OPEN-FILE REPORT 05-01

MINE SITE HISTORY AND WATERSHED CHARACTERIZATION OF THE CINNAMON GULCH AREA, DILLON RANGER DISTRICT, WHITE RIVER NATIONAL FOREST, SUMMIT COUNTY, COLORADO

By

Robert H. Wood II,
David A. Bird,
and
Matthew A. Sares

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Colorado Geological Survey
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FOREWORD

Open-File Report 05-01 describes the history, geology, and environmental setting of several mines in the Cinnamon Gulch area and characterizes constituent loading during high and low flow in Cinnamon Gulch. All of the mine sites are located at least partly on U.S. Forest Service-administered land. The sites were selected for investigation based on the results of an abandoned mine inventory completed by the Colorado Geological Survey. This information is useful for State and Federal agencies and private owners for developing realistic and cost-effective reclamation plans for mines in the Snake River 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.

Matthew A. Sares
Chief, Environmental Geology Section

Vincent Matthews
State Geologist and Director

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LIST OF ABBREVIATIONS AND SYMBOLS

~	approximate value
bk.	book
cm	centimeter(s)
CBM	Colorado Bureau of Mines
CDMG	Colorado Department of Minerals and Geology
CDPHE	Colorado Department of Public Health and Environment
CGS	Colorado Geological Survey
°	degree
$	dollars
EDR	Environmental Degradation Rating
FR	Forest Road
gpm	gallons per minute
GPS	Global Positioning System
>	greater than
<	less than
≤	less than or equal to
µg/L	micrograms per liter
µS/cm	microSiemens
mg/L	milligrams per liter
NFS	National Forest System
n/a	not applicable
no.	number
#	number
p.	page(s)
ppm	parts per million
%	percent
lb	pound(s)
PBS	Primary Base Series
quad	quadrangle (7.5-minute)
trec	total recoverable
oz	troy ounce(s)
U.S.	United States
USEPA	Environmental Protection Agency
USFS	United States Department of Agriculture - Forest Service
BLM	United States Department of Interior - Bureau of Land Management
v.	Volume

INTRODUCTION

During the fall of 1993, the Colorado Geological Survey (CGS) inventoried mines in the Cinnamon Gulch area (Figure 1) of the Dillon Ranger District, White River National Forest. This project was part of an eight-year, Statewide inventory of abandoned mines on USFS-administered lands in Colorado. Not all of the mines were on National Forest System (NFS) lands; in some instances the forest boundary or mine locations were incorrectly located on Primary Base Series (PBS) maps. Some mines close to NFS lands were inventoried, and mines that potentially impacted NFS lands were included. In September 2000, the Forest Service requested a watershed characterization study for Cinnamon Gulch, and more detailed studies on five mines in the area. The five mines requested are in four areas (Silver Spoon, Brittle Silver Mountain, Lower Cinnamon, and Pennsylvania Mine) inventoried in 1993 (Figure 2). All of the selected mines had received Environmental Degradation Ratings (EDRs) of 4 (slight) or worse from CGS. This study presents the results of the additional work performed by CGS on the Cinnamon Gulch watershed and five area mines. The report is organized according to inventory areas. Inventory forms are attached in Appendix A.

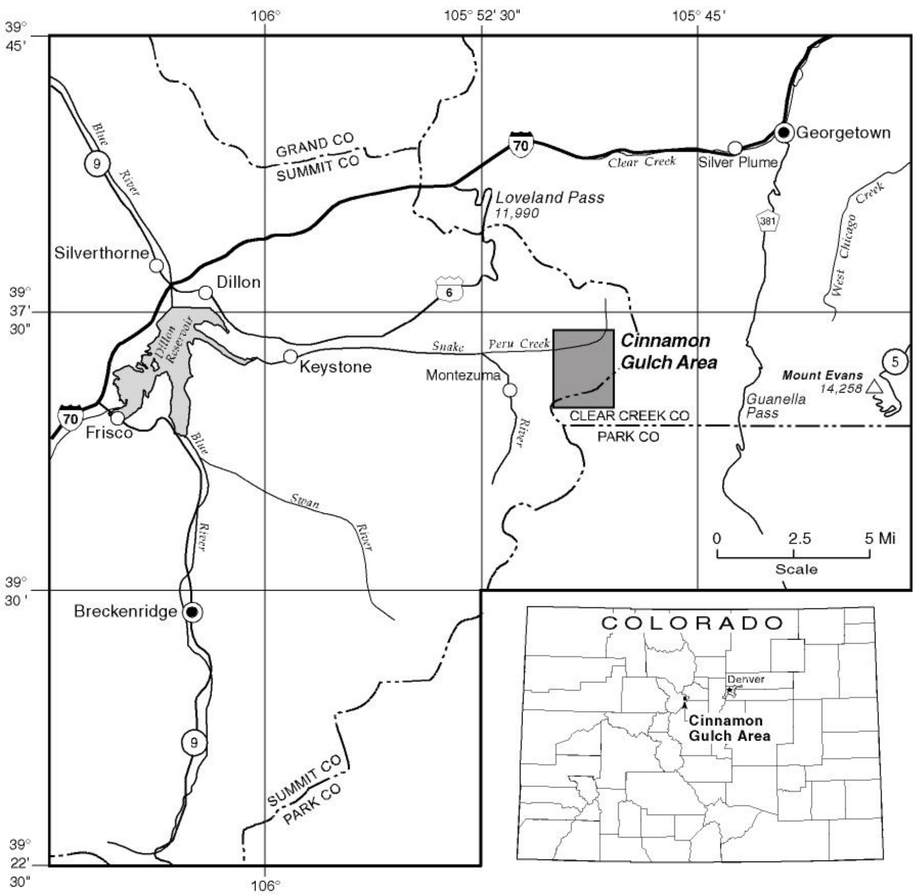


Figure 1. Index map of the Cinnamon Gulch area.

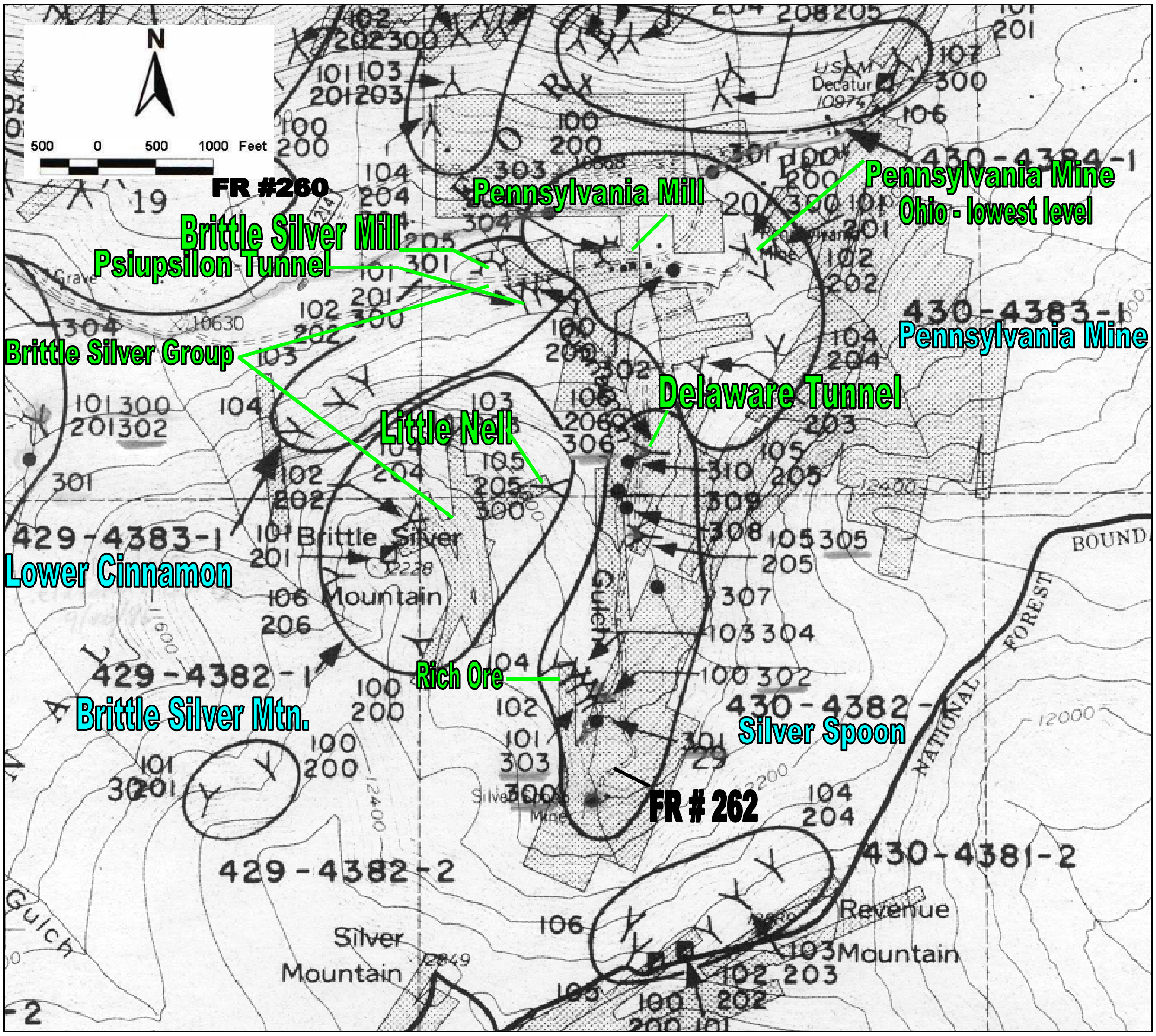


Figure 2. Map of inventory areas and mine features in the Cinnamon Gulch area. Silver Spoon inventory area #430/4382-1 includes the Rich Ore Lode (#103) and Delaware Tunnel (#106). The Brittle Silver Mountain inventory area #429/43821-1 includes the Little Nell Lode (#105). The Lower Cinnamon inventory area #429/4383-1 includes the Psiupsilon Tunnel (#101) and the Brittle Silver Mill tailings (#205). The Brittle Silver Mtn. inventory area and the Lower Cinnamon inventory area comprise the Brittle Silver group. The Pennsylvania Mine inventory area (#430/4383-1) includes the lower (Ohio) level of the Pennsylvania Mine (#100) and Pennsylvania Mill tailings (#206). (Scale is approximate; shaded areas represent patented mining claims; inventory areas labled in green, features in blue.)

Mining district names associated with Cinnamon Gulch area mines include Peru, Argentine, Montezuma, and Snake River. Many of the smaller mines in the district(s) were worked in the late 1800's and early 1900's. Some of the mines may have shipped very small quantities of ore, if any, or shipments were combined with another mine. Other workings could have been developed for exploration or as access for another mine. Very little historical information is usually available regarding these mines. Obtaining historical information is usually impossible if a mine or claim name cannot be determined.

METHODS OF INVESTIGATION

Several sources of historical information are used in this report. Mining claim records (location certificates, assessment records, ownership, and various other transactions) are filed at the Summit County Courthouse, Breckenridge, Colorado. Location certificates describe and locate the claim, identify all of the locators, and list the discovery and/or location date(s) and the date recorded in the county. Surprisingly, many location notices are not very useful in determining the actual location of the claim. Some location notices locate the claim from a location monument on the claim on take a bearing from distant mountain. Early mining claim records were filed in a series of numbered books and pages abbreviated bk. #, p. # in this report. More recent records are filed under serial/reception numbers. In 1976, the Federal Land Policy and Management Act required the filing of unpatented mining claims and evidence of assessment work or notice of intention to hold the claim with the BLM. This requirement was in addition to the required filing with the county.

Reports by the Director of the Mint, annual mineral-resources reports by the U.S. Geological Survey, and various newspapers and mining journals provided useful information for some of the mines that were active in the late 1800's and early 1900's. This was the case for most of the mines in this study. Colorado Bureau of Mines (CBM) inspector and mine manager's reports from the early 1900's were also excellent sources for historical information. Annual mineral resources reports by the U.S. Bureau of Mines document activity from about 1924 onward. Most of the later reports primarily focus on larger producing mines and county production.

Frequently, discrepancies were observed among county assessor's records, county recorder's records, BLM master title plats, and Forest Service PBS maps. Surveys and/or title searches are essential sources of information for some of the mine sites. Mineral surveys locate and describe mine features associated with the claim at the time of the survey. Usually these features can be located on the ground.

Field work for this study included a visit to each site to see if major changes had occurred since the inventory work in 1993 (Streufert, 1994, p.9-10). Although water samples were collected at some of the sites in 1993, additional samples and water tests were collected in 2001. Instream samples were collected from some of the receiving streams in efforts to bracket selected mines or groups of mines and better quantify impacts to the watersheds. In addition, waste-rock piles on some of the mines were sampled on a grid pattern to assess their potential environmental effects. Waste-rock samples were analyzed for gold, silver, mercury, paste pH, acid neutralization potential, and potential acidity. Samples are also analyzed using X-Ray fluorescence to determine a suite of major, minor, and trace elements.

Filtered (0.45 µ) and unfiltered water samples were collected from selected streams and springs for laboratory analyses. Sample bottles were preserved as needed before sampling, and refrigerated afterward until delivery to the lab. Field sampling protocols, laboratory analytical methods, and QA/QC information are documented in Appendix B.

At locations where a sample was collected from running water, effort was made to measure the streamflow using either a portable Baski cutthroat flume or instream flowmeter. Where the use of either the flume or flowmeter was impractical due to channel conditions or low flow, streamflow was estimated visually or with a catchment such as a 5-gallon bucket.

For consistency in reporting data from different stream segments, analytical results were compared to statewide water quality standards established by the State Water Quality Control Commission (available at http://www.cdphe.state.co.us/op/regs/waterregs/100231.pdf). Specific stream-segment standards should be used for regulatory purposes. The relevant standards are shown in the tables alongside the laboratory analytical data. The most stringent of either the domestic-water-supply standard, the aquatic-life standard, or the agricultural standard is shown. Of the metals analyzed during this study, the aquatic life standards for dissolved cadmium (Cd), copper (Cu), manganese (Mn), lead (Pb), nickel (Ni), silver (Ag), and zinc (Zn) are dependent upon the hardness of the water. Thus, each water sample will have a unique set of water quality standards for those metals, which will be a function of the hardness of the water sample. To determine hardness, CGS uses method 2340B (Clesceri and others, 1998), which relies on a mathematical calculation rather than a laboratory analysis. The hardness is calculated from the concentrations of calcium (Ca) and magnesium (Mg) by the formula:

$$\text{Hardness (as mg/L } CaCO_3 \text{ equivalent)} = 2.497(\text{mg/L Ca}) + 4.118(\text{mg/L Mg})$$

The aquatic life standards for dissolved aluminum (Al) and total recoverable iron (Fe), 87 and 1,000 µg/L respectively, are independent of hardness. The dissolved iron standard (300 µg/L) referenced in this report is the secondary (aesthetic) drinking water standard. Table 1 lists the constituents analyzed, the corresponding State standard for each, and the formula for computing the standard from hardness.

A total of 39 water samples were collected from the Cinnamon Gulch watershed over two sampling events in 2001. During the high-flow sampling event in July, 19 water samples were collected including two duplicates and one field blank. During the low-flow event in October, 20 water samples were collected including two duplicates and one field blank. Water chemistry data from both sampling events are reported in Table 2. Water and rock sample locations are shown on Figure 3. No data were collected from the Pennsylvania Mine, due to the significant amount of data already existing from prior investigations (CDMG files).

Table 1. Constituents analyzed and corresponding water quality standards.
Concentrations are as μg/L unless specified otherwise, and dissolved unless specified as total recoverable (trec), .

Parameter	Water Quality Standard	Basis
pH	6.5 – 9.0	Aquatic Life
Aluminum (trec)	None established	N/A
Antimony (trec)	6	Drinking Water - primary
Arsenic (trec)	10	Drinking Water - primary
Iron (trec)	1,000	Aquatic Life
Thallium (trec)	0.5	Drinking Water - primary
Zinc (trec)	2,000	Agricultural
Aluminum	87	Aquatic Life
Cadmium	$(1.10167 – [\ln(hardness) \times (0.04184)]) \times e^{(0.7852[\ln(hardness)]-2.715)}$	Aquatic Life
Chloride	250 mg/L	Drinking Water - secondary
Chromium	11	Aquatic Life
Copper	$e^{(0.8545[\ln(hardness)]-1.7428)}$	Aquatic Life
Fluoride	2 mg/L	Drinking Water - primary
Iron	300	Drinking Water – secondary
Lead	$(1.46203 – [\ln(hardness) \times (0.145712)]) \times e^{(1.273[\ln(hardness)]-4.705)}$	Aquatic Life
Manganese	$e^{(0.3331[\ln(hardness)]+5.8743)}$	Aquatic Life
Nickel	$e^{(0.846[\ln(hardness)]+0.0554)}$	Aquatic Life
Silver	$e^{(1.72[\ln(hardness)]-10.51)}$	Aquatic Life
Sulfate	250 mg/L	Drinking Water - secondary
Zinc	$e^{(0.8473[\ln(hardness)]+0.8699)}$	Aquatic Life

LOCATION AND GEOGRAPHIC SETTING

Cinnamon Gulch is in eastern Summit County about 14 miles east of Dillon and 4 miles northeast of Montezuma, Colorado (Figure 1). From Dillon and Interstate Highway 70, access is via US Highway 6 to Keystone, east on FR No. 5 along the Snake River. Then east on FR No. 260 (on Dillon District map or No. 214 on the PBS map) along Peru Creek to the Cinnamon Gulch road, labeled FR No. 262 on the Dillon District map. Most of the mines are accessible from FR No. 262 or from mine roads off of FR No. 262. Elevations range from about 10,800 feet above sea level at the confluence between the lower branch of Cinnamon Creek and Peru Creek, to 11,800 feet at the Silver Spoon Mine (apparent headwaters of Cinnamon Creek). The highest point in the Cinnamon Gulch watershed is 12,889 feet on Revenue Mountain. Cinnamon Gulch flows between Silver and Brittle Silver Mountains on the West and Revenue and Decatur Mountains on the east.

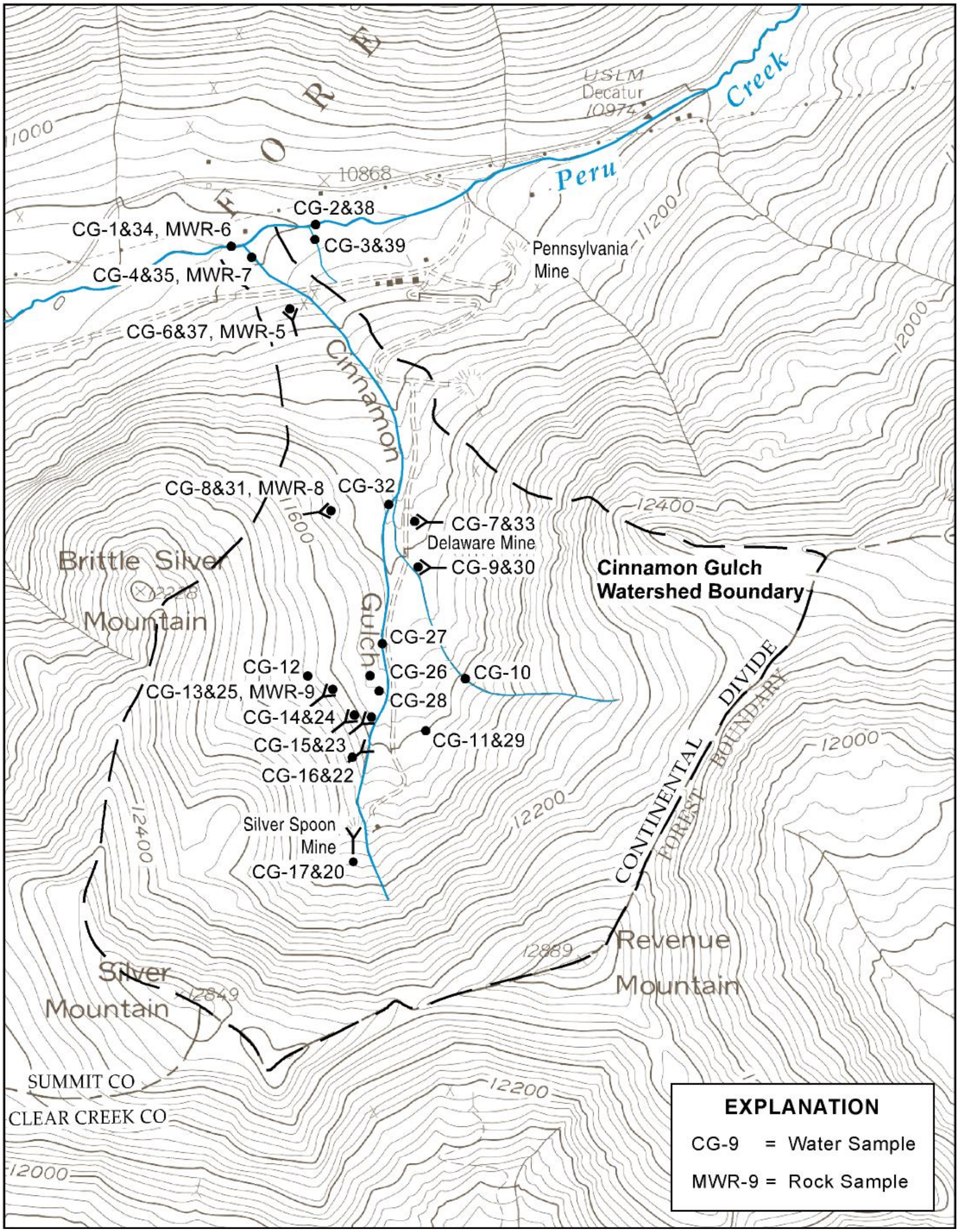


Figure 3. Location map for Cinnamon Gulch water and rock samples.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area.

Sample	CG-01-1, Peru Creek Below Cinnamon (26 July 2001)			CG-01-2, Peru Creek Above Cinnamon (26 July 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	6,800	None		4,880	None	
pH (standard units)	***4.22***	6.5-9.0		***4.35***	6.5-9.0	
Conductivity (µS/cm)	143	None		135	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	45	None		45	None	
Aluminum (trec) (µg/L)	1,900	None	70,427	1,300	None	34,581
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	570	1000	21,128	520	1000	13,832
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	1,400	2000	51,894	1,200	2000	31,921
Aluminum (µg/L)	***1,200***	87	44,480	***540***	87	14,364
Cadmium (µg/L)	***6***	1.2	215	***5***	1.2	136
Calcium (mg/L)	12	None	1,112,004	12	None	798,026
Chloride (mg/L)	<1	250	N/A	<1	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***190***	4.5	7,043	***170***	4.5	4,522
Fluoride (mg/L)	0.28	2	10,379	0.25	2	6,650
Iron (µg/L)	160	300	5,931	120	300	3,192
Lead (µg/L)	0.1	1.1	4	***4***	1.0	106
Magnesium (mg/L)	3.7	None	137,147	3.6	None	95,763
Manganese (µg/L)	***1,300***	1,265	48,187	1,000	1,262	26,601
Nickel (µg/L)	<20	27	N/A	<20	26	N/A
Potassium (mg/L)	<1	None	N/A	<1	None	N/A
Silicon (mg/L)	4	None	140,854	3.4	None	90,443
Silver (µg/L)	<0.4	0.02	N/A	<0.4	0.02	N/A
Sodium (mg/L)	1.4	None	51,894	1.3	None	34,581
Sulfate (mg/L)	58	250	2,149,874	54	250	1,436,448
Zinc (µg/L)	***1,400***	60	51,894	***1,300***	60	34,581

Number in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-3, Cinnamon Upper Fork (26 July 2001)			CG-01-4, Cinnamon Lower Fork (26 July 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	200	None		609	None	
pH (standard units)	***4.01***	6.5-9.0		***3.84***	6.5-9.0	
Conductivity (µS/cm)	195	None		165	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	46	None		41	None	
Aluminum (trec) (µg/L)	3,100	None	3,380	2,700	None	8,963
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	180	1000	196	300	1000	996
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	1,200	2000	1,308	1,000	2000	3,320
Aluminum (µg/L)	***3,100***	87	3,380	***2,600***	87	8,631
Cadmium (µg/L)	***5.8***	1.3	6	***5***	1.2	16
Calcium (mg/L)	12	None	32,706	11	None	89,631
Chloride (mg/L)	<1	250	N/A	<1	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***150***	4.6	164	***130***	4.2	432
Fluoride (mg/L)	0.27	2	294	0.27	2	896
Iron (µg/L)	150	300	164	210	300	697
Lead (µg/L)	***10***	1.1	11	***49***	0.9	163
Magnesium (mg/L)	3.9	None	4,252	3.4	None	11,287
Manganese (µg/L)	***1,900***	1,273	2,071	***1,700***	1,230	5,643
Nickel (µg/L)	<20	27	N/A	<20	24	N/A
Potassium (mg/L)	<1	None	N/A	<1	None	N/A
Silicon (mg/L)	6	None	6,868	6	None	19,254
Silver (µg/L)	<0.4	0.02	N/A	<0.4	0.02	N/A
Sodium (mg/L)	1.8	None	1,962	1.7	None	5,643
Sulfate (mg/L)	79	250	86,126	71	250	235,696
Zinc (µg/L)	***1,200***	61	1,308	***1,000***	55	3,320

Number in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-5, Duplicate of CG-01-4 (26 July 2001)			CG-01-6, Adit 101 Lowermost (26 July 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	609	None		25.1	None	
pH (standard units)	***3.84***	6.5-9.0		***4.39***	6.5-9.0	
Conductivity (µS/cm)	165	None		75	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	41	None		22	None	
Aluminum (trec) (µg/L)	2,700	None	8,963	120	None	16
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	300	1000	996	81	1000	11
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	1,000	2000	3,320	270	2000	37
Aluminum (µg/L)	***2,600***	87	8,631	***110***	87	15
Cadmium (µg/L)	***5***	1.2	17	***1***	0.7	0.08
Calcium (mg/L)	11	None	89,631	7	None	2,326
Chloride (mg/L)	<1	250	N/A	<1	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***130***	4.2	432	<4	2.5	N/A
Fluoride (mg/L)	0.26	2	863	<0.1	2	N/A
Iron (µg/L)	210	300	697	76	300	10
Lead (µg/L)	***49***	0.9	163	***2***	0.5	0.27
Magnesium (mg/L)	3	None	11,287	1.3	None	178
Manganese (µg/L)	***1,700***	1,230	5,643	690	1,008	94
Nickel (µg/L)	<20	24	N/A	<20	15	N/A
Potassium (mg/L)	<1	None	N/A	<1	None	N/A
Silicon (mg/L)	6	None	19,254	4	None	602
Silver (µg/L)	<0.4	0.016	N/A	<0.4	0.006	N/A
Sodium (mg/L)	1.6	None	5,311	1.4	None	192
Sulfate (mg/L)	71	250	235,696	29	250	3,968
Zinc (µg/L)	***1,000***	55	3,320	***260***	33	36

Number in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-7, Adit 106 Blue Box (26 July 2001)			CG-01-8, Adit 105 Brittle Silver Mtn (26 July 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	7.6	None		2.4	None	
pH (standard units)	***3.62***	6.5-9.0		***4.67***	6.5-9.0	
Conductivity (µS/cm)	629	None		104	None	
Alkalinity (mg/L CaCO3)	<10	None		9	None	
Hardness (mg/L CaCO3)	256	None		39	None	
Aluminum (trec) (µg/L)	2,000	None	82	63	None	1
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	3	10	0.12	<1	10	N/A
Iron (trec) (µg/L)	***17,000***	1000	700	360	1000	5
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	***8,400***	2000	346	480	2000	6
Aluminum (µg/L)	***1,900***	87	78	<50	87	N/A
Cadmium (µg/L)	***35***	4.5	1	***2***	1.1	0.02
Calcium (mg/L)	76	None	7,819	12	None	376
Chloride (mg/L)	<1	250	N/A	<1	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***280***	20	12	4	4.03	0.05
Fluoride (mg/L)	0.81	2	33	0.43	2	6
Iron (µg/L)	***14,000***	300	576	44	300	1
Lead (µg/L)	***140***	6.9	6	<1	0.9	N/A
Magnesium (mg/L)	16.0	None	658	2.5	None	32
Manganese (µg/L)	***6,200***	2,254	255	530	1,218	7
Nickel (µg/L)	55	115	2	<20	24	N/A
Potassium (mg/L)	<1	None	N/A	<1	None	N/A
Silicon (mg/L)	7.5	None	309	7.7	None	100
Silver (µg/L)	<0.4	0.38	N/A	<0.4	0.02	N/A
Sodium (mg/L)	3.6	None	148	2.6	None	34
Sulfate (mg/L)	***300***	250	12,347	39	250	506
Zinc (µg/L)	***8,400***	262	346	***480***	54	6

Number in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-9, Adit 105 Silver Spoon (27 July 2001)			CG-01-10, North Trib to Cinnamon Gulch, East Side (27 July 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	4.6	None		1.3	None	
pH (standard units)	***4.03***	6.5-9.0		***4.38***	6.5-9.0	
Conductivity (µS/cm)	219	None		39	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	62	None		12	None	
Aluminum (trec) (µg/L)	2,000	None	50	58	None	0.4
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	***3,800***	1000	95	<10	1000	N/A
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	1,200	2000	30	19	2000	0.1
Aluminum (µg/L)	***2,000***	87	50	56	87	0.4
Cadmium (µg/L)	***12***	1.6	0	<0.3	0.5	N/A
Calcium (mg/L)	16	None	1,028	3	None	56.7
Chloride (mg/L)	<1	250	N/A	<1	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***110***	5.9	3	<4	1.4	N/A
Fluoride (mg/L)	0.52	2	13	<0.1	2	N/A
Iron (µg/L)	***3,600***	300	90	<10	300	N/A
Lead (µg/L)	***560***	1.5	14	<1	0.2	N/A
Magnesium (mg/L)	5.0	None	125	0.9	None	6.2
Manganese (µg/L)	***2,300***	1,395	58	7	804	0.0
Nickel (µg/L)	21	35	1	<20	8	N/A
Potassium (mg/L)	1.1	None	28	<1	None	N/A
Silicon (mg/L)	8	None	201	2.9	None	20.6
Silver (µg/L)	<0.4	0.03	N/A	<0.4	0.002	N/A
Sodium (mg/L)	2.4	None	60	0.9	None	6.1
Sulfate (mg/L)	93	250	2,332	13	250	92.1
Zinc (µg/L)	***1,200***	78	30	***19***	18.996	0.1

Number in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-11, South Trib to Cinnamon Gulch, East Side (27 July 2001)			CG-01-12, WestTrib to Cinnamon Gulch (27 July 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	8	None		90	None	
pH (standard units)	***4.47***	6.5-9.0		***3.95***	6.5-9.0	
Conductivity (µS/cm)	318	None		84	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	99	None		9	None	
Aluminum (trec) (µg/L)	2,200	None	91	1,700	None	834
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	110	1000	5	29	1000	14
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	840	2000	35	330	2000	162
Aluminum (µg/L)	***2,200***	87	91	***1,700***	87	834
Cadmium (µg/L)	***3***	2.2	0.13	***2***	0.4	1
Calcium (mg/L)	28	None	2,881	2	None	1,962
Chloride (mg/L)	<1	250	N/A	<1	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***150***	8.9	6	***140***	1.1	69
Fluoride (mg/L)	0.53	2	22	<0.1	2	N/A
Iron (µg/L)	36	300	1	28	300	14
Lead (µg/L)	<1	2.5	N/A	***10***	0.2	5
Magnesium (mg/L)	7.0	None	288	1.2	None	589
Manganese (µg/L)	***3,000***	1,624	123	550	737	270
Nickel (µg/L)	<20	51	N/A	<20	7	N/A
Potassium (mg/L)	1.2	None	49	<1	None	N/A
Silicon (mg/L)	6	None	255	5.7	None	2,796
Silver (µg/L)	<0.4	0.07	N/A	<0.4	0.001	N/A
Sodium (mg/L)	2.3	None	95	1.3	None	638
Sulfate (mg/L)	110	250	4,527	26	250	12,755
Zinc (µg/L)	***840***	117	35	***320***	15	157

Number in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-13, Adit 103 Silver Spoon (27 July 2001)			CG-01-14, Adit 101 Silver Spoon (27 July 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	1.01	None		1.5	None	
pH (standard units)	***3.25***	6.5 – 9.0		***3.58***	6.5 - 9.0	
Conductivity (µS/cm)	549	None		287	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	82	None		46	None	
Aluminum (trec) (µg/L)	16,000	None	87	8,600	None	70
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	***11,000***	1000	60	***5,800***	1000	47
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	***6,200***	2000	34	***2,300***	2000	19
Aluminum (µg/L)	***16,000***	87	87	***8,600***	87	70
Cadmium (µg/L)	***37***	1.9	0.2	***12***	1.3	0.1
Calcium (mg/L)	12	None	158	7	None	139
Chloride (mg/L)	<1	250	N/A	<1	250	N/A
Chromium (µg/L)	<100	11	N/A	<20	11	N/A
Copper (µg/L)	***2,000***	7.6	11	***130***	4.6	1.1
Fluoride (mg/L)	0.61	2	3.3	0.35	2	2.9
Iron (µg/L)	***9,900***	300	54	***5,900***	300	48
Lead (µg/L)	***250***	2	1.4	***21***	1.1	0.2
Magnesium (mg/L)	13.0	None	71	7	None	57
Manganese (µg/L)	***15,000***	1,551	82	***6,000***	1,270	49
Nickel (µg/L)	***100***	44	0.5	***51***	27	0.4
Potassium (mg/L)	<5	None	N/A	1.0	None	8
Silicon (mg/L)	12	None	65	9.3	None	76
Silver (µg/L)	***2.0***	0.05	0.01	<0.4	0.02	N/A
Sodium (mg/L)	4.0	None	22	2.1	None	17
Sulfate (mg/L)	250	250	1,363	130	250	1,063
Zinc (µg/L)	***6,100***	100	33	***2,300***	61	19

Number in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-15, Adit 100 Silver Spoon (27 July 2001)			CG-01-16, 301 Silver Spoon (27 July 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	0.84	None		1	None	
pH (standard units)	***3.30***	6.5-9.0		***3.16***	6.5-9.0	
Conductivity (µS/cm)	611	None		503	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	97	None		67	None	
Aluminum (trec) (µg/L)	14,000	None	64	3,700	None	20
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	***40,000***	1000	183	***16,000***	1000	87
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	***7,100***	2000	33	***5,200***	2000	28
Aluminum (µg/L)	***14,000***	87	64	***3,700***	87	20
Cadmium (µg/L)	***42***	2.2	0.2	***22***	1.7	0.1
Calcium (mg/L)	14	None	160	15	None	202
Chloride (mg/L)	<1	250	N/A	<1	250	N/A
Chromium (µg/L)	<100	11	N/A	<20	11	N/A
Copper (µg/L)	***210***	8.7	1	***28***	6.3	0.2
Fluoride (mg/L)	0.95	2	4	0.90	2	5
Iron (µg/L)	***40,000***	300	183	***15,000***	300	82
Lead (µg/L)	***28***	2.4	0.1	***520***	1.6	3
Magnesium (mg/L)	15	None	69	7.2	None	39
Manganese (µg/L)	***15,000***	1,629	69	***6,500***	1,443	35
Nickel (µg/L)	<100	51	N/A	***48***	37	0.3
Potassium (mg/L)	<5	None	N/A	1.2	None	7
Silicon (mg/L)	12	None	55	10	None	53
Silver (µg/L)	<0.4	0.07	N/A	<0.4	0.04	N/A
Sodium (mg/L)	3.7	None	17	2.8	None	15
Sulfate (mg/L)	***280***	250	1,282	160	250	872
Zinc (µg/L)	***7,100***	115	33	***5,000***	84	27

Number in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-17, Dump 300 Silver Spoon Mine (27 July 2001)			CG-01-18, Duplicate of CG-01-17 (27 July 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	30.2	None		30.2	None	
pH (standard units)	***3.11***	6.5-9.0		***3.11***	6.5-9.0	
Conductivity (µS/cm)	485	None		485	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	31	None		31	None	
Aluminum (trec) (µg/L)	8,500	None	1,399	8,400	None	1,383
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	5	10	1	5	10	1
Iron (trec) (µg/L)	***23,000***	1,000	3,786	***23,000***	1,000	3,786
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	***5,000***	2,000	823	***4,900***	2,000	807
Aluminum (µg/L)	***8,500***	87	1,399	***8,400***	87	1,383
Cadmium (µg/L)	***24***	0.9	4	***23***	0.9	4
Calcium (mg/L)	6	None	2,305	6	None	2,305
Chloride (mg/L)	<1	250	N/A	<2	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***530***	3.3	87	***520***	3.3	86
Fluoride (mg/L)	0.19	2	31	0.18	2	30
Iron (µg/L)	***23,000***	300	3,786	***23,000***	300	3,786
Lead (µg/L)	***370***	0.7	61	***370***	0.7	61
Magnesium (mg/L)	4.1	None	675	4.1	None	675
Manganese (µg/L)	***6,900***	1,114	1,136	***6,900***	1,114	1,136
Nickel (µg/L)	***45***	19	7	***44***	19	7
Potassium (mg/L)	1.2	None	198	1.1	None	181
Silicon (mg/L)	7.8	None	1,284	7.8	None	1,284
Silver (µg/L)	<0.4	0.01	N/A	<0.4	0.01	N/A
Sodium (mg/L)	1.7	None	280	1.6	None	263
Sulfate (mg/L)	160	250	26,339	170	250	27,985
Zinc (µg/L)	***4,900***	44	807	***4,900***	44	807

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-19, Trip Blank (27 July 2001)			CG-01-20, Low-Flow Counterpart to CG-01-17 (15 Oct 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	NA	None		4	None	
pH (standard units)	NM	6.5-9.0		***3.42***	6.5-9.0	
Conductivity (µS/cm)	NM	None		280	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	<0.02	None	NA	38	None	
Aluminum (trec) (µg/L)	<50	None	NA	7,800	None	170
Antimony (trec) (µg/L)	<1	6	NA	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	NA	4	10	0.09
Iron (trec) (µg/L)	<10	1,000	NA	***23,000***	1,000	501
Thallium (trec) (µg/L)	<1	0.5	NA	<1	0.5	N/A
Zinc (trec) (µg/L)	<10	2,000	NA	***5,000***	2,000	109
Aluminum (µg/L)	<50	87	NA	***7,800***	87	170
Cadmium (µg/L)	<0.3	<0.03	NA	***21***	1.1	0.46
Calcium (mg/L)	<0.1	None	NA	7	None	371
Chloride (mg/L)	<1	250	NA	<4	250	N/A
Chromium (µg/L)	<20	11	NA	<20	11	N/A
Copper (µg/L)	<4	<0.07	NA	***430***	3.9	9
Fluoride (mg/L)	<0.1	2	NA	0.18	2	4
Iron (µg/L)	<10	300	NA	***22,000***	300	480
Lead (µg/L)	<1	<0.004	NA	***270***	0.9	6
Magnesium (mg/L)	<0.06	None	NA	5.1	None	111
Manganese (µg/L)	<4	383	NA	***8,100***	1,194	177
Nickel (µg/L)	<20	<0.4	NA	***41***	23	1
Potassium (mg/L)	<1	None	NA	1.1	None	24
Silicon (mg/L)	<0.02	None	NA	9	None	188
Silver (µg/L)	<0.4	<0.000004	NA	<0.4	0.01	N/A
Sodium (mg/L)	<0.2	None	NA	2.3	None	50
Sulfate (mg/L)	<5	250	NA	160	250	3,489
Zinc (µg/L)	<10	<1.0	NA	***5,000***	52	109

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-21, Duplicate of CG-01-20 (15 Oct 2001)			CG-01-22, Low-flow counterpart to CG-01-16 (15 Oct 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	4	None		Standing	None	
pH (standard units)	***3.42***	6.5-9.0		***2.91***	6.5-9.0	
Conductivity (µS/cm)	280	None		464	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	38	None		80	None	NA (standing)
Aluminum (trec) (µg/L)	7,600	None	166	4,700	None	NA (standing)
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	NA (standing)
Arsenic (trec) (µg/L)	4	10	0.1	<1	10	NA (standing)
Iron (trec) (µg/L)	***23,000***	1,000	502	***21,000***	1,000	NA (standing)
Thallium (trec) (µg/L)	***1***	0.5	N/A	<1	0.5	NA (standing)
Zinc (trec) (µg/L)	***4,900***	2,000	107	***5,400***	2,000	NA (standing)
Aluminum (µg/L)	***7,800***	87	170	***4,700***	87	NA (standing)
Cadmium (µg/L)	***21***	1.1	0.5	***24.8***	1.9	NA (standing)
Calcium (mg/L)	7	None	371	17	None	NA (standing)
Chloride (mg/L)	10	250	N/A	<4	250	NA (standing)
Chromium (µg/L)	***20***	11	N/A	<20	11	NA (standing)
Copper (µg/L)	***430***	3.9	9.4	***12***	7.4	NA (standing)
Fluoride (mg/L)	0.17	2	3.7	1	2	NA (standing)
Iron (µg/L)	***22,000***	300	480	***21,000***	300	NA (standing)
Lead (µg/L)	***240***	0.9	5.2	***420***	2	NA (standing)
Magnesium (mg/L)	5.1	None	111	9	None	NA (standing)
Manganese (µg/L)	***8,200***	1,194	179	***8,200***	1,530	NA (standing)
Nickel (µg/L)	***40***	23	0.9	***56***	43	NA (standing)
Potassium (mg/L)	1.2	None	26	1.4	None	NA (standing)
Silicon (mg/L)	8.6	None	188	10	None	NA (standing)
Silver (µg/L)	***0.4***	0.014	N/A	<0.4	0.05	NA (standing)
Sodium (mg/L)	2.3	None	50	3.5	None	NA (standing)
Sulfate (mg/L)	170	250	3,707	190	250	NA (standing)
Zinc (µg/L)	***5,000***	52	109	***5,400***	98	NA (standing)

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-23, Low-flow counterpart To CG-01-15 (15 Oct 2001)			CG-01-24, Low-flow counterpart to CG-01-14 (15 Oct 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	1	None		standing	None	
pH (standard units)	***3.14***	6.5-9.0		***3.21***	6.5-9.0	
Conductivity (µS/cm)	593	None		470	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	NA (standing)
Hardness (mg/L CaCO3)	97	None		78	None	NA (standing)
Aluminum (trec) (µg/L)	14,000	None	76	14,000	None	NA (standing)
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	NA (standing)
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	NA (standing)
Iron (trec) (µg/L)	***40,000***	1,000	218	***17,000***	1,000	NA (standing)
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	NA (standing)
Zinc (trec) (µg/L)	***7,300***	2,000	40	***4,700***	2,000	NA (standing)
Aluminum (µg/L)	***14,000***	87	76	***14,000***	87	NA (standing)
Cadmium (µg/L)	***43***	2.2	0.23	***23***	1.9	NA (standing)
Calcium (mg/L)	14	None	191	12	None	NA (standing)
Chloride (mg/L)	<10	250	N/A	<10	250	NA (standing)
Chromium (µg/L)	<20	11	N/A	<20	11	NA (standing)
Copper (µg/L)	***220***	8.7	1	***200***	7.26	NA (standing)
Fluoride (mg/L)	0.96	2	5	0.61	2	NA (standing)
Iron (µg/L)	***39,000***	300	213	***12,000***	300	NA (standing)
Lead (µg/L)	***23***	2.4	0.13	*27*	1.9	NA (standing)
Magnesium (mg/L)	15	None	82	12	None	NA (standing)
Manganese (µg/L)	***15,000***	1,629	82	***12,000***	1,519	NA (standing)
Nickel (µg/L)	***100***	51	1	***88***	42	NA (standing)
Potassium (mg/L)	1.6	None	9	1.4	None	NA (standing)
Silicon (mg/L)	13	None	71	13	None	NA (standing)
Silver (µg/L)	<0.4	0.07	N/A	<0.4	0.05	NA (standing)
Sodium (mg/L)	3.4	None	19	3.3	None	NA (standing)
Sulfate (mg/L)	***280***	250	1,526	220	250	NA (standing)
Zinc (µg/L)	***7,300***	115	40	***4,700***	96	NA (standing)

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-25, Low-flow counterpart To CG-01-13 (15 Oct 2001)			CG-01-26, Natural stream draining north of Silver spoon (15 Oct 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	standing	None		4	None	
pH (standard units)	***3.08***	6.5-9.0		***3.72***	6.5-9.0	
Conductivity (µS/cm)	496	None		106	None	
Alkalinity (mg/L CaCO3)	<10	None	NA (standing)	<10	None	
Hardness (mg/L CaCO3)	76	None	NA (standing)	17	None	
Aluminum (trec) (µg/L)	10,000	None	NA (standing)	3,200	None	70
Antimony (trec) (µg/L)	<1	6	NA (standing)	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	NA (standing)	<1	10	N/A
Iron (trec) (µg/L)	***14,000***	1,000	NA (standing)	<10	1,000	N/A
Thallium (trec) (µg/L)	<1	0.5	NA (standing)	<1	0.5	N/A
Zinc (trec) (µg/L)	***5,000***	2,000	NA (standing)	800	2,000	17
Aluminum (µg/L)	***10,000***	87	NA (standing)	***3,200***	87	70
Cadmium (µg/L)	***29***	1.8	NA (standing)	***5.2***	0.61	0.11
Calcium (mg/L)	12	None	NA (standing)	3	None	153
Chloride (mg/L)	<10	250	NA (standing)	<2	250	N/A
Chromium (µg/L)	<20	11	NA (standing)	<20	11	N/A
Copper (µg/L)	***1,100***	7.09	NA (standing)	***130***	2	3
Fluoride (mg/L)	0.73	2	NA (standing)	0.15	2	3
Iron (µg/L)	***14,000***	300	NA (standing)	<10	300	N/A
Lead (µg/L)	***180***	1.9	NA (standing)	***5***	0.4	0.11
Magnesium (mg/L)	11	None	NA (standing)	2.5	None	55
Manganese (µg/L)	***14,000***	1,505	NA (standing)	***1,800***	918	39
Nickel (µg/L)	***67***	41	NA (standing)	<20	12	N/A
Potassium (mg/L)	1.6	None	NA (standing)	0.71	None	15
Silicon (mg/L)	13	None	NA (standing)	7.7	None	168
Silver (µg/L)	***1.7***	0.05	NA (standing)	<0.4	0.004	N/A
Sodium (mg/L)	3.9	None	NA (standing)	2.1	None	46
Sulfate (mg/L)	220	250	NA (standing)	49	250	1,068
Zinc (µg/L)	***5,000***	94	NA (standing)	***800***	27	17

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-27, Cinnamon Gulch Creek just above road crossing (15 Oct 2001)			CG-01-28, Trib to Cinnamon Gulch Creek, south of CG-01-26 (15 Oct 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	56	None		10	None	
pH (standard units)	***3.35***	6.5-9.0		***3.39***	6.5-9.0	
Conductivity (µS/cm)	258	None		303	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	44	None		49	None	
Aluminum (trec) (µg/L)	9,700	None	2,961	11,000	None	600
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	720	1,000	220	430	1,000	23
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	***2,600***	2,000	794	***3,200***	2,000	174
Aluminum (µg/L)	***9,600***	87	2,930	***11,000***	87	600
Cadmium (µg/L)	***13***	1.2	4	***20***	1.3	1
Calcium (mg/L)	8	None	6,105	7	None	927
Chloride (mg/L)	<4	250	N/A	<4	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***450***	4.4	137	***780***	4.9	43
Fluoride (mg/L)	0.24	2	73	0.31	2	17
Iron (µg/L)	***700***	300	214	***430***	300	23
Lead (µg/L)	***25***	1	8	***80***	1.2	4
Magnesium (mg/L)	5.8	None	1,770	7.8	None	425
Manganese (µg/L)	***4,900***	1,252	1,496	***8,000***	1,300	436
Nickel (µg/L)	***34***	26	10	***49***	28	3
Potassium (mg/L)	1	None	305	1.2	None	65
Silicon (mg/L)	9.4	None	2,869	11	None	600
Silver (µg/L)	<0.4	0.02	N/A	<0.4	0.02	N/A
Sodium (mg/L)	2.5	None	763	3.1	None	169
Sulfate (mg/L)	130	250	39,683	150	250	8,177
Zinc (µg/L)	***2,600***	59	794	***3,200***	65	174

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-29, Low-flow Counterpart to CG-01-11 (15 Oct 2001)			CG-01-30, Low-flow Counterpart to CG-01-9 (15 Oct 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	3	None		1.5	None	
pH (standard units)	***4.41***	6.5-9.0		***4.92***	6.5-9.0	
Conductivity (µS/cm)	288	None		177	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	127	None		65	None	
Aluminum (trec) (µg/L)	1,400	None	23	1,600	None	13
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	56	1,000	1	***3,800***	1,000	31
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	980	2,000	16	1,000	2,000	8
Aluminum (µg/L)	***1,400***	87	23	***1,300***	87	11
Cadmium (µg/L)	***3.4***	2.7	0.06	***10***	1.6	0.1
Calcium (mg/L)	37	None	1,504	18	None	360
Chloride (mg/L)	<4	250	N/A	<4	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***32***	11	1	***84***	6	1
Fluoride (mg/L)	0.66	2	11	0.5	2	4
Iron (µg/L)	<10	300	N/A	***3,200***	300	26
Lead (µg/L)	<1	3.3	N/A	***350***	1.6	3
Magnesium (mg/L)	8.5	None	139	5.2	None	43
Manganese (µg/L)	***4,000***	1,785	65	***2,400***	1,431	20
Nickel (µg/L)	<20	64	N/A	<20	36	N/A
Potassium (mg/L)	1.4	None	23	1.1	None	9
Silicon (mg/L)	7.0	None	114	7.8	None	64
Silver (µg/L)	<0.4	0.1	N/A	<0.4	0.04	N/A
Sodium (mg/L)	2.7	None	44	2.9	None	24
Sulfate (mg/L)	150	250	2,453	89	250	728
Zinc (µg/L)	***970***	145	16	***1,000***	83	8

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-31, Low-flow Counterpart to CG-01-8 (15 Oct 2001)			CG-01-32, Cinnamon Gulch below samples 21 thru 31 (15 Oct 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	0.85	None		185	None	
pH (standard units)	***5.42***	6.5-9.0		***4.1***	6.5-9.0	
Conductivity (µS/cm)	94	None		249	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	37	None		64	None	
Aluminum (trec) (µg/L)	58	None	0.3	6,000	None	6,051
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	240	1,000	1.1	380	1,000	383
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	440	2,000	2	1,800	2,000	1,815
Aluminum (µg/L)	35	87	0.2	***6,100***	87	6,151
Cadmium (µg/L)	***1.4***	1.1	0.01	***9***	1.6	9
Calcium (mg/L)	11	None	125	16	None	40,337
Chloride (mg/L)	<2	250	N/A	<4	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	<3	3.9	N/A	***250***	6	252
Fluoride (mg/L)	0.34	2	2	0.28	2	282
Iron (µg/L)	24	300	0.1	***370***	300	373
Lead (µg/L)	<1	0.9	N/A	***13***	1.5	13
Magnesium (mg/L)	2.5	None	12	5.8	None	5,849
Manganese (µg/L)	440	1,187	2	***3,200***	1,420	3,227
Nickel (µg/L)	<20	23	N/A	26	36	26
Potassium (mg/L)	0.77	None	4	1.0	None	1,008
Silicon (mg/L)	7.5	None	35	8.4	None	8,471
Silver (µg/L)	<0.4	0.01	N/A	<0.4	0.04	N/A
Sodium (mg/L)	2.6	None	12	2.6	None	2,622
Sulfate (mg/L)	40	250	185	120	250	121,012
Zinc (µg/L)	***440***	51	2	***1,800***	81	1,815

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-33, Low-flow Counterpart to CG-01-7 (15 Oct 2001)			CG-01-34, Low-flow Counterpart to CG-01-1 (15 Oct 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	3.4	None		2,450	None	
pH (standard units)	***4.9***	6.5-9.0		***3.85***	6.5-9.0	
Conductivity (µS/cm)	550	None		168	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	256	None		63	None	
Aluminum (trec) (µg/L)	740	None	14	2,400	None	32,052
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	1	10	0.02	<1	10	N/A
Iron (trec) (µg/L)	***16,000***	1,000	297	410	1,000	5,476
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	***4,400***	2,000	82	1,900	2,000	25,374
Aluminum (µg/L)	***600***	87	11	***2,000***	87	26,710
Cadmium (µg/L)	***19***	4.5	0.4	***7.9***	1.6	106
Calcium (mg/L)	76	None	3,521	17	None	560,908
Chloride (mg/L)	<10	250	N/A	<4	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***88***	20	2	***250***	6.1	3,339
Fluoride (mg/L)	0.73	2	14	0.31	2	4,140
Iron (µg/L)	***14,000***	300	259	150	300	2,003
Lead (µg/L)	4	6.9	0.1	***9***	1.5	120
Magnesium (mg/L)	16	None	297	5.2	None	69,446
Manganese (µg/L)	***5,500***	2,254	102	***1,700***	1,416	22,703
Nickel (µg/L)	38	115	1	<20	35	N/A
Potassium (mg/L)	1.1	None	20	0.72	None	9,616
Silicon (mg/L)	6.7	None	124	4.1	None	54,755
Silver (µg/L)	<0.4	0.38	N/A	<0.4	0.03	N/A
Sodium (mg/L)	3.5	None	65	1.7	None	22,703
Sulfate (mg/L)	***300***	250	5,560	90	250	1,201,946
Zinc (µg/L)	***4,400***	262	82	***1,900***	80	25,374

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-35, Low-flow Counterpart to CG-01-4 (16 Oct 2001)			CG-01-36, Duplicate of CG-01-35 (16 Oct 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	150	None		150	None	
pH (standard units)	***3.73***	6.5-9.0		***3.73***	6.5-9.0	
Conductivity (µS/cm)	212	None		212	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	60	None		60	None	
Aluminum (trec) (µg/L)	5,200	None	4,252	5,200	None	4,252
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	290	1,000	237	270	1,000	221
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	1,600	2,000	1,308	1,600	2,000	1,308
Aluminum (µg/L)	***5,200***	87	4,252	***5,200***	87	4,252
Cadmium (µg/L)	***7.8***	1.5	6	***7.9***	1.5	6
Calcium (mg/L)	15	None	31,071	15	None	31,071
Chloride (mg/L)	<2	250	N/A	<2	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***190***	5.8	155	***190***	5.8	155
Fluoride (mg/L)	0.29	2	237	0.31	2	253
Iron (µg/L)	250	300	204	250	300	204
Lead (µg/L)	***49***	1.4	40	***49***	1.4	40
Magnesium (mg/L)	5.3	None	4,334	5.3	None	4,334
Manganese (µg/L)	***2,700***	1,389	2,208	***2,700***	1,389	2,208
Nickel (µg/L)	21	34	17	21	34	17
Potassium (mg/L)	0.92	None	752	0.86	None	703
Silicon (mg/L)	7.9	None	6,459	7.9	None	6,459
Silver (µg/L)	<0.4	0.03	N/A	<0.4	0.03	N/A
Sodium (mg/L)	2.5	None	2,044	2.4	None	1,962
Sulfate (mg/L)	110	250	89,942	110	250	89,942
Zinc (µg/L)	***1,600***	76	1,308	***1,600***	76	1,308

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-37, Low-flow Counterpart to CG-01-6 (16 Oct 2001)			CG-01-38, Low-flow Counterpart to CG-01-2 (16 Oct 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	1.5	None		1,990	None	
pH (standard units)	***4.15***	6.5-9.0		***4.36***	6.5-9.0	
Conductivity (µS/cm)	130	None		153	None	
Alkalinity (mg/L CaCO3)	<10	None		<10	None	
Hardness (mg/L CaCO3)	43	None		63	None	
Aluminum (trec) (µg/L)	470	None	4	1,800	None	19,525
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	55	1,000	0.4	380	1,000	4,122
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	780	2,000	6	1,700	2,000	18,441
Aluminum (µg/L)	***470***	87	4	***1,100***	87	11,932
Cadmium (µg/L)	***2***	1.2	0.02	***6.9***	1.6	75
Calcium (mg/L)	13	None	270	17	None	455,595
Chloride (mg/L)	<2	250	N/A	<4	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	<3	4.4	N/A	***230***	6	2,495
Fluoride (mg/L)	0.15	2	1.2	0.29	2	3,146
Iron (µg/L)	50	300	0.4	100	300	1,085
Lead (µg/L)	***5***	1	0.04	***3***	1.5	33
Magnesium (mg/L)	2.5	None	20	5.1	None	55,322
Manganese (µg/L)	***2,300***	1,247	19	1,400	1,413	15,186
Nickel (µg/L)	<20	26	N/A	<20	35	N/A
Potassium (mg/L)	0.67	None	5.5	0.66	None	7,159
Silicon (mg/L)	5.7	None	47	3.3	None	35,797
Silver (µg/L)	<0.4	0.02	N/A	<0.4	0.03	N/A
Sodium (mg/L)	2.0	None	16	1.5	None	16,271
Sulfate (mg/L)	60	250	491	78	250	846,104
Zinc (µg/L)	***780***	58	6.4	***1,700***	80	18,441

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

Table 2. Results of chemical analyses and measurement of field parameters for water samples from the Cinnamon Gulch area (continued).

Sample	CG-01-39, Low-flow Counterpart to CG-01-3 (16 Oct 2001)			CG-01-40, Field Blank (16 Oct 2001)		
Parameter	Concentration/ measurement	Standard	Load (grams/day)	Concentration/ measurement	Standard	Load (grams/day)
Flow (gpm)	65	None		NM		
pH (standard units)	***3.7***	6.5-9.0		NM		
Conductivity (µS/cm)	227	None		NM		
Alkalinity (mg/L CaCO3)	<10	None		NM		N/A
Hardness (mg/L CaCO3)	65	None		<5	None	N/A
Aluminum (trec) (µg/L)	5,900	None	2,090	<30	None	N/A
Antimony (trec) (µg/L)	<1	6	N/A	<1	6	N/A
Arsenic (trec) (µg/L)	<1	10	N/A	<1	10	N/A
Iron (trec) (µg/L)	200	1,000	71	<10	1,000	N/A
Thallium (trec) (µg/L)	<1	0.5	N/A	<1	0.5	N/A
Zinc (trec) (µg/L)	***2,100***	2,000	744	<10	2,000	N/A
Aluminum (µg/L)	***5,900***	87	2,090	<30	87	N/A
Cadmium (µg/L)	***9.2***	1.6	3	<0.3	0.25	N/A
Calcium (mg/L)	16	None	14,527	<5	None	N/A
Chloride (mg/L)	<4	250	N/A	<2	250	N/A
Chromium (µg/L)	<20	11	N/A	<20	11	N/A
Copper (µg/L)	***230***	6.2	81	<3	0.70	N/A
Fluoride (mg/L)	0.34	2	120	<0.10	2	N/A
Iron (µg/L)	190	300	67	<10	300	N/A
Lead (µg/L)	***12***	1.6	4	<1	0.09	N/A
Magnesium (mg/L)	5.9	None	2,090	<0.02	None	N/A
Manganese (µg/L)	***3,100***	1,413	1,098	<2	611	N/A
Nickel (µg/L)	24	36	9	<20	4.2	N/A
Potassium (mg/L)	0.88	None	312	<0.2	None	N/A
Silicon (mg/L)	8.1	None	2,870	<0.01	None	N/A
Silver (µg/L)	<0.4	0.04	N/A	<0.4	0.0004	N/A
Sodium (mg/L)	2.5	None	886	<0.2	None	N/A
Sulfate (mg/L)	120	250	42,518	<3	250	N/A
Zinc (µg/L)	***2,100***	82	744	<10	9.5	N/A

Numbers in ***bold italics*** indicate a concentration/measurement exceeding water quality standard.

GEOLOGIC SETTING

Cinnamon Gulch lies on the northeastern margin of the Montezuma Stock, a 40 million-year-old (Oligocene) quartz monzonite porphyry (Meyer and others, 1996; Neuerburg and Botinelly, 1972). The Montezuma stock and its associated intrusions are part of a voluminous suite of porphyries that was emplaced 45-35 Ma along the north-central Colorado Mineral Belt from Empire to Climax (Bookstrom and others, 1987). The copper, zinc, lead, silver, gold and molybdenum-bearing hydrothermal systems of the area are related to intrusions of this suite of late Eocene-early Oligocene granitic intrusions. The stock intruded Precambrian hornblende gneiss and schist. A geologic map is shown on Figure 4.

The Montezuma Shear Zone, a band of argillized, sericitized, and pyritized rocks, passes through Cinnamon Gulch (Neuerburg and Botinelly, 1972), and is presumed to have localized mineralizing fluids in the area. Zones of the most intensely altered rock show a strong spatial correlation with the Montezuma Shear Zone (A. Bookstrom, US Geological Survey, oral commun., 2001). Patton (1909, p. 137-138) described several of the mines in the Montezuma District, including Cinnamon Gulch. Figure 5 shows the map published by Patton (1909), which depicts the mines in the district at the time.

Hydrothermally altered rock and sulfide veins are common throughout the district. Sericitic and propylitic alteration are common, and argillic alteration is present locally. The ore deposits within the district are dominantly silver-lead-zinc veins. Pyrite, galena, and sphalerite are the dominant sulfides, generally with tetrahedrite and chalcopyrite and less commonly with sulfosalts of silver and bismuth (Neuerburg, 1971). Minor amounts of other sulfides are present, including chalcopyrite, bismuthinite, molybdenite, and sphalerite. Gold is mostly insignificant. Ferricrete and ferrosinter deposits are common in the areas underlain and flanked by altered rocks.

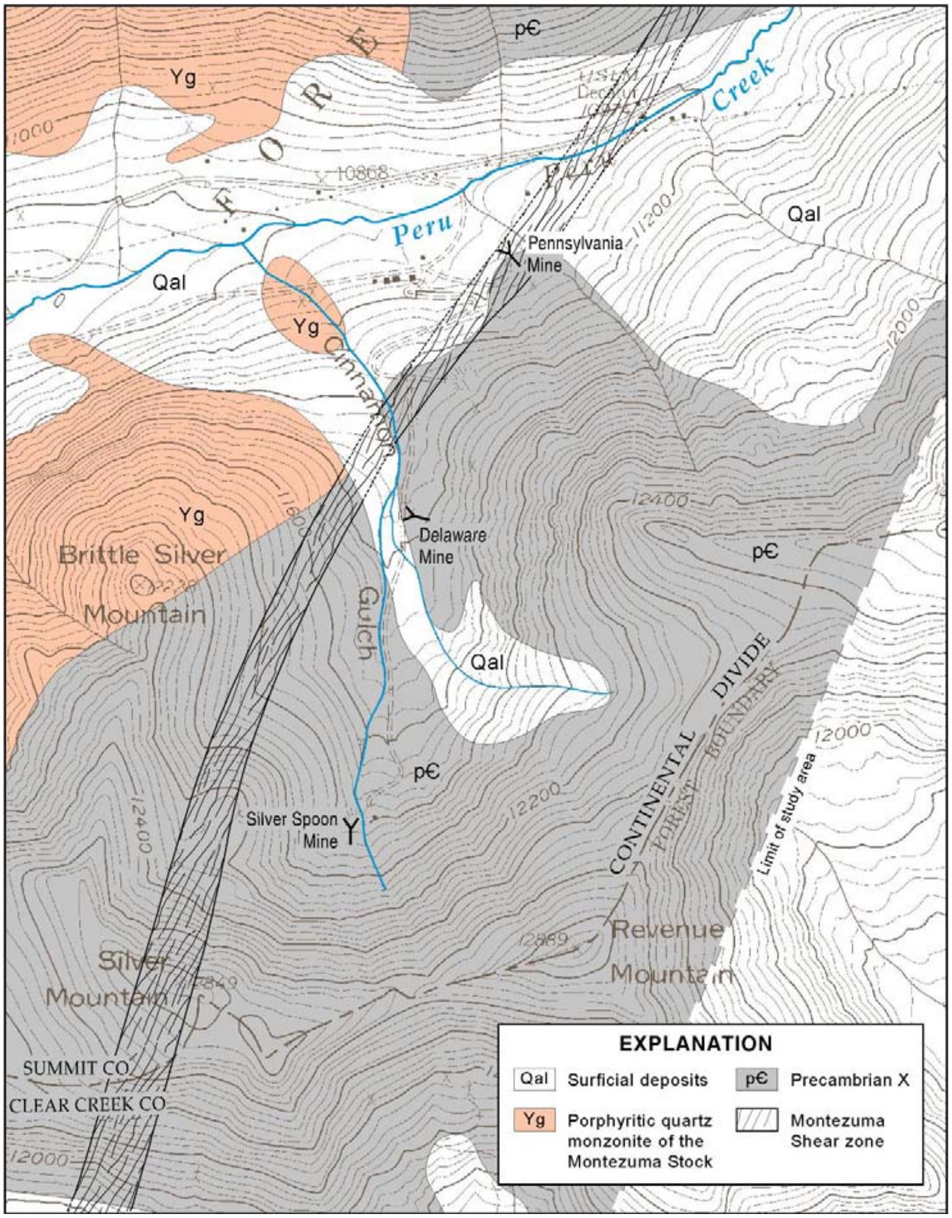
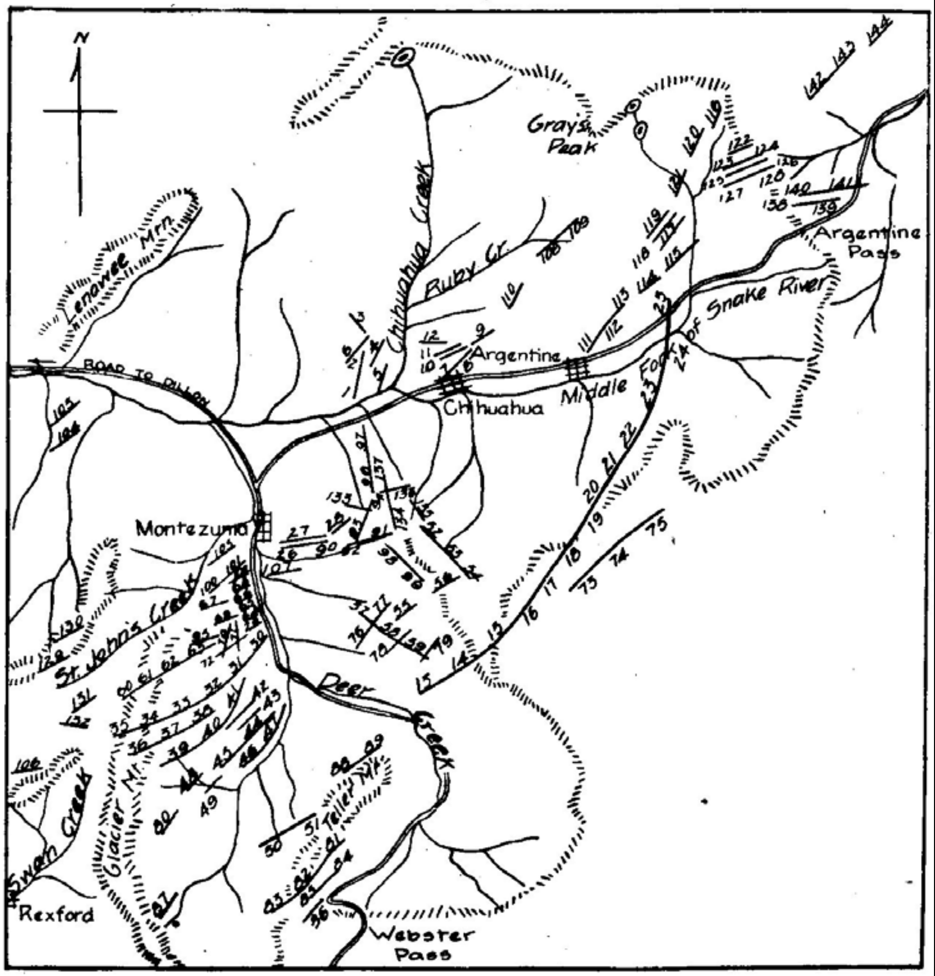


Figure 4. Generalized geologic map of Cinnamon Gulch area (modified from Neuerburg and Botinelly, 1972; Tweto, 1979).



MAP OF MONTEZUMA MINING DISTRICT, SHOWING LOCATION OF MINES.

1 Grand Union, 2 St. Lawrence, 3 Maid of Orleans (Madof Orleanse), 4 Chihuahua, 5 Rosalie, 6 Pella, 7 Bertha, 8 Fifth of July, 9 Grey Eagle, 10 Little Chief, 11 Chicago, 12 Buda, 13 Climax, 14 Lucky Baldwin, 15 Silver Wave, 16 Silver Chord, 17 Mary Ann, 18 Great Republic, 19 Challenger, 20 Sunrise, 21 Delaware Extension, 22 Delaware, 23 Pennsylvania, 24 Pennsylvania Extension, 25 Lone Jack, 26 Waterloo, 27 Old Settler, 28 Surprise, 29 Silver Wing, 30 Eureka, 31 California, 32 Sunburst, 34 Wild Irishman, 35 Silver Prince, 36 Centennial, 37 General Teller, 38 Marxon, 39 Condor, 40 Woodchuck, 41 Walker, 42 Little Emma, 43 Eclipse, 44 Itaska, 45 Scotia, 46 Defiance, 47 Chautauqua, 48 Sampson, 49 Rustler, 50 Radical, 51 Radical, Jr., 52 Carrol, 53 Braganza Extension, 54 Braganza, 55 Atlantic, 56 Sarsfield, 57 Yellow Jacket Extension West, 58 Yellow Jacket, 59 Yellow Jacket Extension, 60 Arctic, 61 New York, 62 Potosi, 63 Tunnel Lode No. 7, 64 Old Timer, 65 Silver King, 66 Moscow, 67 Denver, 68 Celtic, 69 St. Elmo, 70 Tiger, 71 Windsor, 72 St. Coud, 73 Best, 74 Baltic, 75 Revenue, 76 Bullion Extension, 77 Bullion, 78 Aorta, 79 Waukegan, 80 Erie, 81 Champion, 82 Bertha, 83 Cyvert, 84 Cashier, 85 Venus, 86 Silver Medal, 87 Charles Comstock, 88 Red Jacket, 89 Red Jacket Extension, 90 Thunderbolt, 91 Arapahoe, 92 Botts, 93 Tip Top, 94 Monitor, 95 Tunnel Lode No. 5, 97 Ballarat. 98 Rose, 99 Quail, 100 Harrison, 101 Yorkshire, 102 Adder, 103 Fourth of July, 104 Don Pedro, 105 Hunkidori, 106 Erickson, 107 Meteor, 108 Rudolph, 109 Howard, 110 Sylvia, 111 Gold Bug, 112 Rotschild, 113 Rotschild No. 2, 114 Peruvian, 115 National Treasure, 116 Silver Ledge, 117 Minerva, 118 Whale. 119 Silver Falls, 120 Baalbec, 121 Tenth Legion, 122 Rip van Winkle, 123 Little Chief, 124 Little Chief Extension, 125 Lone Star, 126 Lone Star Extension, 127 Queen of the West, 128 Queen of the West Extension, 129 M. & N., 130 Liberty, 131 Marion E., 132 Yankee Doodle, 133 Cross, 134 Florence-Belle, 135 Lelia, 136 Susy, 137 Maggie T., 138 Golden Rule, 139 Simon, 140 Bullion King, 141 Flossie, 142 Santiago No. 9, 143 Santiago, 144 Centennial.

Figure 5. Prominent veins and related mines in the Montezuma district (Modified from Patton, 1909, p. 138). Middle Fork of Snake River now called Peru Creek.

RICH ORE LODE

In the southern part of the Silver Spoon inventory area #430/4382-1 (Figure 2), adit #103 is located about 1,000 feet west of Forest Road #262. Access is by foot from FR #262. Adit #103 is apparently on the Rich Ore Lode (patented) near the north end of the claim. Adit #103 was not included on the 1958 Montezuma quadrangle of PBS maps. Production, if any, was probably small and unrecorded. Very little information is available on the Rich Ore Lode.

MINING HISTORY

1879. The Rich Ore Lode was located on August 16 (Mineral Survey No. 2105).

1884. Mineral Survey No. 2105 was conducted on the Rich Ore Lode owned by Lizzie Rubado and others. A 10-ft-deep discovery cut and 75-ft-long adit were surveyed on the north end of the claim (Figure 6). Inventory feature #103 is presumed to be the adit surveyed on the claim.

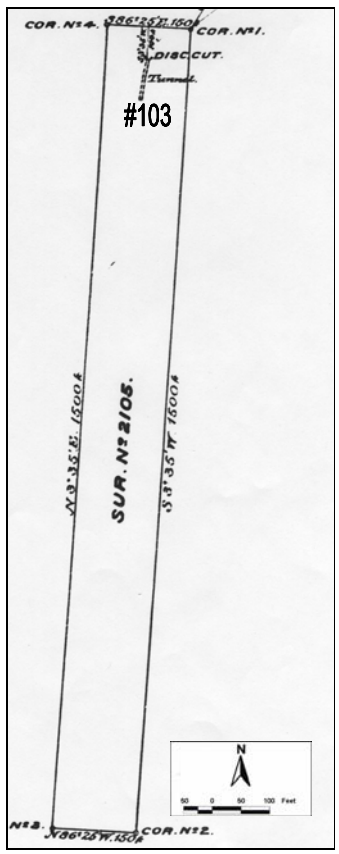


Figure 6. Rich Ore Lode Mineral Survey (No. 2105)
(Modified; scale is approximate.)

1892. Henry Lampi, Lizzie Rubado, Martha Rubado, Mary Rubado, and Mary Wagner were issued a patent for the Rich Ore Lode (BLM files).

GEOLOGY

The mines of the Rich Ore Lode are developed along pyrite-bearing quartz veins in the Precambrian X (referred to as Idaho Springs Formation in older literature), composed of sillimanitic micaceous gneisses and schists (Neuerburg and Botinelly, 1972). Sphalerite and rare galena were found on some of the dumps.

SITE DESCRIPTION

Adit #103 (Silver Spoon inventory area-Rich Ore Lode) is accessed by traveling to the end of the traversable portion of FR 262, about 1¼ miles from the Peru Creek crossing. At one time the road ended at the Silver Spoon Mine, but rocks cover areas of the remaining road. Adit #100 is about 1,000 feet west of the FR 262 at an elevation of 11,600 feet.

Water from a pool just inside the open adit (Figure 7) flows onto the bench and down the southern side of the upper lobe of the waste-rock pile (Figure 8). The effluent eventually disappears in the grass along the southern side of the dump. Reddish-orange precipitate was deposited in the channel from the slightly turbid effluent.

Figure 7. Adit #103 (Rich Ore Lode) showing effluent with orange precipitate.

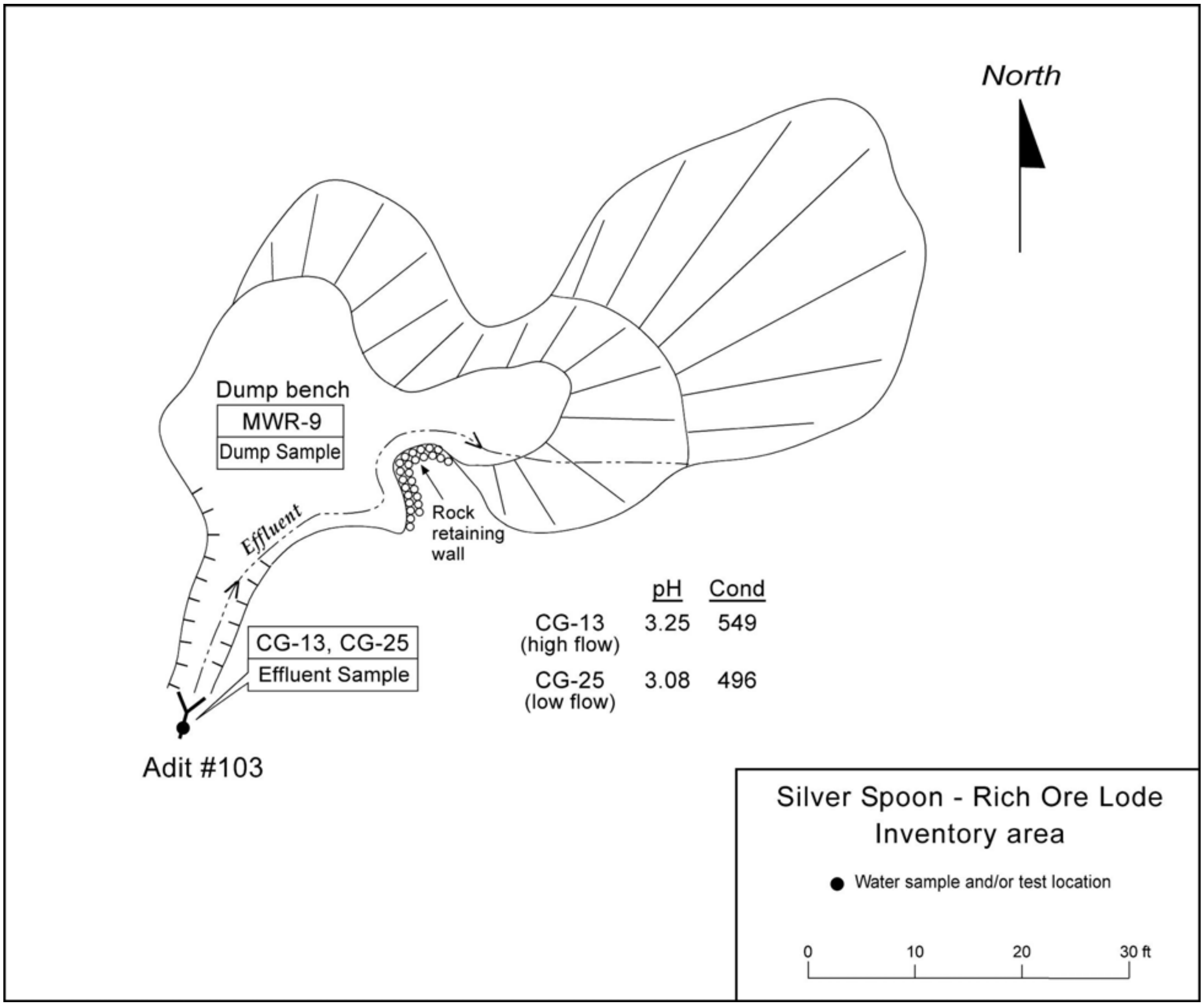


Figure 8. Sketch map of adit #103 and associated waste-rock pile.

The dump contains about 100 cubic yards of mostly uncemented coarse granitic rock (Figure 8, 9) that was not included in the initial inventory. Chunks of quartz vein, mostly on the bench, contained abundant pyrite, moderate amounts of sphalerite, and less common galena. A 2-inch-thick solid piece of galena found on the dump indicates that perhaps some of the galena was hand sorted prior to shipping. Galena from area mines contains high silver concentrations.

WASTE AND HAZARD CHARACTERISTICS

Four separate adits discharge water along the Rich Ore Lode, including adits #100, #101, #103, and an adit that was not inventoried in 1993. In July of 2001, the combined flow from the four adits was measured at about 4.5 gpm. The pH ranged from 3.16 to 3.58, and conductivity ranged from 287 to 611 µS/cm. In October of 2001, only one of the four adits was flowing (adit #100), at a rate of about 1 gpm. Standing water was present at the other three. The pH ranged from 2.91 to 3.21, and conductivity ranged from 464 to 593 µS/cm. Water samples were collected from all adits with flowing or standing water (high-flow samples CG-13 through CG-16, and their low-flow counterparts CG-22 through 25). Sample locations are shown on Figure 3, and water chemistry data are shown on Table 2.

Figure 9. Waste-rock pile and effluent from adit #103.

Numerous constituents exceeded State water quality standards in the effluents from the adits along the Rich Ore Lode. Dissolved aluminum, cadmium, copper, iron, lead, manganese, and zinc, plus total recoverable iron and zinc, exceeded standards in all eight samples. In addition, nickel exceeded standard in seven samples, silver and sulfate in two samples, and total recoverable thallium in one. Sample CG-01-24 carried abundant suspended solids, indicated by reddish precipitate in the stream channel and deposited on the filter during sampling.

Effluent from two adits (#105 and #106) downstream from the Rich Ore Lode, but within the Silver Spoon Inventory Area, were sampled. These are discussed in the Delaware Mine section.

Water sample CG-01-27 was collected at low flow from Cinnamon Gulch Creek downstream from the influence of the Rich Ore Lode workings (Figure 3). The stream at this sample site includes discharge from both the Rich Ore Lode and the upgradient Silver Spoon Mine, as well as some natural sources. Streamflow was measured at 56 gpm. The sample had pH of 3.35, conductivity of 258 µS/cm, and exceeded State water quality standards with respect to total recoverable zinc and dissolved aluminum, cadmium, copper, iron, lead, manganese, nickel, and zinc. Red-orange precipitate was visible in the channel. No high-flow sample was collected at this location.

Samples CG-01-11, -29 (the low-flow counterpart to -11), -12, -26, and -28 were collected from natural springs or streams in the Silver Spoon Inventory Area. The combined flow from these sources was 17 gpm at low flow. The pH of the samples ranged from 3.39 to 4.47 and conductivity ranged from 84 to 318 µS/cm. Constituents exceeding State water quality standards included dissolved aluminum, cadmium, copper, and zinc in all samples, manganese in four samples, lead in three samples, and total recoverable zinc and dissolved iron and nickel in one sample. Samples CG-01-28 and -29 had visible red precipitate, and sample site –28 was associated with a ferricrete deposit.

Three of the five inventoried adits (#100, #101, and #103) along the Rich Ore Lode were assigned EDRs of 2, indicating "significant" environmental degradation. The remaining two were assigned EDRs of 4, indicating "slight" environmental degradation. Adits #100 through #104 were assigned physical hazard ratings of 3, indicating "potential danger." The physical hazard ratings are based on the fact that these adits are partially to completely intact, and entrance is not impeded.

No waste rock dumps were inventoried in the Rich Ore Lode area in 1993, but a composite grab sample was collected (MWR-9) for geochemical analysis in 2001 from the dump associated with adit #103. The rock chemistry data (Table 3) show relatively large concentrations of lead and zinc, plus detectable gold, mercury, and silver. The negative net acid base potential and the acidic paste pH suggest that the dump will be acid generating over the long term.

Table 3. Cinnamon Gulch rock chemistry data

		Sample Number				
Constituent	**Units**	**MWR-5**	**MWR-6**	**MWR-7**	**MWR-8**	**MWR-9**
Gold	oz/ton	0.054	0.016	0.036	0.014	0.003
Silver	oz/ton	18.2	9.98	13.6	1.46	0.49
Mercury	ppm	1.1	1.3	1.4	0.4	0.3
Neutralization Potential	Tons $CaCO_3$/ 1000 tons	<0.1	<0.1	<0.1	2.8	13.8
Potential Acidity	Tons $CaCO_3$/ 1000 tons	11.3	7.7	6.7	17.0	46.8
Net Acid Base Potential	Tons $CaCO_3$/ 1000 tons	-11.3	-7.7	-6.7	-14.2	-33.0
Paste pH	Standard Units	3.9	3.8	4.3	5.1	4.9
Na2O	wt %	0.23	0.08	<0.05	0.99	0.89
MgO	wt %	0.69	0.63	0.58	0.85	0.79
Al2O3	wt %	11.9	11.6	10.4	14.6	15.2
SiO2	wt %	61.2	71.8	76.4	70.2	64.2
P2O5	wt %	0.19	0.2	0.13	0.16	0.18
S	wt %	4.19	1.2	1.5	2.02	4.48
Cl	wt %	<0.02	<0.02	<0.02	<0.02	<0.02
K2O	wt %	3.36	3.22	2.88	4.32	4.35
CaO	wt %	0.09	0.05	0.03	0.54	0.15
TiO2	wt %	0.48	0.38	0.35	0.43	0.42
MnO	wt %	0.02	0.01	0.01	0.14	1.12
Fe2O3	wt %	6.85	5.69	4.75	6.76	9.51
BaO	wt %	0.69	0.17	0.4	0.06	0.07
V	ppm	<100	39	32	47	34
Cr	ppm	<100	292	269	262	205
Co	ppm	<100	<10	<10	<10	<10
Ni	ppm	<100	<10	<10	<10	<10
W	ppm	<100	14	14	11	<10
Cu	ppm	3,410	723	937	406	259
Zn	ppm	19,400	4,111	7,206	471	3,970
As	ppm	267	222	263	56	46
Sn	ppm	<500	293	282	148	124
Pb	ppm	103,000	16,313	26,112	1,312	12,426
Mo	ppm	<100	<10	10	<10	<10
Sr	ppm	262	96	165	153	79
U	ppm	<100	29	38	12	30
Th	ppm	<100	166	180	81	78
Nb	ppm	<100	15	18	19	21
Zr	ppm	275	173	178	168	311
Rb	ppm	<100	157	137	197	170
Y	ppm	<200	48	52	66	54

DELAWARE MINE

The Delaware Tunnel is feature #106, near the north end of the Silver Spoon inventory area (#430/4382-1; Figure 2). Located on the western slope of Decatur Mountain about ½ mile south of Peru Creek, the Delaware Mine was one of the earlier producers in the area. The Delaware Tunnel, on the east side of FR #262, was driven as a crosscut adit to access the vein and drain the Delaware shaft above. A short mine road south of the tunnel and east of FR #262 leads to the Delaware shaft. The Delaware Tunnel was driven on the Annabel Mill Site some time after 1900 when the claim was surveyed. Undercutting the Annex and Fred Williams Lodes, the tunnel is connected to the Delaware shaft on the adjacent Delaware Lode (Figure 13). Although all of the claims mentioned are patented, the effluent reaches Cinnamon Creek. The Delaware, Pennsylvania (to the north), and Delaware Extension (to the south) mines extracted ore from different parts of the Pennsylvania vein. The Pennsylvania Mine is discussed in a later section of this report. Some information on the Delaware Extension (probably accessed through adit #105) is included in this section. It was not determined if an underground connection was ever made between the Delaware and the Pennsylvania or Delaware Extension Mines. Also not determined was whether the Delaware Tunnel extended east from the Delaware Lode and undercut NFS lands and the overlapping Commodore and Ouray Lodes (Figure 14). Level C of the Pennsylvania Mine intersected the Ouray vein, 225 feet east of the Pennsylvania vein (Lovering, 1935, p. 93). The Delaware Mine apparently became part of the Pennsylvania Mine group in 1900, when the Pennsylvania Mines Company owned the Annabel, Annex, and Fred Williams claims. No production was reported from the Delaware Mine after 1900. Subsequent production may have been reported with the Pennsylvania Mine, discussed later.

Significant differences exist between the Montezuma PBS map and Mineral Survey 13686A & B (Annabel Mill Site and Annex and Fred Williams Lodes). On the PBS map, adit #106 (Delaware Tunnel) would be plotted on the Ouray and overlapping Champion Mill Sites. On Mineral Survey 13686A & B, adit #106 would plot on the Annabel mill site. Lovering (1935, plate 33) also positioned the Delaware Tunnel on the Annabel mill. The PBS map appears to be in error and the workings and claim should be resurveyed.

MINING HISTORY

Production reports were not required by the state during the Delaware Mine's productive years, and the quantity of ore removed is unknown. The mine was a "steady producer" in the 1880's, and Lovering (1935, p. 78) estimated that the total production from the Delaware Mine exceeded 1,000 tons. The Delaware Mine was driven on the Pennsylvania vein, an extensive vein that includes the Sunrise claims (Silver Spoon Mine) on the south and the Pennsylvania Mine on the north. Production from the Sunrise claims was small compared to the Delaware and Pennsylvania Mine (Lovering and Goddard, 1950, p. 137).

1879. William Mendenhall and Jacob Cypher discovered the Delaware Lode in the spring (*Colorado Miner*, September 4, 1880, p. 3). Mendenhall and Sypher (Cypher?) started developing the Delaware Mine soon after its discovery (Lovering, 1935, p. 78). The 2-ft-wide ore body was exposed over a length of 100 feet in the Delaware Mine (*Rocky Mountain News*, August 5, 1879, p. 5). First class ore assayed 3,000 oz per ton silver and second class ore assayed

1,000 oz per ton. Similar ore was promptly discovered on the east and west extension of the Delaware vein. J.S.M. Foster discovered the western extension and the Cowles family discovered the eastern extension of the Delaware vein (*Colorado Miner,* August 9, 1879, p. 3). In a conflicting report, according to the Rocky Mountain News (September, 18, 1880, p.2), Harvy Cole discovered the Delaware Lode and sold it to Hurd & Company for $128,000 (*Rocky Mountain News*, September 18, 1880, p. 2). This reference seems to be inaccurate or could refer to a different Delaware Lode.

1880. In April, $50,000 worth of ore was exposed in the Delaware Mine (*Rocky Mountain News*, April 24, 1880, p. 3). A 40-ton stockpile of high-grade ore awaited shipping in May (*Colorado Miner*, May 22, 1880, p. 3). In July, a ton of first class ore, carrying gray copper and a high percentage of lead, was generated with each foot of shaft dug (*Colorado Miner*, July 24, 1880, p. 3). A 75-ft-long crosscut adit intersected the Delaware vein 200 feet southwest of the discovery shaft. Mendenhall and Cypher owned the Delaware Lode. A 100-lb sample from the Delaware Mine assayed 200 oz per ton silver (*Rocky Mountain News*, July 30, 1880, p. 3). In September, a solid 18-inch-wide vein was exposed over the entire length of the 50-ft-deep discovery shaft (*Colorado Miner*, September 4, 1880, p. 3). Assay results ranged from 125 to 150 oz per ton silver. Using an average of 1¾ tons of ore per foot, about $240 worth of ore was recovered from each foot of shaft sunk. Similar ore was exposed in an 85-ft-deep shaft 100 feet northwest of the discovery shaft. Average ore values at the bottom of the 85-ft-deep shaft were between $1,000 and $4,000 per ton. In October, Washington T. Lewis was in charge of the 14 employees working at the Delaware Mine (*Colorado Miner*, October 16, 1880, p. 3). Surface improvements included a road, boarding house, and shaft house complete with an engine. The shaft was retimbered and the shaft and drifts were extended. In September, William Mendenhall and Jacob Cypher sold the Delaware to Tabor (Lieutenant Governor) and Sanders for between $65,000 and $100,000 (*Rocky Mountain News*, September 25, 1880, p. 3). A road was completed to the mine and a boiler and engine was ordered. In October, Delaware ore was milling 250 oz of silver per ton (*Rocky Mountain News*, October 29, 1880, p. 3). According to Corregan and Lingane (1883, p. 773), the Delaware Extension Lode was located.

Mineral Survey No. 1171 was conducted on the Ouray Lode and Mill Site owned by the Leadville and Pennsylvania Consolidated Mining Co. The Ouray Mill Site is west of Cinnamon Creek. According to the Montezuma PBS map, the mill site is on both sides of Cinnamon Creek and would include adit #106. Eventually, the Commodore Lode overstaked the southern ½ of the Ouray Lode. Adit #106 (Delaware Tunnel) trends toward and is about 1,000 feet west of the Ouray Lode. Adit #100 (Pennsylvania Mine-level F) eventually intersected the Ouray vein.

1881. In January, the Delaware Mine was considered one of the best mines in the State (*Rocky Mountain News*, January 4, 1881, p. 2). A solid 2-ft-wide vein was exposed in the shaft. Daily shaft sinking activities included removing about $2,000 worth of ore. Several hundred tons of ore were stored on the dump. At the time, no drifting or stoping activity was done. Daily production from the Delaware Mine was worth between $2,500 and $3,000 (*Denver Republican*, February 14, 1881, p. 2). Proceeds were expected to pay back the owners investment by April. Ore assays range from 250 to 1,000 ounces of silver per ton. About 700 tons of ore were stockpiled. In March, an 18-inch-wide pay zone was exposed in the 200-ft-deep Delaware shaft (*Rocky Mountain News*, March 11, 1881, p. 2). Over a six-month period, the 30 employees had mined and stockpiled about 2,000 of tons ore. The ore averaged 400 oz of silver per ton. In another account (*Rocky Mountain News*, March 24, 1881, p. 2), workers were drifting east and west from the 160-ft-deep shaft. Silver-bearing gray copper ore was contained in the 20- to 22-inch thick zone. About 800 tons of ore from the Delaware was scheduled for processing at the Chihuahua concentration mill (*Rocky Mountain News*, March 27, 1881, p. 6). In April, the 16-inch-wide vein averaged 325 oz per ton silver (*Rocky Mountain News*, April 18, 1881, p. 6). A 50-ton stockpile of ore at the Delaware Mine awaited shipping. A 3-ft-thick bismuth-bearing quartz vein, assaying 70- to 100- oz of silver per ton, was exposed on the Caledonia Lode above the Delaware Mine (*Denver Republican*, June 7, 1881, p. 6). In July, a crosscut adit was being driven to drain the 160-ft-deep Delaware shaft (*Rocky Mountain News*, June 6, 1881, p. 2). The pump was too small to remove the daily accumulation of 1,000 gallons of water. The adit had been driven 400 feet. In July, the 2½-ft-wide vein of galena in the Delaware Mine assayed 150 oz per ton silver and was developed for a length of 300 feet (*Denver Republican*, July 19, 1881, p. 6). Governor Tabor and Mr. Hamill were the sole owners of the Delaware Mine (*Rocky Mountain News*, July 22, 1881, p. 8). In September, Tabor and Mr. Hamill began driving a crosscut adit to intersect with the 70-ft deep Delaware shaft (*Rocky Mountain News*, September 6, 1881, p. 3). Ore removed from the shaft assayed 40 to 350 oz per ton silver. The crosscut adit probably refers to one of the levels, possibly C in the Pennsylvania Mine. Adit #106 (Delaware Tunnel) was most likely started after 1900. The Delaware Mine was sold for $400,000 (*Rocky Mountain News*, September 22, 1881, p.6). In October, work continued driving the 400-ft-long crosscut adit intended to drain the Delaware shaft (*Rocky Mountain News*, October 11, 1881, p.2). The 550-ton ore stockpile contains over 100 oz per ton silver.

The "Pennsylvania and Leadville Consolidated company" (Leadville and Pennsylvania Consolidated Mining Company?) control an 8-claim block west of the Delaware Mine (*Rocky Mountain News*, August 10, 1881, p. 8). The claims covered the western extension of the Delaware vein. Adit #106 could have been included in this claim block. On September 5, H.W. Eddy (president and managing director), B.A. Hopkins (vice president), and James Teal (secretary/treasurer) were elected officers of the Leadville and Pennsylvania Consolidated Mining Company (*Rocky Mountain News*, September 22, 1881, p. 6).

The Delaware Mine was worked for 5 months during 1881 and had 300 feet of development (Burchard, 1882, p. 435). Twenty-five tons of galena and copper ore with an average value of $100 per ton were shipped. About 75 tons of ore remained on the dump. Eventually, the east trending crosscut (adit #106) intersected the Pennsylvania vein, initially worked through the Delaware shaft 500 feet to the east.

Mineral Survey No. 1260 (Figure 10) was conducted on the Delaware Extension Lode owned by W.T. Reynolds and others. An 18-ft-deep discovery shaft and two east trending adits (70 and 80 ft long) were surveyed near the northern end of the claim. Possibly one, if not both of the adits undercut the Delaware Lode and eventually, could have connected with workings on the Delaware Lode. In May, a raise driven from one of the crosscut adits was projected to reach the surface (*Rocky Mountain News*, May 21, 1881, p. 6). Adit #105 in the Silver Spoon inventory area (Figure 2) was probably driven as a crosscut to develop and drain the Delaware Extension.

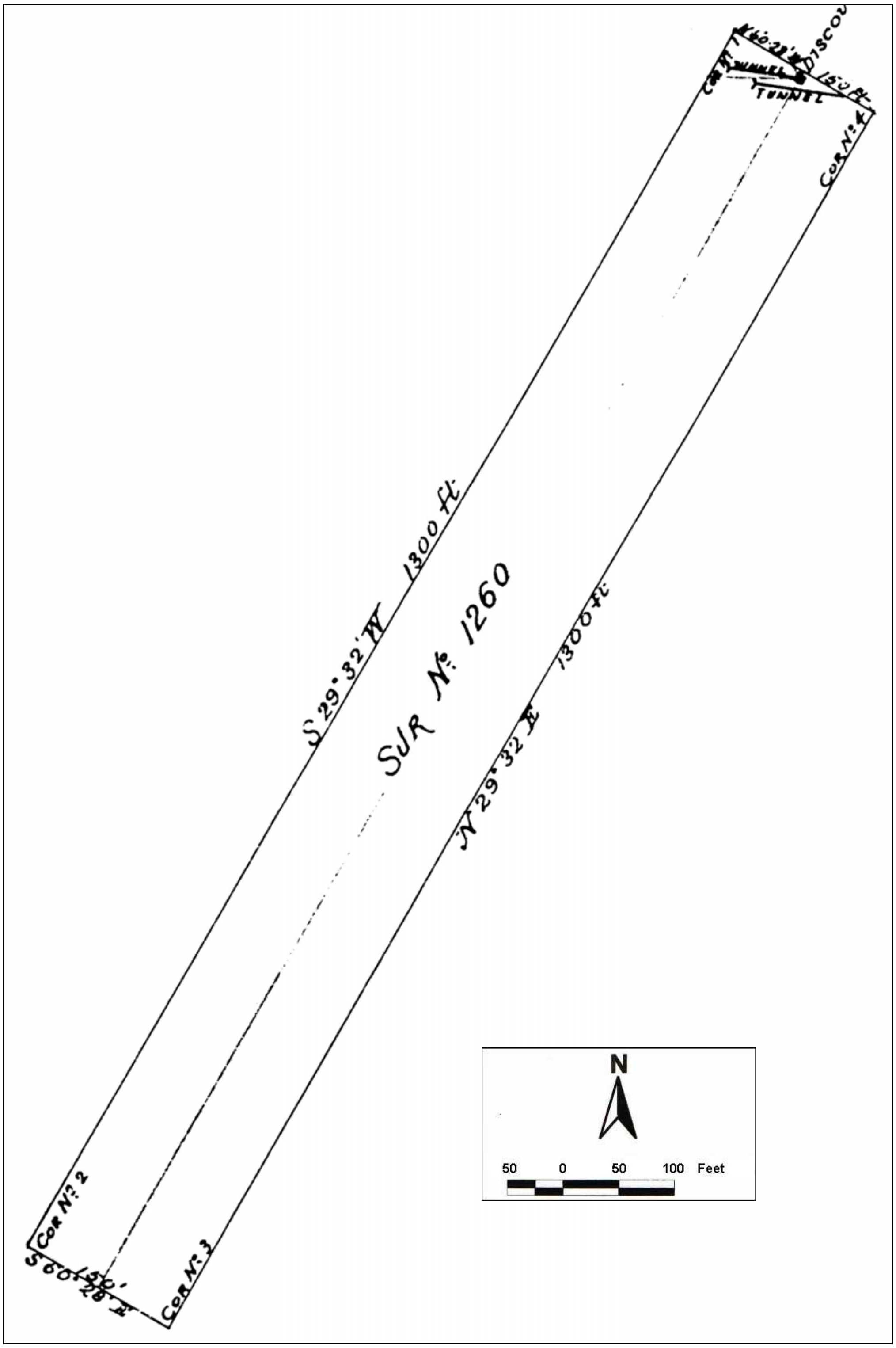


Figure 10. Delaware Extension Lode Mineral Survey (No. 1260) (Modified, scale is approximate).

Oddenkirk, Johnson, Kinsel, and the Speiles Brothers own the New Discovery group, a 5-claim block above the Pennsylvania and Leadville Lodes, near the Delaware Mine (*Rocky Mountain*

News, August 10, 1881, p. 8). The 8-ft-wide galena and yellow chloride-bearing vein on the New Discovery Lode assayed 697 to 897 oz of silver per ton. An adit run from the Homestake Lode intersected the vein. By September, the Speiles Brother's adit had attained a length of 160 feet (*Rocky Mountain News*, September 6, 1881, p. 3). It is not clear that this adit and claim block are related to the Delaware or Pennsylvania Mine located in Cinnamon Gulch.

1882. In March, $2 million in Delaware Mine stock was selling for $10 per share (*Rocky Mountain News*, March 6, 1882, p. 3). Four workers were engaged on a contract to sink 100 feet of shaft (*Denver Republican*, March 15, 1882, p. 6). Over 100 tons of ore were ready to ship. Assay results ranged from 100 to 1,000 ounces of silver per ton. The ore body was exposed in the main tunnel as well as in the crosscut adit. In another account, over 200 tons of ore were ready to ship (*Rocky Mountain News*, March 27, 1882, p. 4). The silver content ranged from 100 to 1,500 ounces per ton. A contract to advance the workings 50 feet, the fourth during the past winter was awarded in May (*Denver Republican*, May 22, 1882, p. 6). The Delaware Mining Company was planning to erect a concentrator (*Denver Republican*, June 1, 1882, p, 2). Workers were driving a crosscut tunnel to intersect and drain the shaft (*Rocky Mountain News*, June 27, 1882, p. 6). The pump was not large enough to remove all of the water. In August, a vein was discovered in the Delaware tunnel, driven to intersect the Delaware vein (*Rocky Mountain News*, August 29, 1882, p. 2). John Davenport discovered a mineralized quartz vein that was considered an extension of the Delaware vein. About 300 tons of ore were ready for the smelter (*Rocky Mountain News*, August 31, 1882, p. 6). The smelter was expected to be operational in 60 days. In October, ore from the Delaware Mine was milling between 40 and 1,000 oz of silver per ton (*Rocky Mountain News*, October 20, 1882, p. 6). Burchard (1883, p. 591) listed the Delaware Mine with other producing mines in the Peru mining district. Frank X. Aicher, R.M. Boyer, and John S. Gates were issued patents for the Delaware Extension Lode (BLM files).

1883. In August, ore from the Delaware Mine was processed at the Brittle Silver Mill (*Colorado Miner*, August 4, 1883, p. 1). Between 6 and 8 tons of ore per day were hauled from the Delaware Mine to Keystone, a distance of about 8 miles (*Rocky Mountain News*, August 16, 1883, p. 2). From Keystone the ore was transported by rail to Leadville for smelting. The ore zone in the Delaware vein varied from 8 inches- to 2-ft-wide and was milling 500 ounces of silver per ton.

Mineral Survey No's. 1983 and 1984 were conducted on the Delaware and Commodore Lodes, owned by the Commodore and Delaware Mining and Milling Company (Figures 11 and 12). Three shafts (10-, 90-, and 165-ft-deep) were surveyed near the center of the Delaware Lode. A 10-ft-deep discovery shaft near the center of the claim and an 84-ft-long adit, bearing toward the southwest corner of the claim, presumably from the Delaware Lode, were included on the Commodore mineral survey. Although the adit is not on the Commodore Lode, it was driven to develop the claim. The Ouray Lode overstaked the northern ½ of the Commodore Lode. Adit #106 undercuts the Delaware Lode and trends east toward the Commodore and Ouray Lodes. The Paymaster, Pennsylvania, and Cross Lodes (discussed in the Pennsylvania Mine section) overlap the northeastern end of the Delaware Lode and extend northeast toward the Pennsylvania Mine. The Delaware and Commodore mines near Decatur shipped a "large" quantity of ore (Burchard, 1885, p. 433). Lovering (1935, p. 78) stated that "by 1883 about 800 tons of ore had been shipped". Underground workings included a 400-ft-long adit and a 165-ft-deep shaft with 3 levels aggregating 400 feet.

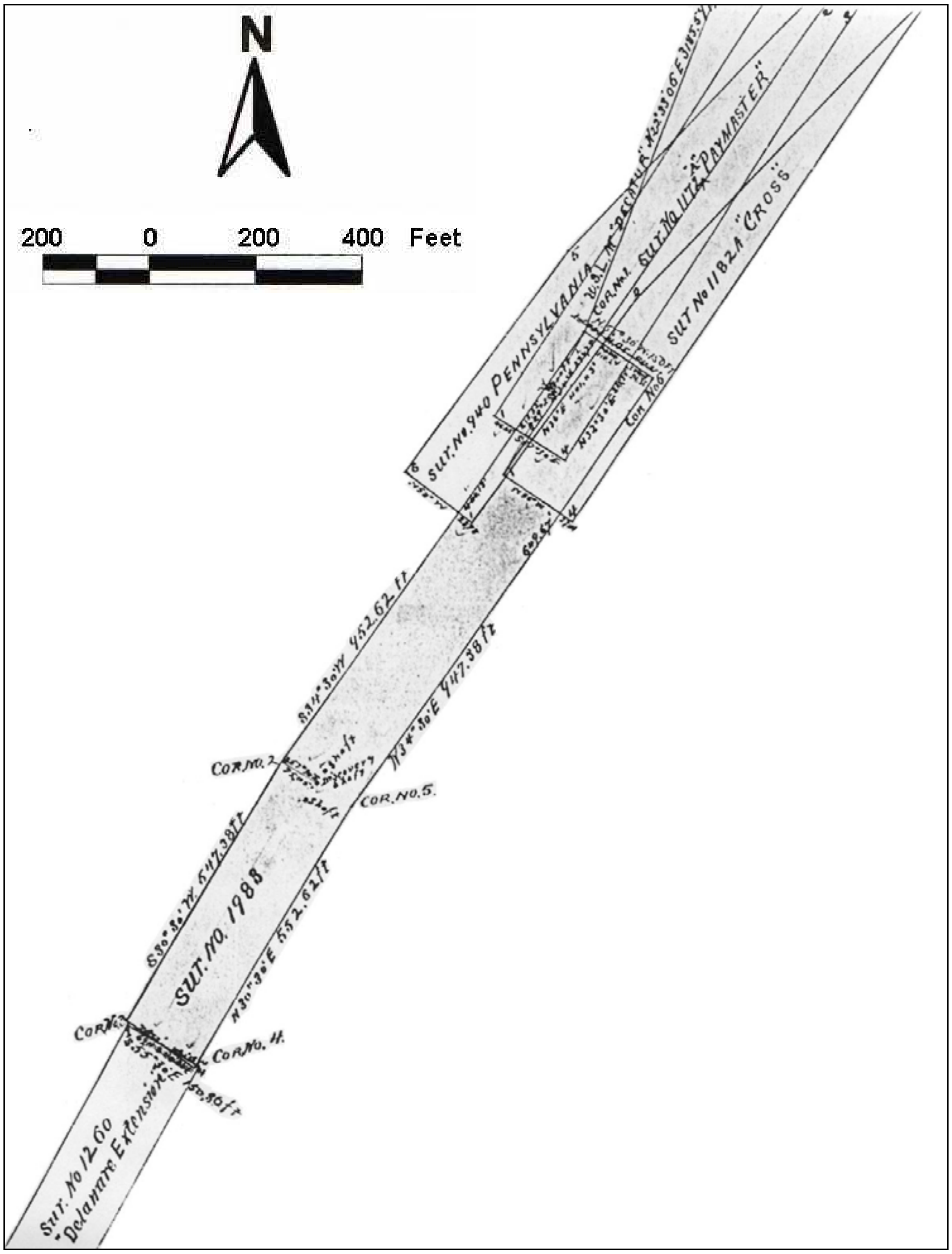


Figure 11. Delaware Lode Mineral Survey (No. 1983) (Modified, scale is approximate).

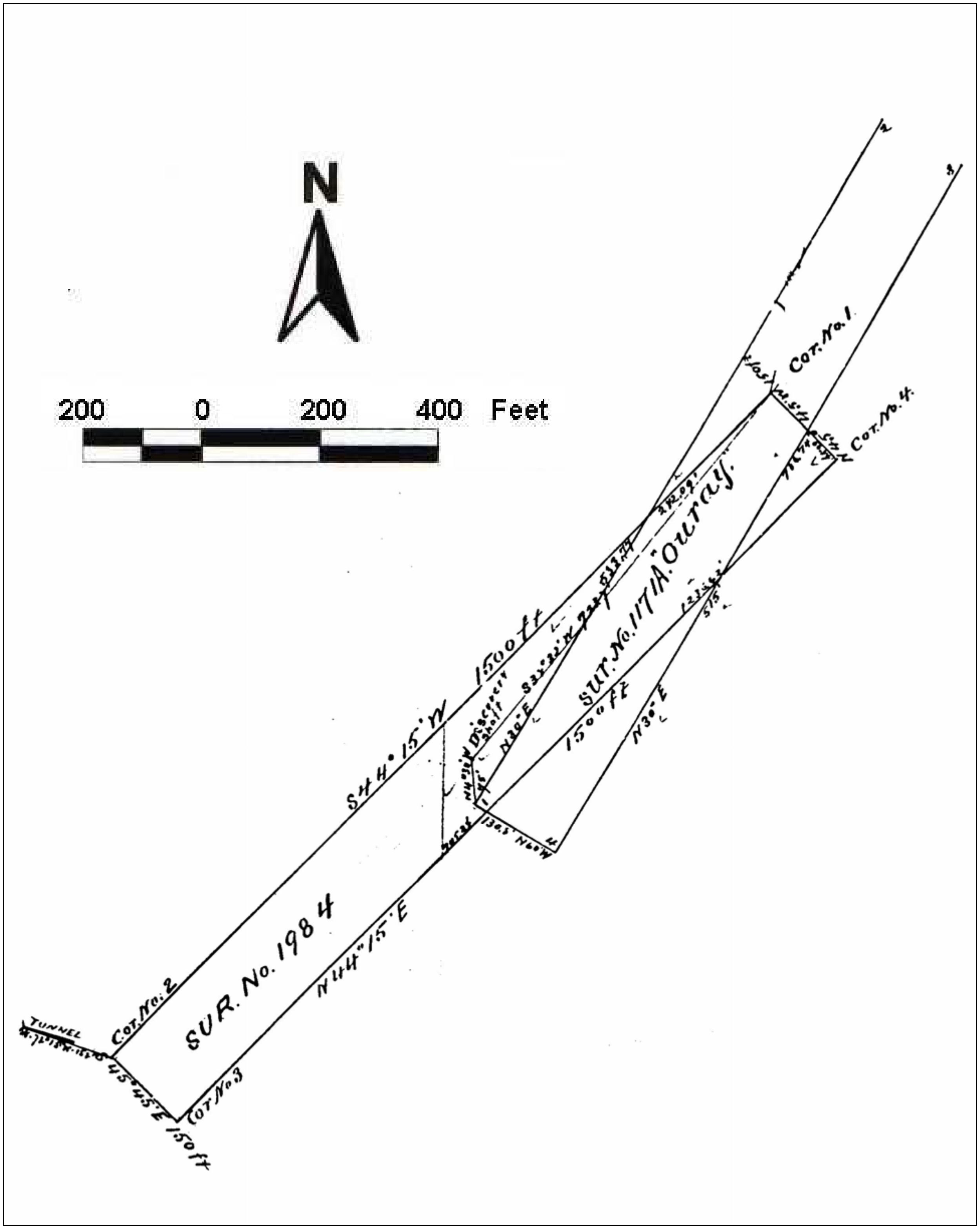


Figure 12. Commodore Lode Mineral Survey (No. 1984) (Modified, scale is approximate).

The Commodore and Delaware Mining and Milling Company (J.G. Newbald-president; William Mendenhall-vice-president; J.B. Coate- secretary; A.S. Hunter-treasurer) owned the Delaware and Commodore Lodes (Corregan and Lingane 1883, p. 767). The fissure vein varied in width between 2 and 12 feet. The ore zone varied in width between 6 inches and 3 feet and contained galena, tetrahedrite, and chalcopyrite in a quartz gangue. Sorted ore milled from 25 to 600 oz of silver per ton (1st class ore yielded 600 oz per ton, 2nd class 250 oz per ton, and 3rd class 100 oz per ton). Workings included a 165-ft-deep shaft with 3 levels (235, 100, and 90 feet in length), a 90-ft-deep shaft, and a 400-ft-long crosscut adit (probably feature #106). Output was 800 tons and about 2,000 tons of ore were stockpiled.

John Gates, William Reynolds, and others owned the Delaware Extension (Corregan and Lingane, 1883, p. 773). The ore zone in the 1- to 2-ft-wide vein varied in width from 6 inches to 2 feet and contained galena, tetrahedrite, and quartz. Assays ranged from 25 to 400 oz of silver per ton. Underground development consisted of a 40-ft-deep shaft.

1884. In April, the Delaware Mine was included in a list of producing mines in the Decatur and Chihuahua mining districts (*Rocky Mountain News*, April 10, 1884, p. 3). In July, about 8 tons (3 wagon lodes) of ore were shipped daily (Lovering, 1935, p. 78).

1887. The Commodore and Delaware Mining Company was issued a patent for the Delaware Lode (BLM files). Gold ore shipped from the Delaware Mine was worth $300 (Munson, 1888, p. 186).

1888. The Commodore and Delaware Mining Company was issued a patent for the Commodore Lode (BLM files). No production was reported for the Delaware Mine (Munson, 1889 p. 126).

1896. The Fred Williams Lode was located (bk. 12, p. 72).

1897. The Annabel Mill Site was located (bk. 12, p. 404).

1899. Pennsylvania Mines Company (Ernest Le Neve-president) located the Annex Lode and amended the location certificate for the Fred Williams Lode and Annabel Mill Site (bk. 14 and 15). A list of producing mines in the Montezuma-Rathbone area included the Delaware Mine (*Denver Times*, December 31, 1899, p. 12).

1900. Mineral Survey No. 13686 A & B was conducted on the Fred Williams, Annex, and Columbine Lodes and Annabel Mill Site owned by the Pennsylvania Mines Company (Figure 13). A 10-ft-long discovery adit and 10-ft-deep shaft were surveyed on the Fred Williams Lode. A 15-ft-long adit was surveyed on the Annex Lode. The last 100 feet of a 170-ft-long tunnel, 728 feet north of the Annex Lode, was driven for the development and to undercut the Fred Williams and Annex Lodes. The 170-ft adit is probably one of the upper levels of the Pennsylvania Mine (Level C, Grant, or Houser Tunnel, described in the Pennsylvania Mine section). Improvements on the Annabel Mill Site included a frame house and a log and plank dam constructed across Cinnamon Creek. Adit #106 must have postdated the mineral survey. The adit surveyed on the Columbine Lode is west of Cinnamon Creek.

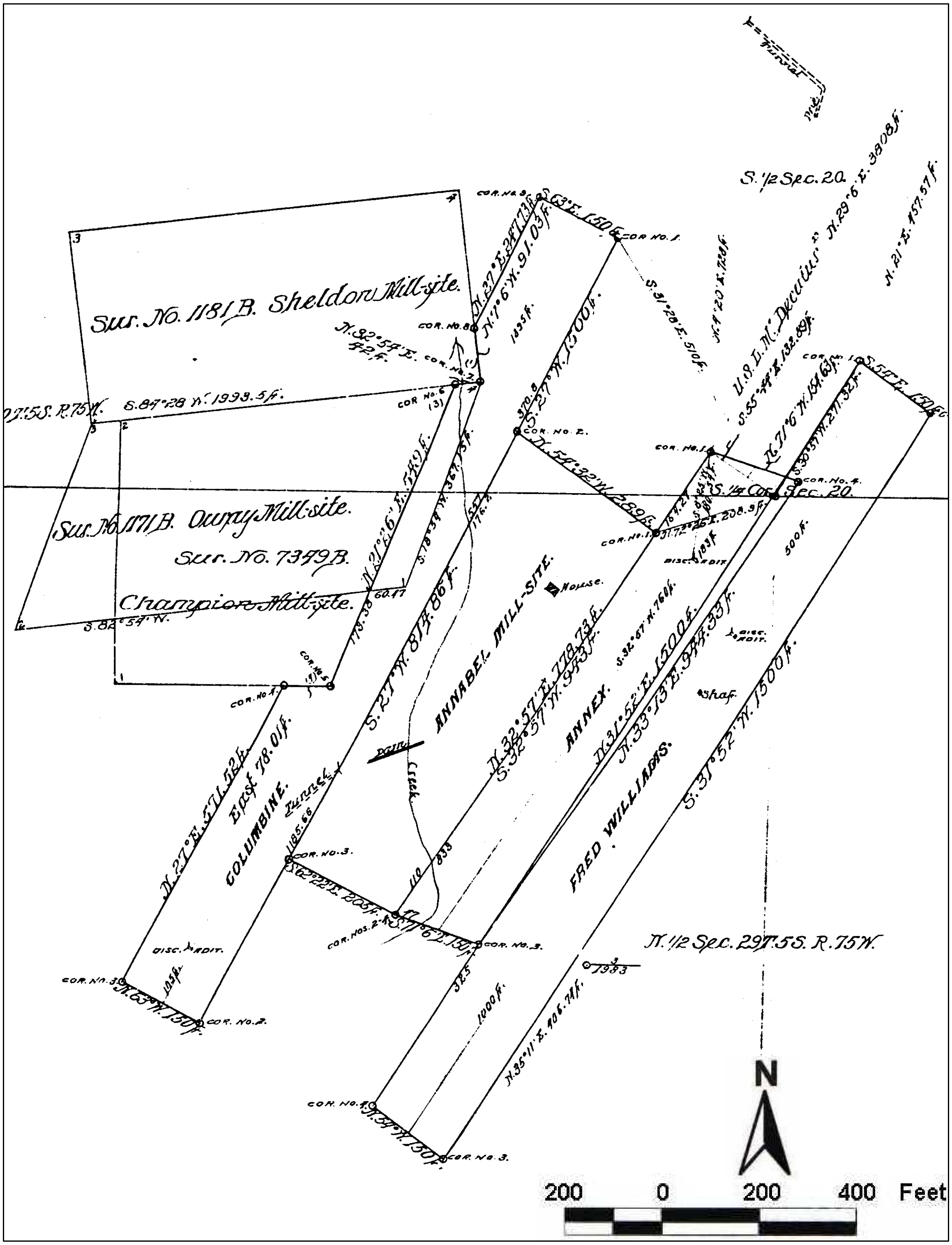


Figure 13. Mineral Survey No. 13686 A & B (Modified, scale is approximate).

1901. Pennsylvania Mines Company was issued a patent for the Fred Williams and Annex Lodes and Annabel Mill Site (BLM files).

1905. The New Pennsylvania Mines Company purchased the property of the Pennsylvania Mines Company (1905 Mine manager report-Pennsylvania Mines Co., p. 274, CBM). The Fred Williams, Annex, and Columbine Lodes and Annabel Mill Site were included with the claims purchased (Schneider and Cox, Inspector report, June 23, 1906-New Pennsylvania Mines Co., p. 66, CBM).

1909. The New Pennsylvania Mines Company (G. Hoffman-president; W.R. Parker-secretary; M.B. LeWald-manager; E.A. LeWald-superintendent) owned and operated the Delaware and Delaware Extension Lodes as well as the Ohio, Pennsylvania, and Sunshine Lodes (1909 Mine manager report-Ohio, p. 128, CBM). Apparently, the mines were idle after 1907. Work resumed on the property in June employing about 60 workers. Underground development for the group (Delaware, Pennsylvania, Ohio, and possibly Sunshine) attained a total depth of 580 feet and included 11,000 feet of tunnels drifts, and raises. Although the Delaware and Pennsylvania mines were on the same vein, it was not determined if they were connected underground.

1910. The New Pennsylvania Mines Company (G. Hoffman-president; W.R. Parker-secretary; M.B. LeWald-manager; E.A. LeWald-superintendent) continued to own and operate the Pennsylvania and Ohio group, including the Delaware and Delaware Extension Lodes (1910 Mine manager report-Pennsylvania, p. 179; 1910 Mine manager report-Ohio, p. 128, CBM).

1913. The New Pennsylvania Mines Company (Louis Aarin-president; A.E. Schunk-secretary/treasurer) owned the Annex, Fred and Williams Lodes (1913 Mine manager report-Pennsylvania Mine, CBM).

1926. Consolidated Pennsylvania Mines Inc. (A.C. Bullock-president; O.M. Troester-vice-president; P. Matuschka-secretary/treasurer) had a royalty and purchase contract with the trustees of the Liberty Mining & Reduction Co. (Victor Schling, A.E. Schimmer, A.J. Scheild and D.W. Strickland) for the Delaware Mine (1926 Mine manager report-Pennsylvania Mine, CBM). Liberty Mining & Reduction Co. owned Delaware, Delaware Extension, Annex, Fred Williams, Annabel mill site, and the Le Neve ditch and pipeline. The Le Neve ditch and pipeline constructed between the dam on the Annabel mill sites and the El Jebel mill site was used to power the Pennsylvania Mill. Five workers were employed to clean up old tunnels in preparation for an examination and sampling (Murray, Inspectors report-Pennsylvania Mine, July 21, 1926, CBM).

1926 and 1929. Lovering (1935, p.1, 93, and plate 33) mapped underground workings in the Montezuma Quad. Lovering published a map of the Delaware Tunnel (Figure 14).

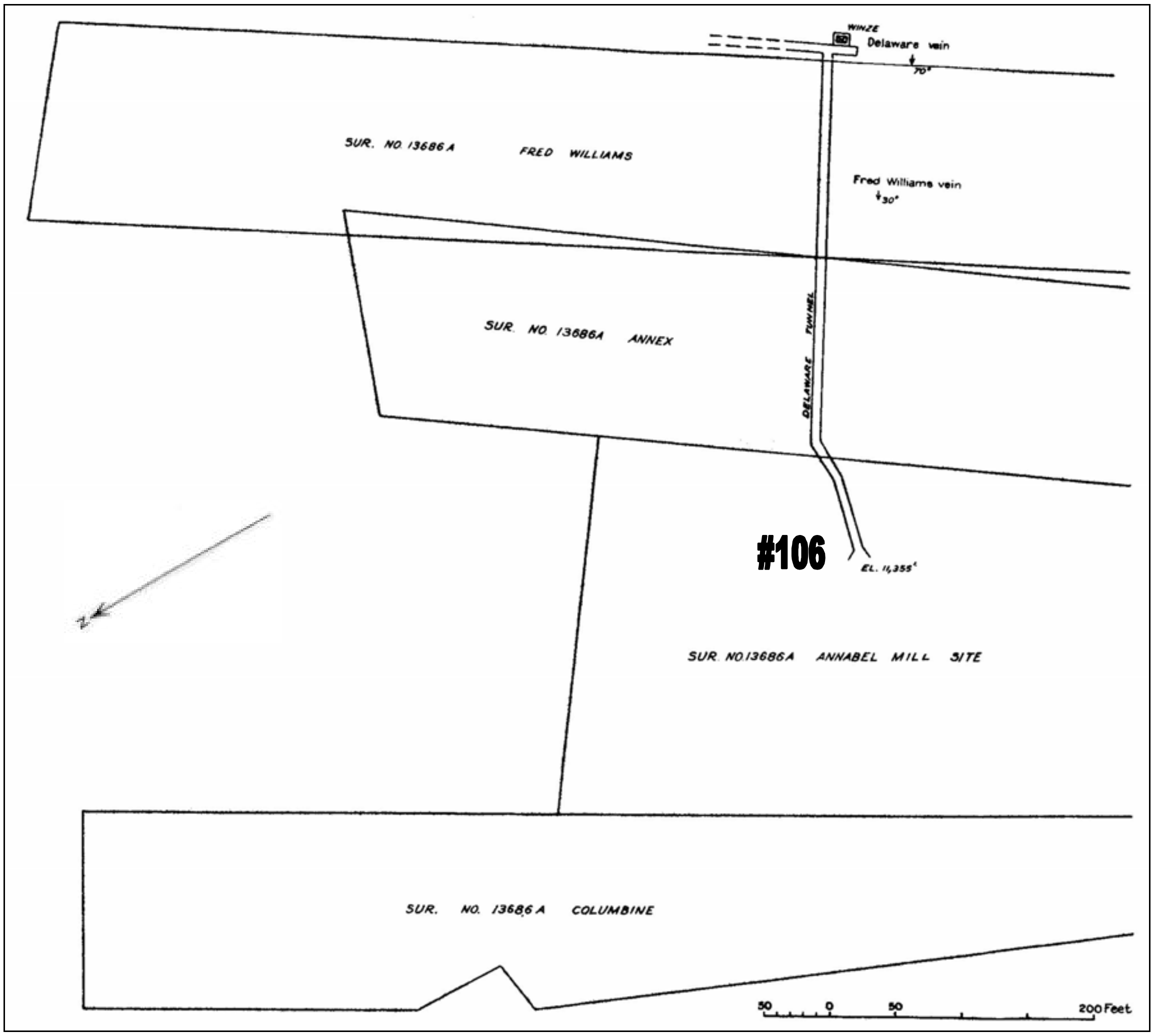


Figure 14. The Delaware Tunnel and overlying claims (Modified from Lovering, 1935, plate 33).

1968. Western Bonanza Inc. (L.G. GeBauer-President; H.L. Chapman-secretary/superintendent) owned and operated the Delaware Mine for 75 days with 9 employees (1968 Mine manager report-Delaware Mine; Doyle, Inspector report, September 20, 1968, CBM). In September, work was concentrated on retimbering and opening the tunnel portal (adit #106). Supposedly, past mining activities drove the 300-ft-long crosscut tunnel and followed the vein, at right angles to the tunnel, for 1,000 feet. Supplies were stored in an oil field steel doghouse, apparently still on the property. The steel doghouse is probably the blue box south of the dump.

GEOLOGY

The Delaware Mine is developed along the Delaware vein, which is a southwestern extension of the Pennsylvania vein (Lovering, 1935, p. 78). The vein was reported to be "several feet wide and contained from 6 to 36 inches of galena, gray copper, and chalcopyrite in a quartz gangue, assaying in shipments from 25 to 600 ounces of silver to the ton" (Lovering, 1935, p. 78). The wallrock of the vein is silicified and pyritized up to 30 feet away from the vein. The host rock is a mixture of quartz schist, quartz-biotite schist, injection gneiss, and granite gneiss (Lovering, 1935, p. 93). Local dikes of granite and quartz monzonite are present.

SITE DESCRIPTION

Adit #106 (Delaware Tunnel) is on the east side of FR #262 about ¾ of a mile south of the Peru Creek crossing (Figure 2). The dump (#206) is on private property. Effluent emerges from the portal area of the completely caved adit, about 10 feet above the floor of the adit trench (Figure 15). The effluent is relatively clear, but has deposited an orange precipitate, and supports the growth of some moss. Low dissolved oxygen at the portal (1 ppm) indicates that minimal oxygen is able to migrate from the surface into the caved adit. From the portal area, the effluent flows down the adit trench and ditch (Figure 16) into a settling pond (Figure 17) constructed on the western side of FR #262. Water from the settling pond appears clear and flows over a steep, 15-ft-high embankment and enters Cinnamon Creek (Figure 18). The combined length of the adit trench and ditch is about 280 feet. Some of the effluent overflows the ditch and infiltrates into the bulldozed portion of the dump and road (Figure 19). The dump (#206), containing about 250 cubic yards (inventoried at 450 cubic yards) of mostly gravel size material, was not sampled. Most of the dump had been extensively bulldozed, and evidently mixed with other material. Quartz vein fragments on the dump contain moderate amounts of pyrite, sparse sphalerite, and rare galena.

WASTE AND HAZARD CHARACTERISTICS

Adit #105, which appears to be on private land, and #106, on NFS land, both discharge water. In July of 2001, the flows from the two adits were measured at 4.6 and 7.6 gpm, respectively. In October of 2001, the flows were 1.5 and 3.4 gpm. Water samples were collected from both adits during both sampling events (CG-7 and -9, and their low-flow counterparts CG-30 and -33). The pH of the samples ranged from 3.62 to 4.92, with conductivity ranging from 177 to 629 µS/cm. Sample locations are shown on Figure 3, and water chemistry data are shown on Table 2.

Constituents exceeding State water quality standards included total recoverable iron, dissolved aluminum, cadmium, copper, iron, manganese, and zinc in all four samples, dissolved lead in three samples, and dissolved sulfate and total recoverable zinc in two. Adit #106 effluent contained, in general, much higher metal concentrations than adit #105, with the notable exceptions of aluminum and lead. In fact, adit#105 low-flow sample CG-9 had the highest lead concentration of all Cinnamon Gulch samples at 560 µg/L. Also, high-flow samples (CG-7 and CG-9) generally have higher metal concentrations than low-flow samples (CG-3- and CG-33).

Adit #106 was assigned an EDR of 2, indicating “significant environmental degradation,” apparently due to the drainage effluent. Adit #105 was assigned an EDR of 4, indicating only “slight” environmental degradation. However, the notes on the inventory field data form report “significant” environmental degradation associated with adit #105. At the time of the inventory, adit #105 had a more neutral pH (6.0) and lower conductivity (200 µS/cm) than adit #106 (pH of 4.0; conductivity of 200 µS/cm). The inventory reports no physical hazards associated with either of the two adits.

Figure 15. Effluent emerging from caved Delaware Tunnel (adit #106).

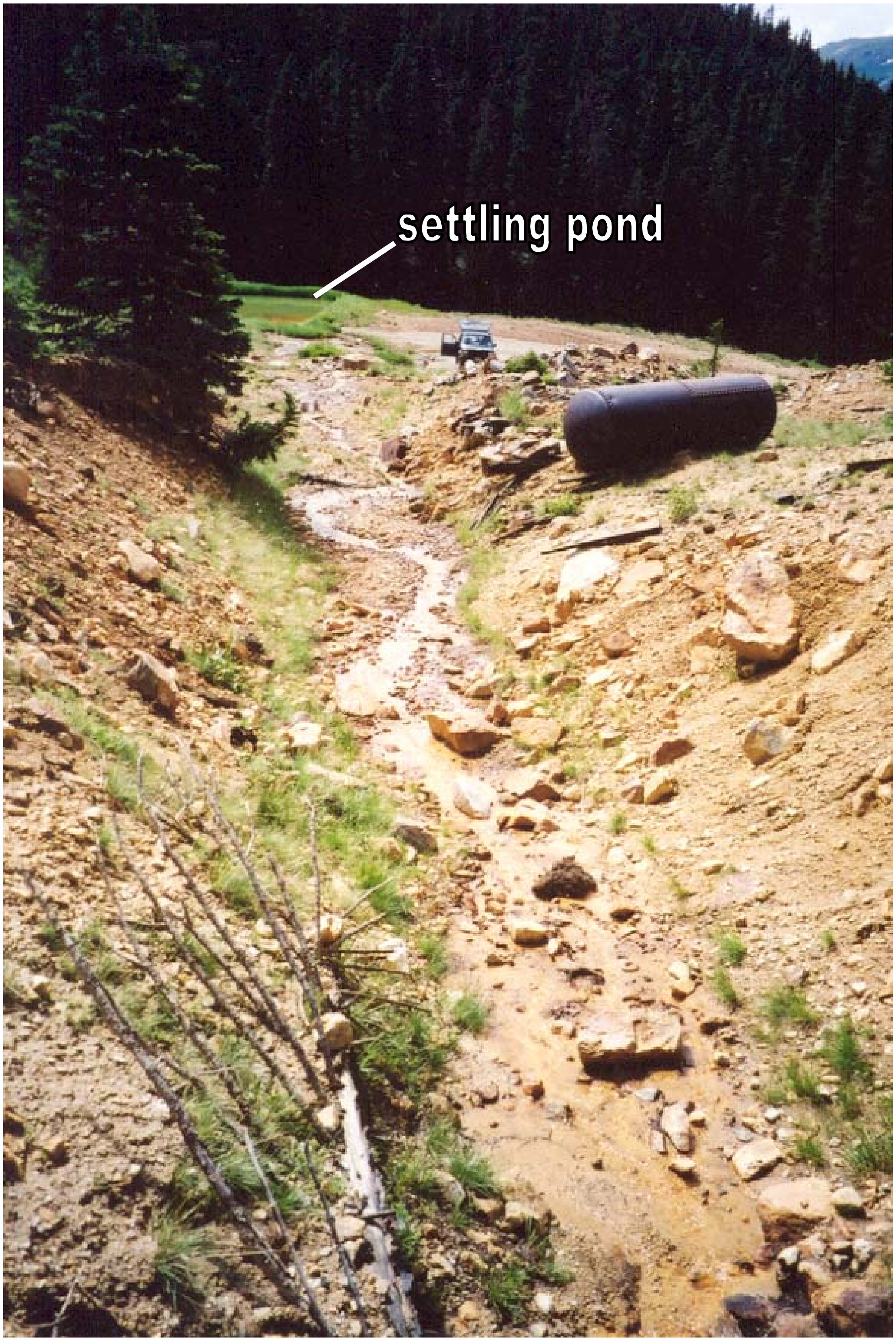


Figure 16. Effluent path from Delaware Tunnel to settling pond.

Figure 17. Effluent path from Delaware Tunnel crossing FR #262 to settling pond.
Photo from September 1993 inventory.

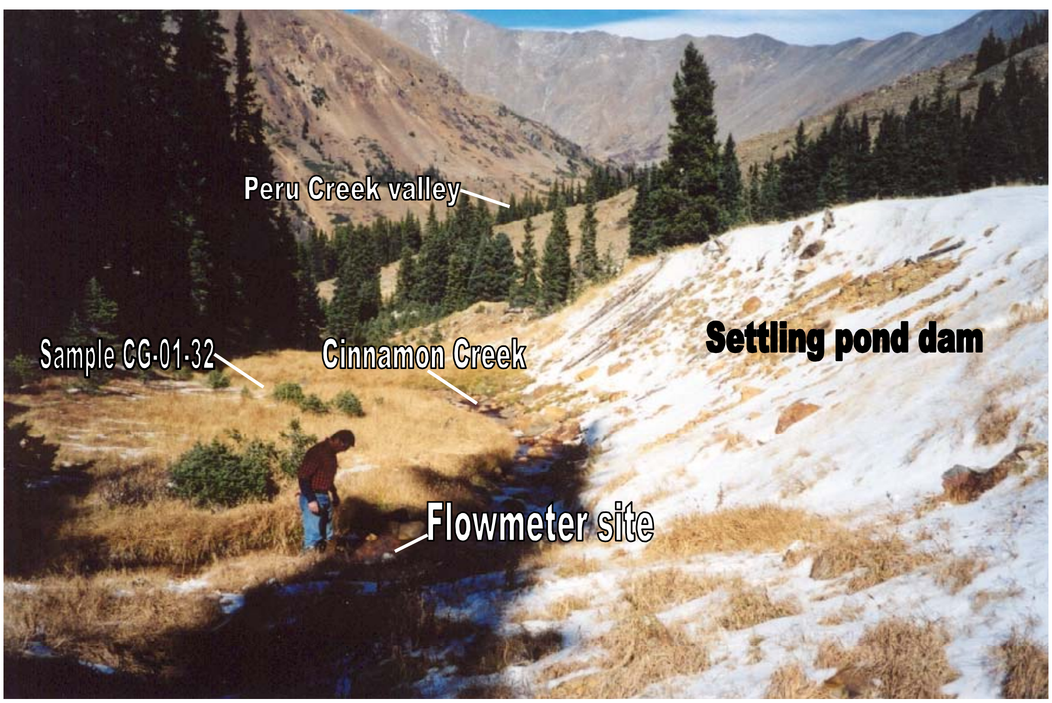


Figure 18. Cinnamon Creek below settling pond dam, Delaware Tunnel area.

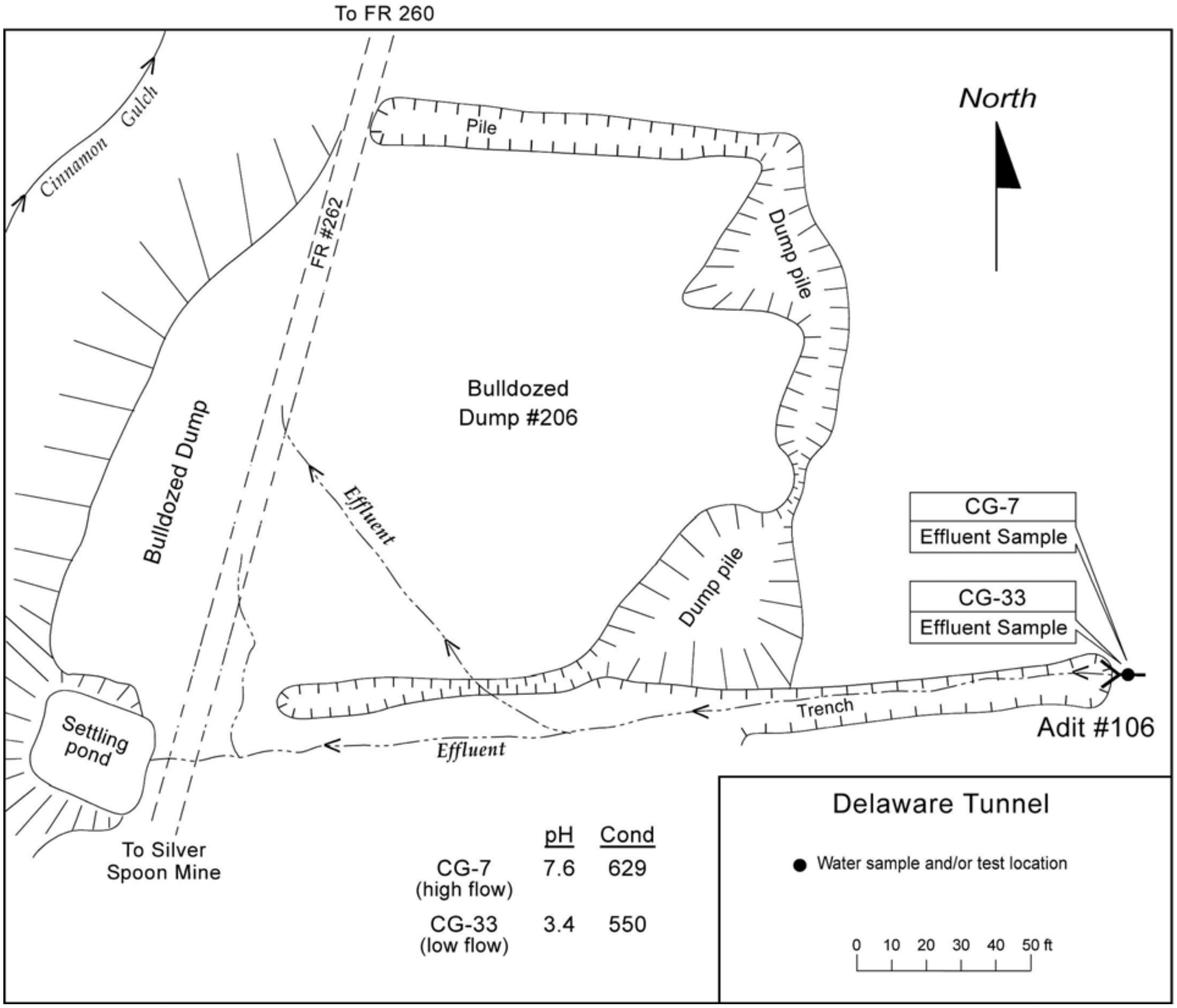


Figure 19. Sketch map of Delaware Tunnel (adit #106) area.

Waste rock dumps #205 and #206, associated with adits #105 and #106, were the only dumps inventoried in the Rich Ore Lode and Silver Spoon Mine areas. The volume of material on the dumps was estimated in the 1993 inventory at 770 and 450 yards respectively. The inventory reports that water was draining across the surface of both dumps. The toe of dump #205 is in contact with Cinnamon Gulch Creek, so it is reasonable to assume that weathering of the dump could be releasing contaminants to the creek. Dump #205 was assigned an EDR of 4, which indicates slight environmental degradation. However, the USFS-AMLI Field Data Form states that the dump has “potentially significant” environmental degradation, which equates to an EDR of 3.

Another discrepancy exists for dump #206, assigned an EDR of 5, which indicates no environmental degradation. However, the Field Data Form states that the dump exhibits “slight” environmental degradation, which equates to an EDR of 4. Erring on the side of the more environmentally conservative rating of 4 seems appropriate, considering that the mine effluent discharges along the south side of the dump and may be picking up contaminants from the dump. Both dumps were assigned physical hazard ratings of 5, indicating no danger.

BRITTLE SILVER GROUP

The Brittle Silver group includes 4 patented lode claims (Brittle Silver, Little Nell, Boston, and White Sparrow) on the eastern side and near the top of Brittle Silver Mountain, and the patented Brittle Silver Mill Site between the Brittle Silver lode claims and Peru Creek. Inventory features #105/205 (top of Brittle Silver Mountain inventory area #429/4382-1), and #101/201 and tailings #205 (Lower Cinnamon Gulch/west side inventory area #429/4383-1) are included in the Brittle Silver group (Figure 2). Feature #105/205 is accessible by hiking about 1,000 feet west of FR 262 from the Cinnamon Creek crossing. Adit #105 was driven on NFS land just below and presumably undercuts the Little Nell Lode. Adit #105 was probably driven after 1882, the date that the Little Nell was surveyed.

Adit #101 and the associated waste-rock pile #201 are above Brittle Silver Mill ruins, south of an undesignated road (possibly an abandoned section of FR 260). Brittle Silver Mill tailings (#205) were deposited at the base of the mill and extend nearly to Peru Creek. Initially, the portal of Psiupsilon Tunnel (adit #101) and associated waste-rock pile (#201) were on the Brittle Silver Mill Site. Eventually, the timbered portal collapsed, possibly even far enough back so that the effluent could be draining from NFS lands above the patented mill site claim. Adit #101 was started in 1882 and undercuts abandoned unpatented claims on NFS lands. The adit was intended to intersect veins associated with the Brittle Silver claim group located near the top of Brittle Silver Mountain. It was not determined if the Psiupsilon Tunnel ever reached its intended destination. Erected in 1882, the Brittle Silver Mill apparently generated the tailing piles (feature #205) that extend from the mill onto NFS lands.

Adit #101, dump #201, the mill, and tailings (#205) plot on NFS land on the Montezuma PBS map. According to Mineral Survey 1810B, the portal of the Psiupsilon Tunnel (adit #101), Brittle Silver Mill, and some of the tailings (#205) are on the Brittle Silver Mill Site. A new survey could verify the position of the adit, mill, and tailings. Adit #105 is close to, and possibly on, the Little Nell Lode, and should be surveyed to determine land ownership.

MINING HISTORY

1880. The Brittle Silver Group (Brittle Silver, Boston, Little Nell, and White Sparrow Lodes) was located (Corregan and Lingane, 1883, p. 756).

1882. In March, assay results ran as high as 10,000 oz of silver per ton on the Brittle Silver Lode (*Denver Republican*, March 15, 1882, p. 6). In June, a Denver based company was driving an adit to undercut the Brittle Silver Lode (*Rocky Mountain News*, June 27, 1882, p. 6). Assays ranged up to 2,700 oz of silver per ton. A wagon road was constructed to access the adit. In October, George Rust & Company was erecting a stamp mill and continued driving the crosscut adit to undercut the Brittle Silver Lode, a projected distance of about 3,000 feet (*Rocky Mountain News*, October 20, 1882, p. 6). The property had been purchased the previous season. The 130 by 36-ft mill and attached 26 by 35-ft engine house were designed to utilize the “Murdock” process to extract the metals from the ore. The Murdock process was a secret chemical process that would allegedly extract all of the metals and leave the tailings barren. The boarding house, constructed next to the mill, was nearly finished. Near the end of October, the crosscut adit had been driven about 100 feet (*Rocky Mountain News*, October 26, 1882, p. 6).

Mineral Surveys No. 1810 A and B, 1811, 1812, and 1813, were conducted on the Brittle Silver Lode and Mill Site and Boston, Little Nell, and White Sparrow Lodes owned by C.H. Dunbrack and others. The Brittle Silver, Boston, Little Nell, and White Sparrow Lodes are near the top of Brittle Silver Mountain. The Brittle Silver Mill Site is near the base of Brittle Silver Mountain. A large reduction mill, office building, boarding house, and the portal of the Psiupsilon Tunnel (adit #101) were surveyed on the Brittle Silver Mill Site (Figure 20). An open cut and discovery adit and drift were surveyed on the Little Nell Lode (Figure 21). Partial interest in the 92-ft-long Psiupsilon Tunnel was included toward the $500 worth of improvements required for patent for the Brittle Silver, Boston, Little Nell, and White Sparrow Lodes. At the time of the survey, the claimants were working in the Psiupsilon Tunnel. Mill tailings (feature #205) were probably generated at the Brittle Silver Mill. Presumably, at least some ore processed at the Brittle Silver Mill was mined from Dunbrack's claims.

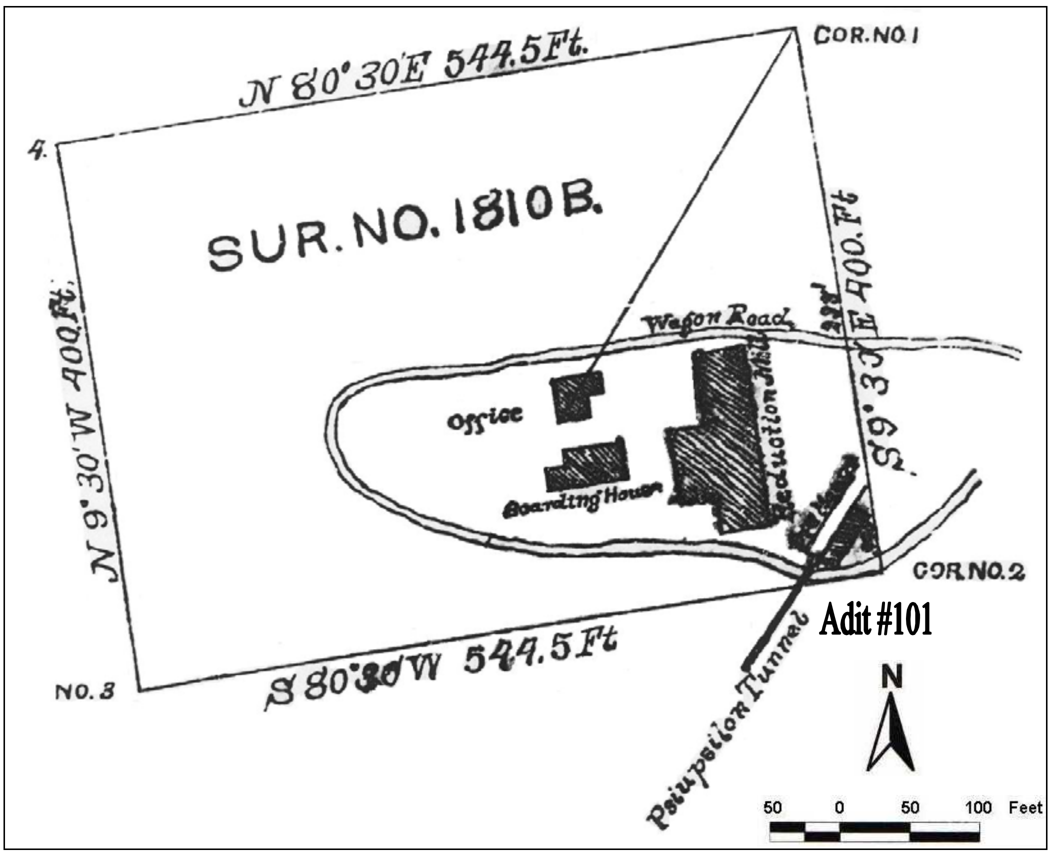


Figure 20. Brittle Silver Mill Site Mineral Survey (No. 1810B). Survey shows the Psiupsilon Tunnel (adit #101) and Brittle Silver Mill. (Modified from Mineral Survey No. 1810B; scale is approximate.)

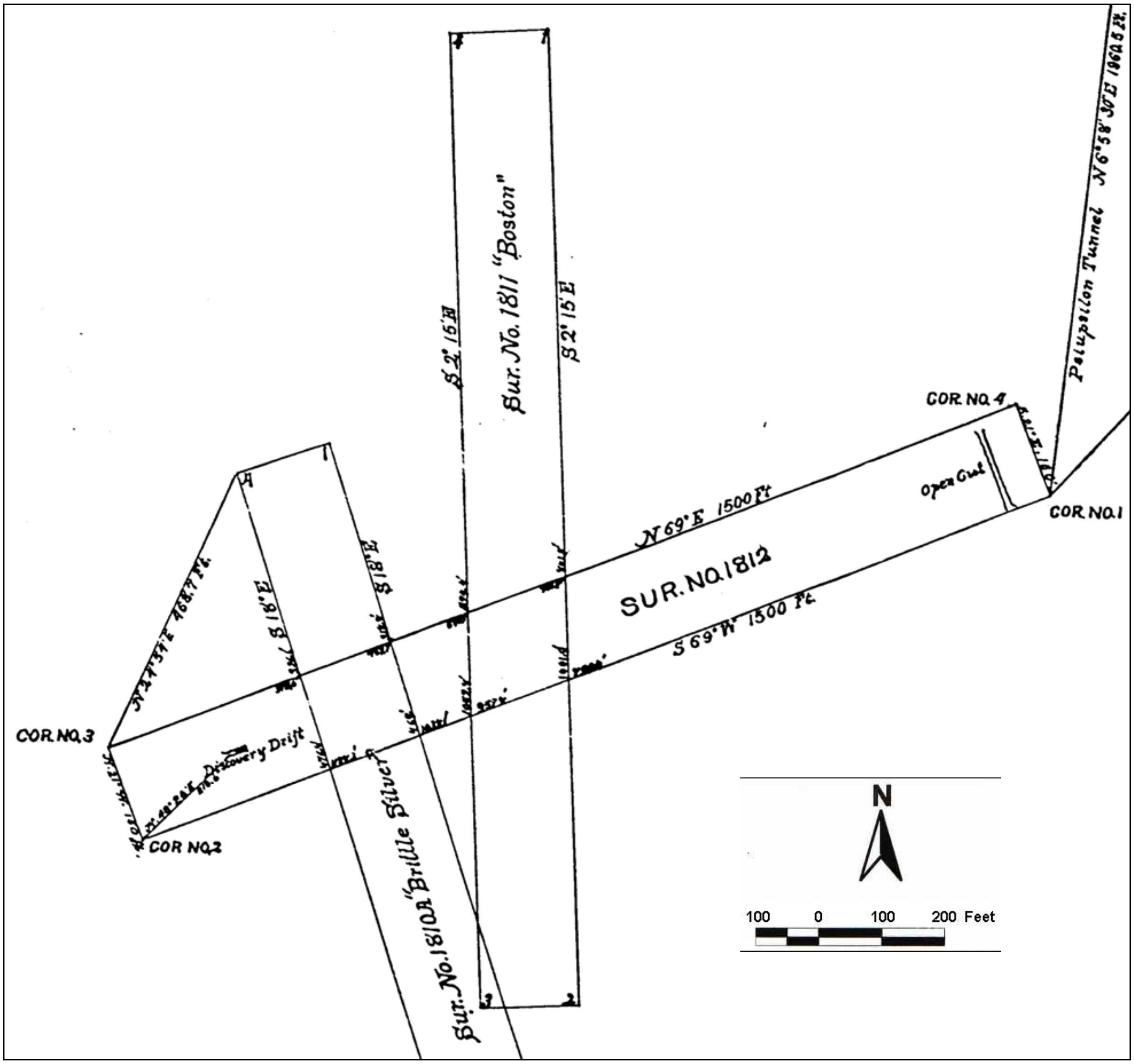


Figure 21. Little Nell Lode Mineral Survey (No. 1812). Note bearing to the Psiupsilon Tunnel and position of other claims on Brittle Silver Mountain (Modified; scale is approximate).

1883. In January, State rejected the Brittle Silver Mining Company's application for incorporation (*Rocky Mountain News*, January 17, 1883, p. 8) because another company was already using the name. In February, the company's 15-ton per day mill was ready for use (*Rocky Mountain News*, February 15 1883, p. 8). The Brittle Silver Mine was considered one of the "principal producing properties" in the Peru mining district. George Rust was recognized as the principal owner of the Brittle Silver Mining and Milling Company of Decatur and a member of Rust Farnsworth & Company (*Rocky Mountain News*, July 11 1883, p. 4). In August, Rust & Company formulated plans to build a smelter in connection with the Brittle Silver Mill below Psiupsilon tunnel (adit #101) (*Colorado Miner*, August 4, 1883, p. 1). Ore from the Delaware Mine was processed at the mill and a contract acquired to process 470 tons of ore from Hall and Kremmling (probably one of the Pennsylvania group mines). Rust & Company continued operating the Brittle Silver Mill and advancing the crosscut adit with two 12-hour shifts (*Rocky*

Mountain News, Aug. 16, 1883). Ore from the St. Elmo Mine was also processed at the Brittle Silver Mill. In November, the Brittle Silver Mill was closed for the season and work on the tunnel stopped (*Rocky Mountain News*, Nov. 20, 1883, p.2).

George Rust and company owned the Brittle Silver Group (Brittle Silver, Boston, Little Nell, and White Sparrow Lodes) managed by C.H. Dunbrack (Corregan and Lingane, 1883, p. 756 & p. 790). The fissure veins ranged from 2 to 4 feet in width. The pay zone varied in width between 3 and 15 inches and contained galena, "gray copper" (tetrahedrite), and "brittle silver" (stephanite) in a quartz gangue. After sorting, the milled ore averaged 100 oz of silver and "some" gold per ton. Development on the claim group included shafts (20- to 60-ft deep), open-cuts, a crosscut adit, and a reduction works. The crosscut adit (adit #101) was intended to intersect the veins at a great depth. George Rust and Company reduction works, housed in a 78 by 36-ft, two-story building, was equipped with 10 stamps, Bracker cylinders and revolving barrels, and a 45-horsepower engine and boiler.

1884. Charles H. Dunbrack and George Rust were issued patents for the Brittle Silver millsite and Brittle Silver, Little Nell, Boston, and White Sparrow Lodes (BLM files).

1885. In October, one carload (about 14 tons) of ore was shipped from the Brittle Silver Mine (*Rocky Mountain News,* Oct. 22, 1885, p. 6; Lovering, 1935, p. 74).

1889. A confidential, probably small, quantity of ore was shipped (Lovering, 1935, p. 74).

1899. The Carrie and Carrie No. 1-4 Lodes were located (bk. 14, p. 145-149).

1908. Frank Heim amended the location of the Carrie claims (bk. 17). Mineral Survey No. 18774 (Figure 22) was conducted on the Carrie claim block owned by Frank Heim. The portal of a 250-ft-long adit (Psiupsilon Tunnel, adit #101) was surveyed on the Brittle Silver Mill Site and underlies part of the Carrie Lode. According to the survey notes, the first 92 feet of adit was constructed for the development of the Brittle Silver, Boston, Little Nell, and White Sparrow Lodes on Brittle Silver Mountain. The remaining 178 feet was for the Carrie claims. Heim "held" and operated the adit and all of the claims mentioned above.

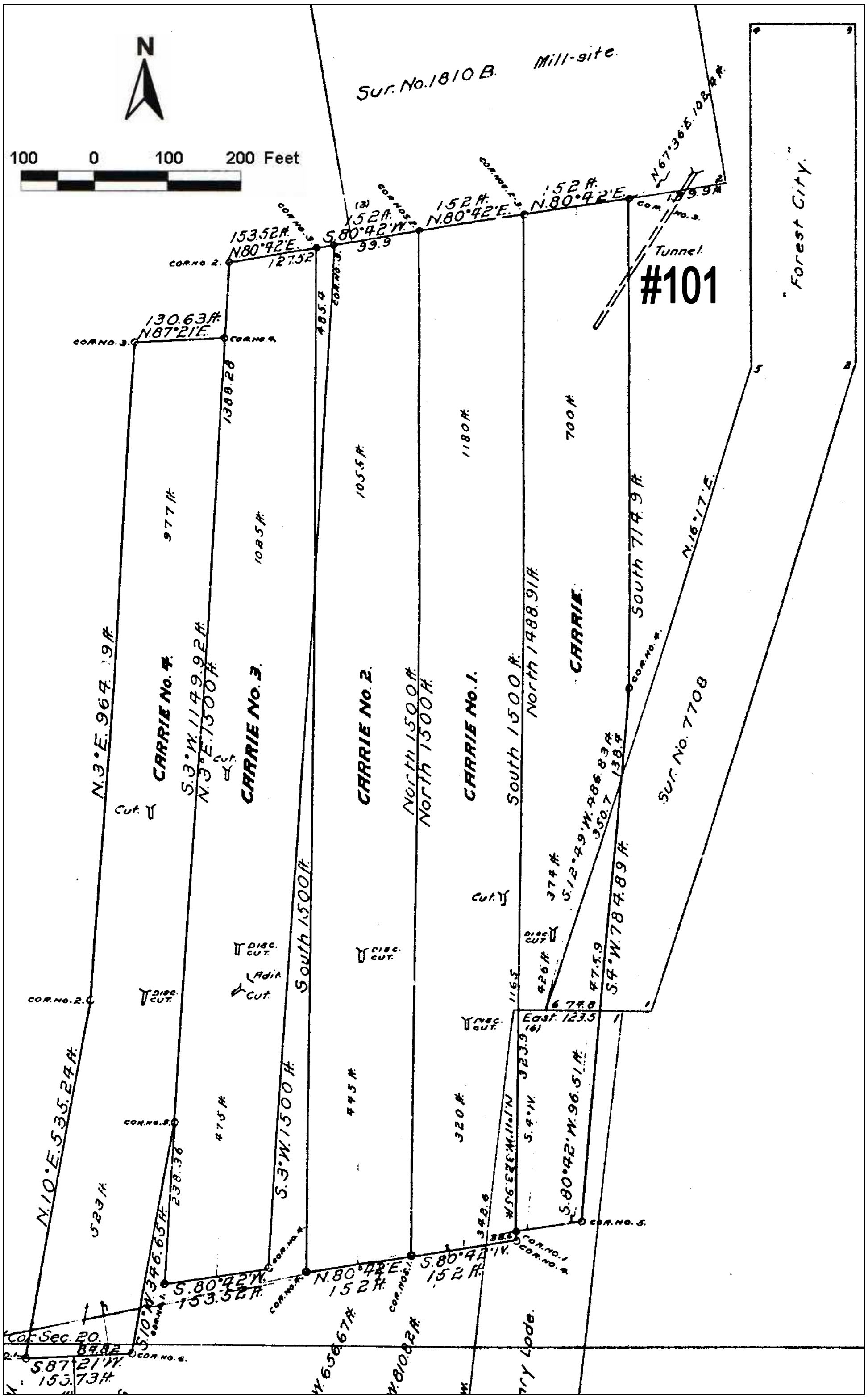


Figure 22. Carrie claim group Mineral Survey (No. 18774) (Modified; scale is approximate).

1907-1910. The Brittle Silver Mining Company (Fred Manlitsch?-president; E.J.K. Mencle?-secretary) owned and operated the Brittle Silver group (Brittle Silver #1-#4, Ice #1-#34, Boston, Little Nell, and White Sparrow Lodes and Brittle Silver millsite and Lode) (1910 Mine manager report-Brittle Silver, CBM). Work commenced in 1907 and stopped on October 30, 1910. Two to ten miners were employed. The value of the gold-silver-lead-copper ore varied from $6 to $300 per ton. Total underground development (tunnels, shafts, and drifts) was about 2,000 feet. Surface improvements included a boarding house, blacksmith shop, and office. The mill was not in use nor listed as one of the improvements.

1926. Consolidated Pennsylvania Mines Inc. (A.C. Bullock-president; O.M. Troester-vice-president; P. Matuschka-secretary/treasurer) had a royalty and purchase contract with the trustees of the Liberty Mining & Reduction Co. (Victor Schling, A.E. Schimmer, A.J. Scheild and D.W. Strickland) for the Brittle Silver group (1926 Mine manager report-Pennsylvania Mine, CBM). Liberty Mining & Reduction Co. owned Brittle Silver (including the Little Nell Lode and Brittle Silver mill site), Carrie, and the Ice claim groups. Five workers were employed to clean-up old tunnels in preparation for an examination and sampling (Murray, Inspectors report-Pennsylvania Mine, July 21, 1926, CBM). It was not determined if any of the Brittle Silver group claims were involved in the work.

GEOLOGY

The Brittle Silver Group consists of veins 3 to 15 inches wide, containing galena, gray copper, “brittle silver” (stephanite), and some gold. The ore averaged about 100 ounces of silver to the ton (Lovering, 1935, p.74). The country rock in the area is quartz monzonite of the Montezuma Stock. These mines lie on the easternmost margin of the Montezuma Stock, near the contact with Precambrian X rocks. Appreciable alteration accompanied the intrusion of the Montezuma Stock. Most of the pyrite precipitated in the veins during the late stages of sericitization alteration. Silicification was the dominant alteration during the vein forming period.

SITE DESCRIPTION

Adit #105 (Brittle Silver Mountain inventory area #429/4382-1) is about 1,000 feet west of FR 262 and ¾ mile south of the FR 262 Peru Creek crossing (Figure 2). Adit #101 (Lower Cinnamon Gulch/West Side inventory area #430/4382-1) is above the Brittle Silver Mill ruins on the south side of the mine road that originally looped back above the mill to adit # 101 and #100 to the east. Apparently, the mine road also continued west and connected to FR 260 across Peru Creek. Tailings #205, from the Brittle Silver Mill were deposited from the base of the mill nearly to Peru Creek. Mineral Survey No. 1810B (Brittle Silver Mill Site) includes the portal of adit #101, the Brittle Silver Mill, and some of the Brittle Silver Mill tailings (#205). Adit #101 undercuts NFS lands south of the Brittle Silver mill site. Adit #105 is on NFS lands and probably undercuts the patented Little Nell Lode (Mineral Survey No. 1812).

Effluent from Adit #105 (Figure 23) flows from a pool just inside the open adit forming a saturated area on the dump bench about 20 feet from the portal (Figure 24). From the saturated area the effluent flows down the south side of the dump and infiltrates into the coarse dump material. The effluent is clear, and supports the growth of grass and moss. Minor red precipitate was visible in the channel and was deposited on the filter during sampling. During episodes of higher flow, the effluent probably discharges to an intermittent creek on the south side of the dump. Most of the water near the base of the dump probably is derived from the intermittent creek. However, some seepage could originate from the base of the dump. The intermittent creek does not appear to flow directly into Cinnamon Gulch Creek. The associated waste-rock dump (dump #205) contains nearly 1,000 cubic yards (inventoried at 2,500 cubic yards) of mostly coarse material (Figures 25 and 26). Quartz vein material on the dump contains abundant pyrite and moderate amounts of sphalerite.

Figure 23. Effluent emerging from adit #105.

Figure 24. Adit #105 dump bench showing vegetation growth along effluent path.

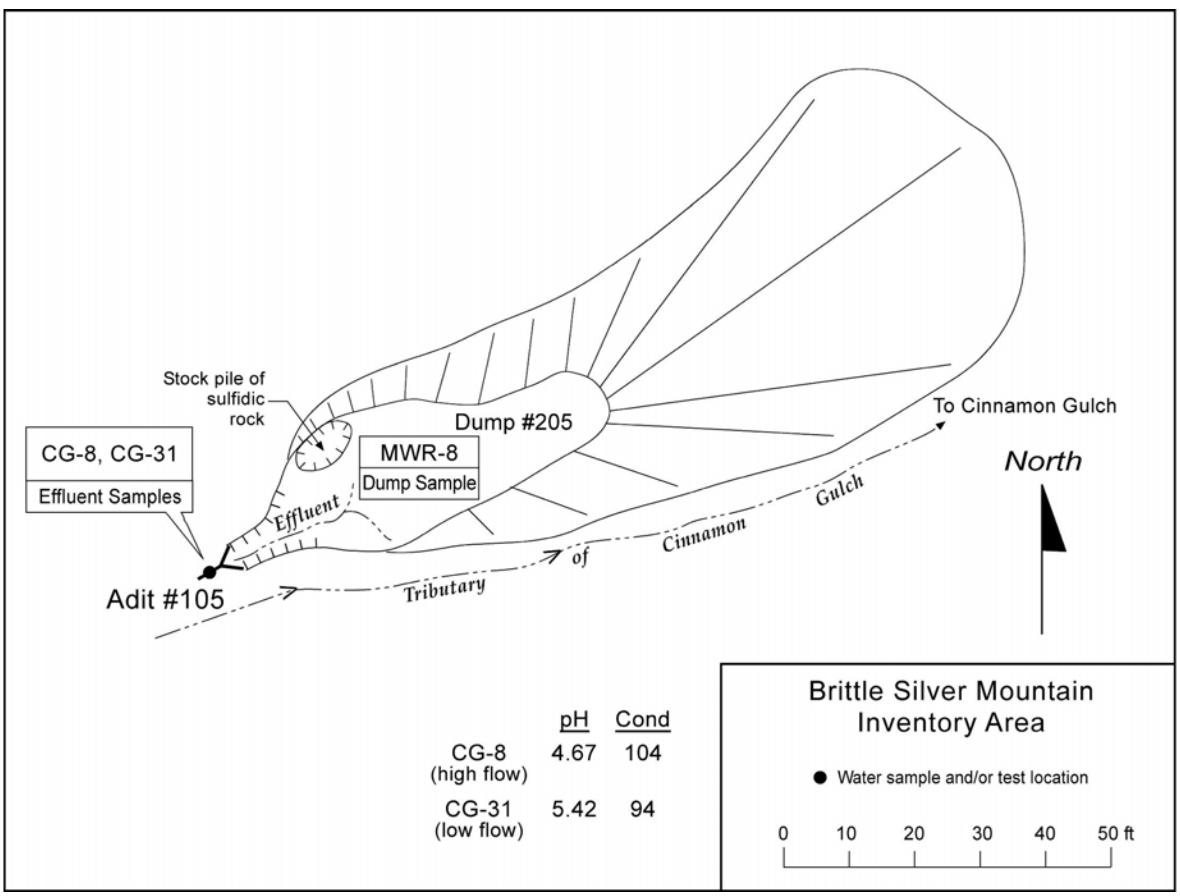


Figure 25. Schematic diagram of adit #105 and waste rock dump.

Figure 26. Waste rock dump associated with adit #105.

Effluent from the caved adit #101 emerges from a rocky area, possibly on NFS land above the Brittle Silver mill site. The effluent flows through the old timbered ruins of the collapsed portal covering and infiltrates between dumps #201 and #200 (Figure 27). The effluent is clear and supports grass and moss below the portal ruins. Minor amounts of reddish precipitate were observed on rocks in the channel, and were deposited on the filter during sampling. Mostly gravel to finer size material covered the surface of the 500-cubic-yard (inventoried at 2,500 cubic yards) dump #201 (Figure 27). Abundant pyrite, minor to moderate sphalerite, and rare galena are associated with the quartz vein material. Cobble size quartz vein material, stockpiled above the western side of the dump, could represent material hauled in from other mines for processing in the Brittle Silver Mill. A retaining wall keeps most of the dump material from the mill area below (Figure 28).

Figure 27. Adit #101 (collapsed portal timbers), dump #201, and dump #200.

A series of retaining walls concentrate the sand and finer size tailings below the mill (Figures 28 and 29). No samples were collected from the 50-cubic-yard pile of tailings retained behind a rock wall near the base of the mill. A seep below the tailings at the base of the mill was too small to test or sample. No samples were collected from a small quantity of tailings mixed with a line of boulders, probably an old retaining wall, about 100 feet below the road. Numerous springs emerge between the road and the line of boulders. Grass, moss, and, filamentous algae flourish in this area. Samples were collected from the tailings partly retained by a wooden wall about 200 feet below the road and from the lowest pile, about 75 feet above Peru Creek (Figures 30-32). The dense growth of grass between the lowest tailings pile and Peru Creek could be covering an earth dam. The main channel of Cinnamon Creek cuts back toward the east between the two lower tailing piles. At one time the creek probably flowed into a settling pond constructed west of the lower tailing pile. During the present investigation, no water was flowing directly into the settling pond from Cinnamon Creek and no water was flowing from the settling pond. During episodes of higher flow, some water could enter the pond and flow into Peru Creek from two low areas along the dam. Most of the area between the road and lowest tailings pile is wet and supports a dense growth of grass. Thicker accumulations of tailings are barren of vegetation. Water from Cinnamon Creek mixing with Peru Creek below the lowest tailings pile produces a reddish-orange precipitate coating on the streambed of Peru Creek (Figures 33 and 34). Upstream from this mixing zone the Peru Creek streambed has a white precipitate coating.

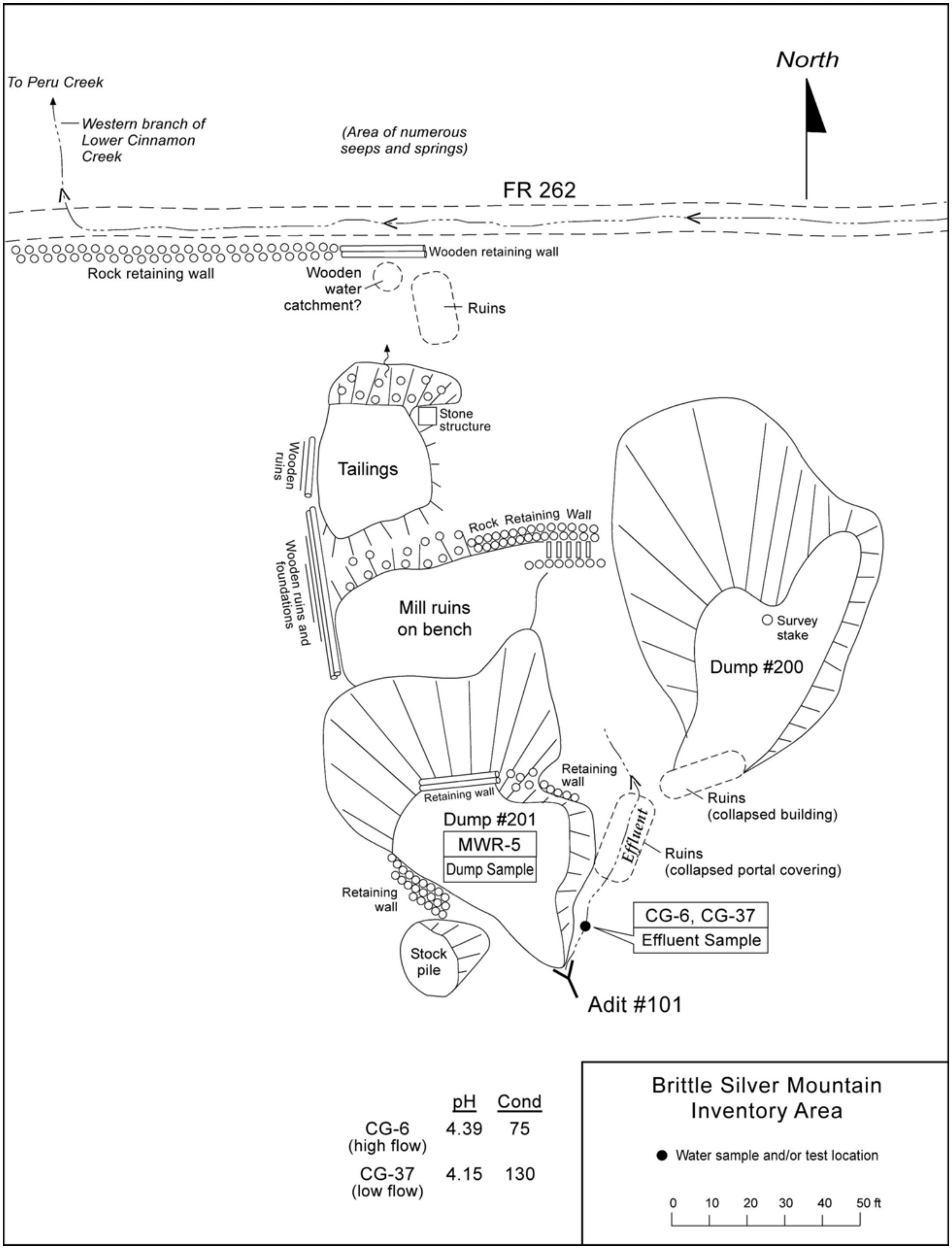


Figure 28. Sketch map of adit #101, dumps #200 and #201, and Brittle Silver Mill ruins.

Figure 29. Brittle Silver Mill ruins. Dump #201 in foreground.

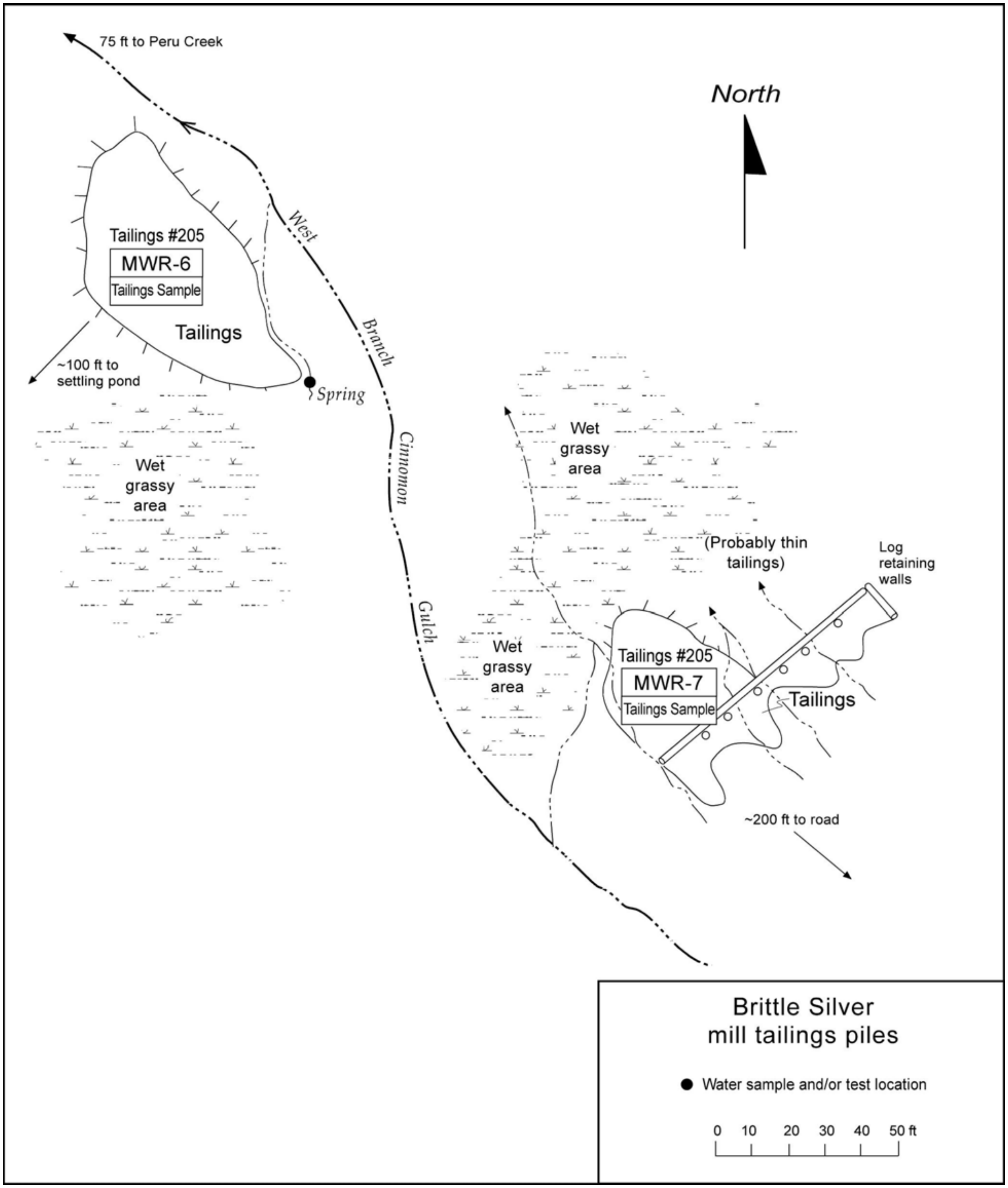


Figure 30. Sketch map of lower two Brittle Silver Mill tailings piles (#205).

Figure 31. Two lower Brittle Silver Mill tailings piles (#205).

Figure 32. Lowest Brittle Silver Mill tailings pile (#205).

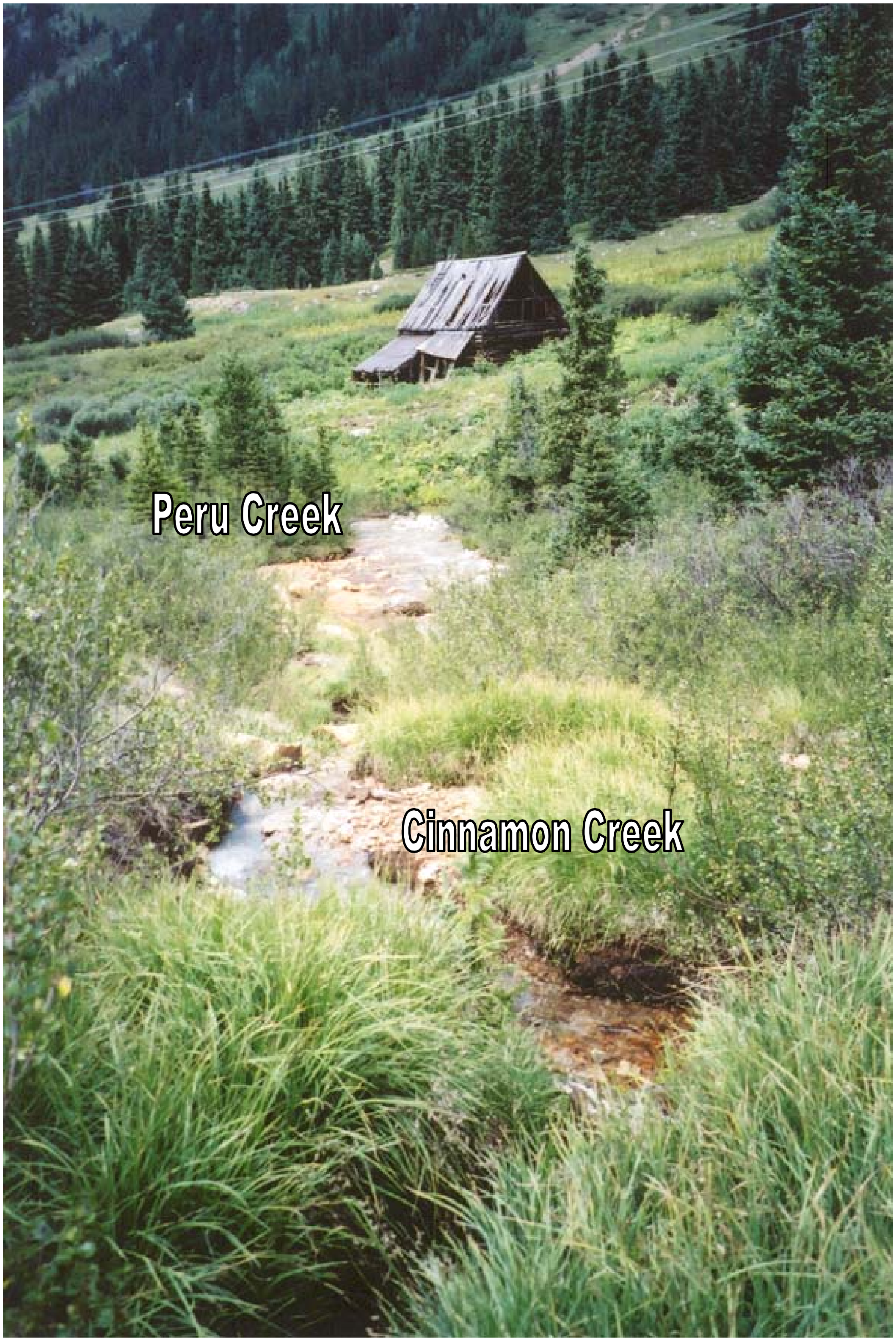


Figure 33. Lower Cinnamon Creek branch above confluence with Peru Creek.

Figure 34. Lower Cinnamon Creek branch at confluence with Peru Creek.

WASTE AND HAZARD CHARACTERISTICS

Adit #101, the Psiupsilon Tunnel, and adit #105, the Little Nell, both discharge water. In July of 2001, the flows from the two adits were measured at 25 and 2.4 gpm, respectively. In October of 2001, the flows were 1.5 and 0.85 gpm. Water samples were collected from both adits during both sampling events (CG-6 and -8, and their low-flow counterparts CG-37 and -31). The pH of the four samples ranged from 4.15 to 5.42, and conductivity ranged from 75 to 130 µS/cm. Sample locations are shown on Figure 3, and water chemistry data are shown on Table 2. Constituents exceeding State water quality standards included dissolved zinc in all four samples, dissolved cadmium in three samples, dissolved aluminum and lead in two samples, and dissolved copper and manganese in one sample. Effluent from the Psiupsilon Tunnel (adit #101) had higher concentrations of metals during low-flow, whereas effluent from the Little Nell (adit #105) had higher concentrations during high-flow.

Adit #101 was assigned an EDR of 4, indicating "slight environmental degradation," apparently due to the drainage effluent. Adit #105 was also assigned an EDR of 4 due to drainage. Adit #101 was assigned a physical hazard rating of 5, indicating no danger. Adit # 105 was assigned a physical hazard rating of 3, due apparently to unobstructed access and its 50-ft depth.

Waste rock dump #201, associated with adit #101, was assigned an EDR of 4, due to the adit effluent discharging onto and eroding into the dump. Waste rock dump #205, associated with adit #105, was also assigned an EDR of 4, due apparently to the observation that "mine drainage goes through the south side of (the) dump." The volume of material on the dump was estimated at 2,500 yds during the 1993 inventory, but was revised to 890 yds during the 2001 investigation. A composite rock sample from dump #205 (MWR-01-8) had 0.1% lead, copper and silver both greater than 400 ppm, plus detectable gold, silver, and mercury (Table 3). The sample had a net acid generation potential (-14.2 tons $CaCO_3$ per 1000 tons), and a paste pH of 5.05, indicating that release of ARD will likely continue in the long term.

The Brittle Silver Mountain tailings (#205, inventory area #429/4383-1) was assigned an EDR of 4, apparently due to water flowing over and through the pile and into the Cinnamon Gulch watershed. Effluent from the tailings was flowing at an estimated 0.5 gpm during the 1993 inventory, with pH of 4.4 and conductivity of 100 µS/cm. The volume of tailings was estimated to be 2,900 yds, and was designated as stable in the 1993 inventory, but the upper pile was described as unstable in the CGS 2001 investigation. Gullies and evidence of sheet wash erosion were observed.

Rock samples (Table 3) of the tailings (MWR-01-6 and -7) contained detectable gold, silver, and mercury, and relatively high concentrations of copper (723 ppm and 937 ppm), lead (1.6% and 2.6%), and zinc (0.4% and 0.7%). Both samples had net acid generating potentials (-7.7 and -6.7 tons $CaCO_3$ per 1000 tons), and acidic paste pH (3.83 and 4.34), indicating that the tailings are capable of releasing ARD in the present and in the long term.

Water samples (high-flow sample CG-01-4 and the low-flow counterpart CG-01-35) collected in Cinnamon Gulch Creek below the tailings, and just before the confluence with Peru Creek, had pH, aluminum, cadmium, copper, lead manganese, and zinc exceeding State standards.

Based on the reported dimensions of the tailings pile, the total surface area is approximately 10,500 sq ft. Assuming 36 inches of annual precipitation (CSU, 2002), it is possible that about 0.5 gpm is infiltrating through the pile, potentially picking up metals and acidity, and discharging to ground water.

PENNSYLVANIA MINE AND MILL

The Pennsylvania Mine is on the northwestern slope of Decatur Mountain, south of Peru Creek. Mine roads off of FR #262 provide access to the Pennsylvania mill and some of the entry levels to the mine, including inventory feature #100/200 of inventory area 430-4383-1. A series of crosscut adits (tunnels) intersected the vein, mined on six levels (A through F) (Lovering, 1935, p. 92-93). Level A, the highest level, is 30 feet above level B and was not connected to level B. The other levels are connected. A crosscut adit intersected the vein on level C, used as the main operating level for many years. An aerial tram at the portal of level C (altitude of 11,290 feet) transported the ore to the mill, erected in 1885. Adit #100 (level F; Ohio tunnel of Ohio Mine), the lowest entry level (crosscut) to the mine is at an altitude of 11,058. Adit #100 was dug on the Giant Mill Site (patented) and undercuts NFS administered lands and a series of patented claims. Level F is connected to the other levels of the Pennsylvania Mine. Recent survey stakes appear to place the portal of adit #100 on NFS lands between the Giant Mill Site and the Badger Lode. Mineral surveys also show that the first 100 feet of the adit was timbered and most likely collapsed. Subsequent mining activities or the instillation of the drainage pipe apparently removed the old timbers and obliterated the location of the original portal. Adit #100 is labeled “Pennsylvania Mine” on the Montezuma quad and PBS maps.

The Pennsylvania Mine was one of the most productive mines in the area. According to Lovering (1935, p. 92, 95), the Pennsylvania vein was discovered by Hall in 1879. Production was intermittent through 1928 (Table 4). Between 1885 and 1923, over 30,000 short tons of ore shipped yielded about 2,800 oz of gold, 760,000 oz of silver, 6,590,000 pounds of lead, 8,000 pounds of copper, and 700,000 pounds of zinc. Between 1910 and 1928, about 36,000 tons of ore were reduced to nearly 4,700 tons of concentrate yielding about 678 oz of gold, 133,000 oz of silver, 876,900 pounds of lead, 66,500 pounds of copper, and 219,000 pounds of zinc.

Mine effluent from the entry levels of the Pennsylvania Mine, including feature #100/200, were not sampled in this study. Previous sample information was obtained from the files of the Colorado Division of Mines and Geology (CDMG).

MINING HISTORY

1879. In September, Mineral Survey No. 940 was conducted on the Pennsylvania Lode owned by Barton H. Hopkins, L.E. Park, William Hollingshead, D.L. Howard, and Mason Hall. A 22-ft-long cut with a 22-ft-long inclined crosscut adit and a 6-ft-deep shaft were surveyed on the claim (**Figure 35**). “Other parties” dug two additional pits on the claim (Mineral Survey No. 940). One of the pits was the discovery for the overlapping Champion Lode. In October, Mineral Survey No. 944 was conducted on the Leadville Lode owned by L.W. Aldrich and others. A discovery shaft and 15-ft-long crosscut adit were surveyed on the claim (**Figure 36**).

J.M. Hall discovered the Pennsylvania vein (Lovering, 1935, p. 92). Hall and associates (Morrison, R.S, Hopkins, B.A., Foster, C.N., and Husted, J.H.) slowly developed the mine during the next decade.

Production of Pennsylvania group

	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Lead, wet assay (pounds)	Copper, wet assay (pounds)	Zinc (pounds)
1885	45	----	----	----	----	----
1886	68	----	----	----	----	----
1887	30	----	----	----	----	----
1889 (Ohio)	(?)	----	9	2,086	----	----
1890 [a]	736.149	73.61	16,681	126,447	----	----
1891 [a]	1,646.829	164.68	74,915	567,847	----	----
1892 [a]	4,670.418	467.04	----	----	----	----
1893 [a]	3,299.577	329.96	138,344	1,048,616	----	----
1894 [a]	1,783.596	178.36	88,538	671,140	----	----
1895 [a]	912.794	91.28	42,428	321,599	----	----
1896 [a]	952.726	95.27	40,114	304,071	----	----
1897 [a]	1,672.987	160.30	63,895	484,330	----	----
1898 [a]	1,098.802	109.88	53,810	407,882	----	----
1899 [a]	852.526	85.25	44,999	341,091	----	----
1900 [a]	900.364	90.04	41,996	318,331	----	----
1901 [a]	1,129.515	112.95	54,104	410,098	----	----
1902 (Ohio)	120	7.50	3,660	56,471	----	----
1903	5,941	594.10	29,705	594,100	----	----
1904	2,430	121.50	12,150	486,000	----	486,000
1905	1,284	38.70	24,504	85,106	----	----
1906	1,000	50.02	3,000	200,000	----	200,000
1907	35	----	3,500	----	----	----
1909	68	38.98	1,088	9,796	----	----
1912	31	7.40	851	6,523	485	----
1914	45	4.70	795	9,677	795	----
1918	37	4.28	1,399	17,289	264	----
1919	117	7.84	6,024	38,496	2,275	----
1920	33	3.64	1,639	9,390	----	----
1921	30	4.70	1,647	5,022	826	----
1922	79	7.80	3,239	32,233	755	10,789
1923	112	7.80	7,986	36,575	2,415	----

	Ore to concentrating mills (short tons)	Concentrates produced (short tons)	Gold (fine ounces)	Silver (fine ounces)	Lead, wet assay (pounds)	Copper, wet assay (pounds)	Zinc (pounds)
1910	9,000	1,167	160.46	28,320	193,421	17,390	----
1911	12,488	1,719	268.62	46,434	288,107	20,115	206,280
1913	3,094	476	61.08	8,989	71,556	3,489	----
1920	1,023	134	12.60	4,351	31,653	2,795	----
1921	8,000	920	154.62	33,728	215,860	16,088	----
1927	1,400	171	8.80	7,003	38,281	4,644	----
1928	1,391	100	12.00	4,200	38,000	2,000	13,000

[a] Content estimated from tonnage, gross value, and average lead, gold, and silver content of ore.

No record available for 1888.

Table 4. Production from the Pennsylvania Mine group. (Modified from Lovering 1935, p. 95.)

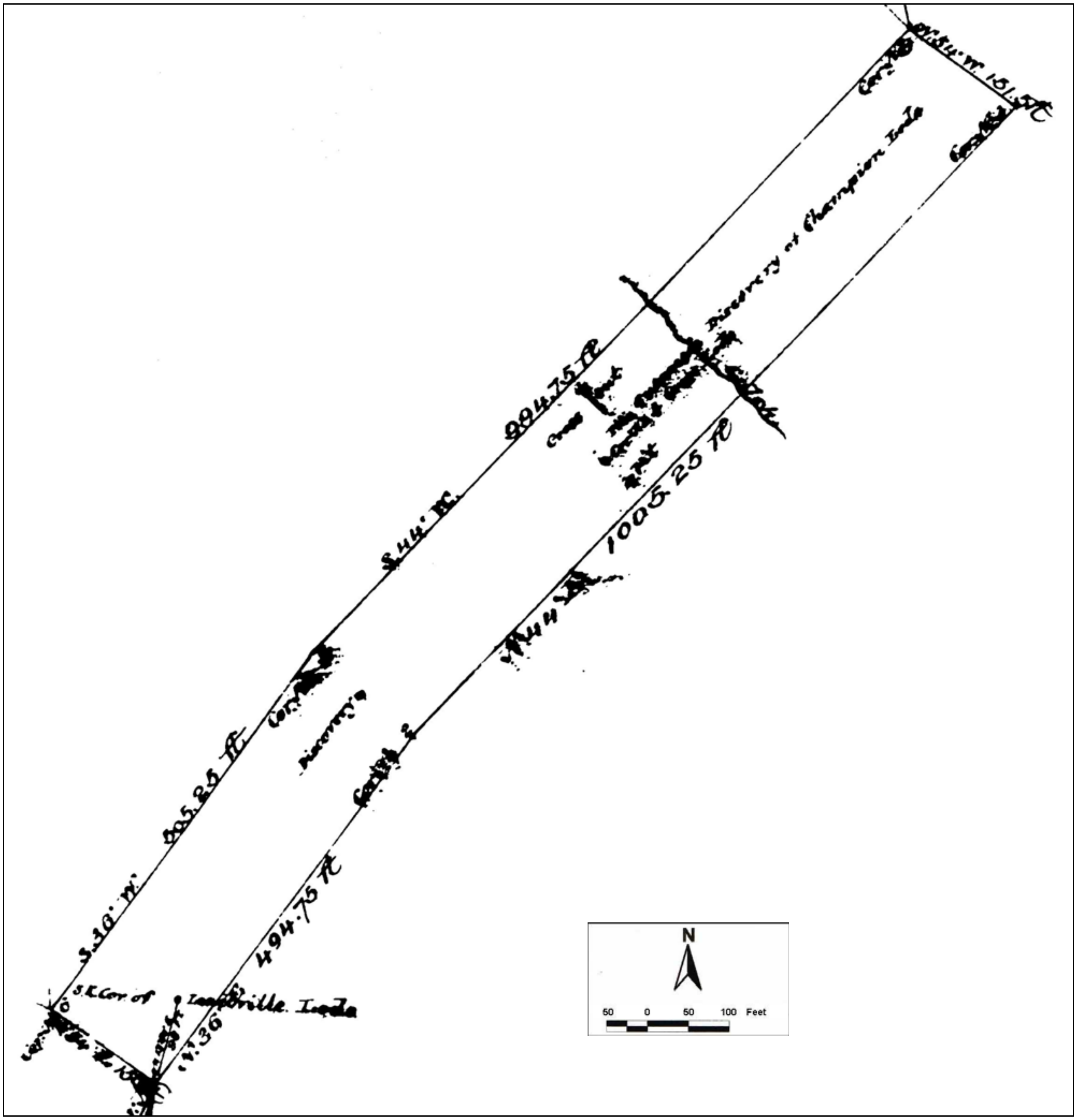


Figure 35. Pennsylvania Lode Mineral Survey (No. 940) (Modified; scale is approximate).

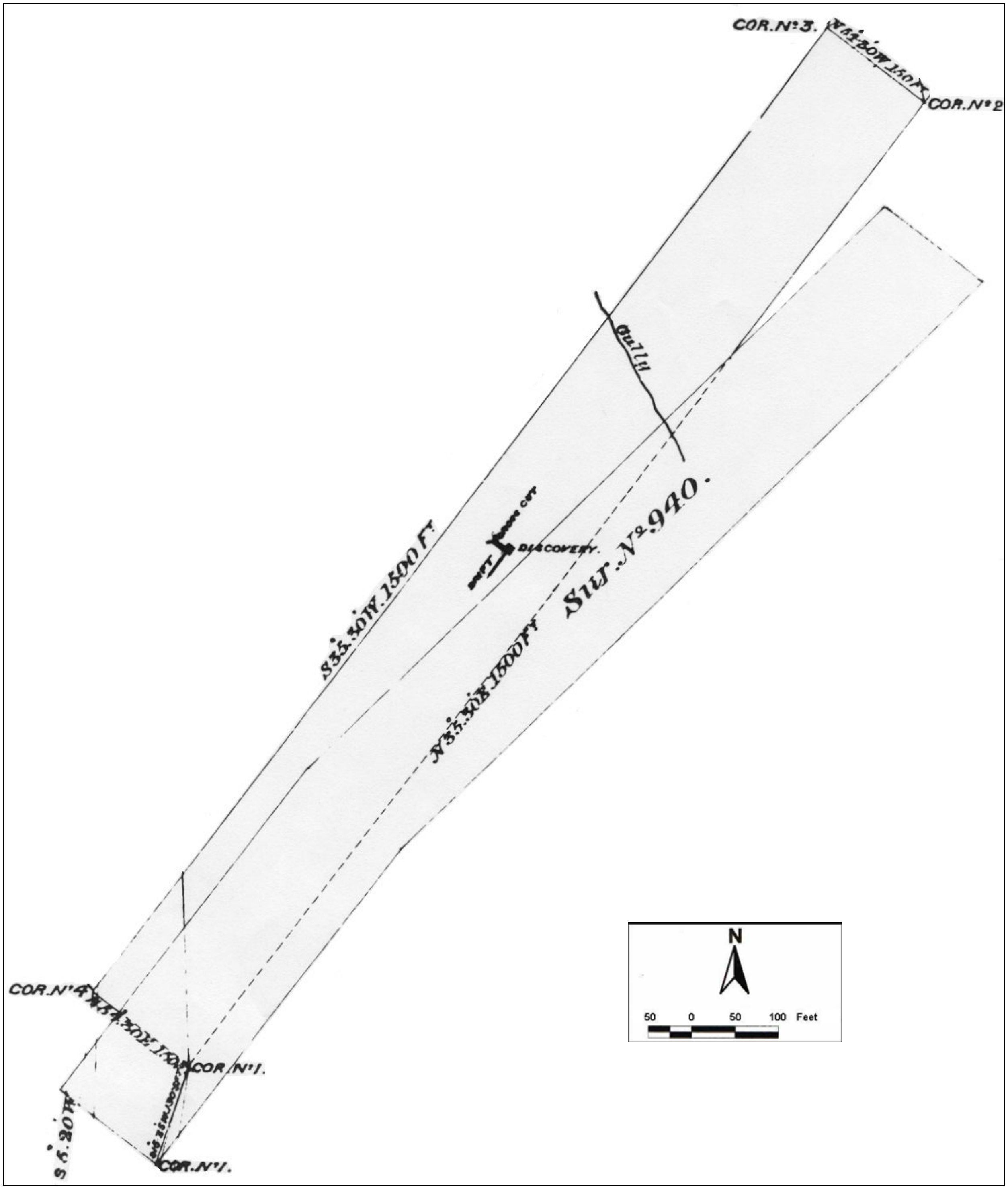


Figure 36. Leadville Lode Mineral Survey (No. 944) (Modified; scale is approximate).

1880. In June, the first 114 feet of a 200-ft-long crosscut adit was driven to intersect a vein on the Pennsylvania Lode (*Colorado Miner*, June 26, 1880, p. 3). The ore body contained bismuth minerals and galena. H.W. Eddy was an active member of an unnamed company engaged in working the Leadville, Paymaster, and Cross Lodes. In July, an 8-inch-wide vein was exposed at the bottom of the 15-ft-deep Paymaster shaft owned by Hall and Ottman (*Colorado Miner*, July 3, 1880, p. 3). The vein contained black sulphurets that assayed 731 oz of silver per ton and streaks of bismuth minerals in quartz. Eddy and Aldrich owned the Leadville, Cross, Ouray, and Grant Lodes located near the Paymaster. In October, a 2-ft-wide vein averaging 70 oz of silver per ton was discovered at the Hall Lode (*Rocky Mountain News*, October 23, 1880, p. 9). A 5-inch-wide vein of gray and yellow copper was discovered in the main shaft of the Paymaster Lode. The Leadville and Pennsylvania Mining Company owned both claims.

Mineral surveys were conducted on the Ouray (1171), Paymaster (1172), Sheldon (1181), Cross (1182), and Hall (1190) Lodes and Mill Sites owned by the Leadville and Pennsylvania Consolidated Mining Company. A 30-ft-long discovery cut and 4-ft-deep pit were surveyed on the Ouray Lode (Figure 37). Improvements surveyed on the Paymaster Lode include the 50-ft-deep discovery shaft, intersected at a depth of 22 feet by an adit, a 16-ft-long crosscut adit, and a 27-ft long adit (Figure 38). A 20-ft-long by 14-ft-deep discovery cut was surveyed on the Sheldon Lode (Figure 39). A 15-ft-long by 12-ft-deep open cut was surveyed on the Cross Lode (Figure 40). Improvements surveyed on the Hall Lode consisted of a 30-ft-long open cut with a 27-ft-long adit and a 10 ft-deep winze at the breast (Figure 41). Northwest of the Ouray, Sheldon, and Cross Lodes, the 47-ft-long Grant Tunnel was included toward the $500 worth of improvements for all three claims. The Hall mill site was labeled as the Grant mill site on the Paymaster mineral survey. This probably reflects an earlier name that could be related to the Grant tunnel, possibly on the Grant Lode. Apparently, the Grant Lode never went to patent. The Houser Tunnel was surveyed on the Hall Lode and appears to be another name for the Grant Tunnel. Neither the Grant nor Houser tunnel was included with the improvements for Paymaster or Hall Lodes. Level C crosscut of the Pennsylvania Mine appears to be the Grant Tunnel. Adit #100 (Pennsylvania Mine-level F) eventually intersected the Ouray vein, presumably below the Ouray Lode.

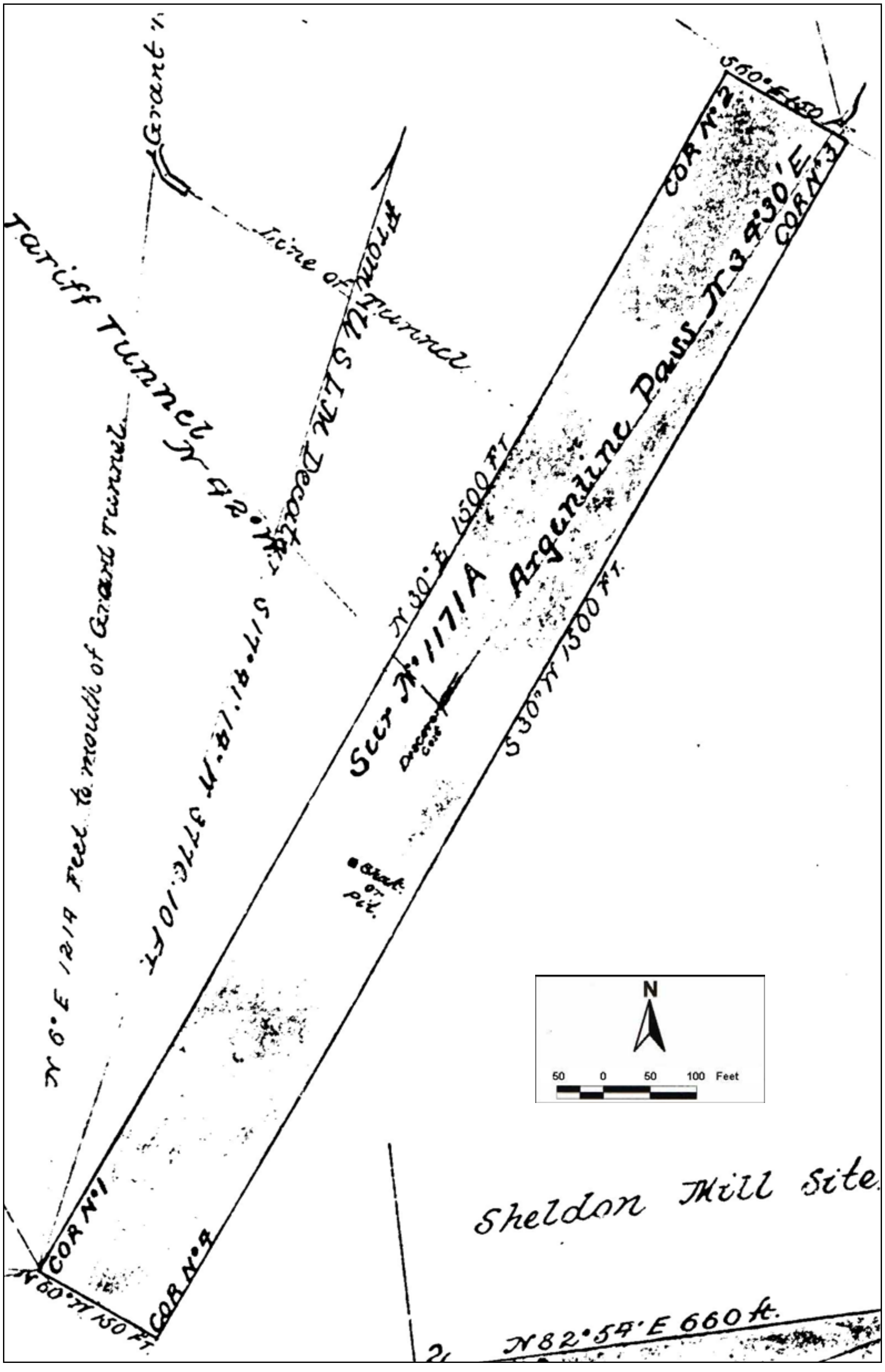


Figure 37. Ouray Lode Mineral Survey (No. 1171A) (Modified; scale is approximate).

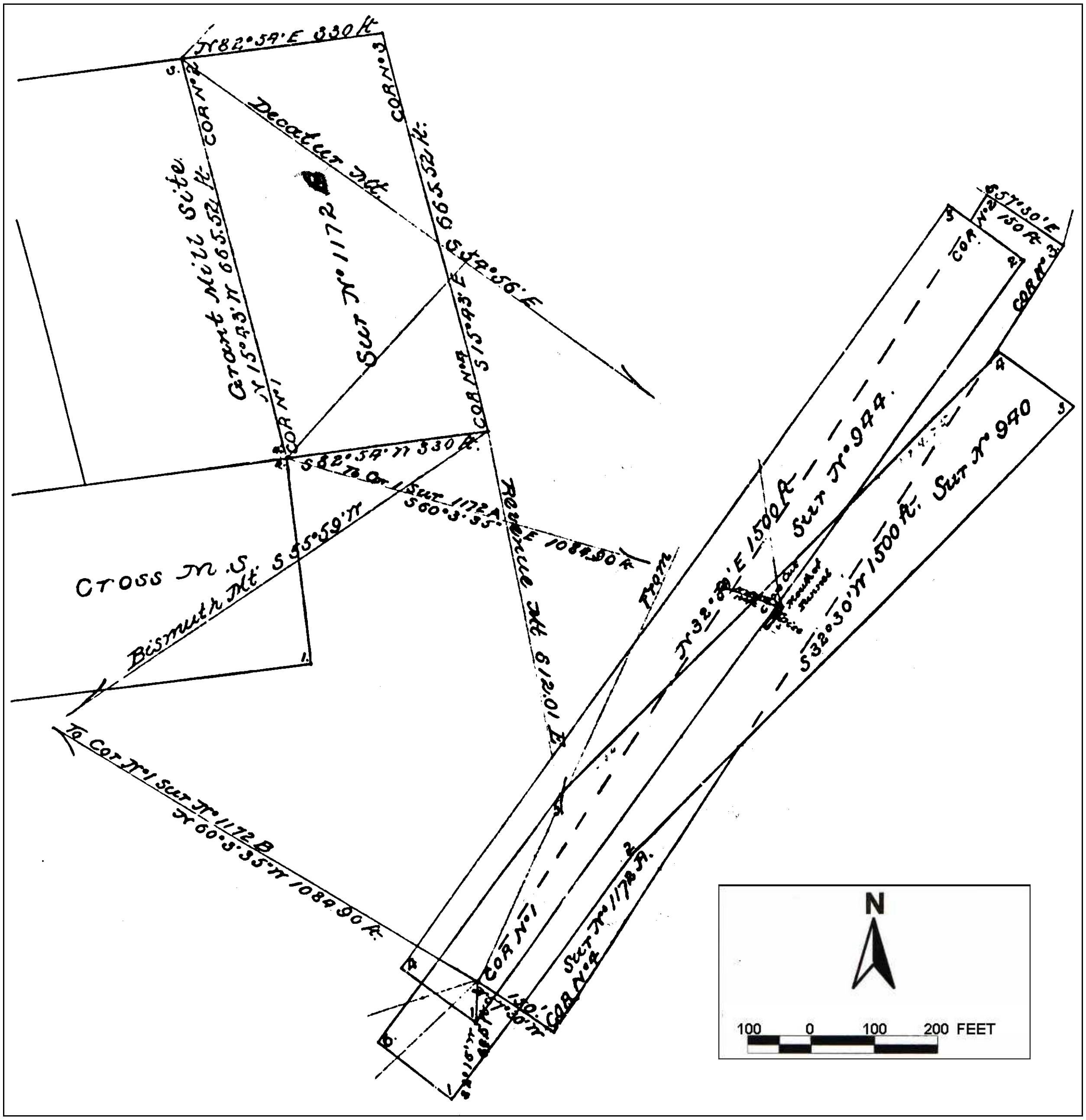


Figure 38. Paymaster Lode and Mill Site Mineral Survey (No. 1172A and B) (Modified; scale is approximate).

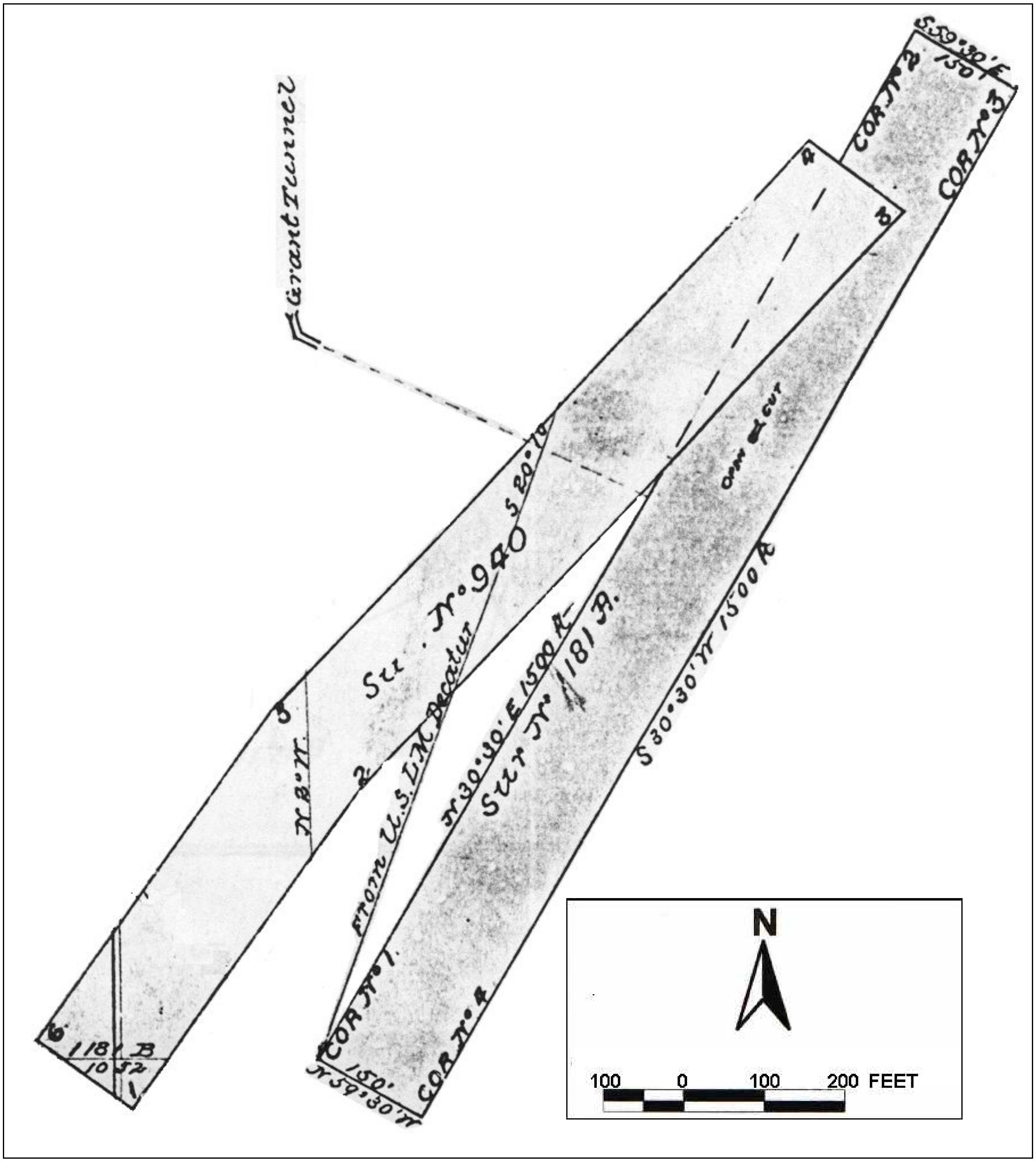


Figure 39. Sheldon Lode Mineral Survey (No. 1181A) (Modified; scale is approximate).

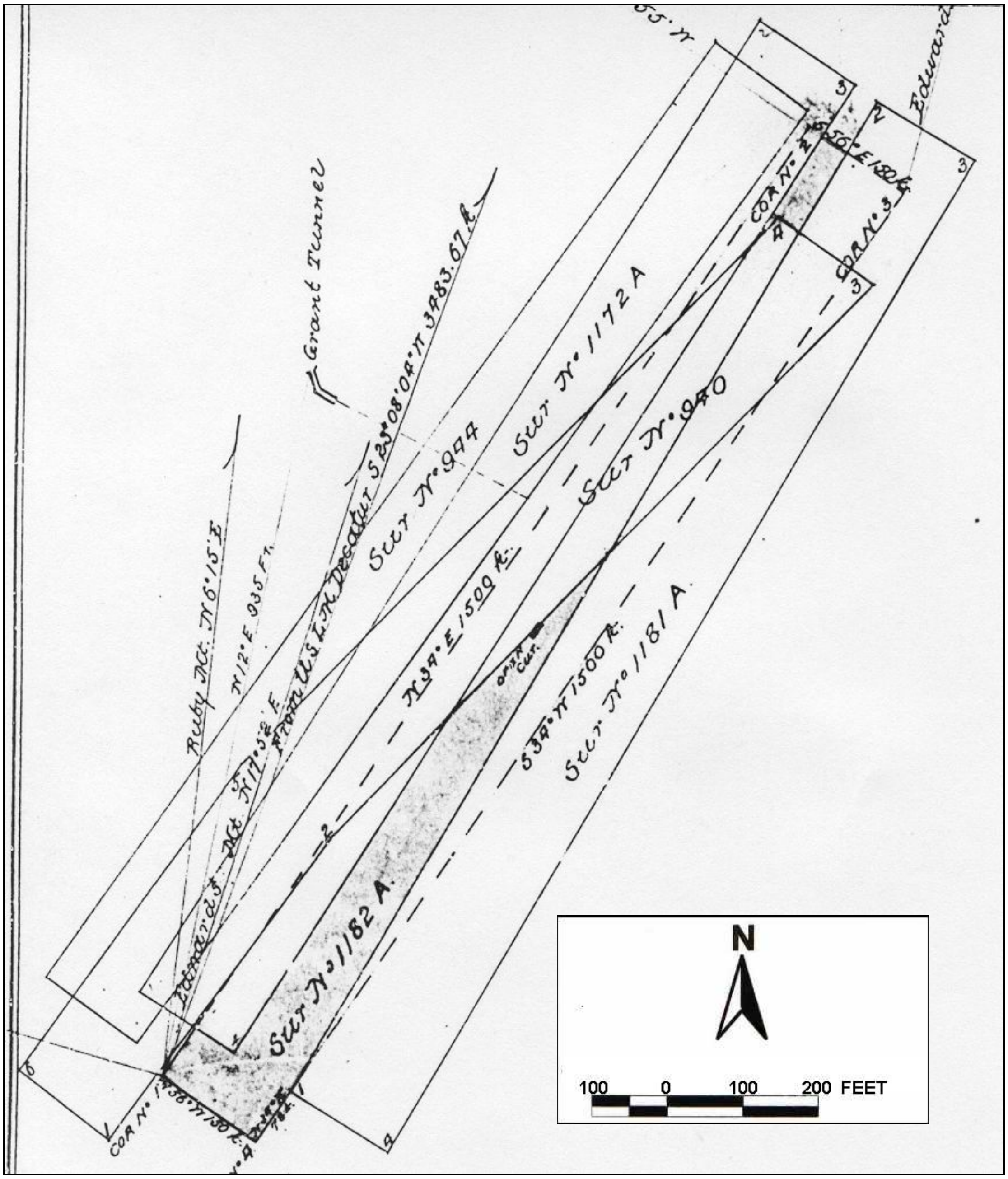


Figure 40. Cross Lode Mineral Survey (No. 1182A) (Modified; scale is approximate).

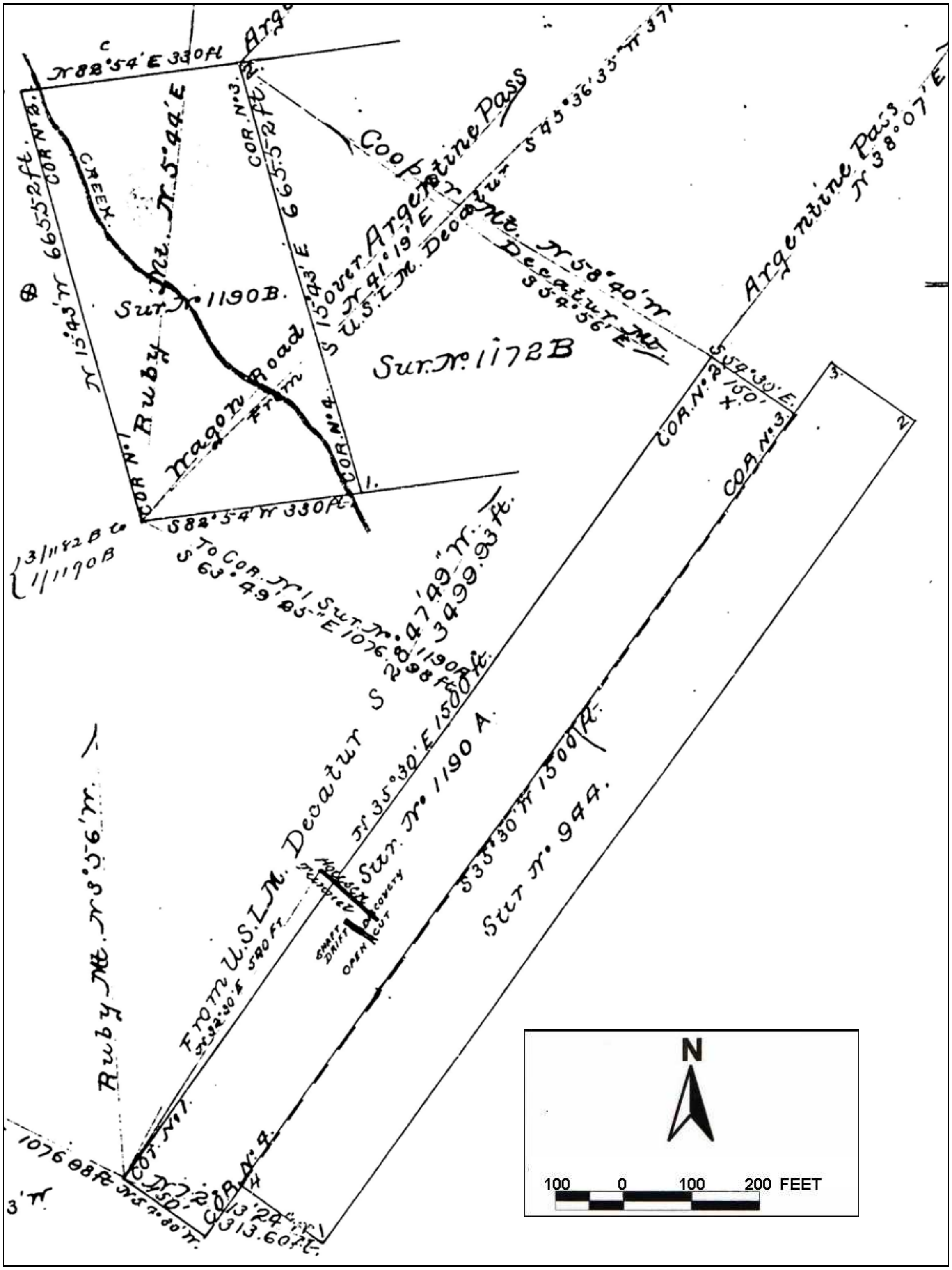


Figure 41. Hall Lode and Mill Site Mineral Survey (No. 1190A and B) (Modified; scale is approximate).

1881. Ore was exposed in the Hall, Pennsylvania, and Paymaster Lode (*Rocky Mountain News*, January 4, 1881, p. 2). An adit was driven on the Paymaster Lode (*Rocky Mountain News*, March 27, 1881, p. 6). A large vein of pyrite was exposed on the claim. L.W. Aldrich, H.W. Eddy, W.T. Lewis, and G.L. Ottman were issued a patent for the Leadville Lode (BLM files).

1882. In May, work on the Paymaster Mine was expected to begin soon (*Denver Republican*, May 22, 1882, p, 6). The 5½-ft-wide vein of solid galena was free-milling and the concentrator was nearly ready for operation. By the end of July, the 40-ton per day wet concentrating mill had been overhauled to treat ore from the Paymaster Mine (*Rocky Mountain News*, July 22, 1882, p. 3). Three to four tons of ore reduces into 1 ton concentrates and mills between 25 and 30 oz of silver per ton before concentration. A 2,000-ft-long tram was used to transport the ore mined from the 3- to- 4-ft-wide vein to the mill. The Paymaster concentrator was in full operation by the end of August (*Rocky Mountain News*, August 31, 1882, p. 6). Ore at the bottom of the 100-ft-deep Paymaster shaft assayed up to 200 oz of silver per ton (*Rocky Mountain News*, October 26, 1882, p. 6). Assay results from a 7-ft-wide vein on one level and from a 5-ft-wide vein on another level were similar.

1883. In August, Hall and Kremmling contracted Rust and Company to process 470 tons of ore at the Brittle Silver Mill (*Colorado Miner*, August 4, 1883, p. 1). It was not determined which mine the ore was from, however, Hall was credited with the discovery of the Pennsylvania vein. Two shifts were working at the Paymaster Mine and mill. The 6-ft-wide vein of solid galena contained a “fair” percentage of silver (*Rocky Mountain News*, August 16, 1883, p. 2). About three tons of ore per day were mined and transported over a 1,000-ft-long wire tramway to the mill, considered one of the best in the State. In December, the Leadville and Pennsylvania Consolidated Mining Company was issued a patent for the Cross and Sheldon Lodes and millsites (BLM files).

The Leadville and Pennsylvania Consolidated Mining Company (H.W. Eddy and D.T. Salem-president; B.A. Hopkins-vice president; James Teal-secretary/treasurer; J.M. Hall-general manager) owned the Leadville, Pennsylvania, Ouray, Cross, Sheldon, Paymaster, and Hall Lodes and associated millsite claims (Corregan and Lingane, 1883, p. 767). The fissure veins varied in width and contained galena, tetrahedrite, and bismuth. The silver content ranged from 50- to 150-oz per ton. Workings included a 240-ft-deep shaft, 5-ft-long adit, and a 170-ft-long adit.

1885. According to the Colorado Miner (May 16, 1885, p. 2), the Leadville and Pennsylvania Consolidated Mining Company owned the Leadville, Pennsylvania, Paymaster, Sheldon, Cross, Ouray, Grant, and Hall Lodes Managed by Barton Hopkins. About 670 oz of silver per ton was recovered from a recent mill-run. Ore from one of the claims consisted of schirmerite ($Ag_3Pb_3Bi_9S_{18}$ to $Ag_3Pb_6Bi_7S_{18}$). According to Lovering (1935, p. 95), 45 short tons of ore were shipped from the Pennsylvania group.

1886. John M. Hall, William H. Hollingshead, Barton A. Hopkins, David L. Howard, and Lucius E. Park were issued a patent for the Pennsylvania Lode (BLM files). Leadville and Pennsylvania Consolidated Mining Company was issued a patent for the Paymaster Lode. According to Lovering (1935, p. 95), 68 short tons of ore were shipped from the Pennsylvania group.

1887. Leadville and Pennsylvania Consolidated Mining Company was issued a patent for the Hall and Ouray, Lodes (BLM files). According to Lovering (1935, p. 95), 30 short tons of ore were shipped from the Pennsylvania group.

1889. Production from the Pennsylvania Group had a value of $350 in gold, $5,830 (coinage value) in silver, and $70 in lead (Smith, 1890, p. 153). According to Lovering (1935, p. 95) 9 oz of silver and 2,086 pounds of lead were recovered from the ore shipped from the Pennsylvania group.

1890. Production from the Pennsylvania Group had a value of $1,320 in gold, $30,048 (coinage value) in silver, and $1,218 in lead (Smith, 1891, p. 141). Lovering (1935, p. 95) estimated about 73 oz of gold, 16,680 oz of silver, and 126,400 pounds of lead were recovered from the 736 short tons of ore shipped from the Pennsylvania group.

1891. John Spieles relocated the Evergreen Tunnel Lode No.1 and located the Giant Mill Site (bk. 9, p. 414, 460). Mineral Survey No. 7317 A & B was conducted on the two claims in December. The portal of a 250-ft-long, southeast trending, adit (apparently the Pennsylvania Mine, feature #100) was surveyed on the Giant Mill Site (Figure 42). According to survey notes, the first 100 feet of the adit was timbered solid. A 135-ft-long adit (probably an upper level in the Pennsylvania Mine) was surveyed on the Evergreen Tunnel Lode No.1. According to Smith (1892, p. 185), production from the Pennsylvania Mine had a value of $94,123 (coinage value) in silver and $20,087 in lead. Lovering (1935, p. 95) estimated about 165 oz of gold, 75,000 oz of silver, and 568,000 pounds of lead were recovered from the 1,647 short tons of ore shipped from the Pennsylvania group.

1892. Decatur Mining Syndicate, Ltd. leased the Pennsylvania Mine from J.M. Hall and associates (Lovering, 1935, p. 92,95). About 470 oz of gold were recovered from 4,670 short tons of ore shipped from the Pennsylvania group. John Spieles was issued a patent for the Evergreen Tunnel Lode No. 1 and the Giant Mill Site (BLM files).

1893. Ohio Mining and Milling Company was issued a patent for the 20 lode claims included in mineral survey No. 7592 (BLM files). Lovering (1935, p. 95) estimated about 330 oz of gold, 138,000 oz of silver, and 1,050,000 pounds of lead were recovered from the 3,300 short tons of ore shipped from the Pennsylvania group.

1894. Lovering (1935, p. 95) estimated about 178 oz of gold, 88,500 oz of silver, and 670,000 pounds of lead were recovered from the 1,780 short tons of ore shipped from the Pennsylvania group.

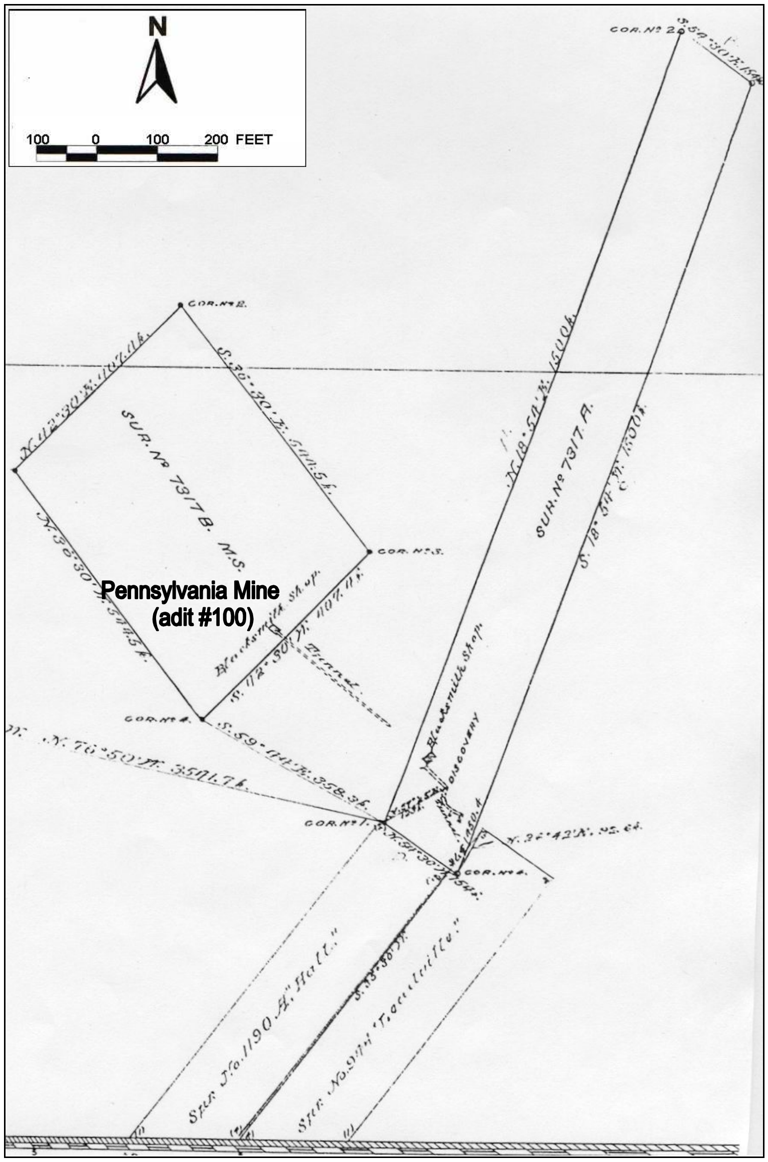


Figure 42. Evergreen Tunnel No. 1 Lode and Giant Mill Site Mineral Survey (No. 7317 A & B). The tunnel originating on the Giant Mill site is the Pennsylvania Mine (adit #100) (Modified; scale is approximate).

1896. Earnest Le Neve Foster located “The Tram” and El Jebel mill sites (bk. 12, p. 389-390). Lovering (1935, p. 95) estimated about 95 oz of gold, 40,000 oz of silver, and 304,000 pounds of lead were recovered from the 950 short tons of ore shipped from the Pennsylvania group.

1895. A cross-section of the Pennsylvania Mine (Figure 43) illustrates the amount of ore stoped from the north vein prior to October (Lovering, 1935, Figure 21). Lovering (1935, p. 95) estimated about 91 oz of gold, 42,000 oz of silver, and 320,000 pounds of lead were recovered from the 900 short tons of ore shipped from the Pennsylvania group.

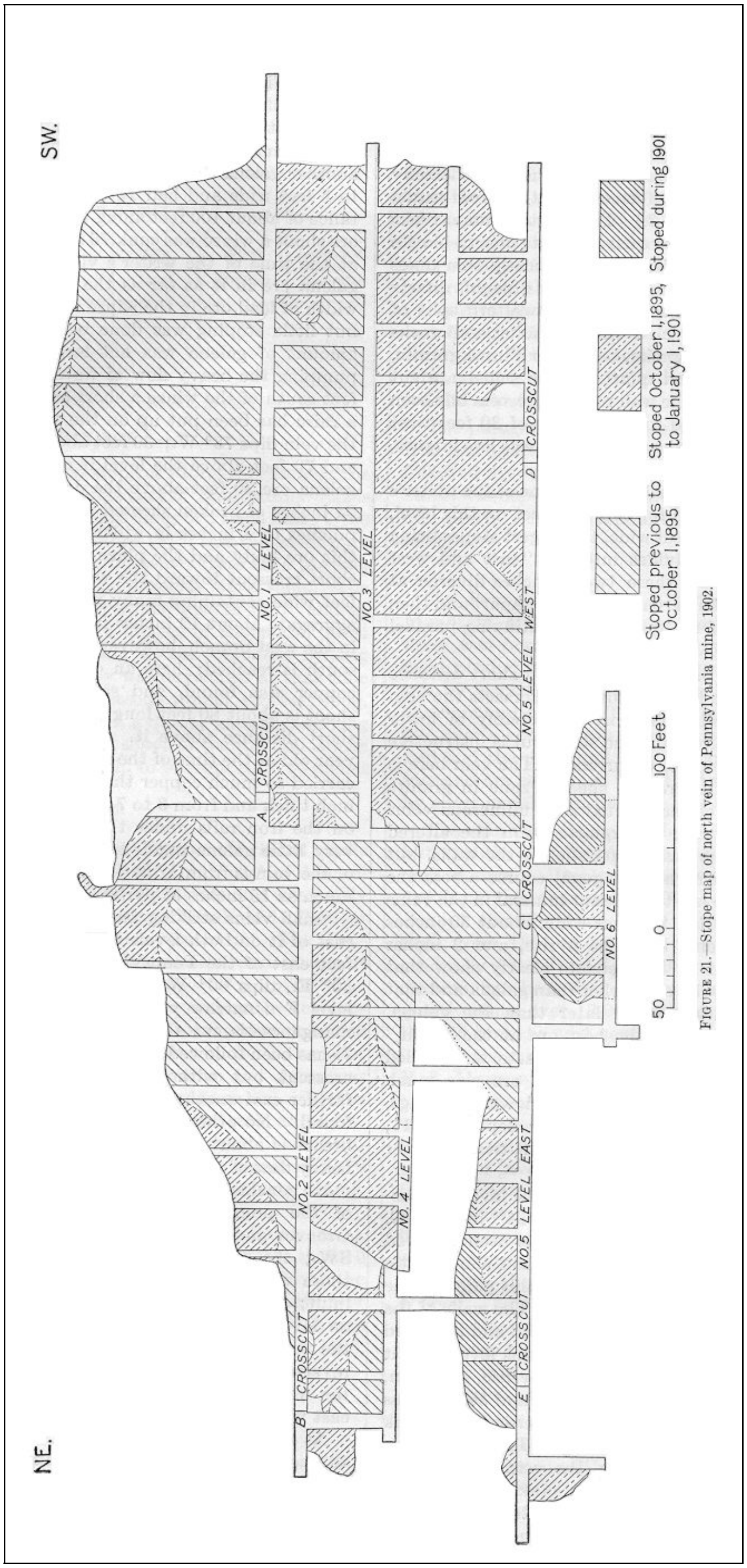


Figure 43. 1902 stope map of the north vein in the Pennsylvania Mine. Modified from Lovering 1935, plate 21.

1897. In April, the Pennsylvania Mines Company purchased the property of the Decatur Mining Syndicate (1899 Pennsylvania Mines Company annual report *in* 1901 Mine manager report-Pennsylvania Mines Co., p. 349, CBM) but did not take possession until the following year. Decatur Mining was deeply in debt and had practically abandoned the property as a worthless undertaking. During the year, Decatur Mining removed all of the large bodies of smelting ore (high-grade ore) and realized a profit of over $5,600. Pennsylvania Mines needed about $33,000 in order to make the mine operational in 1898. Thousands of tons of low-grade ore had been placed on the dump and was broken and blocked out in the mine. Lovering (1935, p. 95) estimated about 160 oz of gold, 64,000 oz of silver, and 484,000 pounds of lead were recovered from the 1,670 short tons of ore shipped from the Pennsylvania group.

Mineral Survey Nos. 11733 and 11734 were conducted on the El Jebel and The Tram mill sites respectively, owned by Earnest Le Neve Foster (BLM files). A 25-ft-long crosscut adit and log mill and powerhouse, containing a boiler and compressor was surveyed on the El Jebel mill site (Figure 44). An office, boardinghouse, ore and sorting house, and the portal of a 210-ft-long adit were surveyed on the Tram mill site (Figure 45). A 1,200-ft-long iron pipe and waterwheel operated mill machinery and a Cornish jig concentrator. The mill building was under construction. Level C of the Pennsylvania Mine is probably the 210-ft crosscut adit.

1898. In January, the Pennsylvania Mines Company (Earnest Le Neve Foster-president and manager; Henry T. Rogers-vice president; William Mitchell-secretary; B.A. Hopkins-treasurer) took possession of Decatur Mining Syndicate's property purchased during the previous year (1899 Pennsylvania Mines Company annual report *in* 1901 Mine manager report-Pennsylvania, p. 349, CBM). Earnest Le Neve Foster was issued a patent for the El Jebel mill site in March and for the Tram mill site in June (BLM files). By July, the Pennsylvania Mine was considered the largest mine in the camp (*Mining Reporter*, July 28, 1898, p. 20). Between 12 and 15 employees were mostly at work on new development. About 10 tons of lead-silver ore per day were mined and shipped by rail to Keystone. In November, a new tramway was built and the concentrating plant was repaired and overhauled to treat large quantities of low-grade ore (*Mining Reporter*, November 17, 1898, p. 17). During the previous 3-year period, the low-grade ore (uneconomic to recover shipping expenses) was placed on the dump. Frank Graham managed 30 employees at the Pennsylvania Mine (Dunbar, 1898, p. 302). Adits were used to access the mine workings.

The Pennsylvania Mines Company mostly performed development work in the mine in preparation for stoping (1899 Pennsylvania Mines Company annual report *in* 1901 Mine manager report-Pennsylvania Mines Co., p. 349, CBM). Nearly 1,150 tons of ore were shipped, yielding a gross value of $41,714, and contained an average of 44 oz of silver per ton, 0.01oz per ton gold, and 21% lead. A concentrating mill was erected and most of the machinery was in place. A dam and ½-mile-long pipeline was constructed for waterpower and an aerial tram was erected between the mine and mill. About 110 oz of gold, 53,800 oz of silver, and 408,000 pounds of lead were recovered from the 1,100 short tons of ore shipped from the Pennsylvania group (Lovering, 1935, p. 95).

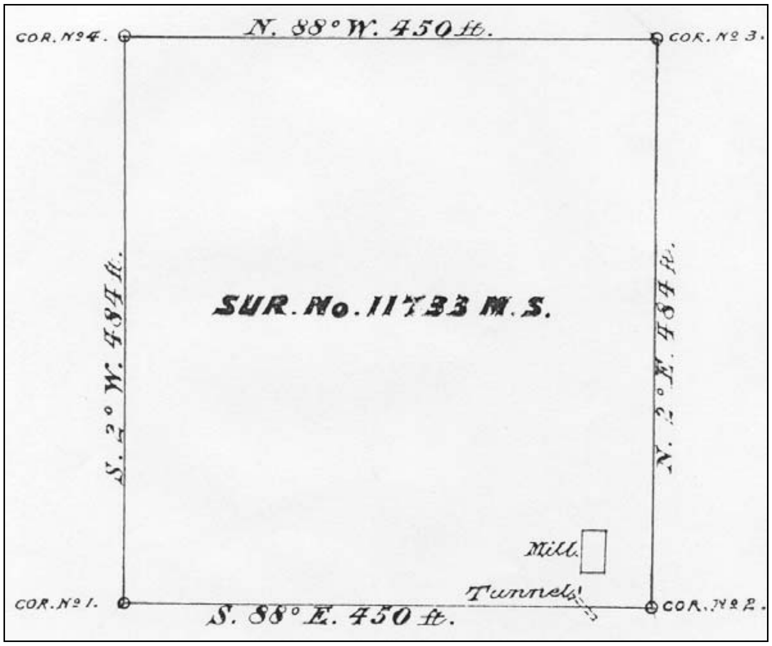


Figure 44. El Jebel Mill Site Mineral Survey (No. 11733) (Modified; scale is approximate).

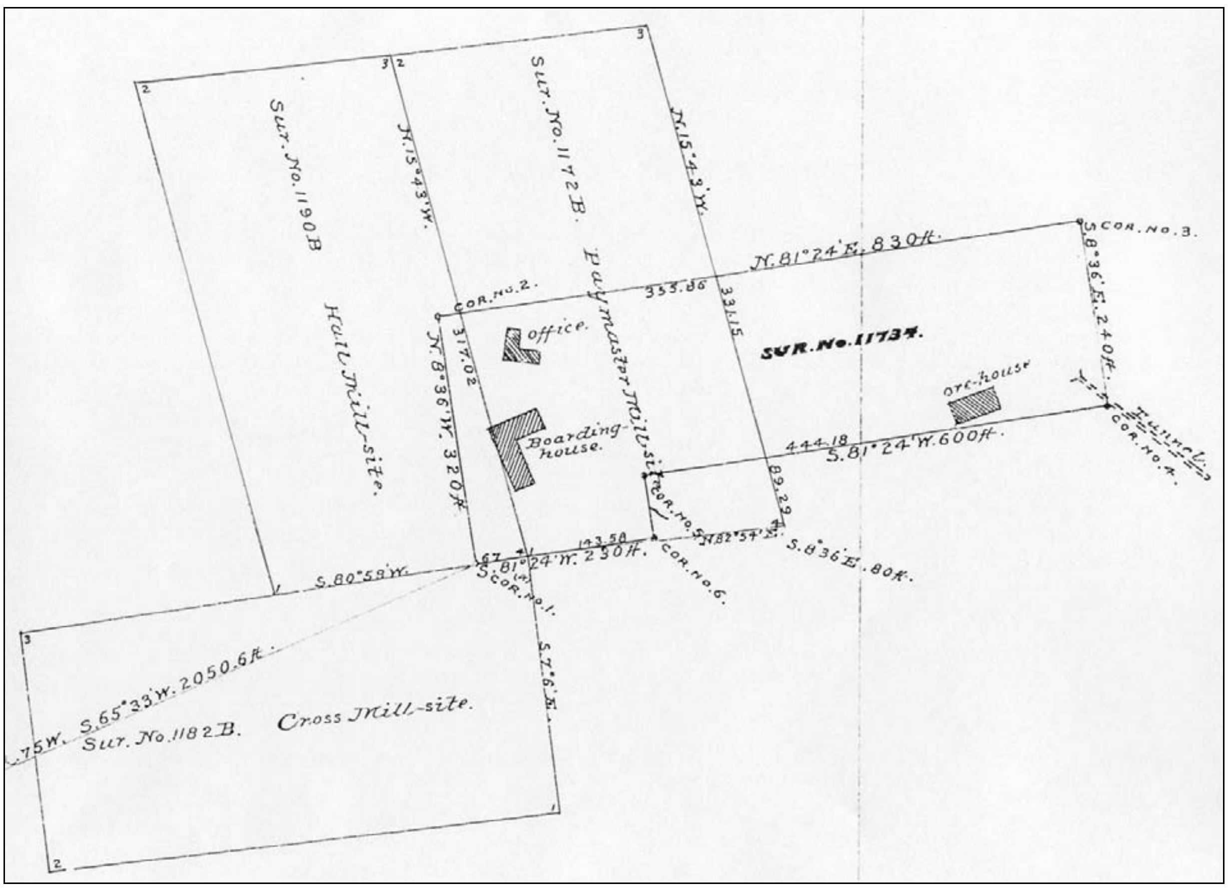


Figure 45. The Tram Mill Site Mineral Survey (No. 11734) (Modified; scale is approximate).

1899. An average of 18 workers, employed by the Pennsylvania Mines Company, shipped 850 tons of ore directly to the smelter from the Pennsylvania Mine (Mine manager report-Pennsylvania, 1899, p. 391, CBM). Ninety tons of ore required milling prior to shipping. Composed of mostly argentiferous galena and sphalerite, the ore averaged 50 oz per ton silver, 0.1 oz per ton gold, and 30% lead per ton. Workings included levels, crosscuts, raises, and winzes, totaling about 2 miles. Lovering (1935, p. 95) estimated about 85 oz of gold, 45,000 oz of silver, and 340,000 pounds of lead were recovered from the 850 short tons of ore shipped from the Pennsylvania group. According to the Denver Times (December 31, 1899, p. 12), total output from the Pennsylvania Mine was worth "several" million dollars.

1900. During the winter, about 100 tons of ore per month were shipped from the Pennsylvania group of mines, one of the largest properties operating in Summit County (*Denver Times*, March 22,1900, p. 12). All of the ore had to be transported by sled to the South Park terminal at Keystone, a distance of about 12 miles. The mine was reportedly at an elevation of about 11,500 feet. This suggests that mining occurred in one of the upper crosscut adits, because the Pennsylvania Mine on the Montezuma topographic quad (adit #100) is at an elevation of about 11,000 feet.

In July, The Pennsylvania Mines Company (Earnest Le Neve Foster-president; William Mitchell-secretary; B.A. Hobkins-treasurer; Frank Graham-superintendent) owned the Pennsylvania Mine and employed 20 workers (Griffin, Inspector report-Pennsylvania Mine, July 13, 1900, v. 4, p. 202, 226; 1900 Mine manager report-Pennsylvania, p. 603, CBM). Claims included the Pennsylvania and 14 other lodes, and the El Jebel and 5 other mill sites. The south 80° dipping, northeast trending quartz vein contained argentiferous galena in streaks. Ore was extracted by drifting and stoping. Underground development included a 500-ft-long crosscut adit that intersected the vein and drifted 500 feet northeast and 400 feet southwest. An 80-ft-long western drift was driven from the bottom of a 50-ft-deep, two-compartment winze, sunk 8 feet east of the crosscut adit. The drift was about 15 feet from connecting to a winze sunk from the western drift above. A 1,000-ft-long tram transported the ore from the mine to the 50-ton per day concentrating mill. Shipments of smelting ore, worth $60 per ton, averaged 125 tons per month and contained 50 oz of silver per ton, $3.00 per ton in gold, and 30% lead. Lovering (1935, p. 95) estimated about 90 oz of gold, 42,000 oz of silver, and 318,000 pounds of lead were recovered from the 900 short tons of ore shipped from the Pennsylvania group. According to the Rocky Mountain News (February 15, 1883, p. 2), E. Le Neve Foster was appointed State geologist in 1883. A cross section of the Pennsylvania Mine (Figure 43) illustrates the amount of ore stoped from the north vein from October 1895 through 1900 (Lovering, 1935, Figure 21).

1901. An average of 20 employees operated the Pennsylvania Mine and 60- to 70-ton per day mill (Mine manager report-Pennsylvania Mines Co., p. 349, CBM). The silver-lead ore had an average value of $60 per ton. Lovering (1935, p. 95) estimated about 113 oz of gold, 54,000 oz of silver, and 410,000 pounds of lead were recovered from the 1,130 short tons of ore shipped from the Pennsylvania group. A cross section of the Pennsylvania Mine (Figure 43) illustrates the amount of ore stoped from the north vein during 1901.

1902. In June, the Pennsylvania Mines Company (Earnest Le Neve Foster-manager) owned the 15-claim block associated with the Pennsylvania Mine (Wahlgreen, 1902, p. 120). In August, the mill was in regular operation and three 4-horse teams were employed to transport the ore

(*Mining Reporter*, August 14, 1902. p. 138). Kern managed the work driving the Ohio tunnel, which had attained a length of 400 feet (*Denver Times,* August 27, 1902, p. 11). Feature #100 is almost certainly the "Ohio tunnel" referenced in the article. In October, Plata-y-Oro Mining Company, an Ohio mines syndicate, purchased the Pennsylvania Mine for $100,000 (*Mining Reporter,* October 2, 1902. p. 278). Over the last 20 years, production from the Pennsylvania Mine was worth more than $1,000,000. Plata-y-Oro's work was concentrated on driving the lower crosscut adit, intended to intersect the Pennsylvania ore body at "great" depth. The tunnel had been driven 800 feet. In another account (CBM, 1903, p. 220), the Ohio Mining Company had revived the Pennsylvanian Mines Company properties and shipped 1,000 tons of silver-lead ore. According to Lovering (1935, p. 95, plate 33), a winze was sunk on the vein near the crosscut from level F. No ore was exposed in the winze; only pyrite was encountered in the quartz vein.

Mineral Survey #7592 was conducted on a 20-claim block (Badger, Union, Tunnel Lode #2, Pennsylvania Extension, Decatur, O.K., Germania, Sheboygan, Giant, Giant Extension, Evergreen, Evergreen Extension, Snow Slide, Snow Slide Extension, Milwaukee, Milwaukee Extension, Silver Coin, Oshkosh, Casino, and Chicago Lodes) owned by the Ohio Mining and Milling Company. Sixteen cuts, two drifts, a shaft, and three tunnels were included on the survey (Figure 46). The company claimed partial interest in two of the three tunnels. One of the tunnels, labeled the Union Tunnel, originated from the Giant Mill Site (Mineral Survey #7592). Feature #100 is apparently the Union Tunnel (Pennsylvania Mine level F).

Lovering (1935, p. 95) reported that about 7.5 oz of gold, 3,660 oz of silver, and 56,000 pounds of lead were recovered from the 120 short tons of ore shipped from the Pennsylvania group. According to Downer (1903, p. 120), the Pennsylvanian Mine was the only continuously producing property at Rathborne (originally known as Decatur). Annual shipments of ore and concentrate had a combined weight of 800 tons.

The mine was worked constantly between 1889 and 1902 and produced $778,000 (Schneider and Cox, Inspector's report, June 23, 1906 – Pennsylvania Mine, p. 66, CBM).

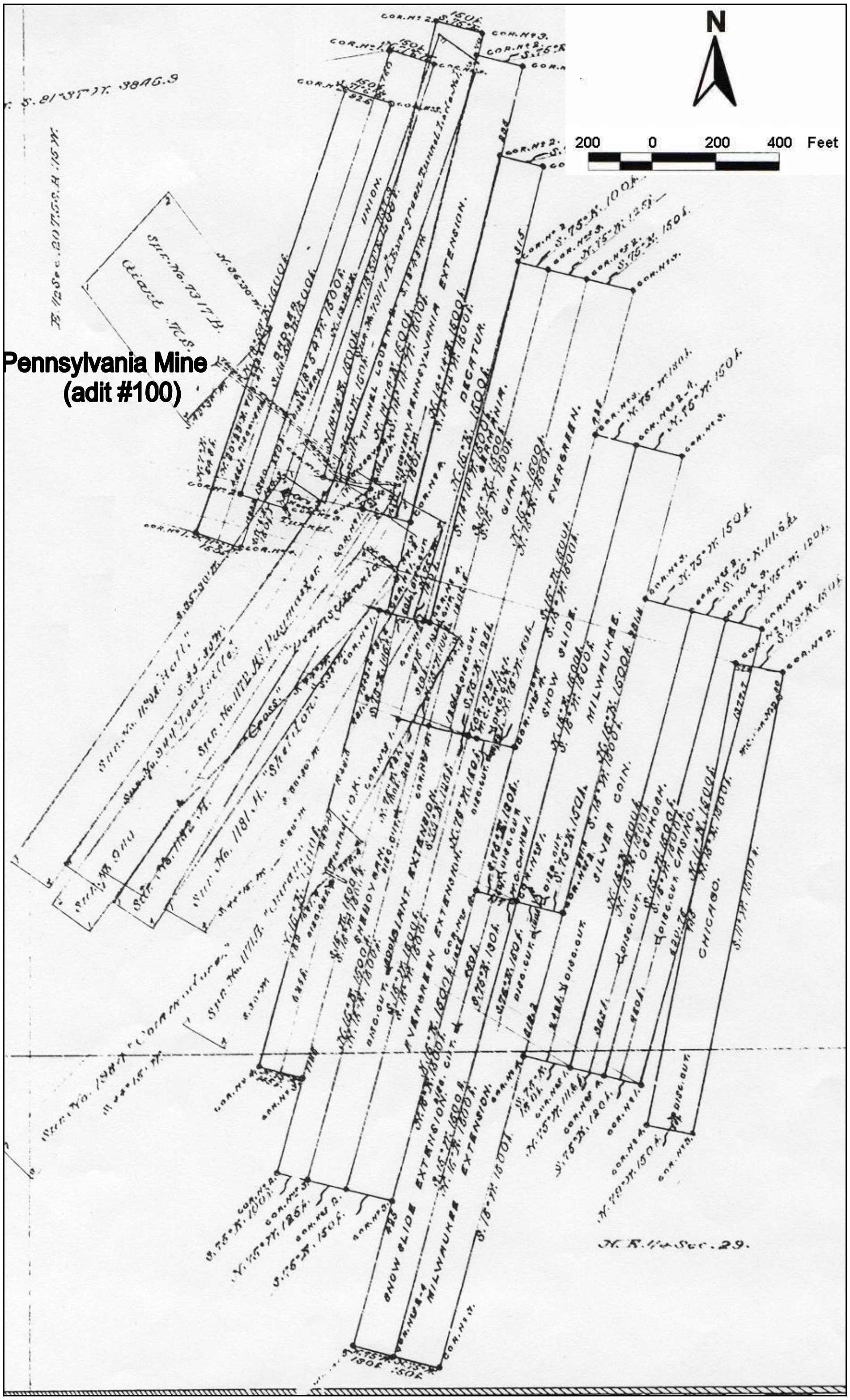


Figure 46. Mineral Survey No. 18774 showing Pennsylvania Mine (adit #100) (Modified; scale is approximate).

1903. Work at the Pennsylvania-Ohio Mine was concentrated on driving the lower crosscut adit expected to intersect the vein 150 feet deeper than the lowest working and facilitate the production of 20 to 30 tons of ore per day (*Mining Reporter*, March 26, 1903. p. 293). In July, the grade of the ore encountered in the lower tunnel was improving (*Mining Reporter*, July 30, 1903. p. 104). Forty workers were employed and two wagons were kept busy hauling the ore to the railroad. It is assumed that adit #100 is the lower working mentioned. Lovering (1935, p. 95) reported that about 594 oz of gold, 29,700 oz of silver, and 594,000 pounds of lead were recovered from the 5,900 short tons of ore shipped from the Pennsylvania group.

1904. About 121 oz of gold, 12,000 oz of silver, 486,000 pounds of lead, and 486,000 pounds of zinc were recovered from the 2,400 short tons of ore shipped from the Pennsylvania group (Lovering, 1935, p. 95).

1905. The New Pennsylvania Mines Company purchased the property of the Pennsylvania Mines Company (1905 Mine manager report-Pennsylvania Mines Co., p. 274, CBM). About 725 tons of ore were shipped (Schneider and Cox, Inspector report, June 23, 1906-New Pennsylvania Mines Co., p. 66, CBM). A "small" quantity of lead-silver ore was shipped from the Peru and Montezuma districts near Argentine, although no mines were mentioned (Lundgren, 1906, p. 211). About 39 oz of gold, 24,500 oz of silver, and 85,000 pounds of lead were recovered from the 5,900 short tons of ore shipped from the Pennsylvania group (Lovering, 1935, p. 95).

1906. The New Pennsylvania Mine Company (M.L. Murphy-president; W.R. Parker-secretary; W.B. LeWald-manager) owned the following claims: Pennsylvania (940), Leadville (944), Paymaster (1172), Hall (1190), Sheldon (1181 A&B), Cross (1182 A&B), Ouray (1171 A&B), Columbine-Annix-Annabel (13686 A&B), Forest City- Nellie Gray-Cinnamon Gulch-Cincinnati (7708A), Tram (11734), El Jebel (11733), and Assistant (Schneider and Cox, Inspector report, June 23, 1906-Pennsylvania Mine, p. 66, CBM). Nineteen workers were employed at the mine and mill. The fissure vein trended north 25° to 32° east, dipped 75°NW, ranged from 2 feet to 12 feet in thickness, and contained lead, zinc, and iron sulfides with gold and silver values. Crude ore contained 15% smelting grade worth $40 per ton, and 85% milling grade worth $22 per ton. The northeast ore shoot was opened along a length of 200 feet by a height of 200 feet. The main ore shoot was opened along a length of 400 feet by a height of 500 feet. The map could not be copied, but the description of the underground development is as follows:

Ohio Tunnel (adit #100)-bears S. 57° E. for 700 feet and intersects the Pennsylvania vein 375 feet from the portal and drifts southwest for 1,350 feet on the vein.
C Tunnel-driven 950 feet S. 35° W. of the Ohio Tunnel, is 232 feet above. Tunnel C intersects the Pennsylvania vein 575 feet from the portal and bears S. 58° E. Drifts were run in both northeast and southwest directions on the vein.
B Level-25 feet above and connects with Tunnel C.
A Tunnel-dug on the vein 185 feet above, connects with the Level B.
Shaft Level-185 feet above the Ohio Tunnel, connects to Level C by a winze sunk 100 feet southwest of the C level portal, and with the Ohio level by a two compartment raise. The 85(?) level connects with the above raise.

The Pennsylvania Mine dominated the output from the Montezuma district (Naramore, 1907, p. 236). The mine was developed through four crosscut adits, and a 60-ton mill concentrated the ore. Lovering (1935, p. 95) reported about 50 oz of gold, 3,000 oz of silver, 200,000 pounds of lead, and 200,000 pounds of zinc were recovered from the 1,000 short tons of ore shipped from the Pennsylvania group.

1907. The Pennsylvania Mine was one of the active properties in the Montezuma district (Naramore, 1908, p. 275). Lovering (1935, p. 95) reported that about 3,500 oz of silver were recovered from the 35 short tons of ore shipped from the Pennsylvania group.

1908. The Pennsylvania Mine and 50-ton mill were idle (Henderson, 1909, p. 401). The New Pennsylvania Mines Company (M.L. Murphy-president; William R. Parker-secretary; M.B. Le Wald-manager; E.A. Le Wald-superintendent) managed the property (1908 Manager report-Pennsylvania Mines Co., p. 185, CBM).

1909. The New Pennsylvania Mines Company (G. Hoffman-president; W.R. Parker-secretary; M.B. LeWald-manager; E.A. LeWald-superintendent) owned and operated the Ohio, Pennsylvania, Delaware, Delaware Extension, and Sunshine Lodes (1909 Mine manager report-Ohio, p. 128, CBM). All work at the mine stopped in 1907. The mine lay idle between 1907 and 1909. In June, operations resumed with a work force of about 60. Smelting ore ranged in value from $50 to $75 per ton. Ore worth $10 per ton was processed at the Pennsylvania mill. Gold, silver, lead, zinc, copper, and iron were recovered from the ore. Underground development attained a total depth of 580 feet and included 11,000 feet of tunnels drifts, and raises. It was not determined if the Delaware, Delaware Extension or Sunshine Lodes were connected underground or were included with the total underground development footages. Shipments from the Pennsylvania Mine were limited to “some” crude ore (Henderson, 1911a, p. 330). Apparently the mill was not in operation. Lovering (1935, p. 95) reported that about 39 oz of gold, 1,000 oz of silver, and 9,800 pounds of lead were recovered from the 58 short tons of ore shipped from the Pennsylvania group.

1910. The New Pennsylvania Mines Company (G. Hoffman-president; W.R. Parker-secretary; M.B. LeWald-manager; E.A. LeWald-superintendent) owned and operated the Pennsylvania and Ohio group of claims (1910 Mine manager report-Pennsylvania, p. 179, CBM). An average of 45 employees worked at the mine and 100-ton concentrating mill. Underground development included 12,000 feet of tunnels drifts, and raises. Smelting ore ranged in value from $22 to $40 per ton and mill ore was worth $8.50 per ton. Gold, silver, lead, zinc, copper, and iron were recovered from the ore. This same company owned and operated the Delaware and Delaware Extension Lodes (1910 Mine manager report-Ohio, p. 128, CBM). It was not determined if the workings had an underground connection.

About 9,000 short tons of ore were mined from the Pennsylvania group and reduced into 1,167 short tons of concentrate (Lovering, 1935, p. 95). Concentrates yielded about 160 oz of gold, 28,000 oz of silver, 193,000 pounds of lead, and 17,000 pounds of copper. The New Pennsylvania Mines Company concentrated a “considerable” quantity of lead ore from the Pennsylvania Mine in the company’s 100-ton mill (Henderson, 1911b, p. 438). The lead concentrate was shipped to Salida, Colorado.

1911. In October, the New Pennsylvania Mines Company (Augustus Hoffman-president; W.R. Parker-secretary; Frank Hines-treasurer; M.B. Le Wald-manager) owned the Pennsylvania, Ohio, Ouray, and Sunrise claims and leased the American Lode, Stuart mill site, and the claims included in Mineral Survey #7592 (J.R. Curley, Inspector report-Pennsylvania Mine, October 11, 1911, p. 149, CBM). Sixty-three workers were mining about 4,800 tons of ore per month. The northeast-southwest trending vein dips 80° south, averages 10-ft-wide, and was opened for a length of 1,500 feet. Underground development included 3,500 feet of tunnels, 15,000 feet of levels, and 500 feet of upraises, for a total combined length of 19,000 feet. The main opening, the 1,200-ft-long Ohio tunnel, was connected through 230-ft-high upraises to two higher tunnels, the 630-ft-long Pennsylvania tunnel and a higher 340-ft-long tunnel. Ore from the two main tunnels (Ohio and Pennsylvania) was transported to the mill by aerial tram. About 12,500 short tons of ore were mined from the Pennsylvania group and reduced into 1,700 short tons of concentrate (Lovering, 1935, p. 95). Concentrates yielded about 270 oz of gold, 46,000 oz of silver, 288,000 pounds of lead, 20,000 pounds of copper, and 206,000 pounds of zinc.

In another account, ore mined at the Pennsylvania Mine exceeded the capacity of the New Pennsylvania Mines Company's mill. Some of the ore was treated at the St. John mill. Both mills shipped the lead concentrate to Salida (Henderson, 1912, p. 562-563). According to the mine manager's report (1911, p. 223, CBM), the New Pennsylvania Mines Co. (Louis Aaron-president; William R. Parker-secretary; M.B. Le Wald-manager; B.G. Jacobs-superintendent) operated the mine with a "full" work force between January and April. Eight workers were employed between April and October. For the remainder of the year, the mine operated 24 hours per day.

1912. Shipments of ore from the Pennsylvania Mine continued although the concentration mill was idle. The mill was equipped with one Blake and one Krom crusher, two Chilean mills, one Akron and two McFarlane rolls, jiggs and trommels, Flood classifiers, 19 Card tables, and Callow tanks (Henderson, 1913, p. 662, 698). In another account (Colorado Bureau of Mines, 1913, p. 34), operations at the New Pennsylvania Mine were suspended early in the year. Shipping costs and excessive low-grade refractory ore rendered mining unprofitable. About 7 oz of gold, 850 oz of silver, 6,500 pounds of lead, and 485 pounds of copper were recovered from the 2,400 short tons of ore shipped from the Pennsylvania group (Lovering, 1935, p. 95).

1913. In August, the New Pennsylvania Mines Company (Louis Aarin-president; A.E. Schunk-secretary/treasurer) resumed operations at the Pennsylvania Mine (1913 Mine manager report-Pennsylvania Mine, CBM). In August, the 3,500-ft-long Ohio tunnel was used as the main opening to the mine (Curley, Inspector report, August 23, 1913, p. 778, CBM). Two 230-ft-high upraises connected the Ohio tunnel to a 555-ft-long upper tunnel. Total development included 4,000 feet of tunnels, 460 feet of upraises, and 15,000 feet of levels. About 190 feet of development was done during the year. Crude ore had a value of $22 per ton and assayed 0.1 oz per ton gold, 8 oz per ton silver, 3% lead, and 15% zinc. The cost of mining, transporting, and treating the ore was nearly $15 per ton. Work stopped in November (1914 Mine manager report-Pennsylvania Mine, CBM). The low-grade ore decreased in value to $14 per ton. About 3,000 short tons of ore were mined from the Pennsylvania group and reduced into 476 short tons of concentrate (Lovering, 1935, p. 95). Concentrates yielded about 61 oz of gold, 9,000 oz of silver, 70,000 pounds of lead, and 3,000 pounds of copper. Henderson (1914, p. 274) reported that "the New Pennsylvania mines and concentration mill operated part of the year".

1914. About 5 oz of gold, 795 oz of silver, 9,700 pounds of lead, and 795 pounds of copper were recovered from the 450 short tons of ore shipped from the Pennsylvania group (Lovering, 1935,

p. 95). Henderson (1916, p. 304) reported that lead ore was shipped from the New Pennsylvania Mine.

1918. Liberty Mining & Reduction Co. operated the Pennsylvania Mine (Earnest LeNeve Foster-president; E.C. Reybold Jr.-secretary/treasurer; John Bawden-lessee) with 5 employees (1918 Mine manager report-Pennsylvania Mine, CBM). Underground development included 40 feet of winzes, 30 feet of upraises, 166 feet of drifts, and 122 feet of crosscuts. About 27 tons of crude ore containing 45 oz per ton silver, 26% lead, 5% iron, and 10% sulfur was shipped. According to Lovering (1935, p. 95), about 4 oz of gold, 1,400 oz of silver, 17,000 pounds of lead, and 264 pounds of copper were recovered from 37 short tons of ore shipped from the Pennsylvania group. Henderson (1921, p. 870) reported that one carload of lead-silver ore was shipped from the Pennsylvania Mine.

1919. Liberty Mining & Reduction Co. (Earnest LeNeve Foster-president; E.C. Reybold Jr.-secretary/treasurer; John Bawden and P.A. Gillin-lessees) operated the Pennsylvania Mine for 90 days with 5 employees (1919 Mine manager report-Pennsylvania Mine, CBM). Underground development included 35 feet of winzes and 57 feet of drifts. About 101 tons of crude ore containing 0.03 oz per ton gold, 51 oz per ton silver, 16% lead, 6% iron, and 14% sulfur was shipped. About 8 oz of gold, 6,000 oz of silver, 38,000 pounds of lead, and 2,000 pounds of copper were recovered from 117 short tons of ore shipped from the Pennsylvania group (Lovering, 1935, p. 95). In another account, the company operated the mine for four months and shipped “several” cars of lead-silver ore (Henderson 1922a, p. 789).

1920. Lessees operated the Pennsylvania Mine owned by the Liberty Mining & Reduction Co. (1920 Mine manager report-Pennsylvania Mine, CBM). Most of the 1,092 tons of ore shipped from the Montezuma district came from the Pennsylvania Mine dumps (Henderson, 1922b, p. 592). Dump material was treated as part of an experiment in the company’s 100-ton gravity-concentration and oil-flotation mill on the property. Liberty Mining & Reduction Co. operated the Pennsylvania Mine and mill during part of the year (Colorado Bureau of Mines, 1921, p. 50). Gold, silver, lead, and zinc were recovered from the ore. Lovering (1935, p. 95), reported that 4 oz of gold, 1,600 oz of silver, and 9,000 pounds of lead were recovered from 33 short tons of ore. The ore was shipped directly to the smelter from the Pennsylvania group. An additional 1,000 short tons of ore were reduced into 134 short tons of concentrate. Concentrates yielded about 13 oz of gold, 4,000 oz of silver, 32,000 pounds of lead, and 3,000 pounds of copper.

1921. Liberty Mining & Reduction Co. (Earnest LeNeve Foster-president; Louis Aaron-secretary/treasurer; Thomas H. Teal-superintendent) owned and operated the Pennsylvania Mine about 300 days with 14 workers (Murray, Inspector report, November 21, 1921-Pennsylvania Mine; 1921 Mine manager report-Pennsylvania Mine, CBM). Nine employees operated the mill for 120 days. Underground development included 85 feet of raises and 115 feet of drifts. About 131 tons of crude ore and 804 tons of concentrates were shipped. Crude ore averaged 0.12 oz per ton gold, 70 oz per ton silver, and 15% lead. The 3,810 tons of ore processed at the mill yielded 801 tons of concentrate containing 0.17 oz per ton gold, 34 oz per ton silver, and 10% lead. Production included nearly 100 tons of ore shipped by 6 lessees that were recovered from dump material and a small block of ground in the mine. In another account, about 50 tons of lead-silver concentrate, mined and milled at Pennsylvania Mine, was shipped (Henderson 1924, p. 507). In another account, Liberty Mining & Reduction Co. operated the Pennsylvania Mine and mill and recovered gold, silver, and lead from the ore (Colorado Bureau of Mines, 1922, p. 43). About 5 oz of gold, 1,600 oz of silver, 5,000 pounds of lead, and 800 pounds of copper were recovered from 30 short tons of ore shipped directly to the smelter from the Pennsylvania group (Lovering, 1935, p. 95). An additional 8,000 short tons of ore were reduced into 900 short tons of concentrate. Concentrates yielded about 154 oz of gold, 34,000 oz of silver, 200,000 pounds of lead, and 16,000 pounds of copper.

1922. Liberty Mining & Reduction Co. leased the Pennsylvania Mine to Rinehart and company (G.A. Barr-manager) (1922 Mine manager report-Pennsylvania Mine, CBM). Rinehart operated the mine with 4 workers, 3 underground and 1 on the surface. Underground development included 75 feet of drifts. Fifty-six tons of ore yielding 41 oz per ton silver and 12% lead were shipped. About 8 oz of gold, 13,000 oz of silver, 32,000 pounds of lead, 755 pounds of copper, and 11,000 pounds of zinc were recovered from 79 short tons of ore shipped from the Pennsylvania group (Lovering, 1935, p. 95). Henderson (1925, p. 551) included the Pennsylvania Mine in a list of the eight "principal producing mines" in the Montezuma district. Colorado Bureau of Mines (1923, p. 45) reported that Liberty Mining & Reduction Co. operated the Pennsylvania Mine and mill during part of the year and recovered silver and lead from the ore.

1923. T.L. Rinehart and associates (T.L. Rinehart-manager) continued to operate the Pennsylvania Mine under a lease agreement with Liberty Mining & Reduction Co. (E. LeNeve Foster-president) (Murray, Inspector report, July 27, 1923-Pennsylvania Mine; 1923 Mine manager report-Pennsylvania Mine, CBM). Four workers underground and one on the surface operated the mine for 192 days. Underground development included 50 feet of drifts. Over 92 tons of crude ore, worth about $12 per ton and containing 70 oz per ton silver, 15% lead, and 20% copper, was hauled 12 miles to Keystone by wagon. At Keystone the ore was loaded onto C&S Railroad cars and shipped to Leadville. In July, "small" bunches of native copper were exposed in the mine in addition to "small" amounts of gray copper (tetrahedrite) and ruby silver (pyrargyrite and proustite) normally associated with the galena. Daley and Ryan (sub-lessees), operating through the McNalty tunnel, shipped 25 tons of ore in July containing 150 oz per ton silver. The 100-ton per day mill was idle. About 8 oz of gold, 8,000 oz of silver, 36,000 pounds of lead, and 2,000 pounds of copper were recovered from 112 short tons of ore shipped from the Pennsylvania group (Lovering, 1935, p. 95). The Pennsylvania Mine was one of the seven "principal producing mines" in the Montezuma district (Henderson, 1927, p. 643).

1926. Consolidated Pennsylvania Mines Inc. (A.C. Bullock-president; O.M. Troester-vice-president; P. Matuschka-secretary/treasurer; W.B. LeWald-manager) had a purchase and option agreement with Liberty Mining & Reduction Co. (trustees Victor Schling, A.E. Schimmer, A.J. Scheild and D.W. Strickland) on the Pennsylvania, Ohio, Delaware, and Brittle Silver mines (1926 Mine manager report-Pennsylvania Mine, CBM). Patented claims owned by Liberty associated with the Pennsylvania and Ohio Mine included mineral surveys 940 (Pennsylvania), 1182A&B (Cross), 1181 A&B (Sheldon), 1190 (Hall), 944 (Leadville), 1172 (Paymaster), 1171 (Ouray), 11734 (Tram), 1733 (El Jebel), 7317 B (Giant) and 7595 (20 claims). Unpatented claims included the Evergreen tunnel No. 1, also known as the Enterprise #1 (7317 A), Assistant (lode and mill site), Princeton, and Woodbridge mill site. Ditches and pipelines included the Le Neve and Foster. Other claims owned by the company were included under the discussion on the Delaware Mine and Brittle Silver group in this report. Five workers were employed to clean-up old tunnels in preparation for an examination and sampling (Murray, Inspectors report-

Pennsylvania Mine, July 21, 1926, CBM). Consolidated Pennsylvania Mines Inc. operated the Pennsylvania Mine and mill during part of the year (Colorado Bureau of Mines, 1927, p. 53). No ore was shipped.

1927. Consolidated Pennsylvania Mines, Inc. operated the Pennsylvania Mine and mill under a purchase option agreement with Liberty Mining & Reduction Co. (Murray, Inspectors report-Pennsylvania Mine, September 16, 1927; 1927 Mine manager report-Pennsylvania Mine, CBM). In September, two drifts were driven from a 7-ft by 8-ft by 700-ft-long tunnel. About 80 tons of ore were removed daily from old filled stopes and were transported over a 2-bucket tram to the mill for processing. New machinery was installed in the 150-ton per day mill. No crude ore was sold. About 190 tons of concentrates were shipped. Underground development included 60 feet of raises, 200 feet of drifts, 100 feet of crosscuts, and 200 feet of stopes. About 1,400 short tons of ore from the Pennsylvania group were reduced into 170 short tons of concentrate (Lovering, 1935, p. 95). Concentrates yielded about 9 oz of gold, 7,000 oz of silver, 38,000 pounds of lead, and 4,600 pounds of copper. Lead ore from the Pennsylvania Mine was concentrated at the company's gravity-concentration mill (Henderson, 1930, p. 563). Colorado Bureau of Mines (1928, p. 58) also recognized Consolidated Pennsylvania Mines, Inc. as the operator of the Pennsylvania Mine and mill.

1928. Consolidated Pennsylvania Mines, Inc. (P. Matuschka-general manager) operated the Pennsylvania Mine for 7 months and the mill for 2 months (1928 Mine manager report-Pennsylvania Mine, CBM). Sixteen hundred tons of crude ore were processed into 160 tons of concentrate at the mill. Crude ore worth $7 per ton contained 0.01 oz per ton gold, 45 oz per ton silver, 3% lead, 0.03% copper, and 2½ % zinc. Concentrates contained 15 oz per ton gold, 39 oz per ton silver, 19% lead, 1% copper, and 8% zinc. In September, ore from the 2- to 10-ft-wide vein and from some of the old filled stopes was trammed to the mill from the 4-ft by 7-ft by 2,100-ft-long main operating tunnel (Murray, Inspectors report-Pennsylvania Mine, September 20, 1928, CBM). The mill was remodeled into a 150-ton per day gravity-flotation-concentration mill. In December, the lower F-level adit intersected the vein 225 feet from the portal and drifted a distance of 1,500 feet on the vein (Becker, Inspectors report-Pennsylvania Mine, December 8, 1928, CBM). An 88-ft raise connected the F level to the E level, where about 50 feet was open in both directions from the raise. The raise continued another 88 feet to the D level, where about 100 feet was open on each side of the raise. The raise continued to the C level, exposing a 6-ft-wide vein assaying $35 per ton. An aerial tram at the portal of the C level transports the ore to the mill. An electric motor was used to haul the ore from the F level to the mill. Ore from the Pennsylvania vein was mined from an outcrop on the Paymaster Lode and treated at the Pennsylvania gravity-concentration-flotation mill (Henderson, 1931, p. 860). The mill was operated only part of the year. Lovering (1935, p. 95), reported that 1,400 short tons of ore from the Pennsylvania group were reduced into 100 short tons of concentrate. Concentrates yielded about 12 oz of gold, 4,200 oz of silver, 38,000 pounds of lead, 2,000 pounds of copper, and 13,000 pounds of zinc. Colorado Bureau of Mines (1929, p. 51-52) concurred that the Consolidated Pennsylvania Mines Inc. operated the Consolidated Pennsylvania Mine and Pennsylvania Mine.

1926 and 1929. Lovering (1935, p.1, 93, and plate 33) mapped underground workings in the Montezuma quad. Level F (adit #100) and the accessible parts of level C (Figure 47) were mapped in the Pennsylvania Mine. Lovering noted that a "heavy" flow of water was issuing from the breast of level F and on level C. The Ouray vein was intersected 225 feet east of the Pennsylvania vein.

1929. Consolidated Pennsylvania Mines, Inc. (A.C Bullock-president; O.M. Troest-vice-president; P. Matuschka-secretary/treasurer) operated the Pennsylvania Mine (Becker, Inspectors report-Pennsylvania Mine, September 17, 1929; 1929 Mine manager report-Pennsylvania Mine, CBM). Henry L. Ebner and Herman Dahms had a contract to purchase the mine, but the deal apparently did not go through. Two workers operated the mine from the surface. The mine was operated underground for 3 months. The mill was idle and no ore was shipped from the mine. Total underground development, about 7,000 feet, included a series of crosscuts, drifts, and raises. Consolidated Pennsylvania Mines Inc. operated the Pennsylvania Mine during part of the year and shipped gold-silver-lead-zinc ore (Colorado Bureau of Mines, 1930, p. 58).

1930. Consolidated Pennsylvania Mines, Inc. operated the Pennsylvania Mine for 2 months (1930 Mine manager report-Pennsylvania Mine, CBM).

1939. “A few lots of smelting ore were shipped from the Pennsylvania group” (Henderson and Martin, 1940, p. 280).

1940. Ore mined at the Pennsylvania Mine was shipped to the Leadville smelter (Henderson and Martin, 1941, p. 308).

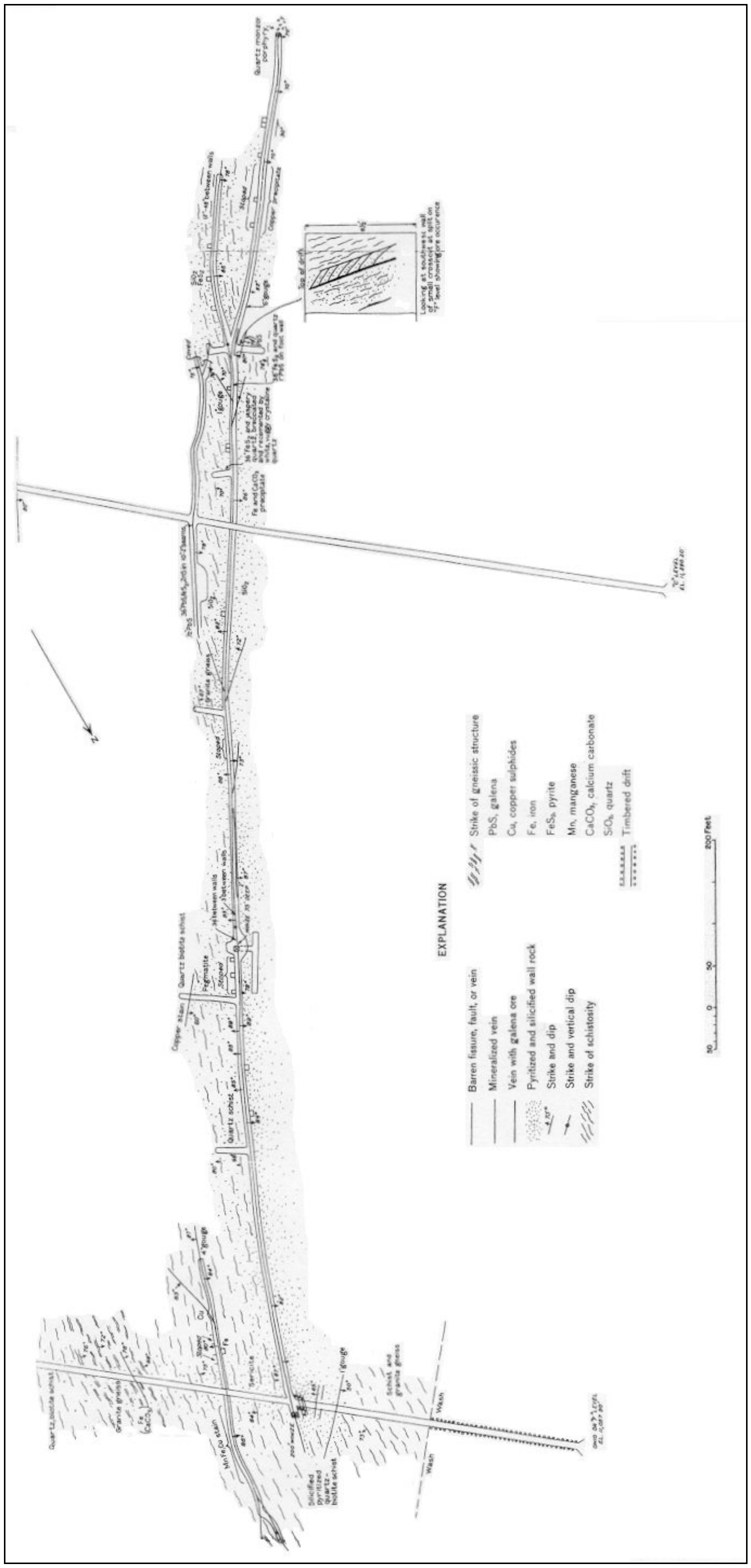


Figure 47. Underground map of Ohio or level F (adit #100) and part of level C in the Pennsylvania Mine. (Modified from Lovering 1935, plate 33.)

1941. In June, Carl Petterson and associates (Carl Petterson-manager) operated the Pennsylvania Mine and mill under a lease agreement (Becker, Inspectors report-Pennsylvania Mine, June 9, 1941, CBM). Work was concentrated on remodeling the mill. The company had plans to remove and process fill material from some of the old stopes. Zinc and lead flotation circuits were installed in the 150-ton per day mill (Henderson and Martin, 1943, p. 313). No ore was mined.

1942. Summit County Lead and Zinc Company (Byron G. Rogers-president; Carl Petterson-manager) operated the Pennsylvania Mine for 9 months under a lease agreement (Becker, Inspectors report-Pennsylvania Mine, June 21, 1942; 1942 Mine manager report-Pennsylvania Mine, CBM). Four employees operating underground and 3 on the surface shipped 5 tons of crude ore worth $65 per ton. In December, following 2 years of development work, the company finally reached the ore body. A few lots of direct-smelting ore were shipped from the Pennsylvania Mine (Henderson, 1943, p. 342).

1943. Randolph J. Swanson and associates operated the Pennsylvania Mine under a lease agreement (Becker, Inspectors report-Pennsylvania Mine, August 3, 1943; 1943 Mine manager report-Pennsylvania Mine, CBM). Work was concentrated on retimbering the No. 2 level between stope #1 and raise #2. In August, ore was stoped from the F level. Twenty-eight tons of direct-smelting ore from the Pennsylvania Mine were shipped to Leadville (Henderson and others, 1945, p. 336).

1953. A small tonnage of direct-smelting ore was shipped from the Pennsylvania Mine (Martin and Kelly, 1956, p. 272).

1985. The Colorado Division of Mined Land Reclamation constructed a diversion system for the Pennsylvania Mine effluent (Emerick and others, 1988, p.346-347).

1986. Emerick and others (1988, p. 346), from the Colorado School of Mines, diverted the effluent from the Pennsylvania Mine into a natural wetland below the Pennsylvania Mill. The project was aimed at evaluating the capability of the wetland in removing metal concentrations.

GEOLOGY

The Pennsylvania Mine is developed along a vein hosted primarily in schistose rocks near the contact with the Montezuma Stock (Lovering, 1935). Quartz schist, quartz-biotite schist, injection gneiss, granite gneiss, quartz monzonite, and granite are common. The vein strikes N20-35E and averages about N30E, dipping steeply west in most places, and locally overturned. The wallrock is silicified and pyritized up to 30 feet from the vein. Galena is the most abundant mineral in the veins, with pyrite and chalcopyrite also common.

SITE DESCRIPTION

Adit #100 (Pennsylvania Mine-level F) is about 1,000 feet east of FR #262 and south of Peru Creek (Figure 2). A mine road off of FR #262 accesses the portal area at the top of the dump. A plumbing system was built in 1990 to handle effluent from the Pennsylvania Mine (DMG files). Effluent from the completely caved portal enters a grated sewer inlet. The system apparently was draining all of the effluent in 1993, however the capacity was exceeded in 2001. A pond was formed over the inlet and some of the effluent overflowed onto the dump (Figures 48 and 49).

Most of the effluent was piped about 1,000 feet to a cinder-block building and into a settling pond (Figures 50 and 51). The building houses an inactive lime/limestone dosing system designed to add alkalinity to the mine effluent. The effluent was then directed into the settling pond to allow metal oxy-hydroxide floc to settle out of solution. Water from the settling pond flows into a wetland area next to Peru Creek. The grassy wetland area contains mill tailings from the adjacent Pennsylvania Mill (Figure 50). Two lined ponds northeast of the settling pond, not present in 1993, did not appear to be in use (Figure 50). One was dry; the other was filled with water. Iron deposits in the pipeline have apparently constricted the pipe and reduced its capacity to remove all of the effluent collected at the portal. Dump #200 contained an estimated 17,700 cubic yards of material (Figure 52).

Figure 48. Close-up view of grated effluent inlet, Pennsylvania Mine-level F (#100). Photo taken Sept, 1993.

Figure 49. Grated effluent inlet and Pennsylvania Mine-level F adit (feature #100). Photo taken 10/2001.

Figure 50. Pennsylvania Mill area, with inactive water treatment facility.

Figure 51. Effluent outlet from the inactive Pennsylvania Mine water treatment facility.

Figure 52. Pennsylvania Mine dump (feature #200).

WASTE AND HAZARD CHARACTERISTICS

The Pennsylvania mine portal is a source of perennial ARD discharging to Peru Creek. The discharge ranged from 0.33 to 0.36 cfs (148 to 162 gpm) when measured by agents for CDMG in June and July of 1978. The pH ranged from 3.0 to 4.85, and conductivity ranged from 1,400 to 1,525 µS/cm. During the CGS inventory in 1993, the portal discharge had pH of 3.6 and conductivity of 700 µS/cm. Flow was measured at only 10 gpm, but notes on the inventory form suggest that the measurement was made in drainage that escaped diversion to the water treatment system. In 2001, CGS personnel observed effluent emerging from the mine, but no measurements were made. Data from the 1978 investigation are shown in Table 5.

Table 5. Selected results of chemical analyses for water samples from Pennsylvania Mine portal and Peru Creek during 1978 sampling events (from Holm and others, 1978). Concentrations in µg/L with exception of pH (standard units), and conductivity (µS/cm).

Analyte	PM-1 Penn Mine effluent before Peru Creek	PM-2 Penn Mine Portal	PC-1 Peru Creek below Penn Mine effluent	PC-6 Peru Creek above Penn Mine effluent
Flow (cfs – July 1978)	0.33	0.33	53	15.3
pH	3.2	3.0	5.5	6.5
Conductivity	1000	1,525	130	80
Hardness	610	110	47	36
Aluminum (dissolved)	14,000	12,000	1,200	ND
Cadmium (dissolved)	60	0.011	7.9	0.9
Copper (dissolved)	8,500	10,600	140	13
Iron (total recoverable)	71,000	112,000	660	ND
Lead (dissolved)	125	83	17	6
Manganese (dissolved)	20,000	27,300	1,300	240
Zinc (dissolved)	36,000	75,600	2,000	150

ND = Not Detected

The Pennsylvania Mine portal was assigned an EDR of 2, indicating significant environmental degradation, due to the effluent discharged to Peru Creek; the physical hazard rating assigned was 5, indicating no hazard.

All six of the waste rock dumps inventoried in the Pennsylvania Mine area received EDR's of 5, indicating no environmental degradation. Tailings feature #206 was assigned an EDR of 3, indicating potentially significant environmental degradation. Spring and mine drainage runs through the tailings and continues down the watershed at a rate of 1.5 gpm. A test of the drainage showed pH of 4.1 and conductivity of 800 µS/cm.

A potential contaminant source worth considering is infiltration through waste-rock dumps. Combining the surface areas of all the waste rock dumps and tailings piles in the Pennsylvania Mine area gives a cumulative surface area of almost 50,000 sq ft. Assuming 36 inches of annual precipitation (CSU, 2002), it is possible that over 2 gpm is infiltrating through the dumps and tailings and reporting to ground water, possibly acquiring contaminants from the facilities and releasing them to ground water.

UNPATENTED CLAIMS FILED WITH BLM

The Federal Land Policy and Management Act required that unpatented mining claims located on BLM land prior to the act had to be filed by October 22, 1979. Claims located after that date must be filed within 90 days of location. A quarter section is the smallest geographic subdivision listed in these BLM records.

For the mines in Cinnamon Gulch, most of the unpatented claims are in the southwest ¼ of section 20. The Denver #1 and #2 claims were first located in 1942 and filed with the BLM by the Pennsylvania Gold and Silver Mining Company. In 1979, the Pennsylvania Gold and Silver Mining Company located the McClain #1 and #2 claims. In 1981, the Pennsylvania Gold and Silver Mining Company filed assessment work for the last time and the Gold Depository Company located the Denver #1 and #2 claims. Gold Depository Company's last assessment year was 2000. In 1987, Transpacific Tourism located the Denver No. 1 and No. 2 and the McClain No. 1 and No. 2 claims. Transpacific Tourism filed assessment work in 1991 for the last time. The Delaware Tunnel, Brittle silver group, and Pennsylvania Mill are in the southwest quarter of section 20.

During 1977, Kennecott located the RUB claim block, consisting of 11 claims, in the northeast quarter of section 20. Kennecott's last assessment work was filed in 1978. In 1979, Kennecott located the RUB 26 and 28, but failed to file assessment work after 1980. On the Montezuma PBS map, the Pennsylvania Mine (adit #100-level F) is near the northern side of the southeast quarter of section 20.

In 1978, Kennecott located the REV claim block (8 claims) mostly in the southwest quarter of section 29. REV #34 and #131 were the only claims located in the northwest quarter of section 29. The Rich Ore Lode is in the northwest quarter of section 29. Kennecott's last assessment work was filed in 1985.

MIGRATION PATHWAYS

SURFACE WATER PATHWAY

The discharge from Cinnamon Gulch at its mouth cannot be directly measured due to the numerous alluvial fan distributaries into which the creek splits before its confluence with Peru Creek. However, the total discharge from Cinnamon Gulch was calculated by measuring the discharge in Peru Creek above and below the various outputs from Cinnamon Gulch. Thus, the discharge from Cinnamon Gulch ranges from 460 gpm at low flow to 1,920 gpm at high flow. At low flow, approximately 8.4 gpm is from discrete anthropogenic sources (9 mine adits), and 3 gpm was measured from discrete natural sources in the watershed. The balance of approximately 449 gpm represents the amount of flow that Cinnamon Gulch gains from ground-water discharge, which amounts to 157 gpm above sample site CG-32, and 292 gpm below CG-32 (Figure 3).

Due to the inflow from Cinnamon Gulch, Peru Creek experiences a drop in pH and increases in concentrations of Al, Cu, F, Fe, Mg, Mn, Si, Na, SO_4, and Zn. This indicates that Cinnamon Gulch perennially has a lower pH than Peru Creek, and higher concentrations of these constituents. Four samples from the two distributaries (CG-3 & -4 at high flow and CG-35 & -39 at low flow) contained concentrations of dissolved aluminum, cadmium, copper, lead, manganese, and zinc exceeding standard in all four samples, and total recoverable zinc exceeding standard in one.

Five of the adits inventoried in Cinnamon Gulch cause “significant” environmental degradation (EDRs of 2), due to drainage effluent impacting the watershed. Five other adits cause “slight” environmental degradation (EDRs of 4), due to lesser amounts of effluent.

The Pennsylvania Mine, which is not part of the Cinnamon Gulch watershed but was included in this investigation, is a source of perennial ARD discharging to Peru Creek, ranging from 0.33 (148 gpm) at low flow to 0.36 cfs (162 gpm) at high flow.

Four waste rock dumps in the watershed cause “slight” environmental degradation (EDRs of 4), due to the toe of the dumps being in contact with surface water. Spring and mine discharge water flows over and through the Brittle Silver Mountain tailings, causing “slight” environmental degradation (EDR of 4).

There are no residences within one mile of the site that could be adversely affected by surface water contamination from the area. However, there are a few residences along Peru Creek downstream from Cinnamon Gulch, between one and two miles from the site. It is not known whether the sources of water for these homes are surface water or ground water, but there are well permits on record in these areas (see discussion in next section).

GROUND WATER PATHWAY

The mines in the Cinnamon Gulch watershed are developed in either the quartz monzonite of the Montezuma Stock, or in the surrounding Precambrian gneiss and schist country rock. Other than the Montezuma Shear Zone, structural disturbances such as faults and fractures are not mapped in significant quantity in the area (Neuerburg and Botinnelly, 1972). However, hydrothermal alteration is widespread in the watershed and secondary porosity associated with the alteration may enhance ground water movement. It is impossible to make any quantitative assessments of ground water flow at this time because no aquifer test data are available for the area.

There are no permitted wells within a mile of the site (DWR Well Records, 10 February 2004), so contamination of nearby wells is not an issue. However, there are 183 permit applications in the adjacent downstream township (T5S, R76W), west of and hydrologically downgradient from Cinnamon Gulch. There are seven well permits on record for Sections 23 and 24, which encompass Peru Creek between one and two miles downstream from the site. Scenarios are conceivable during which contamination from Cinnamon Gulch could affect these wells, for example during times of depressed ground-water levels that cause Peru Creek to become a losing stream adjacent to the home sites, allowing contamination to be captured by the wells.

The main stream of Cinnamon Gulch gains almost 400 gpm at low flow between sample site CG-27 and its confluence with Peru Creek. However, discrete measurable sources along this reach total less than 8 gpm. The reach therefore appears to be a ground-water discharge zone. The water chemistry data indicate that there is little appreciable dilution along this reach, which suggests that contaminants are being transported in the subsurface to the ground-water discharge zone. The source of these contaminants may not be entirely anthropogenic, due to the widespread hydrothermal alteration in the watershed. Hence, remediation of anthropogenic surface features, and removal of sources of surface water contamination, may not remove the major sources of metals and acidity from the watershed.

A less obvious source of contamination could originate from the waste rock dumps and tailings scattered around the watershed. At least 11 dumps and tailings piles were measured in the four inventory areas, totaling over 50,000 sq ft in surficial area. Assuming annual precipitation of 36 inches (CSU, 2002), and neglecting evaporation, over 2 gpm of precipitation could be infiltrating into the waste dumps, picking up metals and acidity, and discharging to the ground water system. The actual loading from these sources is unknown until further testing is done, but these dumps are a potential source of contaminants that should not be ignored in the assessment of remediation alternatives.

SOIL EXPOSURE PATHWAY

The possibility of ingesting toxic levels of metals is the primary concern regarding this pathway. There are no residences in the immediate vicinity, but the area is used for recreational activities such as camping and hunting. Metal concentrations as great as 2.6% lead, 1.9% zinc, and 0.3% copper were measured in selected waste rock dumps (Table 3). A detailed assessment of soil exposure pathways is beyond the scope of this investigation, but lack of residences within the watershed probably reduces the potential for exposure.

AIR EXPOSURE PATHWAY

There are no residences in the immediate vicinity, which reduces the potential for exposure, but the area is used for recreational activities such as camping and hunting. A detailed assessment of air exposure pathways is beyond the scope of this investigation.

WATER CHEMISTRY CHARACTERIZATION

The pH is acidic throughout the Cinnamon Gulch watershed, ranging from a low of 2.91 (CG-22) to a high of 5.42 (CG-31). Eighteen of 33 water samples collected by CGS in 2001 had pH below 4. Numerous ions are consistently elevated in samples from around the watershed. Average dissolved concentrations of selected metals at low flow were 5.5 mg/L aluminum, 5.5 mg/L manganese, 2.8 mg/L zinc, 14 μg/L cadmium, 260 μg/L copper, and 82 μg/L lead.

Numerous ions exceed State of Colorado water quality standards. Four examples at low flow are shown in Figure 53 (copper, lead, sulfate, and zinc), which are plotted with respect to position from upstream sampling locations to downstream, compared to relevant water quality standards.

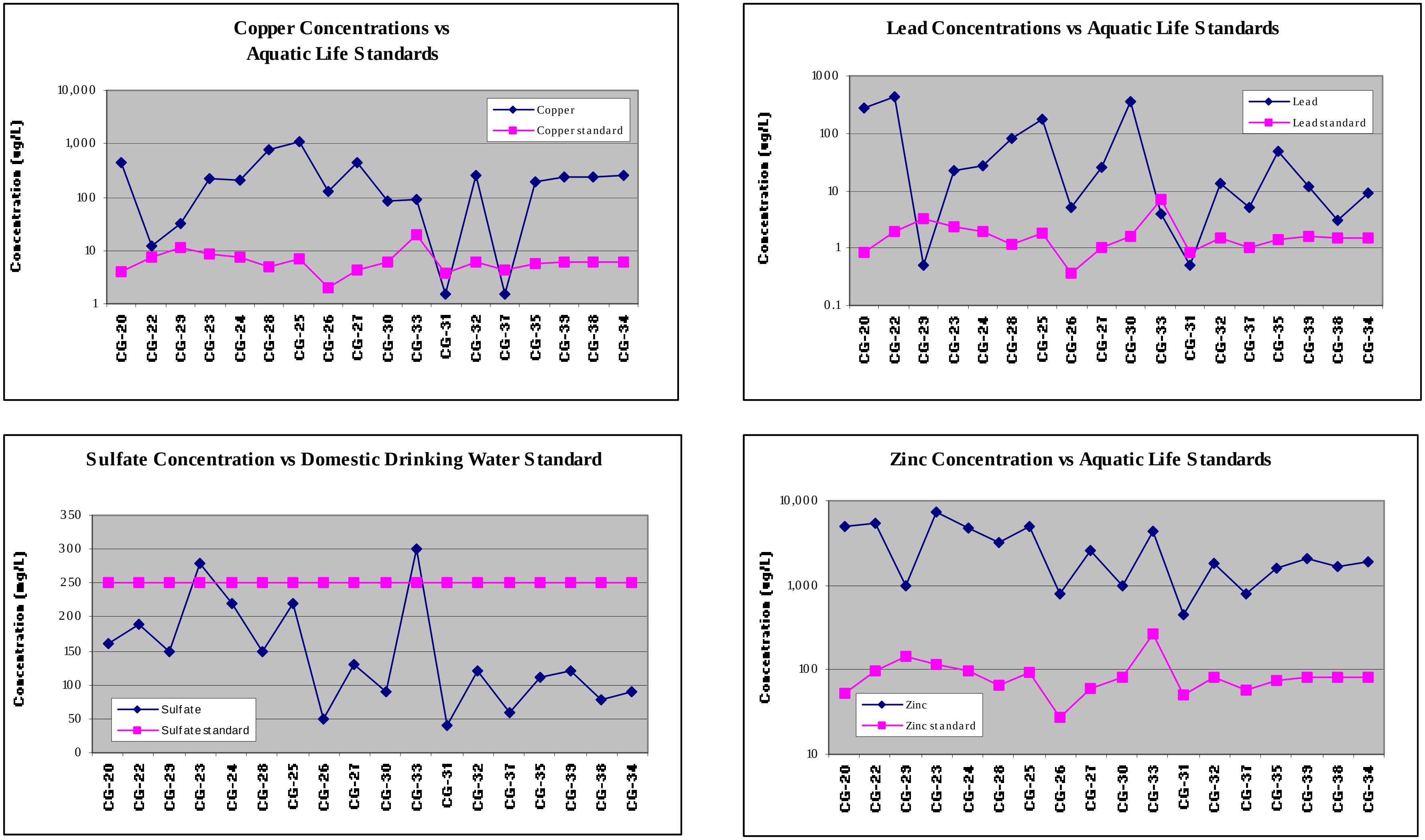


Figure 53. Concentrations of Selected Ions (dissolved) at Low Flow versus Relevant Water Quality Standard

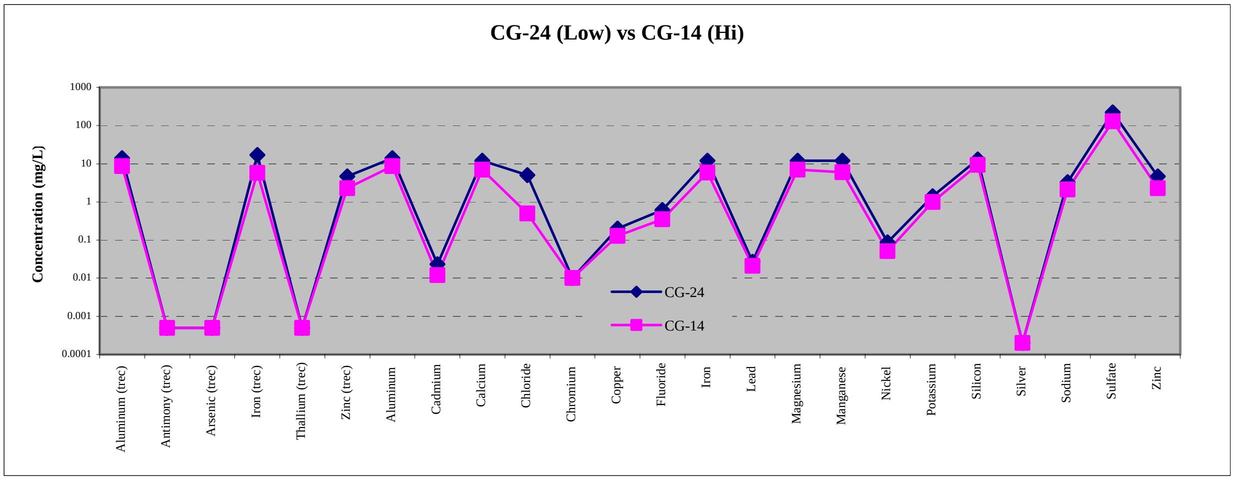
For copper, lead, and zinc, the standard shown is the Colorado statewide aquatic life water quality standard for chronic exposure. Colorado has no aquatic life standard for sulfate, so the standard shown is the secondary drinking water standard of 250 mg/L. Figure 53 shows zinc exceeding standard in all samples, copper exceeding standard in all but two samples, and lead exceeding standard in all but three. Not shown is cadmium, which exceeds standard in all samples; iron and nickel, which exceed standard in about half of the samples; aluminum, which exceeds standard in all but one sample; and manganese, which exceeds standard in all but two samples. Only two samples exceed the secondary drinking water standard for sulfate.

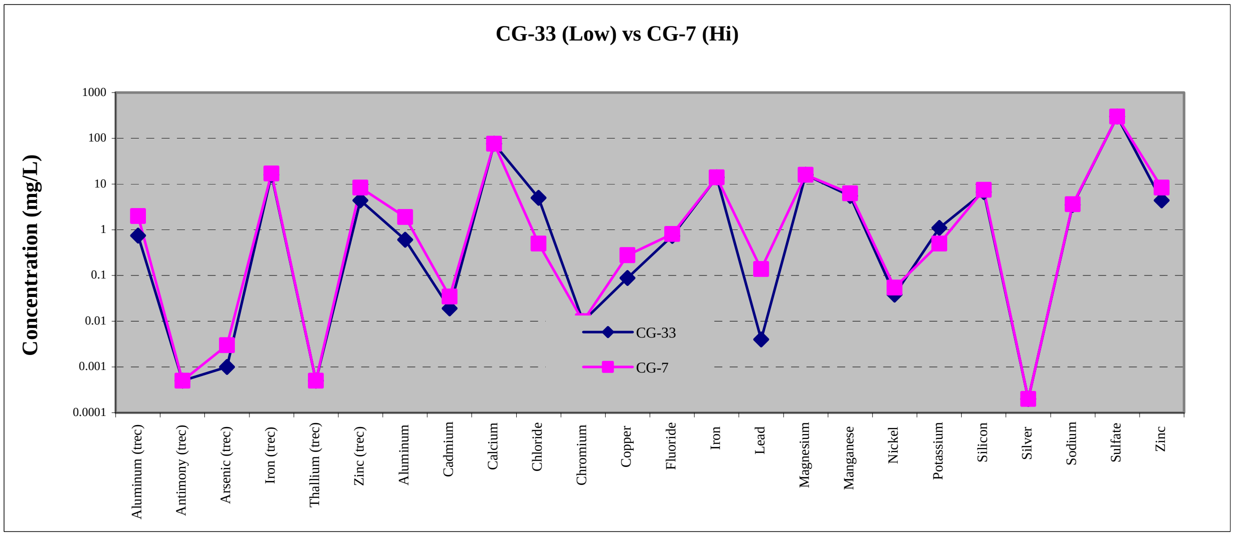
A comparison of water chemistry data from low-flow versus high-flow conditions reveals minimal difference between the concentrations of most constituents during the two flow regimes, with only minor exceptions. Three examples are provided in Figure 54. The top plot shows a comparison of sample CG-24 (low-flow) versus CG-14 (high-flow), taken from an adit accessing the Rich Ore Lode. This plot reveals what one might expect – that low-flow conditions produce higher concentrations than high-flow conditions. High flow should provide some dilution from snowmelt and storm precipitation, and hence lower overall concentrations. However, the middle plot, which shows a comparison of sample CG-33 (low-flow) versus CG-7 (high-flow), Delaware Mine effluent, reveals the opposite. None of the constituents measured during low-flow conditions has a higher concentration than its counterpart during high-flow conditions. This phenomenon was not investigated in detail, and further study would be required to determine why some stations returned higher concentrations at low-flow and others did not. One possible explanation could center around the fact that samples CG-33 and CG-7 were collected from adit effluent. The water chemistry could be a reflection of a dampening effect that the unsaturated zone has on recharge, such that weathering products flushed by seasonal recharge are discharged over a period of time, rather than in a rapid pulse. The system might be buffering the relatively large pulses of snowmelt and their diluting effects. On examination of data from an in-stream sample site, illustrated by samples CG-34 and CG-1 in the bottom plot of Figure 54, most constituents (14 of 24) show the expected, i.e. higher concentrations during low flow, probably because the stream is more prone to the immediate effects of runoff than are the adits.

QUANTIFICATION OF NATURAL VS ANTHROPOGENIC SOURCES

Figure 55 shows the flows recorded during both high-flow and low-flow conditions. Sample sites that are shaded on Figure 55 are presumed to be from natural sources (i.e., there is no visible hydraulic connection between an anthropogenic feature and the sample site). However, some degree of unmeasurable subsurface hydraulic connection is possible.

Assuming that the anthropogenic sources are fully accounted for, then 8.4 gpm discharges from discrete and measurable anthropogenic sources under low flow conditions. The total discharge from the watershed was measured at 460 gpm, so it appears that anthropogenic sources account





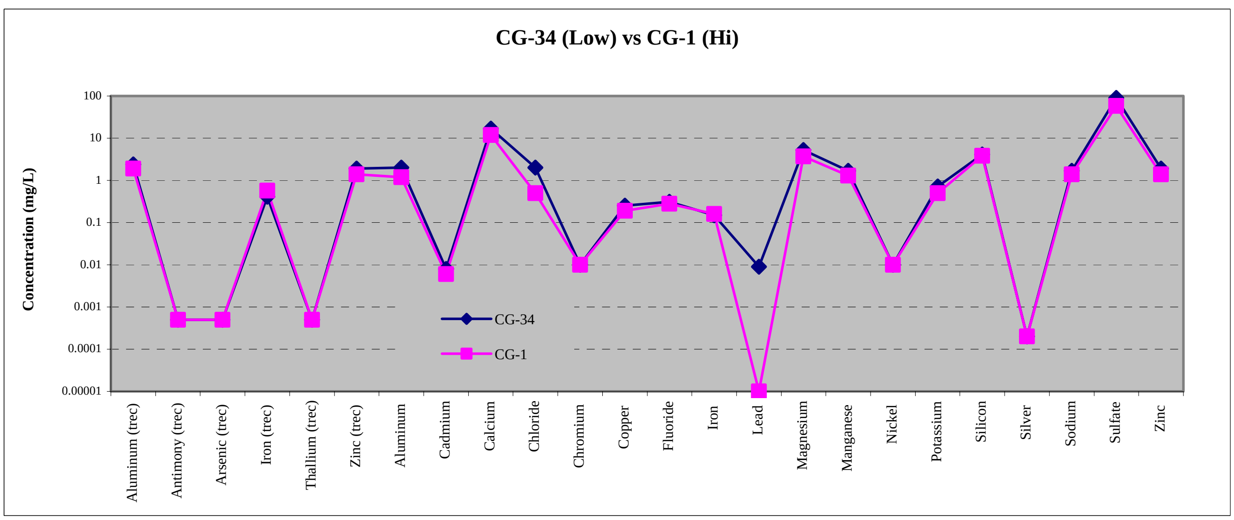


Figure 54. Comparison of chemical concentrations of selected samples in low-flow versus high-flow conditions.

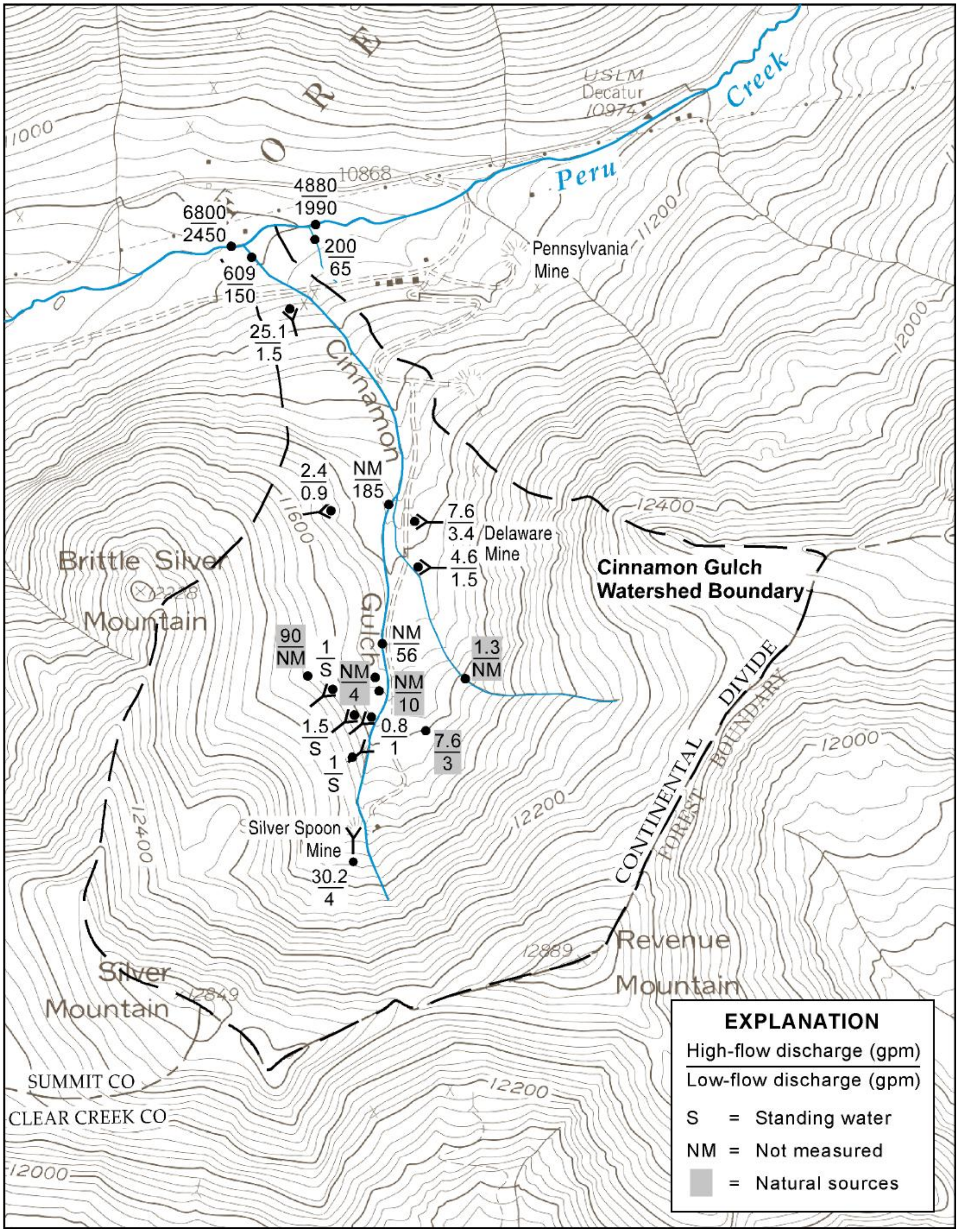


Figure 55. Measured Streamflows During High-Flow (July) and Low-Flow (October) Conditions.

for only about 2% of the total surface discharge from the watershed at low flow. In high flow conditions, the proportion of anthropogenic sources increases slightly to 4% (82 gpm). These proportions could be increased depending on the quantity of ground-water flow derived from infiltration through waste dumps and tailings.

CONTAMINANT LOADINGS

Loadings of selected constituents at the mouth of Cinnamon Gulch during both low-flow and high-flow conditions are shown in Table 6. The loadings at low-flow were calculated by subtracting the loadings at sample site CG-38 from the loadings at sample site CG-34, and for high-flow by subtracting CG-2 from CG-1. Direct measurement of the loadings at the mouth of Cinnamon Gulch was not practical due to the numerous distributaries into which the drainage had split.

Table 6. Loadings of Selected Constituents from Cinnamon Gulch

Constituent	Loading (grams/day)					
	Low-flow Total	Low-flow Anthro-pogenic	% Anthro-pogenic	High-flow Total	High-flow Anthro-pogenic	% Anthro-pogenic
Aluminum (trec)	12,500	277	2	36,000	1,790	5
Cadmium	31	1	3	90	6	7
Copper	844	13	2	2,500	115	5
Iron (trec)	1,350	1,050	78	7,300	4,980	68
Lead	88	9	10	-106	86	NA
Manganese	7,520	400	5	21,600	1,790	8
Nickel	ND	2	NA	ND	11	NA
Sulfate	360,000	12,000	3	700,000	50,000	7
Zinc (trec)	6,900	250	4	17,300	1,360	8

trec = Total recoverable NA = Not applicable ND = Not detected

Several observations can be made from Table 6. First, the percentage of total loading derived from surface anthropogenic features during low flow is in the range of 2-4% for most constituents, which is slightly higher than, but generally in agreement with, the proportion indicated from flow. The notable exception is iron at 78%. Nickel was not calculated due to concentrations below the detection limit at both sample sites on Peru Creek. Second, the total loading from each constituent increases by a factor of two to three from low flow to high flow, and in one case (iron) by a factor greater than 5. The increase seems reasonable and consistent with the streamflow, which increases by a factor of about 4 from low-flow to high-flow (460 gpm vs 1,920 gpm).

In conjunction with an increase in total loadings during high flow, the percentage of the total loading derived from surface anthropogenic features increases at high flow, ranging from 5-8% for most constituents. Again, this is slightly higher than, but generally in agreement with, the increase in anthropogenic contribution indicated by the streamflow data. The notable exception again is iron at 68%. The higher anthropogenic contribution calculated by the loading data versus the streamflow data indicates that ionic concentrations are higher in anthropogenic sources than in natural sources.

Two interesting observations regarding element mobility are seen in the data. First, the total loading of lead during high-flow actually decreases along the reach where Cinnamon Gulch enters Peru Creek (shown as –106 in Table 6). Two possible reasons: 1) the data are within the analytical uncertainty of the laboratory methodology and do not reflect the true concentration, or 2) lead is being removed from solution between CG-2/CG-38 and CG-1/CG-34, by either precipitation or adsorption onto other precipitating phases (see later discussion pertaining to solubility controls).

An interesting question arises concerning the iron data. Why is the proportion of anthropogenic contribution of iron so much greater than the other constituents? The most probable answer is that the anthropogenic contribution of iron is actually no greater than the other constituents. Iron is most likely removed by precipitation along the reach of Peru Creek between sample sites CG-2/CG-38 and CG-1/CG-34. This is discussed in further detail later, under solubility controls.

WATERSHED CAPTURE AND HYDROLOGIC BUDGET

The Cinnamon Gulch watershed covers an area of 0.93 square miles. The annual precipitation rate is approximately 36 inches per year (CSU, 2002), and the annual evaporation rate (lake) is approximately 30 inches per year (CGS, 2003). Thus, with a net precipitation of 6 inches per year over the watershed, total low flow discharge from the watershed, including surface-water flow and ground-water flow, should be around 0.5 cfs (225 gpm). However, surface-water discharge from the watershed was measured at just over 1 cfs (460 gpm) in October 2001. Considering the various hydrologic inputs and their potential short-term deviation from long-term averages, this discrepancy is not unreasonable. Interbasin transfer is not considered to be significant.

The proportion of ground-water flow that has been intercepted by underground workings, and is now discharging from adit portals scattered around the watershed, is relatively low (2.4% of the total low flow discharge from the watershed; 4% in high-flow). From a remediation perspective, this is both good and bad news. It is encouraging in that a very small proportion of the total water budget is discharged from adits, which are difficult to remediate, but discouraging in that removing the adit discharges would remove only a small percentage of the total contamination in the watershed, and would likely have minimal impact.

SOLUBILITY CONTROLS

Selected chemical analyses were modeled in the USGS geochemical modeling code PHREEQC (Parkhurst and Appelo, 1999) to evaluate mineral solubility controls and to verify assumptions regarding precipitation of mineral phases. Selected saturation indices calculated in PHREEQC are shown in Table 7. A saturation index greater than zero indicates that the phase is oversaturated and conditions are favorable for that phase to precipitate from solution. A saturation index less than zero indicates that the phase is undersaturated and conditions favor dissolution of the phase. A saturation index between –1.0 and 1.0 is interpreted as indicating that the phase is at or near equilibrium in the water, and potentially controlling the concentration of the constituent elements in solution.

Table 7. Saturation Indices of Selected Minerals

Mineral	Chemical Formula	Saturation Indices			
		CG-1	CG-31	CG-33	CG-34
Alunite	$KAl_3(SO_4)_2(OH)_6$	-2.41	-7.82	-2.82	-4.07
Basaluminite	$Al_4(OH)10SO_4$	-3.70	-7.70	-3.51	-6.43
Brochantite	$Cu_4(OH)_6SO_4$	-15.92	-17.19	-13.15	-17.61
Chalcedony	SiO_2	-0.38	-0.01	-0.08	-0.33
Diaspore	AlOOH	-0.48	-1.17	-0.53	-1.64
$Fe(OH)_3$-amorphous	$Fe(OH)_3$(a)	-1.42	0.75	2.26	-2.67
$Fe_3(OH)_8$	$Fe_3(OH)_8$	-10.51	-5.07	-0.02	-13.79
Gibbsite	$Al(OH)_3$	-1.62	-2.28	-1.64	-2.75
Goethite	FeOOH	3.70	5.69	7.22	2.31
Gypsum	$CaSO_4:2H_2O$	-2.37	-2.51	-1.10	-2.07
K-Jarosite	$KFe_3(SO_4)_2(OH)_6$	15.78	18.23	25.94	13.30
Na-Jarosite	$NaFe_3(SO_4)_2(OH)_6$	-3.88	-1.43	6.28	-6.47
Jurbanite	$AlOHSO_4$	-0.85	-3.75	-1.38	-0.86
Kaolinite	$Al_2Si_2O_5(OH)_4$	-2.26	-2.85	-1.70	-4.43
Lepidocrosite	FeOOH	2.10	4.27	5.78	0.85
Schwertmannite	$Fe_8O_8(OH)_6(SO_4)$	8.31	23.02	36.99	-0.72
Scorodite	$FeAsO_4:2H_2O$	-2.07	-1.55	-1.13	-2.86
Silica-amorphous	SiO_2(a)	-1.29	-0.94	-1.01	-1.25
	pH	4.22	5.42	4.90	3.85

At sample site CG-33, abundant red-orange precipitate was observed coating the effluent channel draining the adit. The chemical analyses (Table 2) indicate that 2 mg/L suspended iron and 140 μg/L suspended aluminum are present in solution (i.e., the difference between total recoverable iron [16 mg/L] and dissolved iron [14 mg/L] equals 2 mg/L; the difference between total recoverable aluminum [740 μg/L] and dissolved aluminum [600 μg/L] equals 140 μg/L). The modeling confirms that several iron phases (ferrihydrite, goethite, jarosite, $Fe[OH]_{3(a)}$) are oversaturated (Table 7) and possibly contributing to the precipitate in the channel. The modeling revealed no aluminum phases oversaturated, although diaspore is near saturation. Considering the uncertainty in the analyses and calculations, diaspore could be a solubility control for aluminum and may be precipitating to a minor extent in the channel.

Sample site CG-1, collected from the main Peru Creek channel downstream from all Cinnamon Gulch effluent, had abundant white and yellow to reddish precipitate. The chemical analyses (Table 2) indicate that 410 μg/L suspended iron and 700 μg/L suspended aluminum are present in solution. The modeling indicates that goethite and jarosite are oversaturated and possibly responsible for the iron precipitate in the channel. No aluminum phases are oversaturated, but diaspore and jurbanite are near saturation (Table 7) and could be precipitating in the channel and controlling aluminum solubility.

Sample CG-34, the low-flow counterpart to CG-1, had lower pH (3.85 vs 4.22) and slightly higher conductivity than CG-1. However the model reveals only minor differences between the two samples (Table 7).

Sample CG-31 was modeled to evaluate the solubility controls on the water with the highest pH in the watershed. This was a low-flow sample collected from an adit draining less than one gpm. Apparent iron-oxide precipitate was visible in the effluent channel. The model data (Table 7) show several iron phases oversaturated, and silica phases near equilibrium, but overall the model results are not significantly different than for the other samples.

The decrease in iron loading in Peru Creek discussed earlier can be explained by assuming that iron phases are precipitating from solution. Table 7 shows that numerous iron phases are oversaturated in the four samples modeled. The mining features (CG-31 & 33) show more oversaturated phases than the Peru Creek sites (CG-1 & 34). This makes geochemical sense, in that the elevated iron concentrations discharging from the mining features contribute to the loading calculations from Cinnamon Gulch, but a large fraction of that iron is removed during transport, resulting in undersaturation in the downstream Peru Creek samples. This is why the percentage of iron from anthropogenic sources appears much higher than other constituents. Significant amounts of iron are precipitated out of solution before the downstream Peru Creek sample site (CG-1 and CG-34).

The removal of lead is to be expected, because of lead's affinity for adsorption in this type of environment (Karlsson and others, 1988). The precipitation of iron and aluminum phases provide appropriate substrates for adsorption of lead.

SUMMARY AND CONCLUSIONS

The following summarizes the findings from the Cinnamon Gulch watershed characterization:

- Discharge from the watershed ranged from just over 1 cfs (460 gpm) at low flow to 4.3 cfs (1,920 gpm) at high flow.

- Numerous ions are consistently elevated in samples from around the watershed. Average dissolved concentrations of selected metals at low flow were 5.5 mg/L aluminum, 5.5 mg/L manganese, 2.8 mg/L zinc, 14 μg/L cadmium, 260 μg/L copper, and 82 μg/L lead.

- Numerous ions exceed State of Colorado water quality standards for aquatic life (chronic exposure). At low flow, zinc exceeds standard in all samples; copper and lead exceed standard in all but two samples; cadmium and manganese exceed standard in all samples; iron and nickel exceed standard in about half of the samples; and aluminum exceeds standard in all but one sample. Sulfate meets the secondary drinking water standard in all but two samples.

- Comparison of water quality at low-flow versus high-flow shows some peculiarities in the data. At some sample sites, the data reveal the expected, i.e., higher concentrations of most ions at low flow than at high flow, due to dilution from runoff at high-flow. However, other sites show the opposite, i.e., higher concentrations at high flow. The ability of the unsaturated zone to dampen recharge pulses is postulated as a possible explanation.

- Streamflow data indicate that anthropogenic sources account for about 2% of the total discharge from the watershed at low flow and about 4% at high flow. The loading calculations indicate slightly higher anthropogenic contributions - about 4% during low flow and 5-8% at high flow. The discrepancy is likely due to waters discharging from anthropogenic sources having higher constituent concentrations.

- Iron and aluminum precipitate out of solution and onto the streambed in the Cinnamon Gulch watershed and in Peru Creek along the reach where Cinnamon Gulch creek enters. Lead is attenuated as well, likely by adsorption onto precipitated iron and/or aluminum phases along these reaches.

- The rock chemistry data (Table 3) from waste rock dumps and tailings in the watershed consistently show negative net acid-base potential and acidic paste pH, as well as enrichment of copper, silver, lead, and zinc, plus detectable gold and mercury. The data suggest that these features will be acid generating over the long term.

- The lower reach of Cinnamon Gulch is apparently a ground-water discharge zone, because the creek gains almost 400 gpm between sample site CG-27 and its confluence with Peru Creek, but discrete measurable sources along this reach total less than 8 gpm.

- Minimal dilution occurs along this reach, suggesting that contaminants are being transported in the subsurface to the ground-water discharge zone. The source of these contaminants could be mostly natural, with the conclusion that remediation of surface features, and removal of sources of surface water contamination, might not remove the major sources of contamination from the watershed.

- The relatively low proportion of ground-water flow that is intercepted by underground workings is problematic from a remediation perspective. It is encouraging in that a very small proportion of the total water budget is discharged from adits, which are difficult to remediate, but discouraging in that removing the adit discharges would remove only a small percentage of the total contamination in the watershed, and would likely have minimal impact.

REFERENCES

Bookstrom, A.R., Naeser, C.W., and Shannon, J.R., 1987, Isotopic age determinations, unaltered and hydrothermally altered igneous rocks, north-central Colorado Mineral Belt: Isochron/West, no. 49, p. 13-20.

Burchard, H.C., 1882, Colorado *in* Report of the Director of the Mint upon the statistics of production of precious metals in the United States - 1881: Director of the Mint Report, p. 354-445.

Burchard, H.C., 1883, Colorado *in* Report of the Director of the Mint upon the statistics of production of precious metals in the United States - 1882: Director of the Mint Report, p. 390-593.

Burchard, H.C., 1885, Colorado *in* Report of the Director of the Mint upon the production of precious metals in the United States during calendar year 1884: Director of the Mint Report, p. 176-249.

Clesceri, L.S., Greenberg, A.E., and Eaton, A.D. (eds.), 1998, Standard methods for the examination of water and wastewater, 20th edition. Prepared and published jointly by the American Public Health Association, the American Water Works Association, and the Water Environment Federation, Published by the American Public Health Association, Washington D.C., 1325 p.

Colorado Bureau of Mines, 1913, 12th biennial report of the Bureau of Mines of the state of Colorado for the years 1911 and 1912: 200 p.

Colorado Bureau of Mines, 1921, Annual Report for the year 1920: 63 p.

Colorado Bureau of Mines, 1922, Annual Report for the year 1921: 55 p.

Colorado Bureau of Mines, 1923, Annual Report for the year 1922: 58 p.

Colorado Bureau of Mines, 1927, Annual Report for the year 1926: 65 p.

Colorado Bureau of Mines, 1928, Annual Report for the year 1927: 70 p.

Colorado Bureau of Mines, 1929, Annual Report for the year 1928: 56 p.

Colorado Bureau of Mines, 1930, Annual Report for the year 1929: 62 p.

Colorado Division of Minerals and Geology (CDMG), files.

Corregan, R.A. and Lingane, D.F., 1883, The Colorado mining directory and buyers guide: The Colorado Mining Directory Company, Denver, CO, 908 p.

CSU (Colorado State University), 2002, Precipitation map of Colorado, Colorado Water Resources Research Institute, [http://waterknowledge.colostate.edu/prcp_map.htm]

Downer, F.M., 1903, Colorado *in* Report of the Director of the Mint upon the production of precious metals in the United States – 1902: Director of the Mint Report, p. 88-133.

Dunbar, A.R., 1898, Western mining directory and buyers guide 1898: Western Mining Directory Company, Denver, CO, 476 p.

Emerick, J.C., Huskie, W.W., and Cooper, D.J., 1988, Treatment of discharge from a high elevation metal mine in the Colorado Rockies using an existing wetland *in* U.S. Bureau of Mines Information Circular 9183, p. 345-351.

Henderson, C.W., 1909, Gold, silver, copper, lead, and zinc - Colorado *in* Mineral Resources of the United States (part I)-1908: U.S. Geological Survey publication, p. 360-405.

Henderson, C.W., 1911a, Gold, silver, copper, lead, and zinc - Colorado *in* Mineral Resources of the United States (part I)-1909: U.S. Geological Survey publication, p. 290-333.

Henderson, C.W., 1911b, Gold, silver, copper, lead, and zinc - Colorado *in* Mineral Resources of the United States (part I)-1910: U.S. Geological Survey publication, p. 384-445.

Henderson, C.W., 1912, Gold, silver, copper, lead, and zinc - Colorado *in* Mineral Resources of the United States (part I)-1911: U.S. Geological Survey publication, p. 505-569.

Henderson, C.W., 1913, Gold, silver, copper, lead, and zinc - Colorado *in* Mineral Resources of the United States (part I)-1912: U.S. Geological Survey publication, p. 635-705.

Henderson, C.W., 1914, Gold, silver, copper, lead, and zinc - Colorado *in* Mineral Resources of the United States (part I)-1913: U.S. Geological Survey publication, p. 227-278.

Henderson, C.W., 1916, Gold, silver, copper, lead, and zinc - Colorado *in* Mineral Resources of the United States (part I)-1914: U.S.-Geological Survey publication, p. 255-313.

Henderson, C.W., 1921, Gold, silver, copper, lead, and zinc - Colorado *in* Mineral Resources of the United States (part I)-1918: U.S. Geological Survey publication, p. 819-875.

Henderson, C.W., 1922a, Gold, silver, copper, lead, and zinc - Colorado *in* Mineral Resources of the United States (part I)-1919: U.S. Geological Survey publication, p. 751-792.

Henderson, C.W., 1922b, Gold, Silver, copper, lead, and zinc-Colorado *in* Mineral resources of the United States (part I)-1920: U.S. Geological Survey publication, p. 565-595.

Henderson, C.W., 1924, Gold, Silver, copper, lead, and zinc-Colorado *in* Mineral resources of the United States (part I)-1921: U.S. Geological Survey publication, p. 479-511.

Henderson, C.W., 1925, Gold, silver, copper, lead, and zinc - Colorado *in* Mineral Resources of the United States (part I)-1922: U.S. Geological Survey publication, p. 519-556.

Henderson, C.W., 1927, Gold, Silver, copper, lead, and zinc-Colorado *in* Mineral resources of the United States (part I)-1923: U.S. Geological Survey publication, p. 611-648.

Henderson, C.W., 1930, Gold, silver, copper, lead, and zinc in Colorado *in* Mineral Resources of the United States - 1927: Bureau of Mines publication, p. 527-572.

Henderson, C.W., 1931, Gold, silver, copper, lead, and zinc in Colorado *in* Mineral Resources of the United States - 1928: Bureau of Mines publication, p. 817-872.

Henderson, C.W., 1943, Gold, Silver, copper, lead, and zinc-Colorado *in* Minerals Yearbook-1942: Bureau of Mines publication, p. 317-348.

Henderson, C.W. and Martin, A.J., 1940, Gold, Silver, copper, lead, and zinc-Colorado *in* Minerals Yearbook-1940 (review of 1939): Bureau of Mines publication, p. 249-285.

Henderson, C.W. and Martin, A.J., 1941, Gold, Silver, copper, lead, and zinc-Colorado *in* Minerals Yearbook-review of 1940: Bureau of Mines publication, p. 279-314.

Henderson, C.W. and Martin, A.J., 1943, Gold, Silver, copper, lead, and zinc-Colorado *in* Minerals Yearbook-1941: Bureau of Mines publication, p. 285-319.

Henderson, C.W., Mote, R.H., and Cushman, R.V., 1945, Gold, silver, copper, lead, and zinc in Colorado *in* Mineral Resources of the United States - 1943: Bureau of Mines publication, p. 314-342.

Holm, J.D., Sullivan, T., and Stenulson B.K., 1978, The restoration of Peru Creek – Analyzing the feasibility of abating toxicity associated with abandoned mine drainage: Colorado 208 Water Quality Unit, in cooperation with The Colorado Water Quality Control Division and the United States Forest Service.

Lovering, T.S. 1935, Geology and ore deposits of the Montezuma quadrangle, Colorado: U.S. Geological Survey Professional Paper 178, 119 p.

Lovering, T.S. and Goddard, E.N., 1950, Geology and ore deposits of the Front Range: U.S. Geological Survey Professional Paper 223, 319 p.

Lundgren, W., 1906, Gold and silver - Colorado *in* Mineral Resources of the United States - 1905: U.S. Geological Survey publication, p. 185-214.

Martin, A.J. and Kelly, F.J., 1956, The mineral industry of Colorado *in* Minerals Yearbook (volume III)-1953: U.S. Bureau of Mines publication, p. 235-273.

Munson, G.C., 1888, Colorado *in* Report of the Director of the Mint upon the production of precious metals in the United States during calendar year 1887: Director of the Mint Report, p. 148-194.

Munson, G.C., 1889, Colorado *in* Report of the Director of the Mint upon the production of precious metals in the United States during calendar year 1888: Director of the Mint Report, p. 94-133.

Naramore, C., 1907, Gold and silver - Colorado *in* Mineral Resources of the United States (part I)-1906: U.S. Geological Survey publication, p. 199-240.

Naramore, C., 1908, Gold, silver, copper, lead, and zinc in Colorado *in* Mineral Resources of the United States (part I)-1907: U.S. Geological Survey publication, p. 235-279.

Neuerburg, G.J., 1971, Distribution of selected accessory minerals in the Montezuma stock, Summit County, Colorado: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-608, scale 1:31,680.

Neuerburg, G.T. and Botinelly, T, 1972, Map showing geologic and structural controls of ore deposits, Montezuma District, Central Colorado: U.S. Geological Survey Miscellaneous Geologic Investigations, Map I-750.

Parkhurst, D.L., and Appelo, C.A.J., 1999, *PHREEQC* (version 2) - A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations: U.S. Geological Survey Water-Resources Investigations Report 95-4259

Patton, H.B., 1909, The Montezuma mining district of Summit County Colorado *in* Colorado Geological Survey first report, 1908, p. 105-144.

Smith, M.E., 1890, Colorado *in* Report of the Director of the Mint upon the production of precious metals in the United States - 1889: Director of the Mint Report, p. 143-155.

Smith, M.E., 1891, Colorado *in* Report of the Director of the Mint upon the production of precious metals in the United States - 1890: Director of the Mint Report, p. 126-143.

Smith, M.E., 1892, Colorado *in* Report of the Director of the Mint upon the production of precious metals in the United States - 1891: Director of the Mint Report, p. 172-187.

Streufert, 1994, USFS-Abandoned mined land inventory project, summary report, Dillon Ranger District: Colorado Geological Survey, unpublished report, 14 p.

Topper, R. and others, 2003, Ground water atlas of Colorado: Colorado Geological Survey, Special Publication 53, 210 p.

Tweto, O., compiler, 1979, Geologic map of Colorado: U.S. Geological Survey Map, scale 1:500,000.

Wahlgreen, G.A., June 1902, The Colorado mining directory and buyers guide: The Wahlgreen Printing Company, Denver, CO, 205 p.

APPENDIX A

USFS-AMLI FIELD DATA FORMS

USFS-AMLI FIELD DATA FORM

LOCATION AND IDENTIFICATION

(1) **ID#:** 02- 08- 15 - 10 - 429 / 4382 - 1
rgn st fst rd xutm yutm area#

(2) **Sitename:** ____

(3) **Other name/reference:** Top of Brittle Silver Mountain

4 (4) **Highest priority Environmental Degradation occurring in this area:** 1=extreme; 2=significant; 3=potentially significant; 4=slight; 5=none

3 (5) **Highest priority Mine Hazard noted in this area:** E=emergency; 1=extreme danger; 2=dangerous; 3=potentially dangerous; 5=no significant hazard

M (6) **Commodity:** C=coal; U=uranium; M=metals; I=industrial material. (Metal or Indust. material type: ____)

(7) **Quad name and date:** Montezuma 1974

(8) **County:** Summit

(9) **2° map:** Denver ~~Leadville~~

(10) **Water Cataloguing Unit #:** 14010002

(11) **Mining district/coal field:** Montezuma

(12) **Land survey location:** -NE1/4 -NE1/4 sec 30 ,T 5S ,R 75W

(13) **Receiving stream:** Cinnamon Gulch flowing into Peru Creek
nearest named stream next named

(14) **Elevation (ft):** 11,400 — 12,200

2 (15) **General Slope:** 1=0-10°; 2=11-35°; 3=greater than 35°

M (16) **Regional terrain:** R=rolling or flat; F=foothills; T=mesa; H=hogback; M=mountains; S=steep/narrow canyon

N (17) **Type of access:** N=no trail; T=trail; J=jeep road; G=gravel road; M=paved road; P=private/restricted road

X (18) **Quality of access for construction vehicles:** G=good; M=moderate; P=poor; X=very poor

(19) **Nearest town on map:** Montezuma

4.5 (20) **Road distance from nearest town** (#.# miles)

(21) **Nearest road** (name and/or #): ____
FR=forest rd; CR=county rd; SH=state highway; I=interstate

Distance to following types of public uses (#.# miles):

.25 (22) Road
4.75 (23) Dwelling (year-round)
____ (24) Campground/picnic area
1.75 (25) Marked trail
____ (26) Other public use (explain) ____

ENVIRONMENTAL INFORMATION

S (27) **Vegetation density adjacent to site:** D=dense; M=moderate; S=sparse; B=barren

W/G/P/T (28) **Vegetation type adjacent to site:** B=barren; W=weeds; G=grass; R=riparian S=sagebrush/oakbrush/brush; J=juniper/piñon; A=aspen; P=pine/spruce/fir; T=tundra

N (29) **Evidence of intentional reclamation:** Y=yes; N=no (if yes, use comments)

0.5 (30) **Size of disturbed area in acres**

Y (31) **Potential historical structures in area:** Y=yes; N=no (if yes, use comments)

N (32) **Evidence of bats:** G=guano; I=insect remains; B=bat sighting; O=other(use comments); N=no (use comments to expand on any positive evidence)

✓ (33) **Recorded by/date:** Joey Klein 10/1/93

ADITS, SHAFTS, AND OPENINGS													
Feature Nos.		100	101	102	103	104	105	106	107	108	109	110	111
Type of Feature		A	S	A	A	A	A	A					
Opening Size (ft)	H	UNK	6	6	UNK	UNK	3	UNK					
	W	UNK	5	4	UNK	UNK	3	UNK					
Depth (ft)		UNK	5	20+	UNK	UNK	50+	UNK					
Condition		F	F	P	F	F	P	F					
Drainage		N	N	N	N	N	W	N					
Access Deterents		N	N	N	N	N	N	N					
Deterent Condition													
Ratings	Env. Deg.	5	5	5	5	5	4	5					
	Hazard	5	3	3	5	5	3	5					
Photo	Roll No.	—	M-10		—	—	M-10	—					
	Frame No.	—	6	7	—	—	8	—					
Comments?													

DUMPS, TAILINGS, AND SPOIL BANKS										
Feature No.		200	201	202	203	204	205	206	207	208
Type of Feature		D	D	D	D	D	D	D		
Plan view Dimension (ft.)	L	65	70	70	70	60	90	60		
	W	40	60	35	40	30	50	30		
Volume (yds)		1300	1500	1360	1290	910	2500	300		
Steepest Slope Angle (dgr)		R	—	—	—	—	→			
Steepest Slope Length (ft)		55	40	60	50	55	60			
Size of Materials		F→B	—	—	—	—	—	→		
Cementation		W	—	—	—	—	—	→		
Vegetation Type		W/G	—	—	—	—	—	→		
Vegetation Density		S	—	—	—	—	—	→		
Drainage		N	—	—	—	—	—	→		
Stability		S	—	—	—	—	—	→		
Water Erosion	of Feature	N	—	—	—	—	—	→		
	Storm Runoff	N	—	—	—	—	—	→		
Wind Erosion		N	—	—	—	—	—	→		
Radiation Count		NA	—	—	—	—	—	→		
Access Deterents		N	—	—	—	—	—	→		
Deterent Condition										
Ratings	Env. Deg.	5	—	—	—	—	4	5		
	Hazard	5	—	—	—	—	5	5		
Photo	Roll No.	—	—	—	—	—	—	—		
	Frame No.	—	—	—	—	—	—	—		
Comments?										
Soil Sample No.										

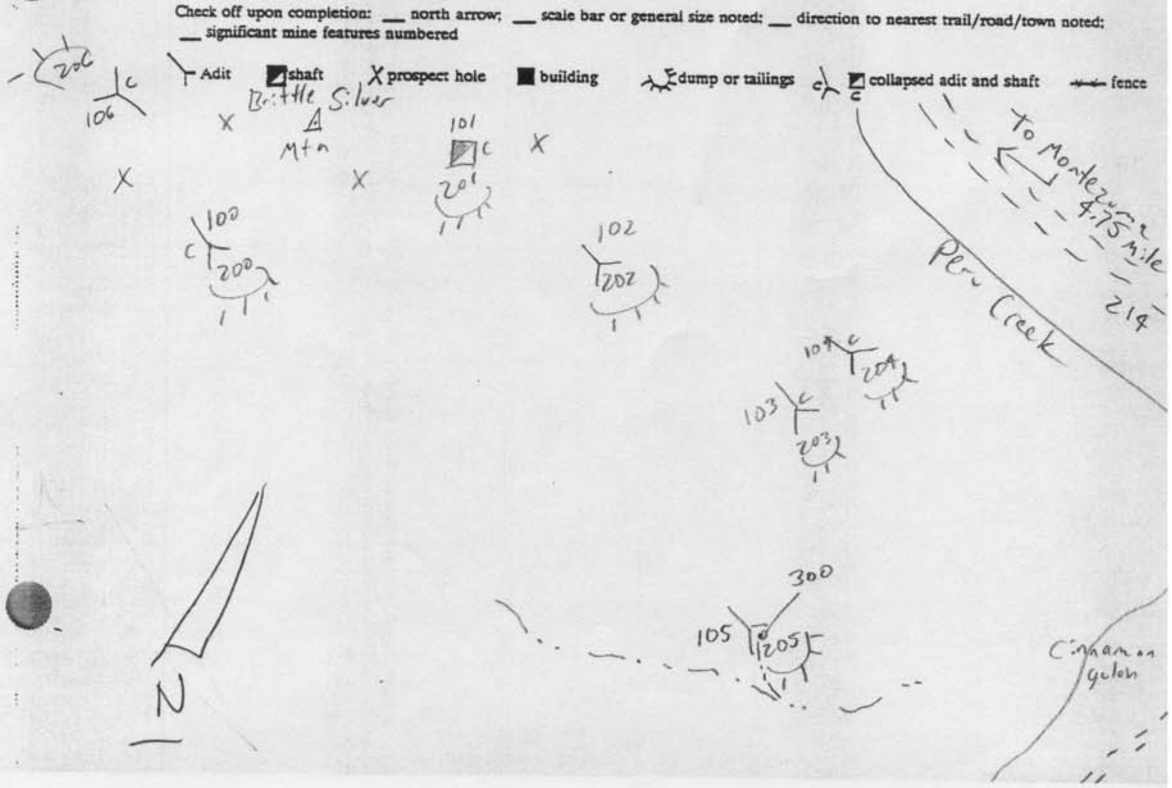
DRAINAGE/WATER SAMPLES						
Item Nos.	300	301	302	303	304	305
Adit/Shaft/Dump No./Other=0 (If other location, describe in comments)	105					
pH (standard units)	6.2					
Conductivity (uS)	100					
Flow (gpm)	1.0					
Method of Flow Measure	D					
Date Flow/Sample (m/d/y)	9/29					
Location of Sample/Flow	A					
Evidence of Toxicity in Site Drainage	N					
Evidence of Toxicity in Receiving Stream	N					
Distance from Stream (ft)	500					
Comments?	Y					
Lab Water Sample No.						

GPS READINGS	
Ptr. No.	Location
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.

DIAGRAM OF PROBLEM AREA (Locate all adits, shafts, dumps, prospects, etc. on topo map.)

Check off upon completion: __ north arrow; __ scale bar or general size noted; __ direction to nearest trail/road/town noted; __ significant mine features numbered

Adit; shaft; X prospect hole; building; dump or tailings; collapsed adit and shaft; fence



●81. Local person interviewed ______________________________

Name Address

●82. Name and address of person desiring a copy of this form: ______________________________

●83. Describe the minimum work needed to mitigate any public health, safety, welfare, or environmental problems observed at the site. Note specific reclamation activities along with an estimated cost and time period to implement each activity described. Code costs as: 1= less $10,000; 2= $10,000 to $100,000; 3= $100,000 to $500,000; 4= more than $500,000. Code estimated time to complete the activity as: 1= less than 1 month; 2= 1 to 12 months; 3= 1 to 3 years; 4= over 3 years

Cost	Time	Recommended reclamation activity

●84. Comments relating to health, safety, welfare, environmental, or restoration problems and any general comments. All comments must be keyed to mine feature # or drainage/water sample item #.

100 Collapsed adit No water No phys. hazards
200 Dump is high and dry

101 Collapsed shaft 5 feet deep. No water Potential hazard.
201 Dump is high and dry.

102 Partially collapsed adit, atleast 20 feet deep. No water but is moist. Potential danger.
202 Dump is high and dry.

103,104,106 Collapsed adits No water No Hazards
203,204,206 Dumps are high and dry.

105 Partially collapsed adit, atleast 50 feet deep. Water draining.
205 Dump for adit 105. Mine drainage goes through South Side of dump. Sulphides observed. Toe of dump is in small spring
300 Water tested from adit 105. No precipitates, looks pristine. 6.2 pH, 100 ns, 1.0 gpm. Mine drainage becomes ground water 50 ft. from origin. Slight degradation

-if more comments use back of page →

General Comment: Most of sight is well above timberline and isn't a problem environmentally. The only leaker is A105 and it is draining natural quality water.

Physically, the shaft 101 is collapsed but is still 5 feet deep and potentially dangerous. Adit 102 is also potentially dangerous because it is atleast 20 feet long. Both features are remote and no trail or road leads to them.

Adit 105 is potentially dangerous and is within 500 ft of road.

-if more comments use back of page →

OFFICE/LITERATURE INFORMATION

●41. Owner of surface ______________________________
●42. Last known operator ______________________________
●43. Estimated production ______________________________
●44. Dates of production ______________________________
●45. Literature not cited in comments ______________________________
●46. Citation of any historical register listing Collapsed Structures near A101, A102

USFS-AMLI FIELD DATA FORM

LOCATION AND IDENTIFICATION

(1) **ID#:** 02- 08- 15 - 10 - 429 / 4383 - 1
rgn st fst rd xutm yutm area#

(2) **Sitename:** ____

(3) **Other name/reference:** Lower Cinnamon Gulch / West Side

4 (4) **Highest priority Environmental Degradation occurring in this area:**
1=extreme; 2=significant; 3=potentially significant; 4=slight; 5=none

3 (5) **Highest priority Mine Hazard noted in this area:**
E=emergency; 1=extreme danger; 2=dangerous; 3=potentially dangerous; 5=no significant hazard

M (6) **Commodity:** C=coal; U=uranium; M=metals; I=industrial material.
(Metal or Indust. material type: ____)

(7) **Quad name and date:** Montezuma 1974

(8) **County:** Summit

(9) **2° map:** Denver ~~Leadville~~

(10) **Water Cataloguing Unit #:** 14010002

(11) **Mining district/coal field:** Montezuma

(12) **Land survey location:** -W1/2 -SW1/4 sec 20 ,T 5S ,R 75W

(13) **Receiving stream:** Peru Creek flowing into Snake River
nearest named stream next named

(14) **Elevation (ft):** 10,900

2 (15) **General Slope:** 1=0-10°; 2=11-35°; 3=greater than 35°

M (16) **Regional terrain:** R=rolling or flat; F=foothills; T=mesa; H=hogback; M=mountains; S=steep/narrow canyon

J (17) **Type of access:** N=no trail; T=trail; J=jeep road; G=gravel road; M=paved road; P=private/restricted road

M (18) **Quality of access for construction vehicles:** G=good; M=moderate; P=poor; X=very poor

(19) **Nearest town on map:** Montezuma

4.5 (20) **Road distance from nearest town** (#.# miles)

(21) **Nearest road** (name and/or #): Peru Creek (FR 214)
FR=forest rd; CR=county rd; SH=state highway; I=interstate

Distance to following types of public uses (#.# miles):

.50 (22) Road
5.0 (23) Dwelling (year-round)
____ (24) Campground/picnic area
2.0 (25) Marked trail
____ (26) Other public use (explain) ____

ENVIRONMENTAL INFORMATION

M (27) **Vegetation density adjacent to site:** D=dense; M=moderate; S=sparse; B=barren

W/G/R/P (28) **Vegetation type adjacent to site:** B=barren; W=weeds; G=grass; R=riparian S=sagebrush/oakbrush/brush; J=juniper/piñon; A=aspen; P=pine/spruce/fir; T=tundra

N (29) **Evidence of intentional reclamation:** Y=yes; N=no (if yes, use comments)

0.4 (30) **Size of disturbed area in acres**

N (31) **Potential historical structures in area:** Y=yes; N=no (if yes, use comments)

N (32) **Evidence of bats:** G=guano; I=insect remains; B=bat sighting; O=other(use comments); N=no (use comments to expand on any positive evidence)

____ (33) **Recorded by/date:** Joey Klein 10/1/93

ADITS, SHAFTS, AND OPENINGS

Feature Nos.		100	101	102	103	104	105	106	107	108	109	110	111
Type of Feature		A	A	A	A/ST	A/ST							
Opening Size (ft)	H	UNK	UNK	UNK	7	4							
	W	UNK	UNK	UNK	5	10							
Depth (ft)		UNK	UNK	UNK	20	20							
Condition		F	F	F	I	P							
Drainage		N	W	N	N	N							
Access Deterents		N	N	N	N	N							
Deterent Condition													
Ratings	Env. Deg.	5	4	5	5	5							
	Hazard	5	5	5	3	3							
Photo	Roll No.				M-10	→							
	Frame No.				20	21							
Comments?													

DUMPS, TAILINGS, AND SPOIL BANKS

Feature No.		200	201	202	203	204	205	206	207	208
Type of Feature		D	D	D			T			
Plan view Dimension (ft.)	L	60	70	70			150			
	W	30	55	40			70			
Volume (yds)		1160	1070	1680			2900			
Steepest Slope Angle (dgr)		R					10°			
Steepest Slope Length (ft)		70	30	65			4			
Size of Materials		F→L	F→L	F→L			F			
Cementation		W	W	W			W			
Vegetation Type		W/G/P	B	B			W/G/R/P			
Vegetation Density		M	B	B			M			
Drainage		N	W	N			W			
Stability		S	S	S			S			
Water Erosion	of Feature	N	N	N			G			
	Storm Runoff	N	N	N			S			
Wind Erosion		N	N	N			N			
Radiation Count		NA	NA	NA			NA			
Access Deterents		N	N	N			N			
Deterent Condition										
Ratings	Env. Deg.	5	4	5			4			
	Hazard	5	5	5			5			
Photo	Roll No.	N	N	N			M-10			
	Frame No.	N	N	N			19			
Comments?		Y								
Soil Sample No.										

DRAINAGE/WATER SAMPLES						
Item Nos.	300	301	302	303	304	305
Adit/Shaft/Dump No./Other=0 (If other location, describe in comments)	101	205				
pH (standard units)	4.2	4.4				
Conductivity (uS)	100	100				
Flow (gpm)	2.0	.50				
Method of Flow Measure	D	D				
Date Flow/Sample (m/d/y)	10/1 93	10/1 93				
Location of Sample/Flow	A	B				
Evidence of Toxicity in Site Drainage	P	P				
Evidence of Toxicity in Receiving Stream	N	N				
Distance from Stream (ft)	700	400				
Comments?	Y					
Lab Water Sample No.						

GPS READINGS	
Ftr. No.	Location
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.

DIAGRAM OF PROBLEM AREA (Locate all adits, shafts, dumps, prospects, etc. on topo map.)

Check off upon completion: __ north arrow; __ scale bar or general size noted; __ direction to nearest trail/road/town noted; __ significant mine features numbered

Adit shaft X prospect hole building dump or tailings collapsed adit and shaft fence

●81. Local person interviewed ______________________________
Name Address

●82. Name and address of person desiring a copy of this form: ______________________________

●83. Describe the minimum work needed to mitigate any public health, safety, welfare, or environmental problems observed at the site. Note specific reclamation activities along with an estimated cost and time period to implement each activity described. Code costs as: 1 = less $10,000; 2 = $10,000 to $100,000; 3 = $100,000 to $500,000; 4 = more than $500,000. Code estimated time to complete the activity as: 1 = less than 1 month; 2 = 1 to 12 months; 3 = 1 to 3 years; 4 = over 3 years

Cost	Time	Recommended reclamation activity

●84. Comments relating to health, safety, welfare, environmental, or restoration problems and any general comments. All comments must be keyed to mine feature # or drainage/water sample item #.

100 Collapsed adit no water. No hazard
200 Dump is high and dry Sulphides observed.

101 Collapsed adit with water draining Slight degradation
201 Dump of adit 101 mine drainage goes through feature forming small gully. Slight degradation. Sulphides observed.
300 Water tested at adit 101. 4.2 pH, 100 ns, 2.0 gpm. Some precipitate

102 Collapsed adit No water. No hazard.
202 Dump is high and dry. Dump has been displaced downhill

103 Intact adit/open stope no water. Potentially dangerous 20 feet deep. Dump is small and has been displaced downhill.

104. Partially intact adit/open stope No water. Potentially dangerous, 20 feet deep. Dump is small and has been displaced downhill.

205 Mill tailings from Adit 100, 101. Tailings pile is in wetlands and is on a flat slope. Mine drainage/spring runs through tailings into beaver pond, before reaching Peru Creek. Moderate vegetation but plants seem to be growing back over tailings without any trouble.

301 Water tested below dump in mine drainage/spring.

-if more comments use back of page →

General Comment: ______________________________

-if more comments use back of page →

OFFICE/LITERATURE INFORMATION

●41. Owner of surface ______________________________
●42. Last known operator ______________________________
●43. Estimated production ______________________________
●44. Dates of production ______________________________
●45. Literature not cited in comments ______________________________
●46. Citation of any historical register listing ______________________________

Environmentally the only concern is A101 and T205. The mine drainage from A101 goes downhill through T205. However this drainage seems to get better as it goes through the wetlands and beaver ponds. All vegetation is growing back and the beavers seem fine. These features are with 50ft. of jeep road off of Cinnamon gulch rd. Moderate construction vehicle access.

Physically A103 and A108 could be concern but aren't really worth dealing with. Both feature are remote and hard to get to (let alone find!) Both are combination stope/adit and easy to climb in and out of. Extremely poor vehicle access.

(•)

USFS-AMLI FIELD DATA FORM

LOCATION AND IDENTIFICATION

(1) ID#: 02- 08- 15 - 10 - 430 / 4383 - 1
rgn st fst rd xutm yutm area#

(2) Sitename: Pennslyvania Mine

(3) Other name/reference: ______

2 (4) Highest priority Environmental Degradation occurring in this area:
1=extreme; 2=significant; 3=potentially significant; 4=slight; 5=none

5 (5) Highest priority Mine Hazard noted in this area:
E=emergency; 1=extreme danger; 2=dangerous; 3=potentially dangerous; 5=no significant hazard

M (6) Commodity: C=coal; U=uranium; M=metals; I=industrial material.
(Metal or Indust. material type: ______)

(7) Quad name and date: Montezuma 1974

(8) County: Summit

(9) 2° map: Denver ~~Leadville~~

(10) Water Cataloguing Unit #: 14010002

(11) Mining district/coal field: Montezuma

(12) Land survey location: ___ - ___ - S½ sec 20 ,T 5S ,R 75W

(13) Receiving stream: Peru Creek (nearest named stream) flowing into Snake River (next named)

(14) Elevation (ft): 11,200

2 (15) General Slope: 1=0-10°; 2=11-35°; 3=greater than 35°

M (16) Regional terrain: R=rolling or flat; F=foothills; T=mesa; H=hogback; M=mountains; S=steep/narrow canyon

J (17) Type of access: N=no trail; T=trail; J=jeep road; G=gravel road; M=paved road; P=private/restricted road

M (18) Quality of access for construction vehicles: G=good; M=moderate; P=poor; X=very poor

(19) Nearest town on map: Montezuma

4.5 (20) Road distance from nearest town (#.# miles)

(21) Nearest road (name and/or #): Peru Creek (FR214)
FR=forest rd; CR=county rd; SH=state highway; I=interstate

Distance to following types of public uses (#.# miles):

.25 (22) Road

4.75 (23) Dwelling (year-round)

___ (24) Campground/picnic area

___ (25) Marked trail

___ (26) Other public use (explain) ______

ENVIRONMENTAL INFORMATION

M (27) Vegetation density adjacent to site: D=dense; M=moderate; S=sparse; B=barren

W/G/P (28) Vegetation type adjacent to site: B=barren; W=weeds; G=grass; R=riparian S=sagebrush/oakbrush/brush; J=juniper/piñon; A=aspen; P=pine/spruce/fir; T=tundra

Y (29) Evidence of intentional reclamation: Y=yes; N=no (if yes, use comments)

2.0 (30) Size of disturbed area in acres

N (31) Potential historical structures in area: Y=yes; N=no (if yes, use comments)

N (32) Evidence of bats: G=guano; I=insect remains; B=bat sighting; O=other(use comments); N=no (use comments to expand on any positive evidence)

✓ (33) Recorded by/date: Joey Klein 9/24/93

ADITS, SHAFTS, AND OPENINGS													
Feature Nos.		100	101	102	103	104	105	106	107	108	109	110	111
Type of Feature		A	A	A	A	A	A						
Opening Size (ft)	H	UNK	UNK	——→									
	W	UNK	UNK	——→									
Depth (ft)		UNK	UNK	——→									
Condition		F	F	——→									
Drainage		W	N	——→									
Access Deterents		N	N	——→									
Deterent Condition													
Ratings	Env. Deg.	2	5	——→									
	Hazard	5	5	——→									
Photo	Roll No.	M-9			M-9								
	Frame No.	18			21?								
Comments?													

DUMPS, TAILINGS, AND SPOIL BANKS										
Feature No.		200	201	202	203	204	205	206	207	208
Type of Feature		D	D	D	D	D	D	T		
Plan view Dimension (ft.)	L	200	75	70	180	100	120	200		
	W	120	60	65	100	60	70	100		
Volume (yds)		17,700	1040	1680	16,600	2700	7000	3000		
Steepest Slope Angle (dgr)		K								
Steepest Slope Length (ft)		80	25	40	100	50	90	4		
Size of Materials		F→B	F→L	F→B	F→B	F→B	F→B	F		
Cementation		W	W	W	W	W	W	W		
Vegetation Type		B	G/PW	B	B	B	B	W/G/R		
Vegetation Density		B	S	B	B	B	B	M		
Drainage		Ø W	N	N	N	N	N	W		
Stability		S	S	S	S	S	S	S		
Water Erosion	of Feature	N	N	N	N	N	N	N		
	Storm Runoff	N	N	N	N	N	N	S		
Wind Erosion		N	N	N	N	N	N	N		
Radiation Count		NA	NA	NA	NA	NA	NA	NA		
Access Deterents		N	N	N	N	N	N	N		
Deterent Condition										
Ratings	Env. Deg.	5	5	5	5	5	5	3		
	Hazard	5	5	5	5	5	5	5		
Photo	Roll No.	M-9			M-9			M-10		
	Frame No.	19			22?			15, 16		
Comments?										
Soil Sample No.										

DRAINAGE/WATER SAMPLES

Item Nos.	300	301	302	303	304	305
Adit/Shaft/Dump No./Other=0 (If other location, describe in comments)	100 [redacted]	0	0	0	206 [redacted]	
pH (standard units)	3.6	7.1	3.4	6.3	4.1	
Conductivity (uS)	700	100	800	100	800	
Flow (gpm)	10.0	4488	10.0	4488	1.5	
Method of Flow Measure	D	D	D	D	D	
Date Flow/Sample (m/d/y)	9/28	9/24	9/24	9/24	10/1	
Location of Sample/Flow	A	RU	C	RD	C	
Evidence of Toxicity in Site Drainage	P	N	P	P	P	
Evidence of Toxicity in Receiving Stream	P	N	P	P	P	
Distance from Stream (ft)						
Comments?						
Lab Water Sample No.						

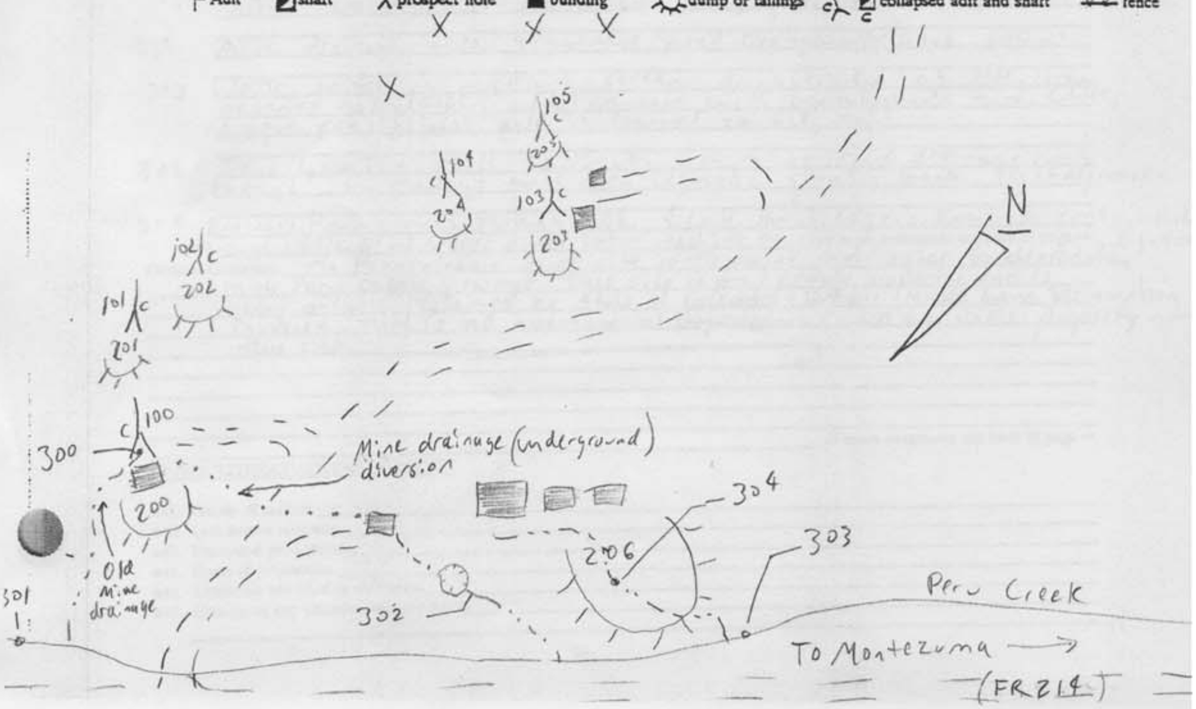
GPS READINGS

Ftr. No.	Location
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.

DIAGRAM OF PROBLEM AREA (Locate all adits, shafts, dumps, prospects, etc. on topo map.)

Check off upon completion: __ north arrow; __ scale bar or general size noted: __ direction to nearest trail/road/town noted; __ significant mine features numbered

Adit; shaft; prospect hole; building; dump or tailings; collapsed adit and shaft; fence



●81. Local person interviewed ______ Name ______ Address

●82. Name and address of person desiring a copy of this form: ______

●83. Describe the minimum work needed to mitigate any public health, safety, welfare, or environmental problems observed at the site. Note specific reclamation activities along with an estimated cost and time period to implement each activity described. Code costs as: 1 = less $10,000; 2 = $10,000 to $100,000; 3 = $100,000 to $500,000; 4 = more than $500,000. Code estimated time to complete the activity as: 1 = less than 1 month; 2 = 1 to 12 months; 3 = 1 to 3 years; 4 = over 3 years

Cost	Time	Recommended reclamation activity

●84. Comments relating to health, safety, welfare, environmental, or restoration problems and any general comments. All comments must be keyed to mine feature # or drainage/water sample item #.

100 Large collapsed adit. Main adit for Pennsylvania Mine. Site is patent[ed]
Water is draining and is being diverted into treatment pond.
Significant Env. degradation, No phys. hazard. Remediation and reclamation is ongoi[ng]
200 Large dump high and dry. Sulphides observed.
300 Old Mine drainage from adit 100. Very Rusty 3.6 p.H, 700 mS, 10 gpm.

101, 102 Small collapsed adits no water No hazards
201, 202 Dumps are both high and dry Sulphides observed

103 Largest adit besides 100. Adit is collapsed no water no hazards
203 Large dump, high and dry, Sulphides observed.

104, 105 collapsed adits no water No hazards
204, 205 Dumps are high and dry sulphides observed.

301 Water tested in receiving stream above confluence with mine drainage. No precipitates looks pristine. 7.1 p.H, 100 mS

302 Mine drainage below treatment pond. Orange color, 3.4 pH, 800 mS

303 Water tested in receiving stream downstream of site. Stream becomes nasty looking after contact with pennsylvania mine. White, opaque precipitates. p.H. is lowered to 6.7, 100 mS.

206 Pennsylvania Mill tailings. Spring or Mine drainage runs through it. Tailings have much vegetation growing back. Slight degradation

304 Drainage/Spring runs through 206. 4.1 p.H, 800 mS, 1.5 gpm. Eventually runs through wetlands and beaver ponds before reaching Peru Cr. Significant potential

-if more comments use back of page →

General Comment: The Pennsylvania Mine site is the major contributor to degradation in the Peru Creek drainage. This site is on private property and is being actively reclaimed by State of Colorado - DMG - Mined Land Reclamation Division. There is no environmental degradation caused by USFS property at this site.

-if more comments use back of page →

OFFICE/LITERATURE INFORMATION

●41. Owner of surface ______
●42. Last known operator ______
●43. Estimated production ______
●44. Dates of production ______
●45. Literature not cited in comments ______
●46. Citation of any historical register listing ______

USFS-AMLI FIELD DATA FORM

LOCATION AND IDENTIFICATION

(1) ID#: 02- 08- 15 - 10 - 430 / 4381 - 2
rgn st fst rd xutm yutm area#

(2) Site name: ______

(3) Other name/reference: Saddle between Silver and Revenue Mtns

5 (4) Highest priority Environmental Degradation occurring in this area:
1=extreme; 2=significant; 3=potentially significant; 4=slight; 5=none

3 (5) Highest priority Mine Hazard noted in this area:
E=emergency; 1=extreme danger; 2=dangerous; 3=potentially dangerous; 5=no significant hazard

M (6) Commodity: C=coal; U=uranium; M=metals; I=industrial material.
(Metal or Indust. material type: ______)

(7) Quad name and date: Montezuma 1974

(8) County: Summit

(9) 2° map: Denver ~~Leadville~~

(10) Water Cataloguing Unit #: 14010002

(11) Mining district/coal field: Montezuma

(12) Land survey location: ___ - N1/2 - S1/2 sec 29 ,T 5S ,R 75W

(13) Receiving stream: Cinnamon Gulch flowing into Peru Creek
nearest named stream next named

(14) Elevation (ft): 12,800

2 (15) General Slope: 1=0-10°; 2=11-35°; 3=greater than 35°

M (16) Regional terrain: R=rolling or flat; F=foothills; T=mesa; H=hogback; M=mountains; S=steep/narrow canyon

N (17) Type of access: N=no trail; T=trail; J=jeep road; G=gravel road; M=paved road; P=private/restricted road

X (18) Quality of access for construction vehicles: G=good; M=moderate; P=poor; X=very poor

(19) Nearest town on map: Montezuma

5.0 (20) Road distance from nearest town (#.# miles)

(21) Nearest road (name and/or #): ______
FR=forest rd; CR=county rd; SH=state highway; I=interstate

Distance to following types of public uses (#.# miles):

.50 (22) Road

5.5 (23) Dwelling (year-round)

___ (24) Campground/picnic area

2.5 (25) Marked trail

___ (26) Other public use (explain) ______

ENVIRONMENTAL INFORMATION

S (27) Vegetation density adjacent to site: D=dense; M=moderate; S=sparse; B=barren

T (28) Vegetation type adjacent to site: B=barren; W=weeds; G=grass; R=riparian S=sagebrush/oakbrush/brush; J=juniper/piñon; A=aspen; P=pine/spruce/fir; T=tundra

N (29) Evidence of intentional reclamation: Y=yes; N=no (if yes, use comments)

0.5 (30) Size of disturbed area in acres

N (31) Potential historical structures in area: Y=yes; N=no (if yes, use comments)

N (32) Evidence of bats: G=guano; I=insect remains; B=bat sighting; O=other(use comments); N=no (use comments to expand on any positive evidence)

___ (33) Recorded by/date: Joey Klein 9/28/93

ADITS, SHAFTS, AND OPENINGS

Feature Nos.		100	101	102	103	104	105	106	107	108	109	110	111
Type of Feature		S	S	A	A	A	A	A					
Opening Size (ft)	H	6	8	UNK	UNK	UNK	UNK	UNK					
	W	3	4	UNK	UNK	UNK	UNK	UNK					
Depth (ft)		4+	4+	UNK	UNK	UNK	UNK	UNK					
Condition		P	P	F	F	F	F	F					
Drainage		N	N	N	N	N	N	N					
Access Deterents		N	N	N	N	N	N	N					
Deterent Condition													
Ratings	Env. Deg.	5	5	5	5	5	5	5					
	Hazard	3	3	5	5	5	5	5					
Photo	Roll No.	M-8?		—	—	M-8	—	M-8					
	Frame No.	28	29	—	—	30	—	31					
Comments?													

DUMPS, TAILINGS, AND SPOIL BANKS

Feature No.		200	201	202	203	204	205	206	207	208
Type of Feature		D	D	D	D	D				
Plan view Dimension (ft.)	L	45	80	75	85	80				
	W	70	70	80	40	45				
Volume (yds)		580	1290	1660	1800	1300				
Steepest Slope Angle (dgr)		R								
Steepest Slope Length (ft)		20	25	30	60	40				
Size of Materials		F>L	F>L	F>B	F>L	F>L				
Cementation		W	W	W	W	W				
Vegetation Type		B	B	B	B	G				
Vegetation Density		B	B	B	B	S				
Drainage		N	N	N	N	N				
Stability		S	S	S	S	S				
Water Erosion	of Feature	N	N	N	N	N				
	Storm Runoff	N	N	N	N	N				
Wind Erosion		N	N	N	N	N				
Radiation Count		NA	NA	NA	NA	NA				
Access Deterents		N	N	N	N	N				
Deterent Condition										
Ratings	Env. Deg.	5	5	5	5	5				
	Hazard	5	5	5	5	5				
Photo	Roll No.	—	—	—	—					
	Frame No.	—	—	—	—					
Comments?										
Soil Sample No.										

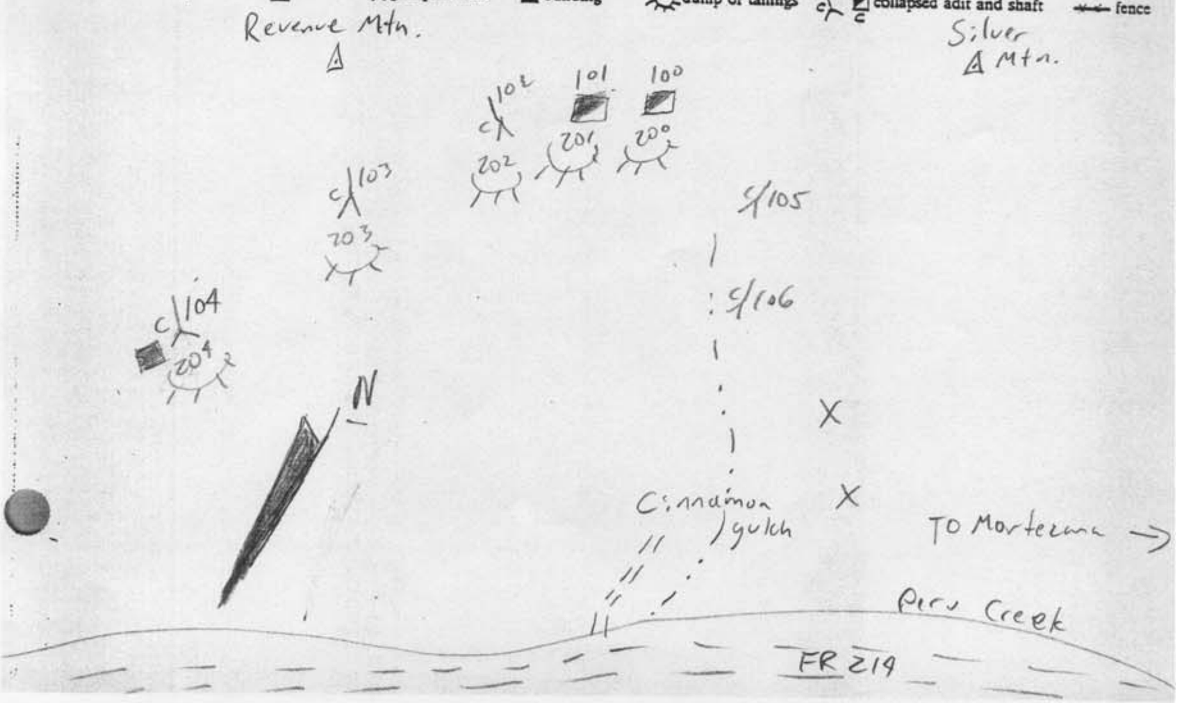
DRAINAGE/WATER SAMPLES						
Item Nos.	300	301	302	303	304	305
Adit/Shaft/Dump No./Other=0 (If other location, describe in comments)						
pH (standard units)						
Conductivity (uS)						
Flow (gpm)						
Method of Flow Measure						
Date Flow/Sample (m/d/y)						
Location of Sample/Flow						
Evidence of Toxicity in Site Drainage						
Evidence of Toxicity in Receiving Stream						
Distance from Stream (ft)						
Comments?						
Lab Water Sample No.						

GPS READINGS	
Ftr. No.	Location
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.

DIAGRAM OF PROBLEM AREA (Locate all adits, shafts, dumps, prospects, etc. on topo map.)

Check off upon completion: __ north arrow; __ scale bar or general size noted; __ direction to nearest trail/road/town noted; __ significant mine features numbered

Adit   shaft   X prospect hole   building   dump or tailings   collapsed adit and shaft   fence



●81. Local person interviewed ______________________________
Name ______ Address ______

●82. Name and address of person desiring a copy of this form: ______________________________

●83. Describe the minimum work needed to mitigate any public health, safety, welfare, or environmental problems observed at the site. Note specific reclamation activities along with an estimated cost and time period to implement each activity described. Code costs as: 1= less $10,000; 2= $10,000 to $100,000; 3= $100,000 to $500,000; 4= more than $500,000. Code estimated time to complete the activity as: 1= less than 1 month; 2= 1 to 12 months; 3= 1 to 3 years; 4= over 3 years

Cost	Time	Recommended reclamation activity

●84. Comments relating to health, safety, welfare, environmental, or restoration problems and any general comments. All comments must be keyed to mine feature # or drainage/water sample item #.

100, 101 Partially collapsed shafts. Appears to be only 4 foot deep but is filled with snow. Potentially dangerous. No water. Maybe on private claim

200,201 Dumps from shafts 100,101 both are high and dry. Sulphides observed

102 Collapsed adit No water No hazards

202 Dump is high and dry. Sulphides observed

103 Collapsed adit No water No hazard

203 Dump is high and dry. Sulphides observed

104 Collapsed adit with snow filling entrance may be partially open. No water at this time but ground near portal is mossy and moist.

204 Dump is high and dry. Sulphides observed

105,106 Collapsed adits in avalanche gully. No water. Dumps are displaced below from avalanches.

General Comment: ______________________________ -if more comments use back of page →

OFFICE/LITERATURE INFORMATION -if more comments use back of page →

●41. Owner of surface ______
●42. Last known operator ______
●43. Estimated production ______
●44. Dates of production ______
●45. Literature not cited in comments ______
●46. Citation of any historical register listing ______

for Adit #103 ...
Rich Ore Lode

USFS-AMLI FIELD DATA FORM

LOCATION AND IDENTIFICATION

(1) **ID#:** 02- 08- 15 - 10 - 430 / 4382 - 1
rgn st fst rd xutm yutm area#

(2) **Sitename:** Silver Spoon

(3) **Other name/reference:** Mid. Cinnamon Gulch

2 (4) **Highest priority Environmental Degradation occurring in this area:** 1=extreme; 2=significant; 3=potentially significant; 4=slight; 5=none

3 (5) **Highest priority Mine Hazard noted in this area:** E=emergency; 1=extreme danger; 2=dangerous; 3=potentially dangerous; 5=no significant hazard

M (6) **Commodity:** C=coal; U=uranium; M=metals; I=industrial material. (Metal or Indust. material type: ____)

(7) **Quad name and date:** Montezuma 1974

(8) **County:** Summit

(9) **2° map:** Denver ~~Leadville~~

(10) **Water Cataloguing Unit #:** 14010002

(11) **Mining district/coal field:** Montezuma

(12) **Land survey location:** ___-___-W½ sec 29 ,T 5S ,R 75W

(13) **Receiving stream:** Cinnamon Gulch flowing into Peru Creek
nearest named stream next named

(14) **Elevation** (ft): 11,600

2 (15) **General Slope:** 1=0-10°; 2=11-35°; 3=greater than 35°

M (16) **Regional terrain:** R=rolling or flat; F=foothills; T=mesa; H=hogback; M=mountains; S=steep/narrow canyon

J (17) **Type of access:** N=no trail; T=trail; J=jeep road; G=gravel road; M=paved road; P=private/restricted road

M (18) **Quality of access for construction vehicles:** G=good; M=moderate; P=poor; X=very poor

(19) **Nearest town on map:** Montezuma

5.5 (20) **Road distance from nearest town** (#.# miles)

(21) **Nearest road** (name and/or #): Peru Cr. (214 FR)
FR=forest rd; CR=county rd; SH=state highway; I=interstate

Distance to following types of public uses (#.# miles):

___ (22) Road

___ (23) Dwelling (year-round)

___ (24) Campground/picnic area

___ (25) Marked trail

___ (26) Other public use (explain) ____

ENVIRONMENTAL INFORMATION

M (27) **Vegetation density adjacent to site:** D=dense; M=moderate; S=sparse; B=barren

W/G/R/P (28) **Vegetation type adjacent to site:** B=barren; W=weeds; G=grass; R=riparian S=sagebrush/oakbrush/brush; J=juniper/piñon; A=aspen; P=pine/spruce/fir; T=tundra

Y (29) **Evidence of intentional reclamation:** Y=yes; N=no (if yes, use comments)

0.2 (30) **Size of disturbed area in acres**

~~Y~~ N (31) **Potential historical structures in area:** Y=yes; N=no (if yes, use comments)

N (32) **Evidence of bats:** G=guano; I=insect remains; B=bat sighting; O=other(use comments); N=no (use comments to expand on any positive evidence)

✓ (33) **Recorded by/date:** Joey Klein 9/29/93

Silver Spoon

ADITS, SHAFTS, AND OPENINGS													
Feature Nos.		100	101	102	103	104	105	106	107	108	109	110	111
Type of Feature		A	A	A	A	A	A	A					
Opening Size (ft)	H	4	4	6	6	2	UNK	UNK					
	W	4	4	4	4	3	UNK	UNK					
Depth (ft)		20	25+	25	30+	15+	UNK	UNK					
Condition		P	I	I	I	P	F	F					
Drainage		W	W	S	W	S	W	W					
Access Deterents		N	N	N	N	N	N	N					
Deterent Condition													
Ratings	Env. Deg.	2	2	4	2	4	4	2					
	Hazard	3	3	3	3	3	5	5					
Photo	Roll No.	M-9	→	M-10									
	Frame No.	35	36	3	4	5	10	11					
Comments?													

DUMPS, TAILINGS, AND SPOIL BANKS										
Feature No.		200	201	202	203	204	205	206	207	208
Type of Feature							D	D		
Plan view Dimension (ft.)	L						70	70		
	W						40	70		
Volume (yds)							770	450		
Steepest Slope Angle (dgr)							R			
Steepest Slope Length (ft)							30	10		
Size of Materials							F>B	F>B		
Cementation							W	W		
Vegetation Type							W/G/P	W/G		
Vegetation Density							S	S		
Drainage							W	W		
Stability							S	S		
Water Erosion	of Feature						N	N		
	Storm Runoff						C	N		
Wind Erosion							N	N		
Radiation Count							NA	NA		
Access Deterents							N	N		
Deterent Condition										
Ratings	Env. Deg.						4	5		
	Hazard						5	5		
Photo	Roll No.						M-10			
	Frame No.						10	13.		
Comments?										
Soil Sample No.										

DRAINAGE/WATER SAMPLES	A100	A101		A103		A105
Item Nos.	300	301	302	303	304	305
Adit/Shaft/Dump No./Other=0 (If other location, describe in comments)	0	0	100	101	103	105
pH (standard units)	3.0	3.2	3.2	3.5	3.5	6.0
Conductivity (uS)	300	400	700	500	300	200
Flow (gpm)	3.0	1.5	1.5	1.5	1.5	2.5
Method of Flow Measure	D	D	D	D	D	D
Date Flow/Sample (m/d/y)	9/29 93	→				→
Location of Sample/Flow	A	A	A	A	A	A
Evidence of Toxicity in Site Drainage	P	P	P	P	P	P
Evidence of Toxicity in Receiving Stream	P	P	N	N	N	N
Distance from Stream (ft)						
Comments?						
Lab Water Sample No.	.300 430/4382	.301	.302	.303	NONE TAKEN	.305
	10/5	10/5	10/5			

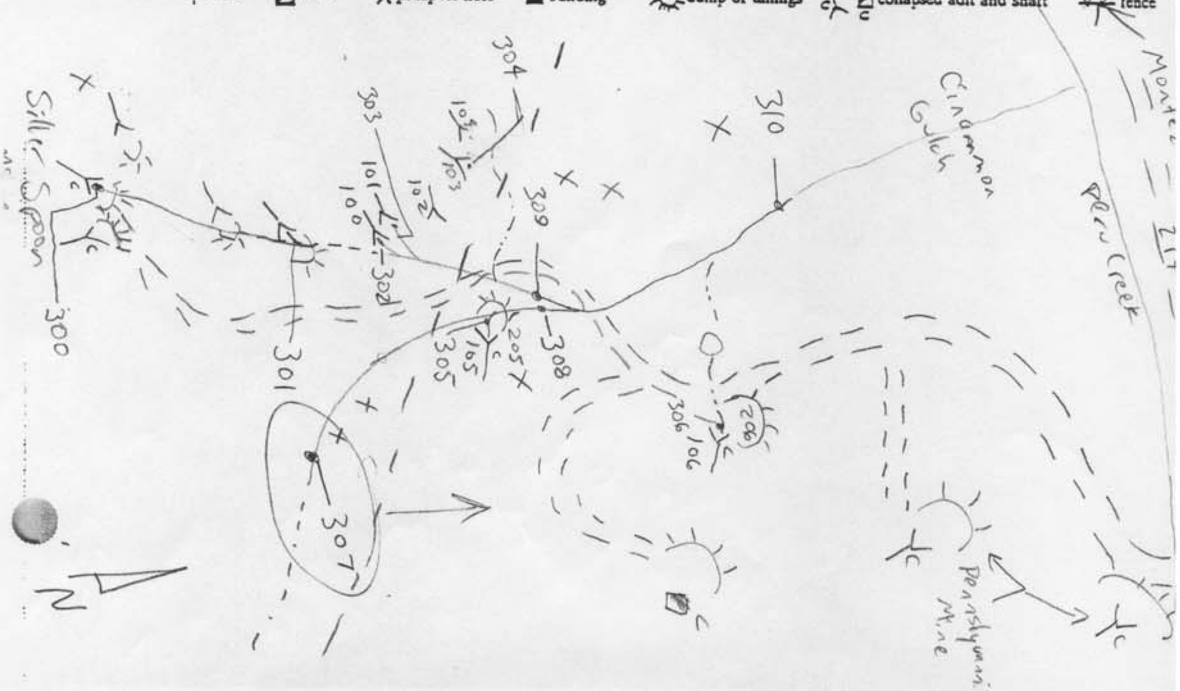
GPS READINGS	
Ftr. No.	Location
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.
	Lat. Long.

→ more on back →

DIAGRAM OF PROBLEM AREA (Locate all adits, shafts, dumps, prospects, etc. on topo map.)

Check off upon completion: ___ north arrow; ___ scale bar or general size noted; ___ direction to nearest trail/road/town noted; ___ significant mine features numbered

Adit | shaft | X prospect hole | building | dump or tailings | collapsed adit and shaft | fence



Item	306	307	308	309	310		
Adit/Shaft/other	106	0	0	0	0		
p.H. (Standard units)	4.0	5.2	4.5	4.0	4.0		
Conductivity (µS)	600	100	200	200	200		
Flow (gpm)	2.5	6.0	6.0	6.0	12.0		
Method of flow measure	D	D	D	D	D		
Date Sample	9/29	9/29					
Location Sample	A	RU	RD	RD	RD		
Evidence toxicity Drainage	-	N	P	P	P		
Evidence toxicity, Stream		N	P	P	P		
Distance from Stream							
Comments							
Lab Water Sample #	.306-1 4304382-1						
	10/5						

430/45							Long.

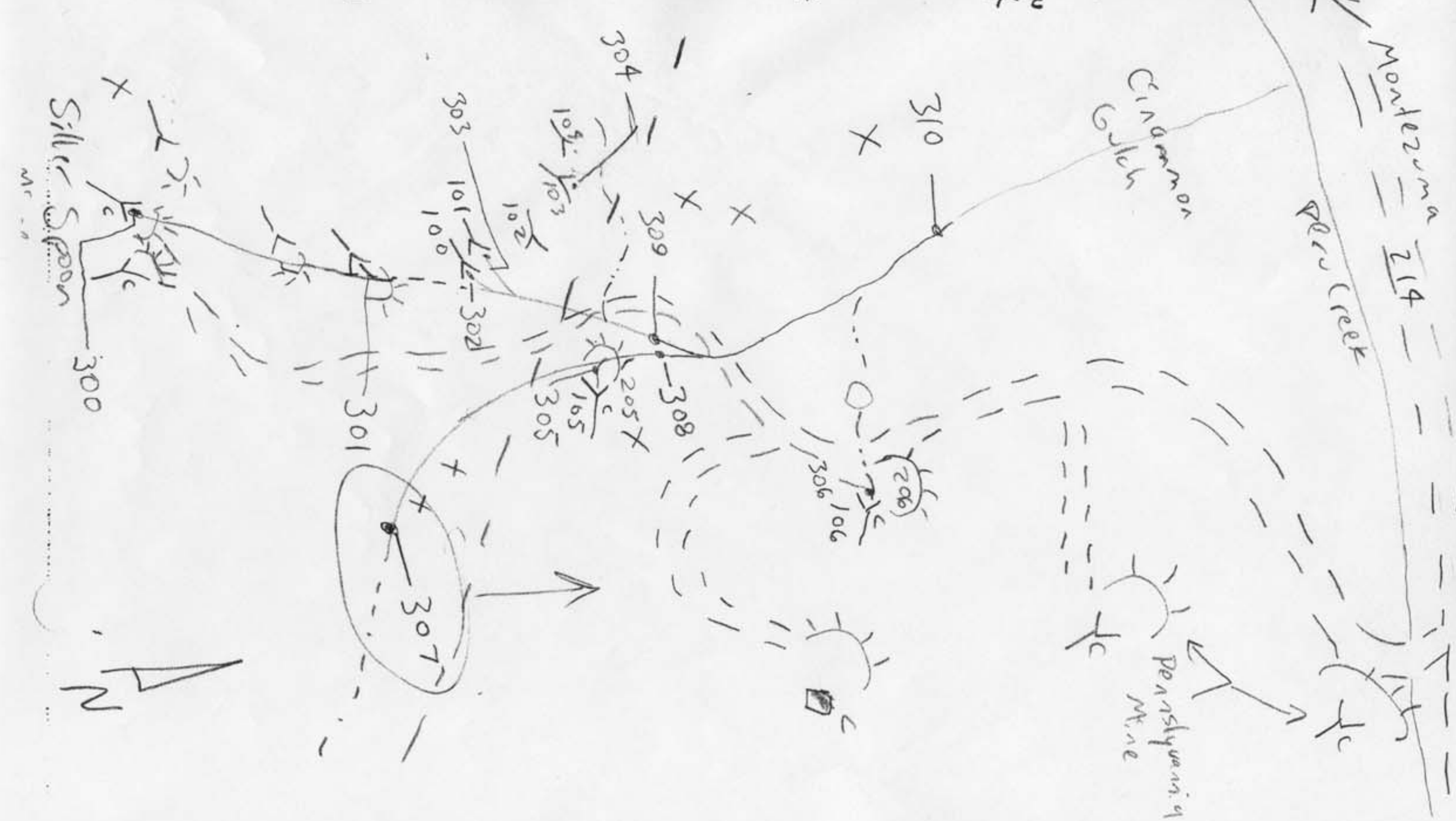
10/5 10/5 10/5

→ more on back →

DIAGRAM OF PROBLEM AREA (Locate all adits, shafts, dumps, prospects, etc. on topo map.)

Check off upon completion: __ north arrow; __ scale bar or general size noted; __ direction to nearest trail/road/town noted; __ significant mine features numbered

Adit   shaft   X prospect hole   building   dump or tailings   c collapsed adit and shaft   fence



•81. Local person interviewed ______________________ Name ______________________ Address

•82. Name and address of person desiring a copy of this form: ______________________

•83. Describe the minimum work needed to mitigate any public health, safety, welfare, or environmental problems observed at the site. Note specific reclamation activities along with an estimated cost and time period to implement each activity described. Code costs as: 1= less $10,000; 2= $10,000 to $100,000; 3= $100,000 to $500,000; 4= more than $500,000. Code estimated time to complete the activity as: 1= less than 1 month; 2= 1 to 12 months; 3= 1 to 3 years; 4= over 3 years

Cost	Time	Recommended reclamation activity

•84. Comments relating to health, safety, welfare, environmental, or restoration problems and any general comments. All comments must be keyed to mine feature # or drainage/water sample item #.

300 Mine drainage originating from collapsed adit with two prospect pits immediately above it. This mine drainage is the main source of water in Cinnamon gulch. Significant Environmental degradation. p.H 3.0, Conductivity 300 mS., Flow 3.0 gpm. Appears to be on private claim. Rusty precipitates.

301 Another mine drainage which originates from an intact adit approximately 250 ft downstream of feature 300. Drainage has dark maroon precipitates. p.H 3.2, 400 mS, flow 1.5 gpm. Significant degradation.

100 Partially intact adit with water draining. Adit is about 20 feet deep with a 4x4 foot portal opening. Potentially physically dangerous. Feature may be partially on private claim. Dump is very small but mine drainage flows right over it. Environmentally, dump is potentially significant.

302 Mine drainage from adit 100. Yellow, orange precipitates which are forming terraces on dump and in adit. 3.2 p.H, 700 mS., 1.5 gpm. Significant degradation.

101 Partially intact adit with water draining. Adit is atleast 25 ft. long, with a portal opening of 4x4 ft. Appears to be on forest service land. Potentially physically dangerous. Dump is very small but mine drainage bisects it. Potentially Significant Env. degradation.

303 Mine drainage from adit 101. Yellow/orange precipitates, p.H. 3.5, 500 mS., flow 1.5 gpm. Significant degradation.

102 Intact adit with water standing.. Adit is about 25 ft deep with an opening of 6x4 feet. Adit has a 15 foot highwall. Potentially dangerous. Very small. Water is not draining at this time. -if more comments use back of page →

General Comment: ______________________

-if more comments use back of page →

OFFICE/LITERATURE INFORMATION

•41. Owner of surface ______________________
•42. Last known operator ______________________
•43. Estimated production ______________________
•44. Dates of production ______________________
•45. Literature not cited in comments ______________________
•46. Citation of any historical register listing ______________________

103. Intact adit with water draining. Adit is atleast 35ft deep with an opening of 6x4 feet. Potentially dangerous. Dump is small but drainage bisects it. Potentially significant degradation.

304 Mine drainage from Adit 103, orange precipitate. 3.5 p.H., 300 m.S., Flow 1.5 gpm. Potentially significant degradation.

104. Partially intact adit with water standing 4 ft below grade. Adit is 15 ft deep with an opening of 2x3 ft. Potentially Dangerous. Small adit, only slight degradation.

105 Collapsed adit with water draining. No phys. hazard, but there is significant env. degradation.

205 Dump of adit 105. Toe of dump is in stream and mine drainage bisects dump. Potentially significant degradation. 6.0 p.H., 200 mS, 2.5 gpm.

305 Mine drainage from adit 105. Drainage has tan/yellow precipitates.

106 Collapsed adit with water draining. No phys. hazard but there is significant env. degradation. Drainage goes into small pond before it reaches cinnamon gulch. This seems to help matters. May be on private claim

206 Dump from adit 106. Dump has been dozed and is displaced. Mine drainage runs along south side of remaining dump. Slight degradation. Site may be on private claim.

306 Mine drainage from adit 106. Drainage has tan/red precipitates. 4.0 p.H., 600 mS, flow 2.5 gpm. Significant degradation.

307 Water tested at headwaters of east fork of cinnamon gulch. (Before contact with mine dumps and drainages) Stream is of natural quality 5.2 p.H., 200 mS, 6.0 gpm.

308 Water tested in same stream as 307 after contact with mines. Rusty precipitates, 4.5 p.H., 200 mS, 6.0 gpm.

309 West fork of cinnamon gulch (which is mostly a mine drainage) Rusty precipitates, 4.0 p.H., 200 mS, 6.0 gpm.

310 Water tested after east and west forks of cinnamon gulch join. Rusty precipitates 4.0 p.H., 200 mS, 12.0 gpm.

CODES FOR TABULAR INFORMATION

ALL TABLES: If appropriate code is not listed, use: **N** = none or no; **N/A** = not applicable; **UNK** = unknown; **O** = other, explain in #84

ADITS, SHAFTS, & OPENINGS

- Type of feature: **A** = adit; **S** = vertical shaft; **I** = incline shaft; **P** = prospect hole; **ST** = stope; **G** = glory hole; **SU** = subsidence feature; **PT** = open pit; **O** = other, explain in #84.
- Condition: **I** = intact; **P** = partially collapsed or filled; **F** = filled or collapsed; **N** = feature searched for but not found (mine symbol on map)
- Drainage: **N** = no water draining; **W** = water draining; **S** = standing water only (note at what depth below grade)
- Access deterents: **N** = none; **S** = sign; **F** = fence; **C** = sealed or capped; **D** = open door or hatch; **L** = locked door or hatch; **G** = open grill; **O** = other, explain in #84.
- Deterent condition: **P** = prevents access; **D** = discourages access; **I** = ineffective
- Ratings: Hazard: **E** = emergency; **1** = extreme danger; **2** = dangerous; **3** = potential danger; **5** = no significant hazard
  Env. Deg.: **1** = extreme; **2** = significant; **3** = potentially significant; **4** = slight; **5** = none
- Comments?: **Y** = yes; **N** = no

DUMPS, TAILINGS, AND SPOIL AREAS

- Type of feature: **D** = mine dump; **T** = mill tailings; **W** = coal waste bank; **S** = overburden or development spoil pile; **DS** = dredge spoil; **HD** = placer or hydraulic deposit; **H** = highwall; **P** = processing site
- Size of materials: **F** = fine; **S** = sand; **G** = gravel; **L** = cobbles; **B** = boulders
- Cementation: **W** = well cemented; **M** = moderately cemented; **U** = uncemented
- Vegetation Type: **G** = mixed grass; **S** = sagebrush/oakbrush/brush; **J** = juniper/piñon; **A** = aspen; **P** = pine/spruce/fir; **T** = tundra; **R** = riparian; **F** = tilled crops; **B** = barren/no vegetation; **W** = weeds
- Vegetation Density: **D** = dense; **M** = moderate; **S** = sparse; **B** = barren
- Drainage: **N** = no water draining; **W** = water draining across surface; **S** = standing water only; **SP** = water seeping from side of feature
- Stability: **U** = unstable; **P** = potentially unstable; **S** = stable
- Water erosion: of Feature: **N** = none; **R** = rills; **G** = gullies; **S** = sheet wash
  Storm Runoff: **C** = in contact with normal stream; **S** = near stream or gully, but only eroded during storm or flood; **N** = no storm/flood runoff erosion
- Wind erosion: **N** = none; **D** = dunes; **B** = blowouts; **A** = airborne dust
- Radiation Count: **N** = none taken; record value of reading if taken
- Access deterents: **N** = none; **S** = sign; **F** = fence; **O** = other, explain in #84
- Ratings: Hazard: **E** = emergency; **1** = extreme danger; **2** = dangerous; **3** = potential danger; **5** = no significant hazard
  Env. Deg.: **1** = extreme; **2** = significant; **3** = potentially significant; **4** = slight; **5** = none
- Comments?: **Y** = yes; **N** = no

DRAINAGE/WATER SAMPLES

- Adit/Shaft/Dump No./Other: Indicate Feature No. associated with water information; **0** = other, explain in comments
- Flow (cfs): record seeps as 0.01 cfs (Rule of Thumb: a cfs ≈ one full-blast garden hose)
- Method of flow measure: **E** = estimate; **T** = bobber/stopwatch/x-section; **W** = weir; **D** = catchment; **F** = flow meter
- Location of sample and flow: **A** = immediately adjacent to adit/shaft; **B** = below dump/tailings; **C** = immediately above confluence with receiving stream; **SW** = standing water in/on feature; **RU** = receiving stream upstream of feature; **RD** = receiving stream dowmstream of feature;
- Evidence of toxicity: **N** = none; **A** = absence of benthic organisms; **W** = opaque water; **P** = yellow or red precipitate; **S** = suspended solids; **D** = salt deposits
- Comments?: **Y** = yes; **N** = no

APPENDIX B

WATER SAMPLING PROTOCOLS AND QA/QC RESULTS

AT SAMPLE SITE:

1. **Calibration**

Check pH and conductivity meter calibration. Re-calibrate if necessary. Log date, time, and calibration results into field notebook.

2. **Data Sheet**

Begin completing a Water Sample Data Sheet. Perform requisite measurements of GPS location, pH, conductivity, temperature, physical description, etc.

3. **Water Sample**

1) Put on gloves.

2) If sub-sampling at a location other than the sample site, rinse a clean, unused 1000-mL sample bottle with the sample water *3 times*. Then fill it with sample water. If flow at the site is too low to allow using the sample bottle without stirring up the bottom sediment, use a syringe **--rinsed with sample water 3 times** to transfer the water into the sample bottle. *Do not touch the inside of the bottle, the lid, or the sample water.*

3) Label the 1000-mL bottle with the sample number. If a syringe is used to transfer sample water into the sample bottle, the same syringe can be used for the subsequent sub-sampling of this sample. Therefore, return the syringe to its packaging and label the packaging with the sample number as well. Place the labeled syringe into a ziplock bag.

4) Place sample bottle(s) and any syringes to be re-used for sub-sampling into separate ziplock bags.

4. **Flow measurement or estimation**

After sampling and/or on-site subsampling is complete, use a flume to measure the volume of flow. In many cases, use of a flume is not practical. A flowmeter may be a viable option in larger streams. In small streams or streams with a steep gradient, using a liter bottle or 5-gallon bucket as a catchment may be effective. Depending on site conditions, these methods should be accurate to within about 20%. Estimation of flow is the last alternative, if the other options are not practical.

<u>AT THE SUBSAMPLING LOCATION:</u>

1) Label each sub-sample bottle <u>before</u> beginning the subsampling procedure.

Record the following:

1) Name of sample site
2) Sample number
3) Subsample type
   The subsamples will be one of the following:
   a) Filtered metals, acidified (FMA)
   b) Unfiltered metals, acidified (MA)
   c) Unfiltered unacidified (NEUT)
4) Time
5) Date

2) Put on gloves and safety goggles.

3) Begin subsampling:

A) **<u>Unfiltered metals acidified (MA) sample</u>**
This sample **<u>is not</u>** filtered, and has acid added. It is for analysis of total metals (**Note:** If the samples are to be sent to the State Inorganic Laboratory or to Analytica Laboratory, acid will not be added in the field. It will already be in the FMA and MA bottles).

1. **(Perform this step only if the laboratory has not added acid to the bottle)**
   Rinse the new acid-cleaned, 250-mL, MA plastic bottle with 10-20 mL of raw sample water three times.

2. After shaking the 1000-mL sample bottle to adequately mix any sediment or suspended material, pour the water into the 250-mL "MA" subsample bottle to just below the neck of the bottle.

3. **(Perform this step only if the laboratory has not added acid to the bottle)**
   Add 20 drops of concentrated (16 molar) nitric acid to this sample if the pH is greater than 4.5. If pH is less than 4.5 only ten drops are needed. (must be preserved to a pH=2 or lower, so if sample is very basic, more nitric acid may be required) **<u>Use care when working with nitric acid.</u>**

4. After tightly securing the lid, lightly shake the bottle to mix the acid with the subsample.

B) **<u>Filtered metals acidified (FMA)</u>**

This sample is filtered and has acid added. It is used for analysis of dissolved metals (**Note:** If the samples are to be sent to the State Inorganic Laboratory or to Analytica Laboratory, acid will not be added in the field. It will already be in the MA and FMA bottles).

1. Put on new gloves (only if necessary)

2. Rinse a new 60-cubic centimeter (cc) syringe (or, if a syringe was used on site, rinse and re-use this syringe) by drawing in 10 mL of raw sample water. Then pull up on the syringe so that the entire syringe barrel can be exposed to the 10 ml of sample. Shake, discard and repeat twice. Then fill the syringe with sample water from the 1,000-mL bottle. Purge the syringe of any air bubbles to prevent an "air-lock" in the filter.

3. Rinse a new 0.45 μm disposable filter, by attaching the filter to the rinsed syringe and forcing 20 cc of sample water through the filter. Point the syringe away from the subsampling area.

4. **(Perform this step only if the laboratory has not added acid to the bottle)**
   Rinse the new, acid-cleaned, 250-mL FMA plastic bottle with 10 mL of filtered sample water three times.

5. Filter sample water into a new, acid-cleaned, 250-mL FMA plastic bottle. Fill the bottle to just below the neck of the bottle. If pushing water through the filter becomes difficult, place the syringe with the filter into a caulking gun (covered with plastic tape). The filter should be outside the end of the gun with the syringe barrel inside the gun. If filtering in the caulking gun becomes difficult, attach a new filter. Rinse this filter with 20 mL of sample, and then resume filtering into bottle.

6. **(Perform this step only if the laboratory has not added acid to the bottle)**
   Add 20 drops of concentrated (16 molar) nitric acid to this sample if the pH is greater than 4.5. If pH is less than 4.5 only ten drops are needed. (must be preserved to a pH = 2 or lower, so if sample is very basic, more nitric acid may be required) **<u>Use care when working with nitric acid.</u>**

7. After tightly securing the lid, lightly shake the bottle to mix the acid with the subsample.

C) **Unfiltered unacidified sample (NEUT)**
This sample is **not** filtered and does **not** have acid added. It is used for analysis of anions.

1. Put on new gloves (only if necessary)

2. Rinse a new, **non**-acid cleaned, 250 mL "NEUT" plastic bottle three times with about 10 mL of sample water and discard.

4. Pour sample water into the "NEUT" bottle to just below the neck of the bottle. Preserve by refrigeration (at 4º C) in a cooler.

D) **Alkalinity Determination**-(Only performed on samples with a pH of 4.5 or greater.)

1. Use a CHEMetrics, Inc. K-9810 (10 to 100 ppm) or K-9815 (50-500 ppm) total alkalinity titration kit.

2. Fill a syringe from the 1,000 mL bottle and inject 20 mL of sample water through a 0.45 μm filter into the small cylinder supplied with the kit.

3. Add six drops of actuator solution to the filtered water sample. The actuator solution will cause the sample water to become green.

   Note: The water is turned green, titrated to pink/red, and then to green again, at which time the meniscus is read. See below.

4. Attach the soft, pliable end of the short tubing piece to the ampule.

5. Break the scored tip of the ampule by hand and insert it into the device supplied in the titration kit. This device allows the user to admit small volumes of sample water into the evacuated ampule.

6. Immerse the stiff end of the tubing in the sample water.

7. Carefully add sample water to the ampule until a pink/red color appears. This is done by pressing the control bar on the device supplied with the titration kit, which squeezes the plastic ball in the pliable tubing. Mix the solution thoroughly in the ampule between additions. Add sample water until the solution just turns green.

8. After the solution turns green, invert the ampule and read the number at the meniscus. This number is the alkalinity as calcium carbonate expressed as milligrams per liter (mg/L) or ppm of $CaCO_3$.

QA/QC Samples

Field duplicate sample - a field duplicate is an independent sample of the same medium (water, solids), collected at the same time and same location as another sample. This is used to confirm the reproducibility of the analytical results.

Laboratory duplicate sample - a laboratory duplicate is a split from a sample analyzed in the lab. It is used to confirm the reproducibility of the laboratory analyses.

Equipment Blanks - Are created by reproducing the entire sampling process with de-ionized water (reagent grade). Clean, unused sampling equipment should be used.

QA/QC RESULTS

Two equipment blanks were collected during the course of the water sampling program. No constituents were detected in either of the blanks. Analytical results are assumed to be valid representations of the chemical composition of the water at the sample sites.

Four duplicate water samples were collected (sample CG-01-5, a duplicate of CG-01-4; CG-01-18, a duplicate of CG-01-17; and CG-01-21, a duplicate of CG-01-20). Only two significant departures were observed in the analytical results between the samples and their duplicates: Chloride was reported as 4 mg/L in sample CG-01-20, and 10 mg/L in the duplicate, sample CG-01-21 (relative percent difference of 86%). Lead was reported as 270 μg/L in CG-01-20, and 240 μg/L in the duplicate (relative percent difference of 12%). These departures are not considered to be of sufficient magnitude to warrant investigation into laboratory QA/QC procedures.

Samples were analyzed by the laboratory at the Colorado Department of Public Health and Environment. This is a USEPA certified laboratory and follows QA/QC procedures required by the USEPA. Some of these procedures include adding spikes on 10% of the samples and analyzing duplicates on 10% of the samples. Calibration of the analytical equipment is also checked every 10 samples. All of the spikes, laboratory duplicates, and calibration parameters fell within laboratory requirements. Original laboratory QA/QC documentation may be viewed, upon request, at the CGS offices.

ANALYTICAL METHODS

USEPA Method 200.7 (ICP/Atomic Emission Spectrometry) was used to analyze most parameters (aluminum, arsenic, calcium, chromium, copper, iron, magnesium, manganese, molybdenum, nickel, potassium, silicon, sodium, and zinc). Antimony, cadmium, lead, silver, and thallium were analyzed by USEPA Method 200.8 (ICP/Mass Spectrometry). USEPA Method 300.0 (Ion Chromatography) was used for chloride and sulfate. Fluoride was analyzed by Method SM 4500-F-E (Complexone Method).