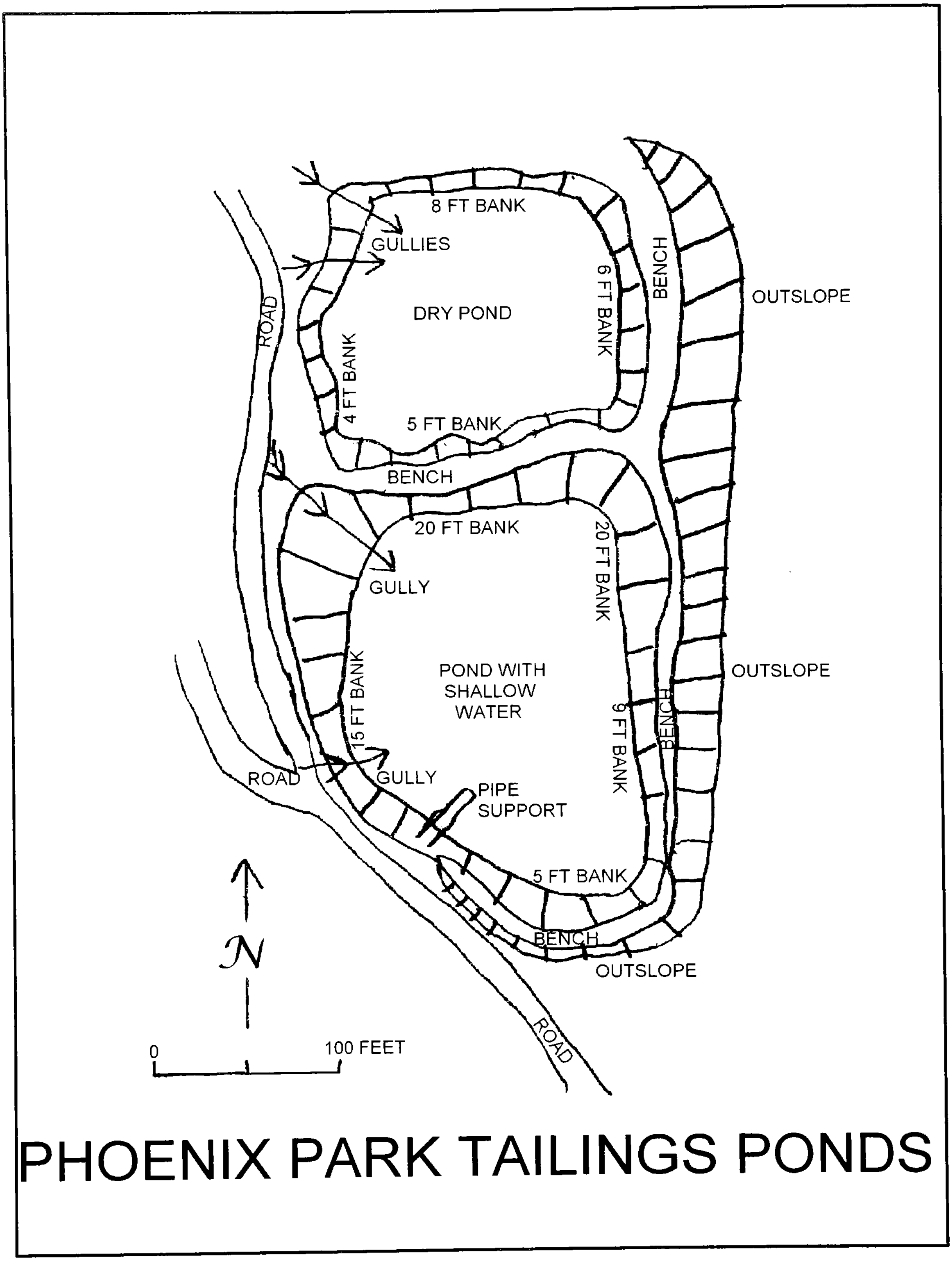


Figure 3. Surface map of the Phoenix Park tailings ponds.

Table 10. Water, stream-sediment, and tailings sample results for East Willow Creek and the Phoenix Park Millsite. [Water sample results are shown in dissolved concentrations and μg/L unless noted. Solid samples are in ppm. Blank columns indicate the parameter was not analyzed or the results are not known. Samples were collected in late May or early June, 1995, and are reported in O'Grady (1997).]

Analyzed or tested parameter	E. Willow Creek above Phoenix Park Millsite	E. Willow Creek below Phoenix Park Millsite	Sediment-E. Willow above Phoenix Park Millsite	Sediment-E. Willow below Phoenix Park Millsite	Sediment-southern tailings pond	Sediment-northern tailings pond
Flow (cfs)	25.64	23.65				
pH	7.62	7.60				
Conductivity	35 μS	52 μS				
Total suspended solids	<4.00	<4.00				
Hardness	17.56 mg/L	18.40 mg/L				
Alkalinity	21.90 mg/L	22.10 mg/L				
Aluminum	230 449 (trec)	156 460 (trec)	3,120	4,790	11,500	9,580
Antimony	<1.90 (both)	<1.90 (both)	<0.56	<0.61	2.00	0.64
Arsenic	<3.20 (both)	<3.20 (both)	1.50	1.30	261.00	47.10
Barium	5.90 5.80 (trec)	5.10 6.10 (trec)	112.00	66.30	38.40	36.10
Beryllium	<0.37 (both)	0.34 <0.30 (trec)	<0.23	<0.30	0.63	0.38
Cadmium	<0.30 (both)	<0.30 (both)	<0.09	<0.10	38.80	13.80
Calcium	5,850 5,980 (trec)	6,050 6,260 (trec)	2,260	2,640	483	270
Chloride	<3.00	<3.00				
Chromium	<0.90 (both)	<0.90 (both)	1.00	3.20	0.72	0.75
Cobalt	<0.60 (both)	<0.60 (both)	2.00	4.70	4.10	3.90
Copper	<0.70 1.80 (trec)	<0.70 1.30 (trec)	3.40	4.80	111	118
Fluoride	<0.10	<0.10				
Iron	72.00 218 (trec)	52.20 246 (trec)	4,710	12,400	22,200	20,700
Lead	<1.90 (both)	<1.90 (both)	8.80	6.80	10,100	9,360
Magnesium	601 638 (trec)	622 672 (trec)	1,120	1,790	9,960	8,880
Manganese	5.40 8.10 (trec)	3.10 9.70 (trec)	128	246	1,770	1,680
Mercury	<0.20 (both)	<0.20 (both)	<0.14	<0.14	0.17	<0.12
Nickel	<1.40 (both)	<1.40 (both)	0.77	1.30	<0.38	<0.33
Potassium	691 674 (trec)	674 676 (trec)	1,010	997	1,300	917
Selenium	<4.40 (both)	<4.40 (both)	<1.30	<1.40	3.00	2.10
Silver	<0.50 (both)	<0.50 (both)	<0.15	<0.16	3.70	3.60
Sodium	2,940 3,090 (trec)	2,850 3,010 (trec)	211	<65	1,420	625
Sulfate	3.80 mg/L	3.80 mg/L				
Thallium	<4.50 (both)	<4.50 (both)	<1.30	<1.40	2.60	2.30
Vanadium	1.50 1.00 (trec)	1.50 (both)	11.70	34.60	12.60	8.70
Zinc	<6.80 (both)	3.20 <8.00 (trec)	17.50	27.40	4,050	2,150

East Willow Creek relatively close to the millsite. A group of seeps on the south side of the road, south of the mill site was tested in June 1998. These seeps apparently drain the slopes west-southwest of Phoenix Park and are probably not hydrologically connected to the tailings ponds. The combined

The closest registered wells for household use are two shallow wells about 2.5 miles downstream in North Creede. These wells probably draw from the surficial aquifer of East Willow Creek. The Phoenix Park Millsite has no apparent effect on the surface water, and presumably no effect on the surficial aquifer of East Willow Creek. The millsite has no significant impact on wells in North Creede or on any wells associated with the Willow Creek surficial aquifer further downstream.

Surface Water Pathway

Water sample results suggest that the Phoenix Park Millsite does not affect surface water in East Willow Creek. Brook trout and a healthy benthic community thrive in this area (O'Grady, 1995a, p. 4).

Downstream targets within 15 miles downstream of this inventory area include excellent trout fisheries on the Rio Grande, extensive wetlands, and habitat for Threatened and Endangered Species. Habitats suitable for peregrine falcons, bald eagles, wolverines, and Mexican spotted owls are present in this area. (See O'Grady, 1997, p. 6.)

Soil Exposure Pathway

No one lives within 2 miles of the Phoenix Park Millsite. In the summer, tourists frequently drive the East Willow Creek Road adjacent to the millsite, but few get out of their vehicles. Although the tailings are moderately mineralized, the metal concentrations are not high enough to pose a risk for brief exposures.

Air Exposure Pathway

The tailings are unconsolidated and consist of sand-size and smaller particles (USFS-AMLIP inventory form #09-04-331/4196-1). Much of the year the tailings are wet and/or are covered by snow or shallow water. Certain times of the year, however, the tailings may be windblown. No residences are within 2 miles and exposures to tourists are brief. Although a small amount of tailings may become windblown at times, this pathway is considered insignificant because of the small surface area of the tailings ponds and the lack of long-term exposure to the public.

OUTLET TUNNEL

The Outlet Tunnel (inventory area #09-04-331/4195-1) is on East Willow Creek, about 3 miles north of Creede (Figure 1). It lies between the Solomon Mine to the south and the Phoenix Park Millsite to the north. The adit was driven as a northwest-trending crosscut to intersect the Solomon-Holy Moses vein system.

The USFS administers most of the land at the Outlet Tunnel site, including the portal and the waste-rock pile. Although mineral surveys that included the adit were completed on two occasions in the late 1800s and early 1900s, the claims were never patented.

Mining History

Mineral Survey No. 8924A and B was conducted on the S.A. Beddall, Great Eastern, and Valley Queen Lodes, and Schuylkill Mill-site on May 3, 1894. At the time of the survey, the adit labeled the Outlet Mine on the USFS PBS map was about 500 feet long, and its portal was on the Valley Queen Lode. F.P. Rosengarten owned the claims. (See Mineral Survey No. 8924A and B, available at the Bureau of Land Management, Colorado State Office.)

The Outlet claim was staked in 1903 by J.W. Skinner (Mineral County courthouse records).

Mineral Survey No. 18348A and B was conducted on the Ada, Ada No.1, Ada No.3, and Outlet Lode claims and Outlet Mill-site on June 10, 1907. By that time, the Outlet Tunnel was about 1,200 feet long with over 300 feet of side drifts. The portal was on the Outlet Lode claim, and the side drifts were on the Ada No. 3 claim. J.W. Skinner and others owned the claims. (See Mineral Survey No. 18348A and B, available at the Bureau of Land Management, Colorado State Office.)

This mine was apparently inactive for most of the first half of the 20th century.

In October 1955 Outlet Mining Company planned to enlarge the 1,156-foot-long Outlet Tunnel from the existing 4-foot-wide by 6-foot-high opening to 7 feet wide by 8 feet high. Additionally, they planned to drift 1,000 feet north to intersect the Phoenix Mine through a 600-foot raise, and to drift along the vein 2,000 feet to the south. (See John Doyle, Mine Inspector, Information report-Outlet Tunnel, October 31, 1955, Colorado Bureau of Mines.)

In 1956 a raise was driven from the Outlet Tunnel to a winze developed in the Phoenix Mine (Meeves and Darnell, 1968, p. 27). About 600 tons of ore (worth $23,000 after smelter deductions) was shipped from the Outlet Tunnel. Seven men were employed. A $108,506 DMEA (Defense Minerals Exploration Administration) grant was awarded to the Outlet Mining Company and Sublet Mining Company for exploration work at the Outlet Tunnel. Outlet Mining Company was owner, Sublet Mining Company was the listed operator, and Gormax Mining Company was a sublessee. The owners and operators included Paul Snyder, Charles King, Gavin Skinner, and James Muir. (See Operators Annual Report for 1956-Outlet Tunnel, to Colorado Bureau of Mines, February 18, 1957; Kelly and others, 1958, p. 293-294.) Gormax Mining Company apparently never operated the Outlet, but subleased the Gormax Mine, north of the Outlet Tunnel, from the

Outlet Mining Company (John Jackson, personal communication with Les Dobson, USFS, March 1999).

In 1957 the Outlet Mining Company shipped 75 tons of ore worth about $2,642 (162 units of lead-$421; 1,776 oz of silver-$1,598; and 120 units of copper-$623). Five men were employed. (See Operators Annual Report for 1957-Outlet Tunnel, to Colorado Bureau of Mines, January 13, 1959.)

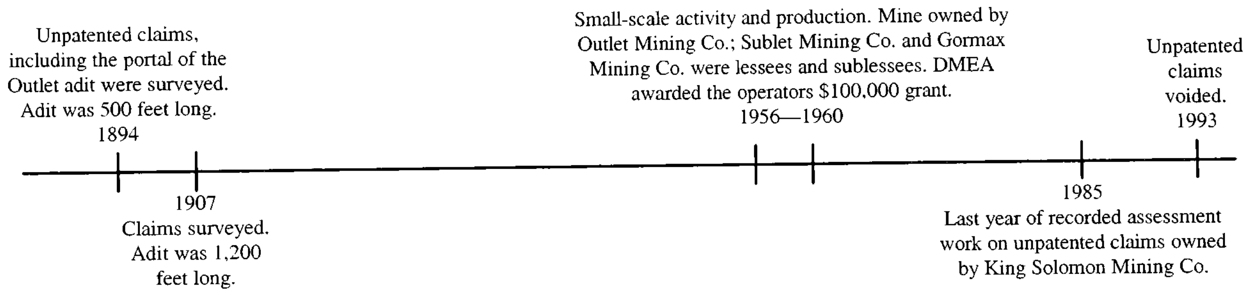
The Outlet Tunnel was listed as a producing mine in 1960 (Howes, 1961, p. 241).

According to John Jackson (personal communication with Les Dobson, USFS, March 1999), the Outlet Tunnel never produced. Production listed for the Outlet Tunnel actually came from the Phoenix Mine, which was operated by the same company.

No production is recorded from the Outlet Tunnel after 1960.

In 1985 the last known owner of the unpatented mining claims that included the Outlet Tunnel was the King Solomon Mining Corporation (P.O. Box 10022, Santa Ana, CA 92711, Henry Muir-President). The last year of assessment work on the group was 1985. These claims were voided in 1993. (See BLM files.)

Timeline summarizing highlights in the mining history of the Outlet Tunnel



Geology

The Outlet Tunnel is driven in the Outlet Tunnel Member of the La Garita Quartz Latite and extends into the Willow Creek Member of the Bachelor Mountain Rhyolite. The Willow Creek Member is associated with the Bachelor Mountain caldera and overlies the Outlet Tunnel Member, which is associated with the older La Garita caldera. Underground in the Outlet Tunnel, these rock units often have a steep contact because of their original depositional boundary and because of faulting. Also, the Outlet Tunnel Member rocks are propylitically altered and fractured, but the Willow Creek Member rocks are relatively fresh. (See Steven and Ratté, 1965, p. 51, plates 1, 2, 6.)

The Outlet Tunnel was driven to intersect the Solomon-Holy Moses fault zone and vein, described in the Solomon Mine section of this report. Vein mineralogy is similar to that previously described for the Solomon Mine. In addition, near the Outlet Tunnel and higher in the vein system, an unidentified uranium mineral and leadhillite (lead-sulfate-carbonate-hydroxide) occur (John Jackson, personal communication with Les Dobson, USFS, March 1999). At the Outlet

Tunnel, the vein varies from thoroughly oxidized limonitic mud to fresh material containing fine-grained pyrite and localized pods of galena in a clay or chlorite matrix. A 0.5- to 1-foot-wide zone of galena exposed in a shallow winze follows the hanging wall of the fault zone. Evidence of multiple episodes of brecciation and subsequent healing of the vein is common at the Outlet Tunnel. The southern end of the mine exposes a small, post-mineral fault that truncates the vein. (See Steven and Ratté, 1965, p. 80.)

The Outlet Tunnel cuts a few smaller lead-zinc-silver veins before it reaches the Solomon-Holy Moses vein. In general, the smaller veins strike north to northwest, dip steeply west, and are less than 0.5 feet wide to as little as 1 inch wide. One of these veins, about 1,000 feet from the Outlet Tunnel portal, balloons out to 4 feet wide about 75 feet north of the Outlet Tunnel, but quickly pinches down to about 1 inch wide slightly further to the north. "Blowholes" in shattered host rock contain lead and zinc minerals about 950 feet from the portal. (See Emmons and Larsen, 1923, p. 182.)

Site Description

The Outlet Tunnel is on the western side of East Willow Creek. The site includes a caved portal, ore-car track supports (the track has been removed), an ore bin, some building ruins, and a large dump (Figure 4). The bridge that provided access to this mine and the Holy Moses Mine from the East Willow Creek Road has washed out. East Willow Creek is actively eroding the Outlet Tunnel dump along its northern toe. Much of the dump face is quite steep, lying at the angle of repose. As East Willow Creek erodes the dump toe, additional dump material sloughs from the steep face into the creek, contributing a slow, but steady supply of mineralized material to the surface water.

Waste and Hazard Characteristics

The most significant environmental aspect of the Outlet Tunnel site is the large waste-rock pile that extends into East Willow Creek. The dump is about 600 feet long, 150 feet wide, and contains 10,000 to 15,000 cubic yards of material. East Willow Creek is actively eroding the toe of the dump along much of the northern half.

Because much of the Outlet Tunnel was driven as a crosscut to access the Solomon-Holy Moses vein system, a significant percentage of the dump should be barren country rock, posing little threat in terms of metal contamination. In some places, the barren country rock of the dump may have been buried by later waste rock associated with the vein system. This latter generation of waste rock should be more mineralized. Most of the dump contains oxidized red, light red, brown, tan, and gray volcanic rocks. Waste rock beneath the ore-car track supports is fresh gray porphyry. A composite sample from the entire dump collected in June 1998 shows that although the waste rock has an acidic component, the overall composition is more basic than acidic (Table 11). Concentrations of antimony, silver, zinc, and especially arsenic and lead, are elevated. A sample collected from the dump by CDPHE in 1995 was probably from a pocket of well mineralized material. It contained more than 1% each of arsenic and lead, and was also high in antimony, cadmium, copper, silver, and zinc.

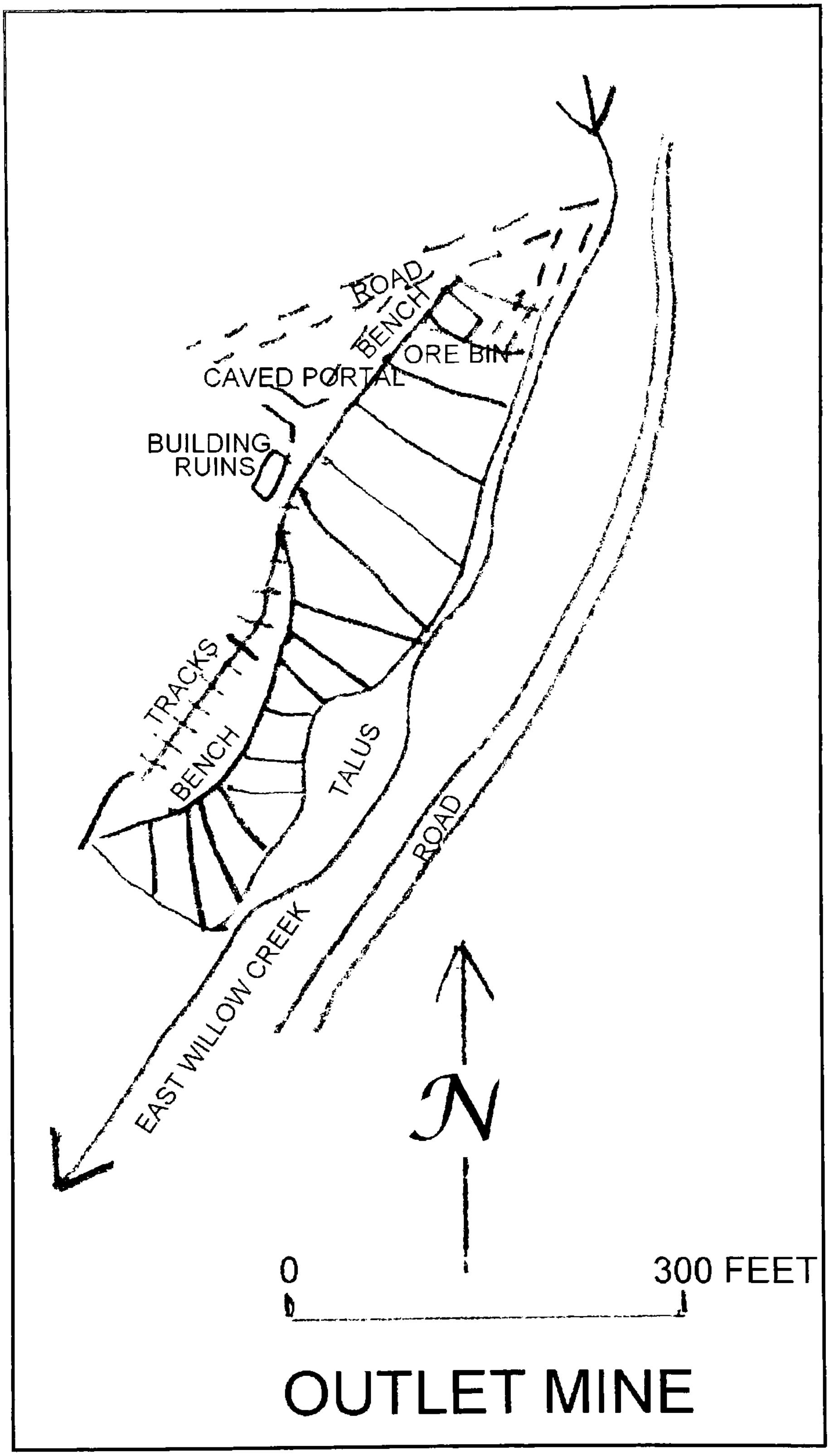


Figure 4. Surface map of the Outlet Tunnel area.

Water sampled from East Willow Creek by the Water Quality Control Division of CDPHE in April 1990 revealed cadmium concentration of 0.37 μg/L below the Outlet Mine. No other metals were detected in samples from above or below the mine during the 1990 sampling program (O'Grady, 1995).

Water samples from East Willow Creek above and below the Outlet Tunnel collected by CDPHE in late May and early June of 1995 are similar in metal concentrations (Table 11). Neither reveals evidence of stream degradation.

Stream-sediment samples collected at the water sampling locations by CDPHE in 1995 are inconclusive for this specific site. Although arsenic and lead increase at the downstream sample site, zinc decreases (Table 11). Slight increases in arsenic and lead concentrations in the sediments may be related to erosion of the Outlet Tunnel dump.

Table 11. Water, stream-sediment, and waste-rock sample results for East Willow Creek and the Outlet Tunnel. [Water sample results are shown in dissolved concentrations and μg/L unless noted. Solid sample results are in ppm unless noted. Blank columns indicate the parameter was not analyzed or the results are not known. Except for the composite sample, the samples were collected in late May or early June, 1995, and are reported in O'Grady (1997).]

Parameter	E. Willow above Outlet Tunnel	E. Willow below Outlet Tunnel	Sediment above Outlet Tunnel	Sediment below Outlet Tunnel	Outlet Tunnel waste rock	Outlet Tunnel waste rock (composite)
Flow (cfs)	28.33	27.39				
pH	7.64	7.71				6.88
Conductivity	44 μS	45 μS				
Hardness	18.29 mg/L	18.26 mg/L				
Alkalinity	23.60 mg/L	20.60 mg/L				
Total suspended solids	<4.00 mg/L	<4.00 mg/L				
Neutralization potential						7.4 tons $CaCO_3$/1,000 tons
Potential acidity						2.1 tons $CaCO_3$/1,000 tons
Net acid-base potential						5.3 tons $CaCO_3$/1,000 tons
Al_2O_3						0.81%
CaO						0.33%
Fe_2O_3						3.46%
K_2O						0.40%
MgO						0.23%
Na_2O						0.03%
Sulfur						0.28%
Aluminum	212 693 (trec)	233 621 (trec)	3,310	3,810	4,080	
Antimony	<1.90 (both)	<1.90 (both)	<0.61	<0.61	626	230
Arsenic	<3.20 (both)	<3.20 (both)	1.30	6.20	11,400	1,730
Barium	6.80 7.10 (trec)	6.30 6.40 (trec)	53.40	49.50	277	185
Beryllium	<0.50 (both)	<0.46 (both)	<0.22	<0.40	0.28	<1
Bismuth						<50
Boron						<5
Cadmium	<0.30 (both)	<0.30 (both)	<0.11	<0.47	107.00	7.2
Calcium	5,670 6,220 (trec)	5,850 6,190 (trec)	1,790	2,330	376	
Chloride	<3.00	<3.00				
Chromium	<0.90 (both)	<0.90 (both)	2.00	1.60	0.71	
Cobalt	<0.60 (both)	<0.60 (both)	3.40	2.40	0.48	<10
Copper	<0.70 1.20 (trec)	<0.70 1.60 (trec)	5.50	5.50	2,410	228
Fluoride	<0.10 mg/L	<0.10 mg/L				
Gold						0.052
Iron	67.10 283 (trec)	65.90 262 (trec)	8,260	5,230		
Lead	<1.90 2.40 (trec)	<1.90 (both)	11.20	25.20	13,700	5,759
Lithium						6

Parameter	E. Willow above Outlet Tunnel	E. Willow below Outlet Tunnel	Sediment above Outlet Tunnel	Sediment below Outlet Tunnel	Outlet Tunnel waste rock	Outlet Tunnel waste rock (composite)
Magnesium	563 669 (trec)	593 681 (trec)	1,530	1,200	50.70	
Manganese	4.00 7.10 (trec)	7.00 9.60 (trec)	199	270	27.70	427
Mercury	<0.20 (both)	<0.20 (both)	<0.13	<0.18	5.20	2.42
Molybdenum						33
Nickel	<1.40 (both)	<1.40 (both)	1.20	0.74	<0.30	9
Phosphorus						429
Potassium	697 703 (trec)	698 686 (trec)	893	655	2,130	
Selenium	<4.40 (both)	<4.40 (both)	<1.40	<1.60	13.40	<50
Silver	<0.50 (both)	<0.50 (both)	<0.16	<0.19	91.60	24.8
Sodium	2,730 2,940 (trec)	2,840 3,020 (trec)	148	118	592	
Strontium						28
Sulfate	3.80 mg/L	3.80 mg/L				
Thallium	<4.50 (both)	<4.50 (both)	<1.40	<1.70	11.70	<100
Tellurium						<50
Tin						<50
Titanium						47
Tungsten						<20
Vanadium	<1.70 (both)	<1.40 (both)	22.20	12.10	20.10	14
Zinc	7.80 16.50 (trec)	6.60 10.80 (trec)	46.70	27.00	1,770	474

Migration Pathways

Groundwater Pathway

No surface discharge is evident at the Outlet Tunnel or the associated waste-rock pile. Rain and snow that falls on the dump probably soaks quickly through the surface, which is mostly gravel-size material. Because of the steep slopes and paucity of unconsolidated material on the steep slopes underlying the dump, most of this water probably enters East Willow Creek relatively quickly, with little residence time as groundwater. The waste-rock pile at the Outlet Tunnel probably has little or no effect on bedrock groundwater in this area.

The closest registered wells for household use are two shallow wells about 2 miles downstream in North Creede. These wells presumably draw from the surficial aquifer of East Willow Creek. The Outlet Tunnel apparently has little or no effect on the surface water, and probably has a similar effect on the surficial aquifer of East Willow Creek. Any contribution to degradation of East Willow Creek or its surficial aquifer from the Outlet Tunnel is obscured by the more severe impact from downstream sites such as the Solomon and Ridge Mines.

Surface Water Pathway

Water sample results indicate that surface water in East Willow Creek is not significantly affected by the Outlet Tunnel or its moderately mineralized waste-rock pile. Weak evidence of increased metals in the sediments below the mine suggests that mine waste that has eroded and been redeposited in East Willow Creek may be an ongoing source for metals leaching and contamination. Brook trout and a healthy benthic community thrive in this area (O'Grady, 1995a, p. 4).

Downstream targets within 15 miles downstream of this inventory area include excellent trout fisheries on the Rio Grande, extensive wetlands, and habitat for Threatened and Endangered Species. Habitats suitable for peregrine falcons, bald eagles, wolverines, and Mexican spotted owls are present in this area. (See O'Grady, 1997, p. 6.)

Soil Exposure Pathway

No one lives within 2 miles of the Outlet Tunnel, however, tourists frequently drive by this site. Access to the waste-rock pile is not easy, and requires rock-hopping across East Willow Creek during low water, and wading during high water. Although the dump is moderately mineralized, the metal concentrations are not high enough to pose a risk for brief exposures.

Air Exposure Pathway

Most of the mine dump is composed of moderately well cemented, gravel-size material (USFS-AMLIP inventory form #09-04-331/4195-1). Windblown particles from this site are not likely. No residences are within 2 miles, and any exposures to tourists are brief. This pathway is not considered a significant risk.

MAMMOTH TUNNEL

The Mammoth Tunnel (inventory area #09-04-331/4192-1) is along the east side of East Willow Creek, about 1.5 miles north of Creede (Figure 1). Surface disturbances at the site are entirely on USFS-administered land, however the underground workings probably extend beneath patented lands to the southeast. Accurate surface and underground surveys would be required to determine which, if any, patented claims are cut by this adit.

Mining History

Scant and somewhat contradictory information is available regarding this site. Any production was unreported and probably insignificant.

In 1900 a lower tunnel at the Mary Anderson claim, which is slightly above and southeast of the Mammoth Tunnel, was operating two shifts/day (Denver Times, April 19, 1900, p. 10). This "lower tunnel" is probably referring to the Mammoth Tunnel. By early in 1901 the adit was 2,000 feet long, and the operators were drifting on a vein with irregular values (Denver Times, March 5, 1901, p. 11). Although the mine name is not mentioned, this is probably the Mammoth Tunnel. In 1900 and 1901, the Mary Anderson and Mammoth claims, adjacent to the Mammoth Tunnel, were operated by Mammoth Mountain Consolidated (Denver Times, April 19, 1900, p. 10; March 5, 1901, p. 11). It is believed that they operated the Mammoth Tunnel, too.

In 1904 the Mammoth Mountain group, which included the Mary Anderson, Mammoth, and Nancy Hanks claims, had an adit about 1,800 feet long and was operated by lessees. Reportedly, the adit cut beneath the three claims and was within a hundred feet of the vein exposed on the Nancy Hanks claim. (See Mining Reporter, v. 49, May 12, 1904, p. 489.) Although not mentioned by name, this adit was probably the Mammoth Tunnel. There is a slight discrepancy in the length of the adit when this account is compared with the newspaper article from 1901.

Sometime around 1911 or 1912, the Mammoth Tunnel was 2,280 feet long and followed a S.77°E. trend. The original intent of the mine was to intersect the Mammoth vein, which is exposed at the Mammoth Mine, about 1,200 feet higher on the mountain to the southeast (Figure 1). The adit never intersects, but roughly parallels the trend of the Mammoth vein. (See Emmons and Larsen, 1923, p. 184-185, plate 1.) This mine description differs from the descriptions in earlier accounts. It is not known which account is more accurate, because it is not known if the authors of any of these descriptions had underground access. No mine maps were discovered during this investigation.

By 1913 the adit was 2,700 feet long. It was driven as a crosscut tunnel into Mammoth Mountain. Before the adit reached the vein, a coal strike stopped work. Mammoth Mining and Development Company (formerly the Mammoth Mining, Milling, and Tunnel Company, J. P. Clark sole stock owner) was operating the mine. (See Managers report for 1913-Mammoth Mining and Development Company, to Colorado Bureau of Mines, February 9, 1914.)

According to Larsen (1930, p. 98), the Mammoth Tunnel had been extended to an unspecified length, but no significant ore bodies had been exposed.

No information regarding mining activities after the Larsen (1930) report was found.

In 1980 the Outhouse #5 claim was staked by Chevron U.S.A., Incorporated (Golden, Colorado). This claim is very close, and probably includes the portal of the Mammoth Tunnel. The claim was voided in 1993. (See BLM files.)

A large area that includes the Mammoth Tunnel was staked by Todilto Exploration and Development Corporation (311 Washington SE, Albuquerque, NM 87108) as part of the Rat unpatented claim group in 1982. The claims were voided in 1993. (See BLM files.)

Timeline summarizing the mining history of the Mammoth Tunnel

Geology

The Mammoth Tunnel is driven in the Willow Creek Member of the Bachelor Mountain Rhyolite. In this locality, the host rock is pervasively brecciated and silicified. The Mammoth Tunnel is situated near the northern limit of this mass of brecciated rocks. (See Steven and Ratté, 1965, p. 53-54, plate 1.)

The brecciated Bachelor Mountain Rhyolite and associated northwest-trending faults are probably related to subsidence of the Bachelor caldera, which is centered near the town of Creede and pre-dates the formation of the Creede caldera. The Mammoth Mine (not the Mammoth Tunnel) exposes a mineralized, northwest-trending, southwest-dipping normal fault that was active during subsidence of the Bachelor caldera. This fault zone merges with the Amethyst fault zone to the northwest. (See Steven and Ratté, 1965, p. 53-56, plate 2.) The Mammoth Tunnel apparently never intersected this vein, however.

Underground, the Mammoth Tunnel exposes several minor, north-northeast-trending, west-dipping faults and fissures. No significant mineralization was reported. (See Emmons and Larsen, 1923, p. 184-185.)

Site Description

The Mammoth Tunnel is situated on the eastern side of East Willow Creek. This caved adit is discharging a significant quantity of water with no precipitate. Virtually no waste rock is associated with this adit, which is reportedly a crosscut more than 2,000 feet long. The whereabouts of the dump is a mystery, unless it was completely washed away by East Willow Creek, which flows at the base of a very steep slope immediately below the adit.

In the past, water from the Mammoth Tunnel was piped to East Willow Creek to the inlet works for the Creede water supply, where the effluent discharged onto the valves to prevent freezing (Figure 1). This surface-water-supply inlet is no longer used because Creede converted to a groundwater source south of town in the mid-1990s (O'Grady, 1997, p. 6). As of 1992, the pipe was broken and effluent was draining into the steep talus slope between the pipeline and East Willow Creek. (See Kirkham, 1993, p. 16.)

Waste and Hazard Characteristics

A sample of Mammoth Tunnel effluent collected by Colorado Division of Minerals and Geology in 1989 revealed moderate to high concentrations of aluminum, copper, cadmium, and lead (Table 12). The effluent was sampled again in April 1990. The flow was estimated at 0.11 cfs, pH was 7.18, and no metals were detected. During the abandoned mine inventory in May 1992, the effluent had an estimated flow of 0.25 cfs, pH of 7.1, and conductivity of 90 µS. (See Kirkham, 1993, p. 16.) A sample collected by CDPHE in 1995 shows the effluent is slightly degraded with lead, but with lower metal concentrations than East Willow Creek below the site (Table 12). It is not clear why there are such significant discrepancies in the Mammoth Tunnel sample results from year to year. It could be lab error, sample contamination, or variances in the quality of the effluent.

Sediment sampled downstream of the Mammoth Tunnel contained extremely elevated concentrations of lead and zinc. This is probably the result of erosion and redeposition of mill tailings and mine waste rock from upstream mines, especially the Solomon and Ridge Mines (Kirkham, 1993, p. 10-11).

Migration Pathways

Groundwater Pathway

This long crosscut adit evidently intersects water-bearing fractures in the subsurface. Much of this water escapes to the surface at the portal, however, some may reenter the groundwater system through fractures. The water emerging from the portal is slightly degraded with lead, and similar water chemistry is likely for the water that may reenter the groundwater system. The low concentration of lead combined with the low volume of water that may be reentering the bedrock ground-

Table 12. Water and stream-sediment sample results for East Willow Creek and the Mammoth Tunnel. [Water sample results are shown in dissolved concentrations and µg/L unless noted. Solid sample results are in ppm unless noted. Blank columns indicate the parameter was not analyzed or the results are not known. Unless noted, all samples were collected in late May or early June, 1995, and are reported in O'Grady (1997). The 1989 sample was collected by Colorado Division of Minerals and Geology and was reported in Kirkham (1993, p. 16).]

Parameter	Mammoth Tunnel effluent, 1989	Mammoth Tunnel effluent	E. Willow below Mammoth Tunnel	Sediment below Mammoth Tunnel
Flow (cfs)		0.16	30.12	
pH	6.3	7.49	7.50	
Conductivity	67 µS	45 µS	36 µS	
Hardness		18.33 mg/L	20.09 mg/L	
Alkalinity			<10.00 mg/L	
Total suspended solids			<4.00	
Aluminum	0.7 mg/L	<87.30 85.70 (trec)	212 620 (trec)	3,540
Antimony		<1.90 (both)	2.60 (both)	0.60
Arsenic		20.60 19.20 (trec)	<3.20 (both)	17.00
Barium		3.80 3.20 (trec)	7.40 10.90 (trec)	47.80
Beryllium		<0.25 (both)	<0.50 (both)	<0.31
Cadmium	0.01 mg/L	<0.30 (both)	1.30 0.70 (trec)	10.90
Calcium		6,240 6,410 (trec)	6,260 6,790 (trec)	1,990
Chloride			<3.00 mg/L	
Chromium	0.05 mg/L	<0.90 (both)	<0.90 (both)	1.40
Cobalt		<0.60 (both)	<0.60 0.92 (trec)	3.20
Copper	0.08 mg/L	<0.70 (both)	<0.70 1.40 (trec)	17.20
Fluoride			<0.10 mg/L	
Iron	0.04 mg/L	<7.70 (both)	47.50 252 (trec)	6,540
Lead	0.14 mg/L	<1.90 2.60 (trec)	13.50 19.60 (trec)	1,090
Magnesium		574 566 (trec)	676 762 (trec)	1,470
Manganese	0.01 mg/L	2.40 2.90 (trec)	16.80 22.30 (trec)	439
Mercury		<0.20 (both)	<0.20 (both)	<0.13
Molybdenum	0.04 mg/L			
Nickel	0.02 mg/L	17.80 <1.40 (trec)	<1.40 (both)	<0.40
Potassium		822 750 (trec)	703 671 (trec)	742
Selenium		<4.40 (both)	<4.40 (both)	<1.30
Silver		<0.50 (both)	<0.50 (both)	0.71
Sodium		5,810 5,810 (trec)	2,940 2,810 (trec)	464
Sulfate			4.31 mg/L	
Thallium		<4.50 (both)	<4.50 (both)	<1.30
Vanadium		<0.71 (both)	<2.10 (both)	14.30
Zinc		22.70 20.70 (trec)	201.00 209.00 (trec)	1,630

water system minimize the significance of this pathway. Although the effluent spilling from the broken pipe disappears into talus before reaching East Willow Creek, it does not enter groundwater. The flow continues down the steep slope beneath a thin veneer of talus and enters East Willow Creek quickly, virtually as surface flow.

The closest registered wells for household use are two shallow wells about 0.5 mile downstream in North Creede. These wells presumably draw from the surficial aquifer of East Willow Creek. The Mammoth Tunnel apparently has little or no effect on the surface water, and probably has a similar effect on the surficial aquifer of East Willow Creek. Any contribution to degradation of East Willow Creek or its surficial aquifer from the Mammoth Tunnel is masked by the much more serious impact from upstream sites such as the Solomon and Ridge Mines.

Surface Water Pathway

Water sample results indicate that the effluent from the Mammoth Tunnel does not apparently affect surface water in East Willow Creek. Although fish do not live in this segment of the creek, metal contamination and habitat destruction related to upstream mines, especially the Solomon and Ridge Mines, are probably the causes. In addition to the obvious source of metals, i.e., effluent from the Solomon Mine, significant quantities of metals may be leached from the saturated, metal-rich sediments of East Willow Creek below the Solomon Mine. The metal-rich sediments are believed to result from erosion and redeposition of mill tailings and mine waste rock originating from the Solomon and Ridge Mines. (See Kirkham, 1993, p. 10-11.)

Downstream targets within 15 miles downstream of this inventory area include excellent trout fisheries on the Rio Grande, extensive wetlands, and habitat for Threatened and Endangered Species. Habitats suitable for peregrine falcons, bald eagles, wolverines, and Mexican spotted owls are present in this area. (See O'Grady, 1997, p. 6.)

Soil Exposure Pathway

Although people reside within about ½ mile of the Mammoth Tunnel, the soil exposure pathway is insignificant because there is no associated mine dump.

Air Exposure Pathway

Because no dump is associated with the Mammoth Tunnel, the air exposure pathway is insignificant.

ACE MINE

The Ace Mine (inventory area #09-04-326/4191-1) is located along the east side of Miners Creek, about 2.5 miles west of Creede (Figure 1). This small site lies completely on USFS-administered land. The adit is gated and is discharging a small volume of effluent.

Mining History

Very little information regarding history or production of this mine was located in the records. The small dump and lack of mineralized rock on the dump suggest that any production was minor.

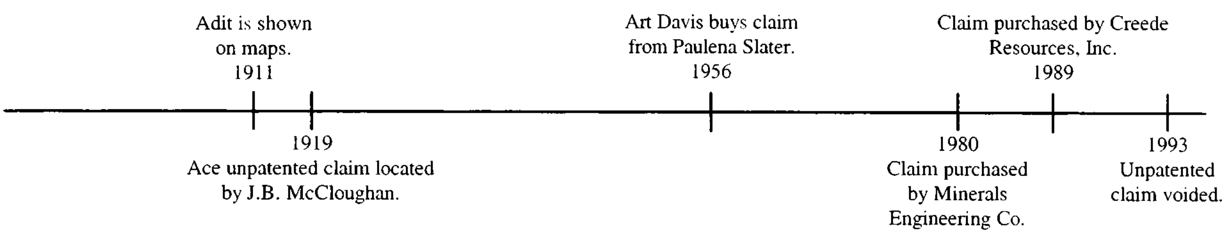
The mine apparently existed as early as about 1911 or 1912 when Emmons and Larsen (1923) did their field work, because this adit is shown on their plates 1 and 2. The extent of the adit at that time is not known, and the adit is not named on their plates.

The Ace unpatented mining claim, which includes the adit, was located in 1919 by J.B. McCloughan(?) and relocated in 1921. The claim name before that is not known.

Arthur Davis of Del Norte, Colorado, bought the Ace mining claim from Paulena Slater in 1956. He sold the claim to Minerals Engineering Company of Denver in 1980. Minerals Engineering changed their name to CoCa Mines Incorporated in 1988. Creede Resources Incorporated of Denver purchased the Ace claim from CoCa Mines Incorporated in 1989. (See BLM files.)

The most recent assessment work was recorded in 1989. Creede Resources Incorporated was the listed owner of the Ace unpatented mining claim when the claim was voided in 1993. (See BLM files.)

Timeline summarizing the mining history of the Ace Mine



Geology

The Ace Mine is driven in the Willow Creek Member of the Bachelor Mountain Rhyolite and probably extends to the Alpha-Corsair fault zone. This north-northwest-trending, east-dipping fault zone has the highest displacement of any of the faults in the western part of the Creede graben. The fault is well mineralized south of the Ace Mine at some mines on patented land. At the Ace Mine, a dike of Fisher Creek latite has apparently intruded the hanging wall of the fault zone. (See Steven and Ratté, 1965, p. 85, plate 1; Emmons and Larsen, 1923, p. 188.)

The nature of the Alpha-Corsair fault zone and vein at the Ace Mine is not known. In general, the Alpha-Corsair vein is a mineralized, brecciated fault zone, often sandwiched between the rhyolite and latite. The breccia zone is up to 30 feet wide and consists of gouge and crushed rhyolite and latite. Ribbon structures and banding in the vein suggest that open-space filling was the primary mode of mineralization. The vein is highly oxidized at the Alpha and Corsair Mines to the south of the Ace Mine (Figure 1). Quartz, limonite, pyrite, and green and blue copper sulfates are abundant; barite is common. Silver chloride was the most important ore mineral. Stibnite (an antimony sulfide) and stephanite (a silver-antimony sulfosalt) reportedly occurred in the lower levels. Further north, at the Kreutzer Mine, sphalerite, galena, pyrite, native silver, and argentite (silver sulfide) are the most abundant metallic minerals in the Alpha-Corsair vein. (See Emmons and Larsen, 1923, p. 187-191.)

Site Description

This site includes an adit that is draining water and a small dump (Figure 5). The adit has a locked grated door and is discharging effluent. The effluent flows south, adjacent to the top of the 500-cubic-yard dump, crosses the Miners Creek Road through a culvert, and discharges into Miners Creek. Staining in the midsection of the dump, directly in front of the portal, indicates that during times of higher flow some effluent crosses the face of the dump before entering a roadside ditch and flowing to the culvert.

Waste and Hazard Characteristics

Effluent flowing from the portal is the most important environmental feature of the Ace Mine. The effluent deposits abundant light-red to orange precipitate where it emerges from rockfall and talus at the portal. The volume of precipitate gradually decreases throughout the 200-foot-long effluent channel, until only minor staining is evident near its confluence with Miners Creek. Apparently, much of the iron and other dissolved metals are precipitated prior to the effluent reaching Miners Creek. Ace Mine effluent has been sampled at least three times in the last 10 years (Table 13). Samples from 1989 showed high concentrations of aluminum, lead, and copper. Water in Miners Creek sampled at the same time had similar metal concentrations, despite the apparent difference in water quality based on precipitate deposition and visual observation (Kirkham, 1993, p. 13).

Because of the questionable data from the 1989 samples, additional testing and sampling of the effluent and Miners Creek water were completed in 1992 (Kirkham, 1993, p. 13). During the sampling, flow from the adit was estimated to be about 7 gpm, and flow in Miners Creek was estimated at about 2,250 gpm. Effluent had a nearly neutral pH, and Miners Creek water was slightly basic. Lab results revealed high concentrations of iron and manganese, and slightly elevated

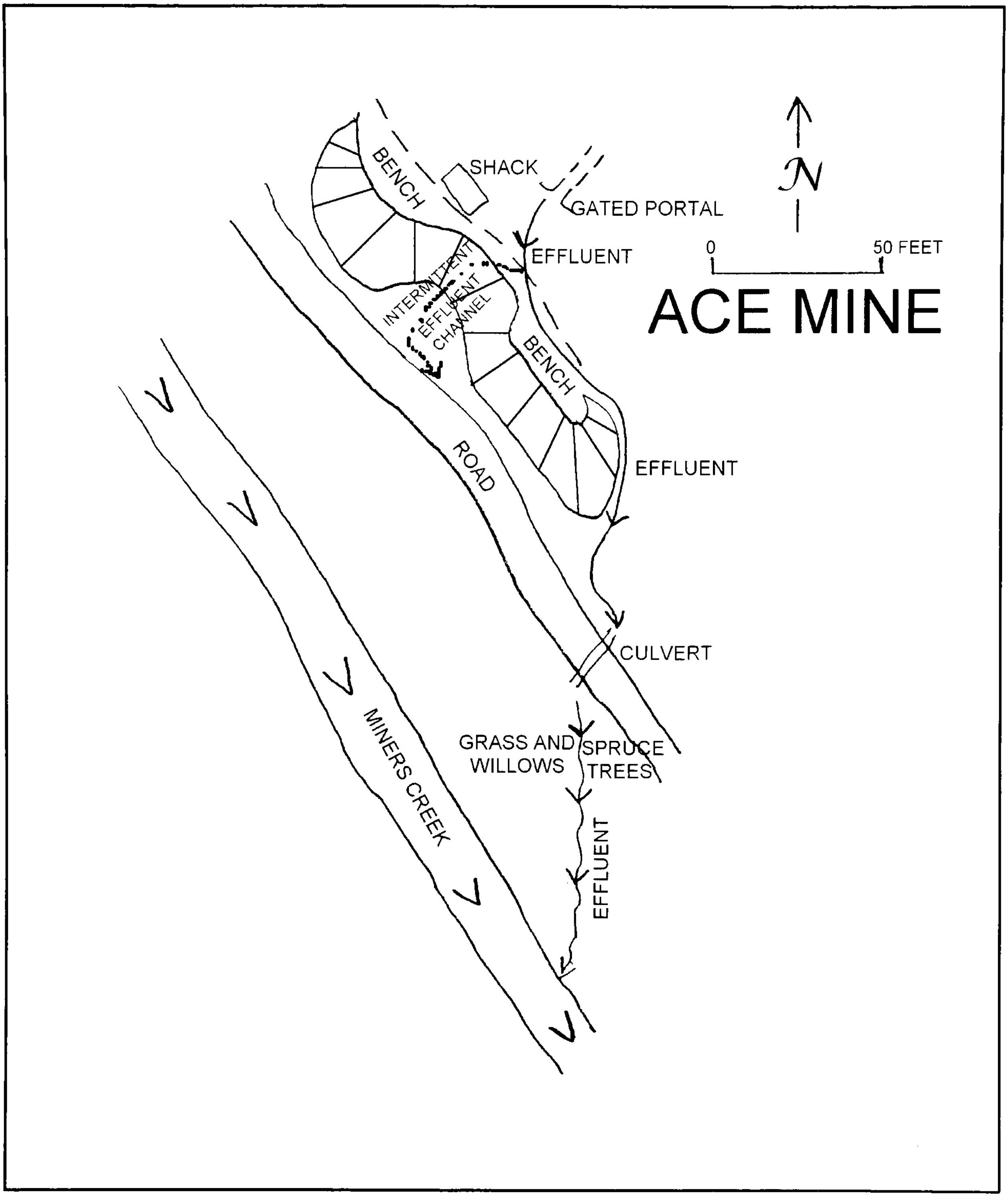


Figure 5. Surface map of the Ace Mine.

Table 13. Ace Mine and Miners Creek water testing and sample analyses results. (Results are shown in dissolved concentrations and µg/L unless noted. Blank columns mean the parameter was not analyzed or the results are not known).

Analyzed or tested parameter	Mine effluent in 1989 (Kirkham, 1993, p. 13)	Mine effluent on 9/28/92	Miners Creek upstream of Ace Mine on 9/28/92	Miners Creek downstream of Ace Mine on 9/28/92	Mine effluent on 6/18/98	State water standard (6/18/98 sample)	Factor above state water standard (6/18/98 sample)
Total alkalinity		32 mg/L	16 mg/L	24 mg/L	80 mg/L	no standard	n/a
pH	6.3	7.51	8.12	7.81	6.92	6.5 – 9.0	within standard
Conductivity	326 µS	335 µS	55 µS	53 µS	401 µS	no standard	n/a
Hardness		89 mg/L	18 mg/L	19 mg/L	93 mg/L	no standard	n/a
Aluminum	700	<50	<50	<50	26 (trec) 6.9	no standard 87	n/a below standard
Antimony					<0.24 (trec)	6 (trec)	below standard
Arsenic		21	<1	<1	31 (trec)	50 (trec)	below standard
Barium		24	3	3		1,000	
Cadmium	10	<0.25	<0.25	<0.25	<0.18	1	below standard
Calcium					34 mg/L	no standard	n/a
Chloride					1.2 mg/L	250 mg/L	below standard
Chromium	60	<10	<10	<10		11	
Copper	80	<4	<4	<4	3.3	10	below standard
Fluoride					0.95 mg/L	2 mg/L	below standard
Iron	60	1,800	63	56	2,410 (trec) 1,920	1,000 (trec) 300	2.4 x standard 6.4 x standard
Lead	150	<5	<5	<5	0.7	3.7	below standard
Magnesium					2 mg/L	no standard	n/a
Manganese	250	790	11	9	870 (trec) 870	50 50	17.4 x standard 17.4 x standard
Molybdenum	50					no standard	
Nickel	30	<20	<20	<20		90	
Potassium					2.2 mg/L	no standard	n/a
Silver		<0.2	<0.2	<0.2	<0.06	0.07	below standard
Sodium					30 mg/L	no standard	n/a
Sulfate		90 mg/L	<5 mg/L	<5 mg/L	110 mg/L	250 mg/L	below standard
Thallium					<0.11 (trec)	0.5 (trec)	below standard
Zinc	40	71	<8	<8	88 (trec) 91	2,000 (trec) 100	below standard below standard

concentrations of arsenic and zinc in the effluent. Miners Creek water had only low concentrations of metals and was nearly unchanged by the addition of effluent from the Ace Mine. (See Table 13.) These results seem reasonable based on visual evidence at the site and the large flow of Miners Creek compared to the mine discharge rate.

The effluent was tested and sampled again during this investigation in 1998. Flow was measured to be 11.3 gpm, and pH was nearly neutral. Lab results were similar to those of 1992. Ace Mine effluent significantly exceeds state water quality standards for manganese and iron concentrations. Zinc and arsenic levels are elevated but within standards. (See Table 13.)

The dump of the Ace Mine appears relatively innocuous. It is mostly rhyolite, but contains minor pyrite. Weak iron staining indicates that effluent occasionally flows down the dump face directly in front of the portal. Minor additional degradation of the mine discharge may occur during times of higher flow, when effluent runs across the face of the dump.

Migration Pathways

Groundwater Pathway

The Alpha-Corsair vein, which the Ace Mine was driven to intersect, apparently is a significant subsurface waterway. Both the Alpha and Corsair Mines to the south of the Ace Mine are flooded, and effluent from the lower Alpha level was depositing limonite prior to 1913 (Emmons and Larsen, 1923, p. 189). Bedrock at the Ace Mine is fractured rhyolite. The fractured bedrock and the fault zone presumably allow groundwater into the mine. Although some of that groundwater is discharged at the portal, some probably reenters the bedrock groundwater table. Most likely, the recharge back into groundwater is less than the mine discharge rate, and the water is probably of comparable quality. The small flow of groundwater through this short adit is negligible when compared to the flow of Miners Creek. Any elevated metal concentrations in groundwater that eventually discharges into Miners Creek would be quickly diluted. Metal loading is not a concern because of the small amount of groundwater involved and the relatively low metal concentrations.

The closest registered wells for household or domestic uses are about 0.5 mile away, to the northeast and east (Colorado Division of Water Resources records). Both of these wells are in the Rat Creek drainage basin and are probably not hydrologically connected to the Ace Mine.

The nearest registered well in the Miners Creek drainage basin is about 1 mile downstream, near the mouth of Sawmill Gulch. This well is only 40 feet deep and presumably draws from the surficial aquifer of Miners Creek. Four additional wells are on the eastern side of Miners Creek about 0.75 mile further downstream. All of these are for household use. Because of distance and dilution, the small amount of groundwater associated with the Ace Mine probably has no effect on these wells.

An unregistered well probably exists at the Boy Scout camp at the patented Kreutzer Mine, about 0.25 mile upstream and upgradient from the Ace. The Ace Mine would not affect this well.

Surface Water Pathway

Effluent from the Ace Mine is the most serious environmental problem at this site. Several samplings and tests of the effluent demonstrate that this effluent does not meet state water standards. The metals exceeding the standards, manganese and iron, are not highly toxic to humans or fish. The small flow from the mine is quickly diluted by Miners Creek. Metal loading of Miners Creek by the mine drainage is insignificant because of the relatively low metal concentrations combined with low flow rates. Vegetation and aquatic life in Miners Creek show no obvious ill effects from the influx of the effluent from the Ace Mine.

Miners Creek is not known to be a water supply for any municipalities or residences. Campers may use the water occasionally. Livestock drink from the creek about 1 mile downstream. Effluent from the Ace Mine probably has negligible effect on the quality of Miners Creek water for these purposes.

Soil Exposure Pathway

The Ace Mine is adjacent to a moderately well used road; but no one lives at the site, and visits to the mine are brief. The Ace Mine dump apparently contains only low metal concentrations, so this pathway is considered insignificant for such brief exposures.

Air Exposure Pathway

This small dump comprises relatively coarse-grained material with low metal concentrations. Also, natural revegetation of the dump is occurring. The nearest year-round resident is more than a mile away. On an intermittent basis, people use a Boy Scout camp and cabin at the patented Kreutzer Mine about 0.25 mile upstream on Miners Creek; and campers settle into some of the meadows along Miners Creek. Because of the limited exposures and the nature of the dump material, the air pathway presents no apparent threats to human health or the environment.

BIG SIX MINE

The Big Six Mine, also known as the Silver Horde (inventory area #09-04-327/4189-1), is located along Miners Creek about 2 miles west-southwest of Creede (Figure 1). The Monon Mine and Monon Hill, shown southeast of the Big Six Mine, are mislabeled on the USFS PBS map and the U.S. Geological Survey topographic map. Monon Hill is the feature immediately to the northeast of the Big Six Mine, and the Monon Mine is on the west side of Monon Hill (Figure 1; Emmons and Larsen, 1923, plate 1). The Big Six Mine was apparently driven as a haulageway for ore shoots exposed by adits, including the Monon Mine, on the north and west sides of Monon Hill.

Mining History

Mineral Survey No. 8325A and B was conducted on the Monon Lode and associated claims (Creede Quintet Mining Company, owner) on April 13, 1893 (Mineral Survey No. 8325A and B, available at the Bureau of Land Management, Colorado State Office). Neither the mineral survey nor the maps prepared by Emmons and Larsen (1923) around 1910 show or mention the Big Six Mine, which lies about 350 feet southwest of the southwest end line of the Monon claim. The Big Six Mine lies on the Annabelle unpatented claim and was probably excavated about 1916 as a haulageway for the rich ore zones discovered in the Monon Mine in about 1915 or 1916.

In 1902 the Quintet Mining Company (Rufe Light, Manager) owned the Monon group (Colorado mining directory and buyer's guide, June 1902, p. 100).

The Monon was listed as a producer in 1913 (Henderson, 1914, p. 263).

The rich ore bodies of the Monon group were discovered about 1915 or 1916 by Samuel Magnusson. Production was mainly from the Monon Mine, but some came from the Manitoba. (See Larsen, 1930, p. 103.)

The Quintette-Monon group was listed as a producer from 1917 to 1922. In 1918, an exceptionally large tonnage of silver ore was shipped from the Quintette-Monon. It is not clear if Monon Mining Company owned or leased the mine. (See Henderson, 1920, p. 833; Henderson, 1921, p. 854; Henderson, 1922a, p. 778; Henderson, 1922b, p. 585; Henderson, 1924, p. 500; Henderson, 1925 p. 541.)

In 1921, 35 feet of drifts were driven on the Annabelle and Liberty unpatented claims (Operators Annual Report for 1921-Silver Horde M & M Company, to Colorado Bureau of Mines, January 22, 1922). In 1920 and 1921, Wabash Company is listed with the Monon Mine (Henderson, 1922b, p. 585; Henderson, 1924, p. 500). It is not clear if Wabash owned or leased the property.

The peak of mining activity at the Monon Mine was 1918 to 1922, when about 20 oz gold; 750,000 oz silver; and 170 tons of lead were produced (Steven and Ratté, 1965, p. 9). Most of the

production from 1915 to 1922 was done by lessees A.B. Collins and H.R. Wheeler (Larsen, 1930, p. 103).
The owners/operators of the Quintette-Monon Group during the peak of production from about 1915 to 1922 are not clear. Magnusson, Collins and Wheeler, Monon Mining Company, Silver Horde Mining and Milling Company, and Wabash Company are all mentioned during those years.

Development work was done at the Monon in 1927 (Henderson, 1930, p. 556).

In 1928, 200 feet of development work was done at the Monon mine (Henderson, 1931, p. 850).

The Silver Horde haulageway was connected to the workings of the Manitoba claim and was about 1,000 feet long when field work was completed in 1928 by Larsen (1930, p. 106, Figure 15).

The Monon Mine was active from 1935 to 1941 and had reported production worth about $50,000 from 1937 to 1939. The ore was treated at the new Creede Mills, Incorporated mill about 1 mile south of Creede. (See Henderson and Martin, 1938, p. 271; Henderson and Martin, 1939, p. 289; Henderson and Martin, 1940, p. 273; Steven and Ratté, 1965, p. 11.) This was the last reported production from this group of mines.

From 1952 to 1958, exploration was the only activity at the Monon Mine (Steven and Ratté, 1965, p. 11).

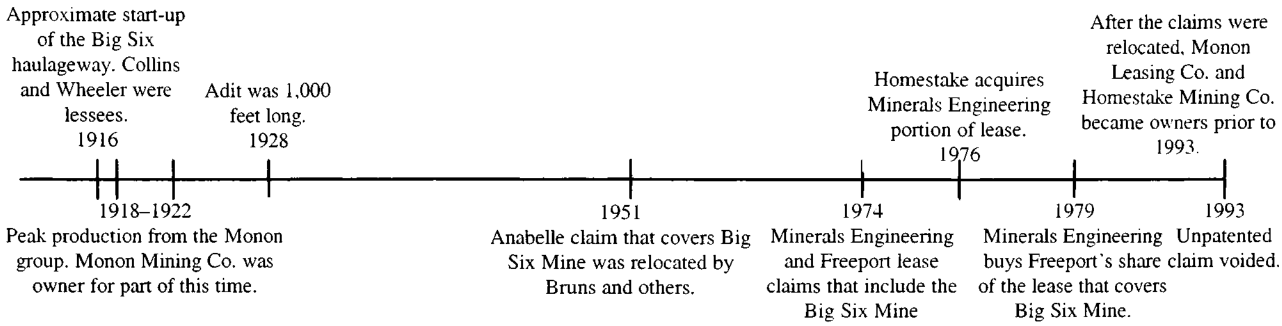
The Anabelle unpatented mining claim apparently includes the portal of the Big Six Mine. The original claim date was not found, but L.E. Bruns, W. Wallace Wright, Ivan Weaver, and J.J. Williams relocated this claim in 1951 (BLM files). In 1974 Freeport Exploration Company and Minerals Engineering Company leased this claim from a large group of private individuals. In 1976 and 1977, Homestake Mining Company subleased, then bought Minerals Engineering's share of the claim block that includes the Big Six Mine. In 1979 Minerals Engineering bought Freeport's share in the claim block (See Nelson, 1989, p. 23-27; various deeds and leases from numerous courthouses, USFS files).

Monon Leasing Company and Homestake Mining Company were listed as the claimants of the Anabelle claim in the 1998 edition of the BLM Geographic Index of Claims. The claim was voided in 1993. (See BLM files.)

In the early 1970s, Freeport Exploration Company conducted surface mapping on the claim group that includes the Big Six Mine (Nelson, 1989, p. 24).

According to Les Dobson (USFS Watershed Management), Adolph Zang of California was an owner of the property in 1998. The Zang family has been involved in mining at the Big Six Mine for many years (John Jackson, personal communication with Les Dobson, March 1999).

Timeline summarizing the mining history of the Big Six Mine



Geology

The Big Six Mine cuts through a geologically complex area of Creede Formation rocks adjoining and overlying Campbell Mountain Member of the Bachelor Mountain Rhyolite. The Creede Formation is a post-caldera sedimentary unit consisting of reworked volcanic rocks and hot-springs deposits. At the Big Six Mine, Creede Formation rocks include fanglomerate, travertine, and thinly bedded shale, siltstone, and sandstone. (See Steven and Ratté, 1965, p. 84-85, plates 1, 5.) The Big Six Mine follows the contact between the igneous and sedimentary rocks (John Jackson, personal communication with Les Dobson, USFS, March 1999).

Metallic minerals occur in veins and disseminated in country rock. Fanglomerate and travertine are the favored host rocks, and ore occurs over a vertical extent of at least 400 feet at or near the contact of Creede Formation rocks with a buried hill of Bachelor Mountain Rhyolite. (See Steven and Ratté, 1965, p. 78-79, plate 5.)

The mineralized rock is silicified, porous, and is generally harder than surrounding rock. Pyrite is the most abundant metallic mineral, and sphalerite, galena, and chalcopyrite are common. The mineralogy of the gangue and ore varies widely within mineralized zones. "Considerable" travertine is found within the Silver Horde, and sulfides are more abundant in the lower workings of the Monon group of mines. (See Steven and Ratté, 1965, p. 79; Larsen, 1930, p. 105, 112.)

Site Description

Two items of environmental concern at the Big Six Mine are the presence of water in the adit and the large surface disturbance associated with this mine. Standing water in the mine was sampled in June of 1998, but by September of 1998, the portal had been bulldozed shut. A sump is about 30 feet south of where the portal was, but no water reached the sump at the surface. The loose, highly fractured and fissile rocks in front of the portal were slightly damp in late June, but no moisture was observed in September. Apparently the Big Six Mine does not transport a large volume of water.

The Big Six Mine has a much larger surface disturbance than seems necessary for this site. A highwall about 600 feet long and up to about 60 feet high forms the boundary of the site on the northeast side. The bench is about 500 feet long and 100 to 150 feet wide. (See Figure 6.)

A set of tracks splits on the bench. One set proceeds straight to the edge of the bench and served an ore load-out hopper that adjoins the Miners Creek Road. The other set curves south, then southeastward, and was used to dump weakly mineralized waste rock.

The volume of mineralized waste rock at this site is small, but is scattered thinly over an area about 200 feet by 40 feet. A small amount of weakly mineralized waste rock was placed on the southwest side of Miners Creek Road, across the road from the hopper, and was probably used for a truck turnaround area. Most of the outslope between the bench and the Miners Creek Road is unmineralized overburden that was pushed over the hill when the bench area was constructed and barren country rock from when this haulageway adit was excavated.

A small borrow pit, probably unrelated to the underground mining activity at this site, lies adjacent to the south end of the bench and mine dump.

Waste and Hazard Characteristics

This adit was driven as a haulageway to the Monon Mine, and most of the waste rock is barren country rock. The large bench and highwall were also excavated in unmineralized Creede Formation rocks, mostly shale with some blocks and boulders of travertine. Although these rocks may be a source for sedimentation, metal contamination is unlikely. Travertine may neutralize any acid formed by sulfide minerals at the site.

The dump contains a small volume of weakly mineralized mine waste, most which was placed along the tracks southeast of the hopper. This mine waste is exposed to rain and snowfall, but the surface area is small, and the Miners Creek Road separates the dump from the floodplain/meadow adjacent to Miners Creek.

Weakly mineralized waste rock was used to build the turnaround area across the road from the hopper, in the floodplain/meadow that adjoins Miners Creek. The surface area exposed to precipitation is only about 50 feet by 25 feet, but some metals may be leached and introduced into the alluvial aquifer associated with Miners Creek.

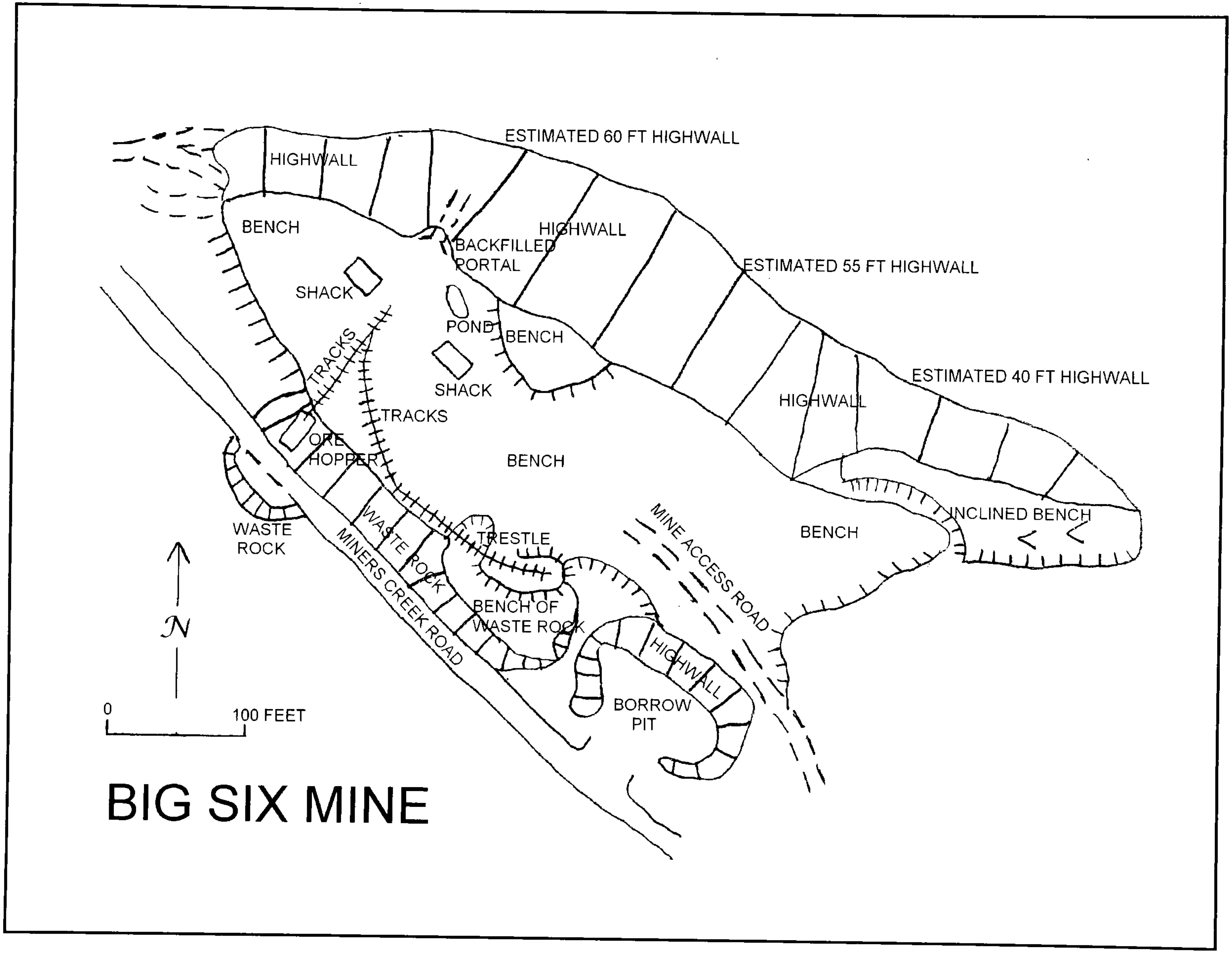


Figure 6. Surface map of the Big Six Mine.

In September 1992, the adit was draining about 1 gpm into a sump. This effluent deposited red-orange precipitate and had pH of 7.77 and conductivity of 1,100 µS. The mine water apparently seeped into the dump and/or evaporated, because the sump had no discharge. (See Kirkham, 1993, p. 13; USFS-AMLIP inventory form #09-04-327/4189-1.) In June 1998, the portal of the adit was nearly closed by sloughing rock from the highwall. Murky, standing water in the adit had pH of 7.39 and conductivity of 1,274 µS. No discharge was observed, but loose material in front of the portal was damp, with minor deposits of white precipitate. A sample of the standing water shows arsenic, iron, manganese, sulfate, and zinc concentrations exceed state standards (Table 14). Because of the dissolution of travertine, the pH is high. Calcium concentration is also high, contributing to high conductivity. By September 1998, the portal was closed completely, and no water was discharging.

In June 1998, a box of powdered acid and three barrels of petroleum distillates were in one of the buildings, but these items were removed by September 1998.

Table 14. Big Six Mine water sample results.

Hardness = 608 mg/L

Analyzed parameter	**Mine effluent***	**State water standard***	**Factor above state water standard**
Aluminum	7.1 µg/L (trec) 0.9 µg/L	n/a 87 µg/L	n/a below standard
Antimony	1.2 µg/L (trec)	6 µg/L (trec)	below standard
Arsenic	96 µg/L (trec)	50 µg/L (trec)	1.9 x standard
Cadmium	<0.18 µg/L	4.7 µg/L	below standard
Calcium	230 mg/L	no standard	n/a
Chloride	2.8 mg/L	250 mg/L	below standard
Copper	2.8 µg/L	55 µg/L	below standard
Fluoride	1.3 mg/L	2 mg/L	below standard
Iron	2,530 µg/L (trec) <10 µg/L	1,000 µg/L (trec) 300 µg/L	2.5 x standard below standard
Lead	<0.1 µg/L	50 µg/L	below standard
Magnesium	8 mg/L	no standard	n/a
Manganese	1,410 µg/L (trec) 1,450 µg/L	n/a 50 µg/L	n/a 29 x standard
Potassium	3.0 mg/L	no standard	n/a
Silver	<0.06 µg/L	1.7 µg/L	below standard
Sodium	18 mg/L	no standard	n/a
Sulfate	500 mg/L	250 mg/L	2 x standard
Thallium	0.40 µg/L (trec)	0.5 µg/L (trec)	below standard
Zinc	1,040 µg/L (trec) 840 µg/L	2,000 µg/L (trec) 489 µg/L	below standard 1.7 x standard

* dissolved concentration unless noted.

Migration Pathways

Groundwater Pathway

Bedrock at the Big Six Mine is primarily fractured and fissile, fine-grained sedimentary rock. Underground, these rocks may allow water to drain through them, leaching metals from mineralized rock into the groundwater. The small discharge from the Big Six Mine suggests that this mine is either not in an area of abundant groundwater or that groundwater entering the mine reenters groundwater before reaching the portal. An underground investigation would reveal more information regarding the groundwater situation. At least some mine water probably migrates through the adit into the groundwater table that flows into Miners Creek.

The turnaround area constructed of weakly mineralized waste rock may contribute small amounts of metals to the surficial aquifer of Miners Creek. The turnaround area is built in the grassy floodplain of Miners Creek. Metals mobilized during precipitation events are probably quickly attenuated by the substantial volume of organic material in the meadow. The meadow may act as a passive treatment system for metal removal. Vegetation adjacent to the turnaround area is healthy.

Any elevated metal concentrations from mine water, and any metals leaching from the waste-rock pile and the turnaround area, are quickly diluted in the large alluvial aquifer of Miners Creek. Metal loading is not a factor because of the small amount of groundwater involved and the relatively low metal concentrations associated with the mine water and waste rock.

The closest registered well is about ¼ mile to the west, on the opposite side of Miners Creek and slightly upgradient from the Big Six Mine. This well is only 40 feet deep and presumably draws from the surficial aquifer of Miners Creek. Because of its location across the creek and upgradient from the mine, this well should not be affected by groundwater associated with the Big Six Mine. Four additional wells are on the eastern side of Miners Creek about 0.75 of a mile downstream of the Big Six. All of these are for household use. Because of distance and dilution, the small amount of groundwater associated with the Big Six Mine probably has no effect on these wells.

Surface Water Pathway

Although sedimentation from this large area of unvegetated and disturbed ground is a possibility, no evidence of significant erosion and sedimentation was observed. Standing water in the adit did not meet state standards for several parameters, including arsenic. This water did not discharge in June 1998, and was not accessible in September 1998 because the portal was closed. No sample data from Miners Creek at the Big Six Mine was available, therefore the effects of the site on the creek are not quantifiable in this study. Vegetation and aquatic life in Miners Creek show no obvious ill effects from runoff from the Big Six Mine.

Miners Creek is not known to be a water supply for any municipalities or residences. Livestock drink from the creek. Runoff from the Big Six Mine probably has negligible effect on the quality of Miners Creek water for these purposes.

Soil Exposure Pathway

The closest residents are about ¼ mile away. The surface disturbance associated with this mine is quite visible and easily accessible to the public, so tourists probably explore the site occasionally. Because the dump and bench are mostly unmineralized country rock, and exposure times are generally short, this pathway is considered insignificant at the Big Six Mine.

Air Exposure Pathway

This large disturbed area comprises mostly moderately well cemented, gravel- and sand-size materials. Occurrences of significant volumes of windblown particles at this site are probably rare. The nearest year-round resident is about 0.25 mile away, and length of visits by tourists is generally brief. The air exposure pathway presents no apparent threats to human health or the environment.

CONCLUSIONS

West Willow Creek becomes uninhabitable for fish in the vicinity of the Amethyst and Last Chance Mines. Effluent is not associated with these sites, however, both of these mines have large waste-rock piles that extend into West Willow Creek. Mineralized rock eroded from the dumps and tailings from a breached tailings pond near the Amethyst Mine have been dispersed downstream. The waste-rock piles should be pulled back, if possible, or the creek diverted to prevent additional erosion of the mineralized dumps. Because these waste-rock piles are mostly privately owned, any clean-up efforts will require accurate surveys and cooperation from a variety of landowners. Previous environmental studies indicate that degradation of West Willow Creek increases downstream, near the Commodore and Nelson Tunnels and their associated waste-rock piles.

Nelson Creek shows evidence of degradation at the Midwest Mine, although the degradation is probably seasonal in nature. Nelson Creek is not a perennial stream at the Midwest Mine. Possible solutions include controlling surface runoff at the site, diverting Nelson Creek away from the dump, removing part or all of the Midwest Mine dump, or capping the dump with a soil cover. No effluent was observed flowing from the adit.

East Willow Creek becomes uninhabitable for fish at the Solomon Mine. Effluent from the Solomon Mine is probably the main cause of degradation, although erosion of mine dumps at the Solomon and Ridge Mines, and dispersion of tailings from a mill at the Solomon Mine are additional sources of metals in the surface water. Previous remediation efforts at the Solomon Mine included rerouting the road to provide a buffer between the dump and East Willow Creek and construction of passive treatment ponds for the effluent from the adit. The road performs as designed, isolating the dump from further significant erosion. The treatment ponds no longer effectively remove metals from the mine effluent. Most of the Solomon site is privately owned, however degradation associated with the site extends downstream onto USFS-administered land.

Other sites along East Willow Creek examined during this study do not significantly affect water quality in the creek. At the Phoenix Park Millsite, surface water should be diverted around the shallow tailings ponds, and the ponds could be backfilled.

At the Outlet Tunnel, the mine dump should be pulled back from the banks of East Willow Creek to prevent additional erosion of the weakly mineralized waste rock. Depositing some of the Outlet Tunnel waste rock in the dry tailings ponds at the Phoenix Park Millsite may be a viable solution, although the arsenic and lead content of the waste rock may be a concern. Outlet Tunnel waste rock had a +5.3 tons $CaCO_3$ net acid-base accounting, indicating a low probability of producing acid rock drainage. A long-term humidity-cell test could be used to corroborate the acid-base accounting results.

Although sample results vary considerably, effluent from the Mammoth Tunnel is probably not a major source of metals to East Willow Creek. Additional samples may help clarify the composition of the effluent.

Sites examined during this study have no noticeable effect on water quality of Miners Creek. The low volume of slightly degraded effluent from the Ace Mine should be channeled to avoid contact with the dump. Visual evidence suggests that many of the metals are deposited in the effluent channel before the mine drainage reaches Miners Creek. Sampling of the effluent near its confluence with Miners Creek would help determine if the discharge is being naturally attenuated.

The Big Six Mine has a large surface disturbance, but the dump is weakly mineralized and the adit is not draining. The turnaround area consisting of mineralized rock on the southwest side of the Miners Creek Road is within the Miners Creek floodplain and should be removed. If it is above the 100-year-flood elevation, the large bench at the Big Six Mine may be a suitable repository for waste rock from other sites in the Creede mining district. The bench is above and isolated from flowing water, so dispersion of the waste rock by erosion would be minimal. This site should be revegetated.

Kirkham (personal communication, June 1999) feels that throughout the Creede mining district large volumes of water can be quickly transported in the numerous, open fissures in the volcanic terrane. These fracture systems may provide major inlets for clean water to enter mines, and outlets for degraded water to exit mines and enter streams. Tracer studies could help determine the importance of this pathway for contaminated and clean groundwater.

Previous studies suggest that most environmental degradation associated with mines in the Creede area originates from sites that are mostly privately owned. Cooperative clean-up efforts will be required to significantly improve the water quality of East and West Willow Creeks.

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