

**Mining Sites on the National Priorities List
NPL Site Summary Reports**

**U.S. Environmental Protection Agency
Office of Solid Waste**

June 21, 1991

FINAL DRAFT

Volume IV

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**Excerpts From Preliminary Health Assessment for Oronogo-Duenweg Mining Belt,
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Department of Health and Human Services and ATSDR; June 18, 1990**



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Mining Waste NPL Site Summary Report

**Oronogo-Duenweg Mining Belt
Jasper County, Missouri**

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ORONOGO-DUENWEG MINING BELT

JASPER COUNTY, MISSOURI

INTRODUCTION

This Site Summary Report for the Oronogo-Duenweg Mining Belt site is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of the summary by the Remedial Project Manager for the site, Mark Bogina.

SITE OVERVIEW

The Oronogo-Duenweg Mining Belt Site, located near the City of Joplin in Jasper County, Missouri, is one of two sites located in the Missouri portion of the Tri-State (Missouri, Kansas, and Oklahoma) Mining District (see Figure 1). The 20-square mile Oronogo-Duenweg Mining Belt site was the location of the most concentrated mining activities in the 2,400-square mile Tri-State Mining District (Reference 1, page 1; Reference 2, page 2-1; Reference 3, page 3).

Horizontal mine shafts, open pits, open vertical shafts, and tailings piles remain from commercial lead and zinc mining operations that were in production from the 1850's through the late 1960's. The Oronogo-Duenweg Mining Belt Site is located within two drainage areas – the Center Creek drainage area located northeast of Joplin, and the Turkey Creek drainage area located immediately north of Joplin. Approximately 4.6 square miles of tailings exist in the Joplin area, two thirds of which are in the Center Creek drainage area (Reference 1, page 1-2). EPA estimated that 20 to 100 million tons of mining waste are present at the site, and that the area affected by the site may be as much as 30 square miles.

The primary contaminants of concern at the site are cadmium, lead, and zinc. All three of these contaminants have been detected at elevated concentrations in ground water, surface water, and sediments. Nickel and mercury have also been detected in environmental media at the site, but their concentrations are presently not considered to be a public health concern. Surface waters from Center and Shoal Creeks (as well as pit water) may be used for crop irrigation, livestock watering, sport fishing, and commercial and recreational purposes (Reference 1, pages 3 and 4).

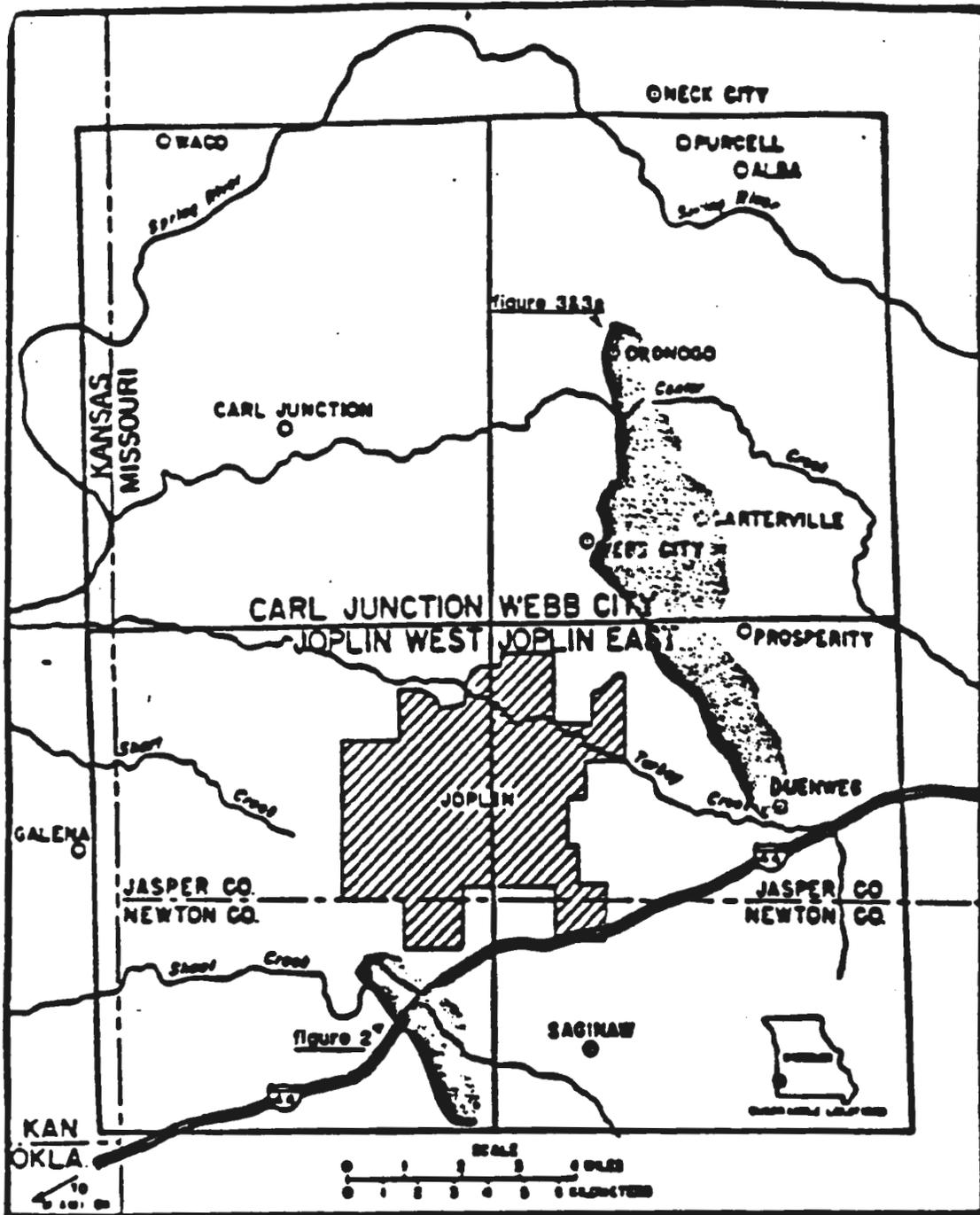


FIGURE 1. LOCATION MAP MISSOURI STUDY AREA, TRI-STATE DISTRICT

However, surface water contained in most abandoned pits is too acidic to support aquatic biota, and is not suitable for that sport fishing, as fish cannot survive in such environments. In addition, most surface waters contained in the mined pits are too corrosive to be used for commercial purposes. Both deep and shallow aquifers are used as sources of drinking water. Industrial, commercial, and retail establishments; recreational facilities; service industries; and residential areas exist within the site boundaries. New housing construction on reworked mine land occurs frequently. In addition, schools, hospitals, and nursing homes are located within the site's boundaries (Reference 1, pages 3 and 4).

According to EPA Region VII, negotiations for the Remedial Investigation/Feasibility Study under an administrative agreement began with 15 Potentially Responsible Parties (PRPs) on March 7, 1991, and may continue into June 1991. Field activities are expected to begin within the last quarter of 1991. Thus, no determinations have been made regarding site remediation.

OPERATING HISTORY

Lead and zinc ore deposits were discovered in the Tri-State Mining District in 1838. Mining began in the area around 1848 and continued until the late 1960's. Between 1850 and 1950, the site generated over \$1 billion in revenue (Reference 1, page 1; Reference 2, page 2-1). As many as 4,000 shallow subsurface mines and some strip mines were worked in the area until 1970 when all commercial mining had ceased. Because the mines were shallow and of limited size, as one location became depleted, the operation moved to a new area (Reference 1, page 2).

Mining activities at the site involved mining crude ores and milling these ores to produce lead and zinc concentrates. Ore-bearing rock was crushed and ground into a fine gravel. Then the separation of mineral from the crude ore was accomplished through a jigging operation. Tailings (also called chat) were skimmed from the jigging table and discarded in large piles (Reference 1, page 2; Reference 2, page 2-1). Waste products from the processing were removed and placed in large tailings piles. Barren rock containing no valuable minerals was also discarded in piles (Reference 2, page 2-1).

SITE CHARACTERIZATION

Contaminants from the site spread over a wide surrounding area by surface-water flow, ground-water migration, and atmospheric dispersion (Reference 1, page 3). Heavy metal contamination of ground water, surface water, and sediment has been documented in the area. The environmental pathways of

Oronogo-Duenweg Mining Belt

concern at the site are contaminated ground water, surface water, sediment, surface soil, and certain components of the aquatic and terrestrial food chain (Reference 1, page 5).

Ground Water

Two aquifers are used for drinking water at the site. The shallow aquifer is encountered near land surface and extends to depths as great as 500 feet in the Joplin area. The deeper aquifer is encountered at a minimum depth of 300 feet, and extends to depths as great as 1,800 feet. The deeper aquifer is separated from the shallow aquifer by relatively impermeable shales; however, hydraulic connection between the shallow and deep aquifers is believed to exist (Reference 1, pages 3 and 6; Reference 3, pages 5, 7 and 12). Specifically, leakage of ground water from the shallow aquifer to the deeper aquifer may occur (Reference 1, pages 3 and 6). In addition, according to EPA, some of the mining pits, shafts, and boreholes may provide conduits by which contaminants can migrate from the shallow aquifer into the deeper aquifer.

Ground-water sampling revealed that lead concentrations in the shallow aquifer range from Not Detected (ND) to 79 parts per billion (ppb). Zinc concentrations ranged from 130 to 8,000 ppb. Cadmium concentrations ranged from ND to 27 ppb (Reference 2, page 6-1). The variation in contaminant levels may be due to differences in the construction, depths, location of wells, and/or changes in ground-water flow rates. Water-quality degradation is caused when subsurface sulfide ores are exposed to an oxidizing environment. Oxidation of metal-sulfide minerals and subsequent dissolution and hydrolysis of soluble sulfates in tailings piles produces sulfuric acid and releases metals into the surrounding environment. Precipitation of metals occurs as the acid is neutralized by calcium carbonate in the native rocks (Reference 2, page 2-1).

Surface Water and Sediment

The major drainage feature of the area is Spring River. Turkey Creek, located at the southern end of the site, and Center Creek, located within the northern portion of the site, are hydraulically connected with the shallow aquifer, and are major tributaries of Spring River. These two creeks establish the two drainage areas on which the site is located. The Center Creek Drainage area, located northeast of Joplin, drains the northern portion of the site, and the Turkey Creek drainage area, located immediately north of Joplin, drains the southern portion of the site. In addition, drainage channels constructed in the early 1900's to divert rain and mine water away from the mining operations now act as tributaries to Center Creek during rainy periods (Reference 3, page 5).

Downstream sediment samples collected from Center Creek contained levels of zinc, lead, and cadmium that were elevated relative to background samples (Reference 2, page 6-1). An EPA Field Trip Report for the site notes that not all contamination should be attributed to mining activities because of the possible presence of local naturally highly mineralized areas (Reference 2, pages 6-1 and 6-2). According to EPA, their findings will be documented in a Remedial Investigation Report and Feasibility Study at the conclusion of field investigations.

The U.S. Geological Survey's (USGS's) investigation at three main surface water bodies that serve to drain area tailings piles (Center Creek, Turkey Creek, and Short Creek) found that chromium, cobalt, mercury, nickel, and silver were present in concentrations similar to those existing in the creeks upstream of the piles. Aluminum, iron, and manganese were found in higher concentrations, but are generally not harmful to aquatic life in the creeks. Concentrations of zinc, lead, copper, and cadmium were also present in higher concentrations, which are harmful to aquatic life (Reference 3, pages 15 and 16).

An August 1977 report prepared by the USGS details the "Effects of Lead and Zinc Mines and Tailings Piles on Water Quality in the Joplin Area, Missouri" (Reference 3). The report found that average concentrations of iron, manganese, cadmium, and zinc in mine waters all exceeded recommended drinking water standards (Reference 3, page 7).

Surface Soils

Soil contamination has not been investigated at the site. Nevertheless, it is expected to exist on (and around) the tailings piles. Airborne transport of dust has probably also contributed to soil contamination (mining, machining, and smelting operations can produce particles small enough to be transported in the air). None of the tailings piles has been stabilized, and the waste materials have been used to backfill mine shafts, for road construction, and in other unspecified ways (Reference 1, page 5).

Biota

Although biological media have not been sampled, environmental fate data suggest that zinc and cadmium may bioaccumulate in aquatic systems, lead may bioaccumulate in some shellfish, and cadmium may be taken up by edible plants (Reference 1, page 5).

ENVIRONMENTAL DAMAGE AND RISKS

A Risk Assessment has not yet been performed for the site. However, public health implications of the site have been discussed in the U.S. Department of Health and Human Services' Preliminary Health Assessment for the site (Reference 1).

The most important human exposure pathways for the site are believed to be ingestion of contaminated ground water and surface water; inhalation of airborne contaminated dust particles; ingestion of contaminated soil by children in residential areas; and ingestion of contaminated aquatic organisms and of foodstuffs grown in contaminated soil. Dermal or mucous membrane contact is possible but unlikely (Reference 1, page 6).

The documented contamination of ground water, surface water, and sediments with heavy metals could potentially adversely affect the surrounding populations. Within the site boundaries are industrial, commercial, retail, and service establishments. There are also residential and recreational areas onsite. In addition, hospitals, nursing homes, and schools are all present onsite, thereby exposing potentially sensitive populations (sick, elderly, and children) to contaminants (Reference 1, page 6).

Preliminary risk calculations indicate that excessive exposure to zinc, cadmium, and lead may be occurring for residents in the Oronogo-Duenweg Mining area (Reference 1, pages 6 and 7). In addition, the State of Kansas has conducted several health surveys indicating a high incidence of tuberculosis and lung cancer among area residents according to EPA. Missouri has also started to examine lead levels in the blood of local individuals.

Surface water at the site, specifically Center Creek, is used for fishing. In addition, surface waters potentially affected by the site may be used for crop irrigation, livestock watering, commercial purposes, and recreational purposes. Consequently, public health risks include the risk of exposure through the food chain and recreational activity (Reference 1, pages 3 through 5).

Individuals in the small towns of the Oronogo-Duenweg area (Webb City, Oronogo, Duenweg, and Carterville) primarily obtain their drinking water from municipal wells screened in the deeper aquifer. An estimated 1,500 people living outside of these Towns obtain their water from private wells tapping the shallow aquifer (Reference 1, pages 3 and 6). Ground-water samples collected in November 1988 contained concentrations of lead and cadmium that exceed EPA proposed Maximum Contamination Levels (Reference 1, page 8). A municipal water supply well within the Site was abandoned some time after 1972 when it began producing water with high concentrations of dissolved solids. The data

for this well indicate that contamination of the deep aquifer with mine water may have occurred (Reference 3, page 13).

Ingestion of the contaminants present at this site (zinc, cadmium, and lead) can cause stomach irritation, kidney damage, liver damage, brain and central nervous system damage, harmful effects to blood, and damage to the reproductive system. Excessive zinc concentrations are thought to contribute to the production of cancerous cells and can block the body's ability to absorb other important minerals. Exposure to high levels of lead can lead to fetal damage, including preterm birth, reduced birth weight, and reduced intelligence in later life (Reference 1, page 6).

REMEDIAL ACTIONS AND COSTS

EPA anticipates that the Remedial Investigation/Feasibility Study will be started in the last quarter of 1991. Consequently, remediation alternatives have not been developed and the estimated cost for completing site remediation has not yet been determined.

CURRENT STATUS

EPA Region VII and the PRPs are presently in the process of negotiations for planning the Remedial Investigation/Feasibility Study. The field activities for the Remedial Investigation are expected to begin in the final quarter of 1991. A Record of Decision is expected in 1993.

Oronogo-Duenweg Mining Belt

REFERENCES

1. Preliminary Health Assessment for Oronogo-Duenweg Mining Belt, Jasper County, Missouri, CERCLIS No. MDD980686281; Department of Health and Human Services and ATSDR; June 18, 1990.
2. Final Report for Tri-State Mining Area, Joplin, Missouri, TDD-R-07-8601-12A; EPA Region VII; June 27, 1983.
3. Effects of Abandoned Lead and Zinc Mines and Tailings Piles on Water Quality in the Joplin Area, Missouri, USGS Water Resources Investigations 77-75; James H. Barks, USGS; August 1977.

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**PRELIMINARY
Health
Assessment
for**

ORONOGO-DUENWEG MINING BELT

JASPER COUNTY, MISSOURI

CERCLIS NO. MDD980686281

JUN 18 1990

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- EPA Region VII. Potential Hazardous Waste Site: Preliminary Assessment, Tri-State Mining (Oronogo-Duenweg Center Creek Area), Missouri. February 24, 1986.
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SUMMARY

The Oronogo-Duenweg Mining Belt site, Jasper County, Missouri, has been proposed by the U.S. Environmental Protection Agency (EPA) for inclusion on the National Priorities List (NPL). Referred to as the Missouri portion of the Tri-State (Missouri, Kansas, and Oklahoma) Mining District, the site comprises approximately 20 square miles and was the location of the most concentrated mining effort in the Tri-State District. As a result of commercial zinc and lead mining operations that occurred from about 1850 until the late 1960s, large open pits (some filled with water) tailings (called chat) piles, open vertical shafts, and subsurface horizontal mining shafts exist throughout the area. Shallow groundwater, surface water, sediment, and surface soil are contaminated with heavy metals (zinc, lead, cadmium, and nickel). Municipalities in the area use both surface water and a deep aquifer for water supplies; individual households outside these centers rely on a shallow aquifer for water.

Based upon information reviewed, the Agency for Toxic Substances and Disease Registry (ATSDR) has concluded that this site is of public health concern because of the risk to human health resulting from probable exposure to hazardous substances at concentrations that may result in adverse human health effects. As noted in the Human Exposure Pathways Section below, human exposure to heavy metals may be occurring and may have occurred in the past via ingestion contaminated groundwater, soil, sediment, and inhalation of soil and sediment particles suspended in air.

Levels of lead and cadmium exceeding the EPA proposed Maximum Contaminant Level (MCL) have been documented in the few wells sampled. Other environmental pathways for which there are no data may represent additional exposure routes. Recommendations for soil and air sampling and a well survey, as well as a suggestion for developing a data base for accidents involving the physical hazards remaining from the mining operations, are presented.

BACKGROUND

A. SITE DESCRIPTION AND HISTORY

The Tri-State Mining District comprises approximately 2,400 square miles of the adjoining areas of three states--Kansas, Missouri, and Oklahoma. After the discovery of valuable ore deposits in 1838, commercial mining and smelting ventures began in the Joplin, Missouri, area in 1848. During the century spanning 1850-1950, this area produced 50 percent of the zinc and 10 percent of the lead used in the United States. Almost 4,000 mostly shallow, subsurface mines and a few strip mines were active at one time or another, mining an estimated 500 million tons of ore. In the late 1950s, production declined, and by 1970 all commercial mining had ceased. Because ore deposits were located close to the surface, and transportation and labor were abundant, most mines in the area were shallow and of limited size. Thus, they became unproductive in a relatively short period of time (5-10 years). When this happened, the independent mine

and mill plants would move to another location and sink another shaft. Such a prospect hole, if successful, would be mined in vertical and multiple horizontal directions until it too became depleted. As a result, the Jasper County-Joplin area is permeated with chat piles (the remains of milled ore), waste rock piles (low-grade ore, soil, and rock), open pits (up to 400 feet deep and filled with varying amounts of water), subsidence areas (where mine shafts have collapsed), and potential subsidence areas

The mined areas in the tri-state are shown in Figure 1. Figure 2 illustrates the portion of the mined area known as the Oronogo-Duenweg Mining Belt. At this time, the majority of investigative activity has centered on this part of the mined area, and the Hazard Ranking Score was based on information obtained from this area. It is our understanding that the EPA, during its Remedial Investigation/Feasibility Study process may consider additional portions of the tri-state mining area as well.

There are two drainage areas associated with the Oronogo-Duenweg Mining Belt, the Center Creek drainage area located northeast of Joplin, which drains the northern portion of the mining belt, and the Turkey Creek drainage area, which is immediately north of Joplin and drains the southern portion of the mining belt. There are an estimated 4.6 square miles of tailings in the Joplin area, with about 2/3 in the Center Creek Drainage area. Towns and private residences are located throughout the mining area.

Important surface water features in the area include the Spring River, which is the main drainage channel in the area. Major tributaries include Turkey Creek, Center Creek, and Shoal Creek, which are in hydraulic connection with the shallow groundwater. In addition, numerous drainage channels were constructed in the early 1900s to divert rain and mine waters away from important production shaft areas. These channels remain as wet-weather branches to Center Creek.

The shallow aquifer consists of cherty limestone, and the deep aquifer consists of dolomite and sandstone. A relatively impermeable, silty limestone and shale layer separates the shallow and deep aquifers. The shallow aquifer reaches land surface in some places and extends as deep as 490 feet in other places. Generally, the shallow aquifer begins 30 to 100 feet below ground surface. The deep aquifer is reached at a minimum of 330 feet and extends as deep as 1,800 feet.

More information on the history of mining in the Joplin area and a detailed description of most of the major areas of mining activity can be found in reference 1.

B. SITE VISIT

Personnel from the Agency for Toxic Substances and Disease Registry (ATSDR) conducted a site visit on March 20, 1989. This included a self-guided automobile tour, as described in reference 1. No additional information was obtained other than that provided in the documents reviewed.

C. COMMUNITY HEALTH CONCERNS

No community health concerns have been reported to ATSDR.

DEMOGRAPHICS, LAND USE, AND NATURAL RESOURCE USE

Surface water, including Center and Shoal Creeks and pit water, may be used for crop irrigation, livestock watering, and sport fishing. Some pits have commercial uses; at least one is used as a SCUBA diving training facility. Some pits are large enough to be part of recreational parks and are used for swimming and boating.

The city of Joplin obtains its water from Shoal Creek, which is located south of Joplin. Figure 1 illustrates that some mining had occurred upstream of this area. Smaller towns in the Oronogo-Duenweg area (Webb City, Oronogo, Duenweg, Carterville) use the deep aquifer as the primary source of drinking water. People living outside these small towns use private wells set in the shallow aquifer. According to one estimate, the population using shallow groundwater for its domestic water supply numbers 1,500. The deep aquifer reportedly is separated from the shallow aquifer by impermeable shales that appear to form an effective aquaclude. Leakage from the shallow aquifer to the deep aquifer may occur as a result of recharge.

The human activities that take place within the site boundaries involve industrial, commercial, and retail establishments; recreational facilities; service industries; and residential areas. Within the site boundaries there are potentially sensitive populations, such as children, patients, and the elderly at schools, hospitals, and nursing homes. New housing construction on reworked mine land occurs frequently.

ENVIRONMENTAL CONTAMINATION AND OTHER HAZARDS

The generally accepted concepts of on- and off-site contamination are difficult to apply here, because of the very large area under evaluation and the possibility that contaminants may be spread widely by surface-water flow, groundwater migration, and atmospheric dispersion. For the purposes of this Preliminary Health Assessment, we will consider the 20-square-mile area delineated in the site map specifically and the Tri-State Mining District in general as being subject to the public health evaluation process. Accordingly, all the data collected relative to this site will be considered as on-site data.

In addition to the heavy metals listed in Table 1, nickel and mercury were found also. However, the reported concentrations of these latter two are believed to be sufficiently low that we do not feel that these metals are of public health concern at this time.

A. ON-SITE CONTAMINATION

The data collected so far in this evaluation are summarized in Table 1. which includes the environmental media and concentration ranges.

Table 1
On-site concentrations of environmental contaminants
Oronogo-Duenweg Mining Belt, Missouri

ENVIRONMENTAL SOURCE	SUBSTANCE	CONCENTRATION RANGE	
	August 1976		
Groundwater	zinc	0.02	8.8 ppm
Surface water	zinc	0.5	35 ppm
	cadmium	0.0	0.06 ppm
	lead	0.0	1.3 ppm
	February 1986		
Private wells	zinc	0.1	8 ppm
	cadmium	0.01	0.03 ppm
	lead		0.08 ppm
Sediment	zinc		39,000 ppm
	cadmium	4	250 ppm
	lead	66	7,300 ppm
	August 1986		
Private wells	zinc	0.2	11 ppm
	cadmium	0.03	0.04 ppm
	lead	ND*	
	February 1988		
Private wells	zinc	0.05	9.1 ppm
	cadmium	ND	0.04 ppm
	lead	ND	0.04 ppm
	November 1988		
Private wells	zinc	ND	2.5 ppm
	cadmium	ND	0.02 ppm
	lead	ND	0.05 ppm

*ND: nondetectable

B. QUALITY ASSURANCE AND QUALITY CONTROL

Little information was provided about quality assurance and quality control. We assume that the data are of sufficient quality for the purposes of this Preliminary Health Assessment.

C. PHYSICAL AND OTHER HAZARDS

Remains of the mining activities cover so vast an area that public access restrictions, such as fencing or posting, would be of little use. Results of a U.S. Bureau of Mines survey in 1983 showed that over 1,500 open mine shafts and nearly 500 subsidence features were in the Tri-State district, with 124 in Missouri. Accidents to people and livestock, damage to buildings and roads above shaft areas and

underground mine workings, have been reported. However, no confirmations or statistical information are available.

PATHWAYS ANALYSES

A. ENVIRONMENTAL PATHWAYS (Fate and Transport)

Mining and milling processes increase the amount of heavy metals available for dissolution by decreasing the ore particle size and increasing the surface area of the particle. When the ores contain sulfides, as do sphalerite (zinc sulfide) and galena (lead sulfide) do, acidic solutions can form as groundwater contacts exposed ore or chat or as rainwater percolates through the piles. Increased contact time results in the solution of greater amounts of lead, zinc, and sulfate after oxidation, thus causing groundwater and surface water contamination. Solutions with long residence times may become highly acidic.

Surface water migration results in the movement of sediment containing small waste-ore particles deposited on the land surface. In addition, the mining and machining (milling) of ore results in the formation of smaller and smaller particles, some of which can become airborne readily. Smelting causes the formation of even smaller and more aerodynamic particles.

Heavy metal contamination of groundwater, surface water, and sediment has been documented in the area. Although surface soil contamination has not been confirmed by sampling, it undoubtedly exists on and around the chat piles, and probably in surrounding areas affected by atmospheric dispersion of dust. For the most part, none of the piles have been stabilized. In addition, waste material has been used in commerce as road fill and perhaps in other ways. Some backfilling of mine shafts has occurred.

Surface waters, notably Shoal and Center Creeks, are used for fishing. Zinc and cadmium bioaccumulate in aquatic systems. Lead does not appear to bioaccumulate significantly in most fish, with the exception of some shellfish (mussels). Cadmium can be taken up by many edible plants; other metals may be transported on improperly washed produce. The levels of acidity (pH) in groundwater and surface water have not been reported.

Therefore, the environmental pathways of concern at this site are contaminated groundwater, surface water, sediment, surface soil, and certain components of the aquatic and terrestrial food chain.

B. HUMAN EXPOSURE PATHWAYS

Several population centers and private residences are located within the boundaries of the Missouri mining area. Any activity that exposes persons to the environmental media listed above can be

considered a potential human exposure pathway. Most important of these potential human exposure pathways are ingestion of contaminated groundwater and surface water, inhalation of airborne contaminated dust particles, ingestion of contaminated soil by children in residential areas, and ingestion of contaminated aquatic organisms and of foodstuffs grown in contaminated soil. Dermal or mucous membrane contact with highly acidic water may be important also, but this is unlikely to occur chronically because symptoms are readily apparent.

PUBLIC HEALTH IMPLICATIONS

Ingestion of media containing heavy metals is the important route of human exposure here. The shallow groundwater is used as a source of drinking water for the approximately 1,500 persons who are not on municipal water systems. Municipal systems in the mining area use the deep aquifer. The deep aquifer may be hydraulically connected to the shallow aquifer and subject to contamination. The some of the pits may extend into the deep aquifer and provide a conduit for contamination of the deep aquifer. Depending on their concentration, heavy metals may cause irritation of the stomach (zinc and cadmium), kidney damage (cadmium and lead), liver damage (cadmium), brain and central-nervous-system damage (lead), effects on the blood (zinc and lead) and reproductive system (cadmium and lead), and possibly high blood pressure (cadmium and lead) if ingested.

The important health effect of excess zinc (zinc occurs naturally in drinking water and many foods) is its interference with the body's ability to absorb and use other essential minerals such as copper and iron. No studies have shown zinc to be associated with the production of cancer. In the United States, the average daily intake of zinc through the diet ranges from 7 to 16 milligrams per day. Using the highest level of zinc measured in groundwater (11 ppm) and assuming a water intake of 2 liters per day for an adult, we can estimate an intake of zinc from water alone of 22 mg per day (equivalent to a dose of 0.3 mg/kg/day for a 70-kilogram adult). Although the health effects of long-term exposure of humans to drinking water containing zinc at this level are not known, 0.3 mg/kg/day is about 3 times the lowest estimated No Observed Adverse Effect Level (NOAEL) reported in (10). Coupled with as yet unknown concentrations in air, food, and soil, excessive exposure to zinc may be occurring to residents of the Oronogo-Duenweg Mining area.

Exposure to lead is particularly dangerous for the fetus--because it is highly sensitive during development--and for young children--because they ingest more lead through normal mouthing activities, absorb more of the lead they ingest, and are more sensitive to its effects. Exposure of a woman during pregnancy is important because lead can transfer to the fetus, and result in preterm birth, and reduced birth weight. Reduced intelligence quotients (IQ) have been reported in children.

Kidney tumors have been reported in laboratory animals fed large doses of lead; the evidence is insufficient to suggest that lead causes cancer in humans, and occupational studies have not supported any such causal relationship. As a toxicant serving no known physiological requirement, lead at any level in the body is unnecessary. Current scientific thinking holds that there may be a risk of some adverse health effect at any level of lead exposure, even though current epidemiologic and analytic methodology may not be sensitive enough to measure these effects. In most of the studies on lead effects in humans, data are reported in terms of blood lead levels (micrograms lead/deciliter of blood (ug/dL). Typical blood lead levels in children, derived from intake calculations considering all routes of exposure (air, food, beverages, water, and soil ingestion), range from roughly 3 ug/dL in the least exposed children to 17 ug/dL in the highest exposed children. Using the data of Pocock, et al. (13), the blood lead level resulting from ingesting groundwater at the highest concentration reported for this site (0.08 ppm), would be approximately 4.8 ug/dL, or on the low end of the exposure spectrum. On the other hand, the average baseline intake of lead by 2-year-old, non-pica, non-urban children has been estimated to be 46.6 ug/day, with 25.1 ug from food, water; and beverages, 0.5 ug from inhaled air; and 21 ug from ingested dust. Considering only the groundwater at this site, the exposure would be 40 ug/day which, when added to the as yet unknown levels of exposure from inhaled air, inhaled and ingested dust, and ingested soil or food, could indicate excessive lead exposure for children and perhaps adults in the Oronogo-Duenweg Mining area.

The health effect of primary importance from cadmium ingestion is kidney injury (kidney stones). Inhalation of airborne cadmium may cause lung disease, including cancer. Cadmium is a common element; typically, the most important source of cadmium exposure for humans is ingestion of food. Consumption of 15-30 ug/day is common. Long-term uptake of up to 350 ug/day for an adult is believed to pose relatively little risk of causing injury to the kidney or to other tissues. Consumption of groundwater contaminated with 0.04 ppm cadmium would result in an intake of about 80 ug/day. Exposure from groundwater alone may pose a public health problem, since levels in excess of the Maximum Contaminant Level (0.01 ppm) have been documented. As yet unknown contributions from inhaled air and dust and ingested foodstuffs and soil may result in excessive cadmium exposure for residents of the Oronogo-Duenweg Mining area.

CONCLUSIONS

Based upon information reviewed, ATSDR has concluded that this site is of public health concern because of the risk to human health resulting from probable exposure to hazardous substances at concentrations that may result in adverse human health effects. As noted in the Human Exposure Pathways Section above, human exposure to heavy metals may be occurring and may have occurred in the past via

ingestion and inhalation of contaminated groundwater, soil, sediment, and air. The most recent groundwater sampling data available to ATSDR (November 1988, ten wells) shows lead and cadmium exceeding EPA proposed MCLs.

No data are available with which to evaluate the potential public health impact from air and soil pathways.

RECOMMENDATIONS

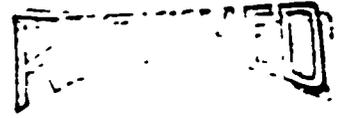
In accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended, the Oronogo-Duenweg Mining Belt site has been evaluated for appropriate follow-up with respect to health effects studies. Since human exposure to on-site contaminants may currently be occurring and may have occurred in the past, this site is being considered for follow-up studies. After consultation with Regional Environmental Protection Agency staff and State and local health and environmental officials, the Division of Health Studies, ATSDR, will determine if follow-up public health actions or studies are appropriate for this site.

The following recommendations are offered:

1. The particle size distribution of the chat piles should be determined to help predict the potential inhalation exposure.
2. Heavy-metal concentrations in soil should be determined. Particular attention should be paid to residential and other high-contact areas, such as schools and playgrounds.
3. A data base should be considered for the accidents and injuries resulting from the open mine shafts and other physical hazards remaining from the mining operations. Whether some sort of intervention strategy (such as posting or notification by mail) is needed could be based on the conclusions drawn from these data.
4. Considering the extensive use of the groundwater in the area, a wider program of private well sampling should be undertaken to characterize exposures. In addition, irrigation wells, private wells, or surface water bodies that are used as a source of water for livestock, gardens, or crops should be identified. Monitoring may be necessary to characterize the potential for bioaccumulation of heavy metals in livestock, crops, other farm produce, or garden foodstuffs.
5. Further sampling should be performed in the deep groundwater, especially in the area of the deeper mine pits, to determine whether the deep aquifer has been affected.

Reference 2

**Excerpts From Final Report for Tri-State Mining Area,
Joplin, Missouri, TDD-R-07-8601-12A;
EPA Region VII; June 27, 1983**



JUN 24 1986

SUPERFUND BRANCH

FINAL REPORT FOR
TRI-STATE MINING AREA
JOPLIN, MISSOURI

TDD-R-07-8601-12A

June 27, 1986

Submitted to: Paul E. Doherty, APRO

Prepared by: Region VII REM/FIT

Task Leader: Steven Vaughn

SECTION 2: SITE HISTORY

Commercial development of the mineral resources of southwestern Missouri began about 1850 and spread into southeastern Kansas and northeastern Oklahoma, forming the Tri-State District with Joplin as the urban center. The value of the Tri-State mineral production from 1850 to 1950 exceeded one billion dollars, and until 1945 the region was the world's leading producer of lead and zinc concentrates, accounting for one-half of the zinc and one-tenth of the lead produced in the United States. By 1950, most of the rich ores had been extracted, and mining and milling operations declined during the 1950's and ceased in the 1960's (Ref. 2).

The mining involved bringing the crude ores to the surface where the ores were milled into lead and zinc concentrates. Barren rock was discarded in piles while the ore-bearing rock was crushed and ground into fine gravel. The minerals were separated from the rock by a jiggling process and the waste products (tailings) skimmed off and discarded in large piles (Ref. 2).

Sphalerite (zinc sulfide) and galena (lead sulfide) were the most important economic minerals in the Joplin area. Other minerals commonly associated with zinc and lead were not economic to mine, such as pyrite, marcasite (both iron sulfides), dolomite, calcite, chert, and jasperoid (Ref. 2). Degradation of water quality is associated with the removal of the sulfide minerals from the subsurface reducing environment. Oxidation of insoluble metallic-sulfide minerals in the mines and tailings to a soluble form and subsequent solution and hydrolysis of these soluble sulfates produces sulfuric acid and liberates metals. However, neutralization of the acid by calcium carbonate in the rocks ultimately results in high concentrations of calcium, sulfate, and zinc in solution. Due to the insolubility of most other metals, rapid precipitation will occur (Ref. 2).

SECTION 6: CONCLUSIONS

Based on the analytical results of the groundwater samples collected from our sampling effort, it does not appear that previous mining efforts in the Joplin area are having a large effect on the quality of the groundwater sampled at the time of sampling. The variance in concentrations between wells may be due to differing well depths, construction, and location. These reported concentrations may also vary with season as groundwater flow rates change. Concentrations in the shallow aquifer ranged from undetected to 79 ppb lead, 130 ppb to 8000 ppb zinc, and undetected to 27 ppb cadmium.

Analytical results of stream sediment samples show high zinc, lead, and cadmium concentrations associated with the mining areas relative to the background samples. In the Shoal Creek drainage area background sediment samples contained 66 ppm lead, 750 ppm zinc, and 4.20 ppm cadmium. Downgradient sediment samples detected lead, zinc and cadmium concentrations as high as 4300 ppm, 26000 ppm, and 90 ppm, respectively. The Center Creek background sediment samples detected lead, zinc, and cadmium concentrations of 290 ppm, 4700 ppm, and 20 ppm. Downgradient sediment samples detected 7300 ppm lead, 39000 ppm zinc, and 250 ppm cadmium.

It would be very difficult to attribute all these concentrations strictly to mining activities as the area is naturally highly mineralized. Since surface water samples were not taken, at the request of EPA, it is not known the extent to which these sediments affect the surface water quality. Due to the near neutral water pH detected at all sediment sampling locations it is unlikely that the metals bound in the sediments would be liberated into solution.

It is difficult to determine how much of an effect, if any, previous mining has had on the Joplin Tri-State area due to the fact that the natural setting does not exist today. Mineralization of the area may be localized making it difficult to determine appropriate background areas. The background areas used in this investigation may be outside of these highly mineralized areas, therefore would not be a natural representation of the nearby mining areas. To document the effects previous mining has had on the Tri-State Mining area would require a much more extensive study and sampling effort than requested during this investigation.

Reference 3

**Excerpts From Effects of Abandoned Lead and Zinc Mines
and Tailings Piles on Water Quality in the Joplin Area, Missouri,
USGS Water Resources Investigations 77-75;
James H. Barks, USGS; August 1977**

EFFECTS OF ABANDONED LEAD AND ZINC MINES AND TAILINGS PILES ON
WATER QUALITY IN THE JOPLIN AREA, MISSOURI

by James H. Barks

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 77-75

Prepared in cooperation with
the Ozark Gateway Council of Governments



August 1977

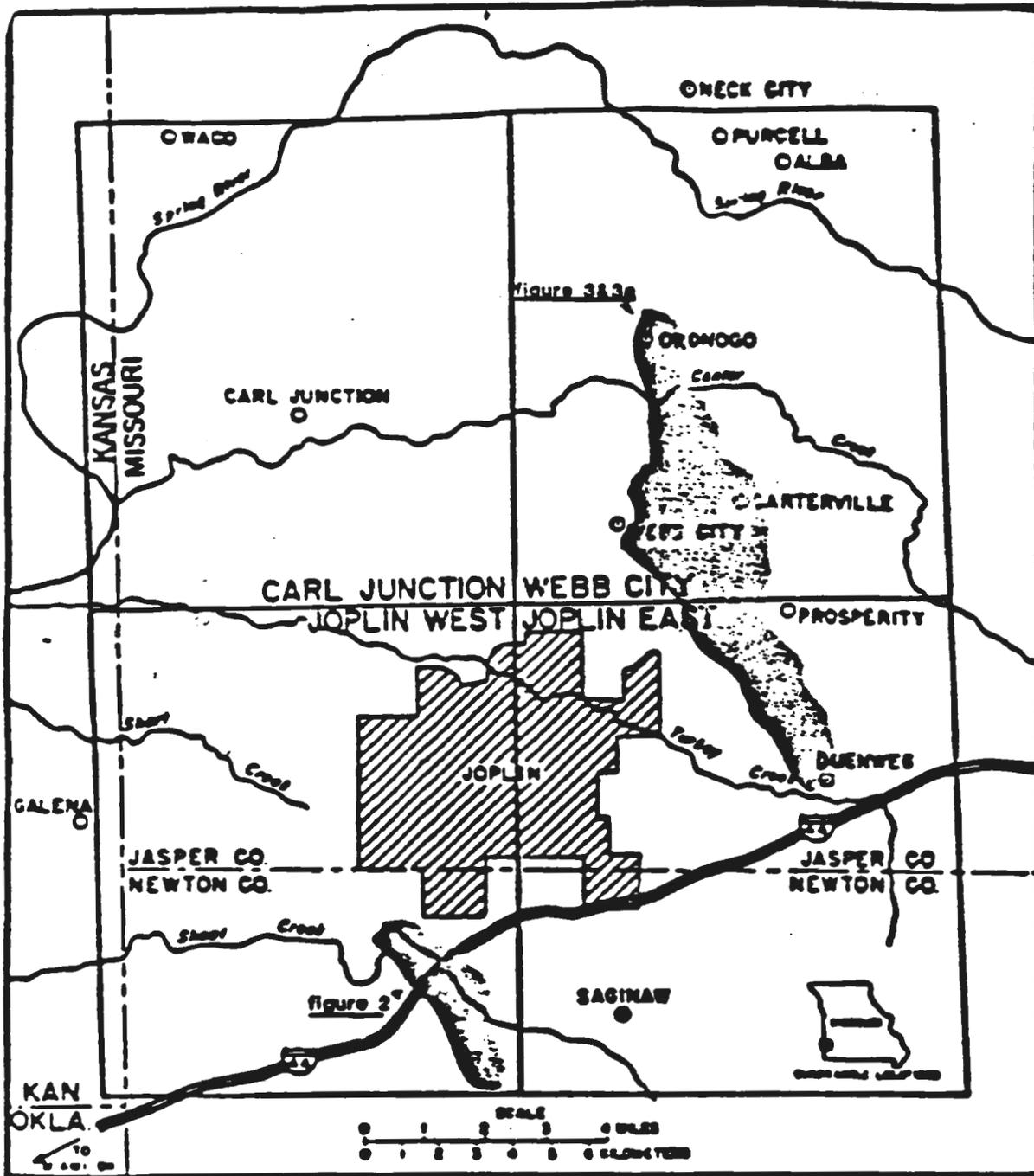


FIGURE 1. - Location map, Missouri study area, Tri-State District, showing U.S.G.S. quadrangle coverage. (Ref.1)

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Water temperature, specific conductance, pH, alkalinity, and dissolved oxygen were determined in the field. Water temperature was measured with a mercury thermometer to the nearest 0.5°C (degrees Celsius). Specific conductance was measured using a portable conductivity meter with temperature compensation designed to express readings in umhos/cm at 25°C (micromhos per centimeter at 25 degrees Celsius). The potentiometric method was used to measure both the pH and alkalinity. The inflection points in the titration for alkalinity with 0.01639 normal sulfuric acid were 8.3 and 4.5 for bicarbonate. The azide modification of the Winkler method was used for dissolved oxygen determinations. The only departure from these methods was the determination of temperature, specific conductance, dissolved oxygen, and pH profiles in mine shafts using an electronic instrument calibrated according to the manufacturer's instructions.

GROUND WATER

~~Important aquifers in the area include the shallow aquifer in cherty limestones of Mississippian age and the deep aquifer in cherty dolomites and sandstone of Ordovician and Cambrian age.~~ The shallow and deep aquifers are separated by relatively impermeable silty limestones and shale of Mississippian and Devonian age. A generalized section of the geologic formations and their hydrologic properties is given in table 1, in the back of the report.

~~The shallow aquifer reaches the surface at places and extends as deep as 500 ft (feet).~~ Brecciated areas generally are highly permeable while surrounding areas of dense limestone have low permeabilities. Mineral deposits in the brecciated areas were mined at depths from 100 to 250 ft. The abandoned mines contain large volumes of highly mineralized water.

A potentiometric map of the shallow aquifer (fig. 2) was prepared from water levels that were measured in approximately 200 shallow wells and mine shafts in September and early October 1976 during a period of little precipitation and low streamflow. The map shows the slope and direction of ground-water movement. Water levels represent the water table except for the few wells and mines that have water under artesian pressure. ~~The water table is usually close to land surface near main streams and from 25 to 100 ft below land surface away from main streams.~~ Center and Turkey Creeks are in hydraulic connection with the shallow aquifer and generally act as drains. Hydrologic divides generally correspond to topographic divides and movement of the ground water is from the divide areas to the streams. Regional movement of the water in the shallow aquifer is toward the west.

A comparison of the September-October 1976 and June 1966 (Feder and others, 1969, p. 28) potentiometric maps shows that except for the area north of Duenweg, the altitude of the water table and movement of the ground water is unchanged. In 1966 heavy pumping in the area north of Duenweg formed a cone of depression and altered the ground-water flow pattern causing water to flow into the cone to replace water that had been pumped out. Most of the pumpage stopped soon after the 1966 water-level measurements were made. The 1976 measurements show a recovery of about 100 to 150 ft in water-table altitude in the Duenweg area. Consequently, the 1976

map does not show a depression in the water table north of Duenweg.

The deep aquifer is reached at a minimum depth of about 300 ft and extends as deep as 1,800 ft. Water in the deep aquifer is under artesian pressure, but water-level measurements indicate that the potentiometric surface of the deep aquifer is below that of the shallow aquifer (Feder and others, 1969, p. 12). This relationship favors downward seepage of water, and where faults, fracture openings, and wells connect the aquifers, water can leak directly from the shallow aquifer to the deep aquifer. Where the aquifers are separated by the Northview Formation, the Chattanooga Shale, or both, these shales act as confining beds permitting little water movement.

In 1976 water samples were collected from 14 mines, 21 shallow wells, and 14 deep wells. Results of analyses of these samples are shown in tables 2, 3, and 4, respectively, in the back of the report. The data are summarized in table 5 and figure 3 and discussed under the topics, "Mines," "Shallow wells," and "Deep wells."

Mines

Dissolved-solids concentrations in water from mine drifts are generally greater than 1,000 mg/L (milligrams per liter). In ground-water recharge areas (higher altitudes away from main streams) downward water movement prevents water in the drifts from circulating up into the mine shafts, and water in these shafts contain less than 500 mg/L dissolved solids. Conversely, in ground-water discharge areas (lower altitudes near main streams or water under artesian pressure) upward water movement causes water in the drifts to circulate up through the mine shafts. This phenomenon is illustrated by the sketch in figure 4 and by specific conductance, pH, temperature, and dissolved oxygen profiles (fig. 5) that represent average characteristics for seven mines (map nos. 101, 102, 103, 106, 107, 108, and 113) in recharge areas and for three mines (map nos. 104, 112, and 114) in discharge areas. Average depth to the water surface was 35 ft in recharge areas and 1 ft in discharge areas. The relation between dissolved solids (DS) and specific conductance (SC) for water in the drifts and shafts is $DS=(0.99XSC)-121$; the standard error of estimate is 49 mg/L DS. In table 2, in the back of the report, those analyses with dissolved-solids concentrations less than 500 mg/L are for water collected from shafts in ground-water recharge areas. Those with dissolved-solids concentrations greater than 900 mg/L are for water collected from drifts in the recharge areas or from shafts in ground-water discharge areas. All of the analyses were used to compute values shown for mines in table 5 and figure 3.

Water in limestone rocks is usually a calcium bicarbonate type, but water in the abandoned mines is a calcium sulfate type (fig. 3), reflecting the sulfide mineralization.

Average concentrations of dissolved iron, manganese, cadmium, and zinc in the mine water (table 5) exceed concentrations of 300, 50, 10, and 5,000 µg/L, respectively, recommended as drinking water standards (U.S. Public Health Service, 1962). Concentrations of other metals in the mine water are

well below the drinking water standards. High concentrations of zinc in the mine water are particularly significant because zinc is highly toxic to aquatic animals and some of the mine water reaches the main streams in the area as discussed later in the report.

Shallow Wells

Many of the 21 shallow wells that were sampled are located between the flooded mines and Center and Turkey Creeks. Average depth of the wells is 243 ft, which is a little deeper than most mines in the area.

Water in the shallow wells is generally a calcium bicarbonate type (fig. 3). Only four of the wells (map nos. 203, 204, 211, and 219) have water with sulfate concentrations greater than 60 mg/L. Three of these are in, or very near, mines and the other is probably in contact with sulfide minerals. One of the wells (map no. 204), known to penetrate a mine, has water-quality characteristics similar to the mine water including a dissolved-solids concentration of 1,190 mg/L, a sulfate concentration of 560 mg/L, and a zinc concentration of 8,800 μ g/L. Water from the other shallow wells is considerably less mineralized than the mine water.

Metals concentrations in water from the shallow wells are generally low, except for zinc. Zinc concentrations average 1,100 μ g/L and are probably influenced by galvanized plumbing and (or) local sulfide mineral deposits as described by Feder and others, 1969, p. 34.

Results of the shallow well sampling indicate that there is not widespread movement of the highly mineralized mine water in the shallow aquifer.

Deep Wells

Water in the deep aquifer is a calcium magnesium bicarbonate type (fig. 3) and it can be distinguished from water in the shallow aquifer by its lower mineral content and lower calcium magnesium (Ca:Mg) ratio. The average Ca:Mg ratio (calcium and magnesium expressed in milliequivalents) is 23 for water in the mines, 23 for water in the shallow wells, and 1.7 for water in the deep wells. The lower ratio for water in the deep aquifer is indicative of the higher magnesium content of the dolomitic rocks.

The Ca:Mg ratios and concentrations of dissolved solids, sulfate, and zinc in water from Webb City Well No. 6 (map no. 305), Webb City Well No. 7 (map no. 308), and Carthage Well No. 1 (map no. 311) indicate mixing with water from the shallow aquifer. The water from the shallow aquifer may be leaking directly into these wells or may be entering the deep aquifer through faults, fracture openings, or wells that connect the aquifers.

The Oronogo-Duenweg mining belt extends along the east edge of Webb City. Water from deep wells on the east side of Webb City is more mineralized than water from deep wells on the west side.

In June 1972 the dissolved-solids concentration in water from Webb City Well No. 10 was 840 mg/L. This well is located near the mining belt and the high dissolved-solids content indicates the possibility of mine-water contamination of the deep aquifer on the east side of Webb City. This well has been abandoned as a source of municipal water because of the high mineralization of the water (Raymond Lawrence, Supt. Webb City Water Dept., oral commun., 1976).

SURFACE WATER

Center Creek, Turkey Creek, and Short Creek drain about 70, 18, and 5 percent of the mining area, respectively. Some physical and hydrologic characteristics of these streams are given in table 6. All three streams flow westward and are characterized by alternating pools and riffles, and mixed sand, gravel, and boulder bottoms.

The lower part of Center Creek, the largest of the three streams, flows through the northern part of the mining area and into the Spring River near the Missouri-Kansas state line. Most of the baseflow originates in the headwater area, with little or no increase and some losses in the lower reach (Feder and others, 1969, p. 54). ~~About 1,970 acres of tailings piles having a total volume of approximately 38 million yd³ (cubic yards), cover the lower part of the basin (Joseph R. Miller, Ozark Gateway Council of Governments, written commun., 1977).~~ Most of these tailings are in the Oronogo-Duenweg mining belt. Discharges from at least three flowing mines enter Center Creek.

Turkey Creek, south of and parallel to Center Creek, flows through the northern part of Joplin and into the Spring River in Kansas, just across the state line. It is located in the center of the mining area. ~~Tailings piles are scattered throughout the basin and cover an area of about 500 acres, with a total volume of about 70 million yd³.~~ The flow and quality of water in Turkey Creek are greatly altered by sewage plant discharge at Joplin, industrial discharges, and mine-water discharge from at least one abandoned mine.

Short Creek, south of and parallel to Turkey Creek is a small stream that originates just west of Joplin. After crossing the state line it flows 4.3 mi (miles) in Kansas before entering the Spring River. ~~Although Short Creek has a total drainage area of 78 mi² (square miles) only about 7.6 mi² contribute to the flow at the state line. Mining activities in the upper part of the basin have left about 185 acres (2.9 million yd³) of tailings piles scattered on the surface.~~

Tailings Areas

The distribution and size of tailings piles on the surface generally correspond to the distribution and size of mines beneath the surface. However, some of the ore was removed from the area for processing and some of the tailings have been removed to be used for road surfacing and railroad ballast, or ground into sand for sand blasting. The greatest concentration of tailings

piles is in the Oronogo-Duenweg mining belt (fig. 6), which is about 2 mi wide and 10 mi long, reaching from Oronogo to Duenweg. This mining area is in the Center Creek basin, except for the southwestern edge which is in the Turkey Creek basin. Outside the Oronogo-Duenweg belt the tailings piles are generally scattered and intermixed with woodlands and farmlands. ~~Regardless of the location, runoff and seepage from the tailings piles reach the main streams, either directly or through natural or man-made drainages!~~

Surface drainage to Center Creek from the Oronogo-Duenweg mining belt is primarily by Mineral Branch, located in the center part of the belt (fig 1). It originates southwest of Prosperity and flows into Center Creek at Highway D about 1.5 mi upstream from Oronogo. Another drainage, Stoutt Branch, originates in the mining belt southeast of Prosperity, but leaves the mining area and runs through farmlands and woodlands before entering Center Creek just downstream from Lakeside. The Sunset mine (map no. 109) and a nearby unnamed mine (map no. 110) discharge about 1 ft³/s of water to Mineral Branch at Carterville during periods of low flow. Otherwise, Mineral Branch is dry upstream from Carterville and Stoutt Branch is dry throughout its length during periods of little or no rainfall, but both carry large volumes of water during periods of heavy rainfall. These two branches are important from the standpoint of the effects of the tailings areas on water quality in Center Creek.

Reconnaissance.—During the reconnaissance sampling in March 1976 water flowing at eight tailings sites was collected and analyzed to determine the variation in types and concentrations of major ions and minor elements, as shown in table 7 in the back of the report. The eight tailings sites are scattered throughout the area, but most are located in the Oronogo-Duenweg mining belt. Sources of the water samples vary from seepage directly out of individual tailings piles to flow in ditches draining areas completely covered by tailings, to flow in ditches draining areas that are only partly covered by tailings. Water at two of the sites, Mineral Branch at Carterville and Leadville Hollow near Joplin, is derived in part from mines that discharge at the surface. The samples were collected during a period of moderate rainfall while surface runoff was taking place.

In table 8 characteristics and dissolved constituents of water from the ~~tailings areas are compared with those for a March 1976 sample collected~~ from Center Creek upstream from the mining area. Water from the tailings areas is more mineralized than water from Center Creek near Fidelity, and is a calcium sulfate type rather than calcium bicarbonate. The higher sulfate concentrations reflect the oxidation and solution of sulfide minerals still present in the tailings.

Chromium, cobalt, mercury, nickel, and silver are present in tailings area water at about the same low concentrations as in water from Center Creek upstream from the mining area. Aluminum, iron, and manganese concentrations are considerably higher in the tailings water, but these metals are generally nontoxic to aquatic animals. ~~Metals that are toxic to aquatic animals~~

Mining Waste NPL Site Summary Report

**Palmerton Zinc
Palmerton, Pennsylvania**

**U.S. Environmental Protection Agency
Office of Solid Waste**

June 21, 1991

FINAL DRAFT

Prepared by:

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DISCLAIMER AND ACKNOWLEDGEMENTS

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Application International Corporation (SAIC) in partial fulfillment of EPA Contract Number 68-W0-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Tony Koller of EPA Region III [(215) 597-3923], the Remedial Project Manager for the site.

PALMERTON ZINC

BOROUGH OF PALMERTON, CARBON COUNTY, PA

INTRODUCTION

This Site Summary Report for Palmerton Zinc is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA mining program activities. In general, these reports summarize the types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of one summary by the EPA Remedial Project Manager for the site, Tony Koller.

SITE OVERVIEW

The Palmerton Zinc Superfund Site is located in the borough of Palmerton, Pennsylvania, at the base of Blue Mountain and at the confluence of the Lehigh River and Aquashicola Creek (see Figure 1). Two primary zinc smelters have produced zinc and other metals for machinery, pharmaceuticals, pigment, and other products. The first smelter, the West Plant, was constructed in 1898, and produced zinc oxide until 1987. A second smelter, the East Plant, was in operation from 1911 to 1980. The East Plant, the main source of air pollutants, concentrated zinc sulfide ores. Palmerton Zinc was added to the NPL in September 1983.

Cadmium, lead, and zinc are the contaminants of concern. Approximately 7,000 people live in the Town of Palmerton. The Palmer Water Company has four production wells, ranging in depth from 200 feet to more than 400 feet at the base of Blue Mountain. The residential water supply for the Towns of Palmerton and Aquashicola is drawn from this source.

The Palmerton Zinc Superfund Site has four problem areas, and each is being studied as an individual Operable Unit. These are: (1) the defoliated portion of Blue Mountain near the smelter slag piles; (2) the Cinder Bank; (3) heavy metal deposition throughout the valley; and (4) the overall ground-water and surface-water contamination. Only the first two Operable Units will be addressed in this summary. Operable Units 3 and 4 are still being studied. The interim remedial actions for the first two Operable Units will be consistent with the comprehensive remedy for the entire Superfund Site.

Palmerton Zinc

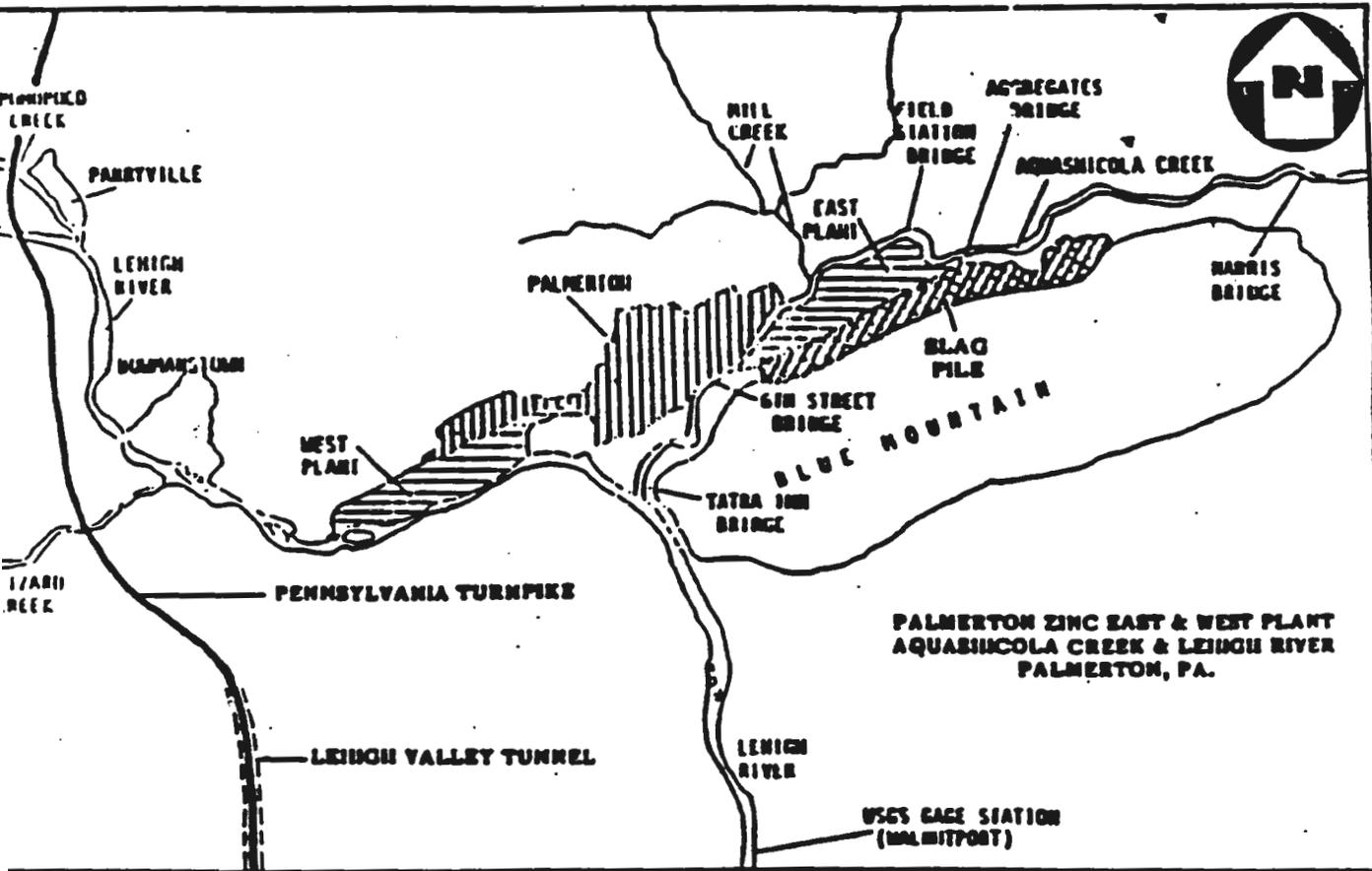


FIGURE 1. PALMERTON ZINC SITE

The interim remedy for the revegetation of Blue Mountain (Operable Unit 1) is described in the Record of Decision (ROD). The ROD was signed by the Region III Administrator in September 1987. Vegetation damage first appeared in 1951 as isolated patches on the steep, north-facing slope of Blue Mountain. By 1985, approximately 2,000 acres had sustained vegetation damage. For assessment purposes, vegetation damage was defined as areas of exposed rock and soil leaving barren, eroded land visible. The selected interim remedial measure focuses on the establishment of a natural, eastern forest ecosystem. The estimated cost for implementing this remedial action will be minimal.

The interim remedial action for the Cinder Bank (Operable Unit 2) was signed by the Regional EPA Administrator in June 1988. Process residues and other plant wastes were deposited on the Cinder Bank until it had become 2.5 miles long, between 500 and 1,000 feet wide, and up to 100 feet above the mineral soil layer. In December 1986, it was estimated to contain 28.3 million tons of leachable metals including lead, zinc, and cadmium. Contaminated leachate percolates down to the ground water and seeps out of the Cinder Bank. The interim remedial action for the Cinder Bank includes slope modification, capping, and application of a vegetative cover on the Cinder Bank; construction of surface-water diversion channels; and a surface-water and leachate-collection and treatment system.

Operable Unit 3 is still in the Remedial Investigation and Feasibility Study stage. It involves the deposition of heavy metals (mainly cadmium, lead, and zinc) throughout the valley as a result of air emissions from the smelters. Funding is to be made available during fiscal year 1991 to conduct a Remedial Investigation/Feasibility Study of Operable Unit 4, which will address the overall ground-water and surface-water contamination.

OPERATING HISTORY

Palmerton Zinc operated two smelters between 1898 and 1987. The first smelter, the West Plant, opened in 1898, and produced zinc oxide from zinc silicate ore until its closure in 1987. A second smelter, the East Plant, was in operation from 1911 until 1980, when primary smelting of concentrated zinc sulfide ores was stopped (Reference 1, page 2; Reference 2, page 4; Reference 3, page 1-1). From 1898 to 1967, the smelters were privately owned by the now defunct New Jersey Zinc Company. In 1967, the smelters were sold to Gulf & Western Inc., which operated the facility until 1981, when it was purchased by its current owner (Zinc Corporation of America) (Reference 1, page 1).

The East Plant was constructed for the concentration of zinc sulfide ores. The process consisted of crushing the ores and removing the sulfur by burning, which replaced the sulfur in the ore with oxygen to produce a low-grade zinc oxide and sulfur dioxide. The crude zinc oxide was further

Palmerton Zinc

treated by sintering and mixing with coal to convert it to either a relatively pure zinc oxide or zinc metal. The sulfur dioxide was converted to sulfur trioxide and absorbed in a weak sulfuric acid to produce a merchant-quality sulfuric acid (Reference 3, page 1-1).

Air emissions from the plants contained large quantities of zinc, lead, cadmium, and sulfur dioxides. The emissions led to defoliation of approximately 2,000 acres on Blue Mountain, and deposited heavy metals throughout the valley (Reference 2, page 4; Reference 1, page 3). Process residues, other plant wastes, and municipal wastes were deposited at a cinder bank waste pile located behind the East Plant (until 1970) (Reference 1, page 6).

SITE CHARACTERIZATION

The ROD (June 1988) indicated that the possible exposure pathways include ground water, surface water, soil, and the food chain. The contaminants of concern are cadmium, lead, and zinc (Reference 1, page 3).

In compliance with the EPA's Administrative Order by Consent, dated September 24, 1985, sampling of all affected media was conducted on behalf of the New Jersey Zinc Company, by R.E. Wright Associates, Inc. Sediment and surface-water samples were taken during March and August 1986 (Reference 5, page 5-1). Ground-water samples were collected during August 1986 and March 1987 (Reference 5, page 4-10). Flows in both Aquashicola Creek and Lehigh River during the March sampling period were high due to precipitation and snowmelt, thus characterizing conditions during the "wet season." Flows during the August sampling period were much lower, and thus characterizing the "dry season" (Reference 5, page 5-1).

Blue Mountain

The Blue Mountain Operable Unit is a defoliated 2,000-acre site on the north-facing slope of Blue Mountain, rising approximately 1,000 feet to an elevation of 1,500 feet above mean sea level (Reference 1, page 3; Reference 3, page 1-3). The environmental impact of the plant emissions are obvious to the naked eye. Vegetation is absent and the soil is eroded (Reference 4, page 4-1). Besides the defoliated vegetation and erosion, the affected area on Blue Mountain is noticeably absent of microflora, lichens, arthropods, and wildlife species (Reference 2, page 5). A 1972 study by Nash, an independent researcher, concluded that the richness and abundance of lichen species had been reduced by approximately 90 percent. In 1984, a study by Beyer, Miller, and Cromartie reported that the mortality rate of arthropods after 8 weeks in Blue Mountain surface litter was 84 to 87 percent (Reference 4, pages 4-1 and 4-2).

Surface-soil samples collected in the Operable Unit recorded cadmium levels ranging from 364 to 1,300 parts per million (ppm); lead samples ranged from 1,200 to 6,475 ppm; and zinc sample levels ranged from 13,000 to 35,000 ppm. The maximum levels are up to 2,600 times the typical regional background levels for cadmium, over 2,000 times the regional background for lead, and over 400 times the regional background for zinc. Depth profiles showed that most metals contamination is located within the top 6 to 10 inches of the soil. This is because the metals are bound in organic materials. Water flowing across the defoliated portions of Blue Mountain has eroded the surface and become contaminated with metals in the soil. The runoff and erosion have carried the metal-laden soil into Aquashicola Creek (Reference 2, page 5).

Cinder Bank

Cinders (residue) from the production facilities have been stockpiled along the north side of Blue Mountain, south and east of the East Plant, since 1913. The Cinder Bank is now approximately 2.5 miles long, between 500 and 1,000 feet wide, and approximately 100 feet above the mineral soil layer. As of December 1986, the Cinder Bank contained 28.3 million tons of waste material (Reference 3, page 1-2). The residue materials have been stocked in designated areas based on metal values. The designated areas are generally divided into boiler house and anthracite coal; horizontal retort; vertical retort; traveling grate furnace (high and low zinc areas) and Waelz kiln residues; slags; and Town refuse (Reference 3, page 1-2). As a whole, the Cinder Bank consists of 16 percent carbon, 2.7 percent zinc, 0.025 percent cadmium, 0.36 percent lead, 0.33 percent copper, and 0.6 ounce per ton indium; the remainder is ash (Reference 3, page 3-2).

Portions of the Cinder Bank Operable Unit smolder continuously, and are posted as fire areas. In physically undisturbed areas, large cracks have developed and large blocks of partially consolidated residue occasionally fall from the waste pile. The cracks and the resulting rough surfaces provide avenues for the infiltration of rain and snowmelt, facilitating leaching of soluble constituents from the waste pile. In addition, the Cinder Bank has been contoured to a slope of 2 to 1, which is unstable (Reference 1, page 9).

In runoff and seepage samples taken from the east end of the Cinder Bank, zinc concentrations were found at background levels ranging from 0.27 to 0.67 milligrams per liter (mg/l) to values as high as 230 mg/l. Increased cadmium concentrations were also highest in this area. At the base of the Cinder Bank, in seeps and springs, average zinc concentrations have been recorded at 35 ppm, and average cadmium concentrations were 0.118 ppm (Reference 1, page 9). The ROD indicates that cadmium concentrations in Cinder Bank runoff were higher than background levels, but the ROD does not indicate the level of concentration.

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Surface Water

The drainage pattern in the area of concern is toward Aquashicola Creek, a tributary of the Lehigh River. Aquashicola Creek flows through a buried valley between Blue Mountain on the south and Stony Ridge on the north. The creek flows southeasterly, and is joined by Buckwha Creek about .5 mile upstream of Harris Bridge and by Mill Creek near the main gate of the East Plant. Aquashicola Creek joins Lehigh River approximately 1.5 miles southwest of the East Plant (Reference 1, page 4).

The reach of the Aquashicola Creek in Palmerton is classified as a Trout-stocking stream by the Pennsylvania Department of Environmental Resources (Reference 1, page 4). According to the criteria of water uses in this classification, the creek should maintain stocked Trout from February 15 to July 31. It should also maintain and propagate fish species and have additional flora and fauna that are indigenous to a warm-water habitat (Reference 2, page 4).

Significant contributions of zinc, cadmium, and manganese enter Aquashicola Creek from the East Plant (Reference 1, page 10). Cross-sectional concentration data showed higher zinc and cadmium levels on the Cinder Bank (south) side of the creek. No significant metal concentrations were found in Mill Creek, which enters Aquashicola Creek from the north at the East Plant (Reference 1, page 11). Most of the zinc and cadmium is contributed to Aquashicola Creek by ground-water and runoff sources (Reference 1, page 11). In addition, the ROD estimates that nonpoint sources, such as ground-water discharge, are responsible for between 80 and 95 percent of metals loadings to Aquashicola Creek (Reference 1, page 15).

Ground Water

Ground water in the site occurs in both unconsolidated deposits and the underlying bedrock. Specific conductivity of ground-water samples from seven shallow wells on the East Plant site ranged from 130 to 800 micromhos per centimeter. Calculated dissolved solid concentrations ranged from 85 to 520 mg/l. Generally, water of this quality is acceptable as public drinking water. However, zinc was detected in all seven wells sampled, and cadmium was found in four of the seven wells sampled. Zinc concentrations ranged from 0.003 to 3.2 mg/l, and cadmium concentrations ranged from 0.002 to 0.024 mg/l (Reference 1, page 14).

Because of the location and presumed direction of natural ground-water flow from south (Blue Mountain) to north (Aquashicola Creek), it is likely that the high metal concentrations in the wells resulted from leachate originating in the Cinder Bank (Reference 1, page 14).

Three deep wells (from 200 to more than 400 feet) at the west end of the East Plant on the lower flank of Blue Mountain were found to have very low concentrations of zinc (the amount was not given in the ROD). One well had a small concentration of cadmium (the amount of cadmium was not given in the ROD either). The deep wells have no direct contact with the shallow aquifer or surface waters (Reference 1, page 14).

Sediments

Samples taken during EPA's Remedial Investigation show elevated concentrations of zinc and cadmium in stream sediment samples taken from monitoring stations adjacent to the Cinder Bank, the East Plant, and on Aquashicola Creek downstream of its confluence with Lehigh River. The high concentrations of heavy metals in Aquashicola Creek and in the Lehigh River are attributable to discharges and erosion from the Cinder Bank (Reference 1, page 12).

Zinc concentrations in background sediment monitoring stations (location unknown) ranged from 420 to 840 milligrams per gram (mg/g), and averaged 620 mg/g. Zinc concentrations at sediment monitoring stations adjacent to the Cinder Bank, the East Plant, and downstream on Aquashicola Creek ranged from 6,200 to 42,000 mg/g, and averaged 19,900 mg/g (32 times the average background concentration). The background zinc concentrations in stream sediments from Southeastern Pennsylvania are generally less than 200 mg/g (Reference 1, page 12).

Cadmium concentrations at background sediment monitoring stations ranged from 2 to 13 mg/l, and averaged 6 mg/l. Cadmium concentrations in sediment monitoring stations adjacent to the Cinder Bank, the East Plant, and downstream on the Aquashicola Creek ranged from 39 to 420 mg/l, and averaged 157 mg/l (26 times the average background concentrations) (Reference 1, page 12).

ENVIRONMENTAL DAMAGES AND RISKS

Neither the RODs nor the Remedial Investigation Report discuss any human health effects associated with the contaminants of concern, except for those people who consume fish caught in contaminated water. The contaminants of concern are cadmium, lead, and zinc. Possible exposure pathways are soil, air, ground water, surface water, and the food chain.

In a February 6, 1987, memorandum, the Agency for Toxic Substances and Disease Registry found that a potential human health risk exists through the consumption of fish from Aquashicola Creek. Specifically, the levels of lead and cadmium in the fish present potential health risks to persons who regularly consume fish caught from Aquashicola Creek (Reference 1, page 15).

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The National Academy of Sciences has estimated the Recommended Dietary Allowance for zinc is 15 milligrams per day. Long-term exposure to excessive levels of zinc (2.1 milligrams per kilogram per day) could cause a copper deficiency. The human body eliminates zinc through excretion and sweat.

The public has been concerned with the potential health effects of soil and ground-water contamination and the potential financial impact on the Zinc Corporation of America of any remedial action costs. Also of concern is the environmental devastation and negative image the barren mountain projects onto the community (Reference 1, page 16; Reference 2, page 16).

The Aquashicola Creek and Lehigh River are not highly productive sites for benthic macroinvertebrates but, in reference stations along the Aquashicola Creek upstream of the Cinder Bank, 29 kinds of organisms were collected. In stations adjacent to the East Plant, conditions begin to deteriorate with a 40-percent reduction in the types of benthic macroinvertebrates, and a 45-percent reduction in the overall benthic macroinvertebrates population. Changes in the benthic macroinvertebrate population is attributed to heavy metal concentrations in the runoff from the Cinder Bank. There was no apparent effect from the Aquashicola Creek's contamination on Lehigh River benthic macroinvertebrate populations (Reference 1, pages 12 and 13).

Periphyton populations decreased from 40,000 organisms per square centimeter (organisms/cm²) upstream of the Cinder Bank to 20,000 organisms/cm² and 5,000 organisms/cm² in the reach adjacent to the Cinder Bank. This decrease was attributed to Cinder Bank runoff, seepage, and low chlorophyll concentrations. Periphyton community numbers and composition in Lehigh River were not influenced by wastes carried by Aquashicola Creek (Reference 1, page 13).

Significant fish mortalities (greater than 10 percent allowable for the control group) occurred in sampling stations extending from the mouth of Aquashicola Creek to 3 kilometers upstream. This stretch of the creek receives Cinder Bank runoff and seepage. There appears to be a correlation between fish mortality and zinc concentrations. Monitoring stations with zinc concentrations of 0.49, 0.71, and 0.87 mg/l had mortality rates of 0, 20, and 40 percent, respectively (Reference 1, pages 13 and 14).

REMEDIAL ACTIONS AND COSTS

The major objective of remedial actions to be taken at the Palmerton Zinc Superfund Site include: (1) minimizing and restricting direct contact with defoliated areas and the Cinder Bank; (2) reducing the volume of runoff; (3) reducing the volume of runoff; (4) reducing the contamination in runoff;

(5) collecting and treating leachate; (6) reducing the windborne contaminated emissions; and (7) reducing particulate erosion (Reference 1, page 16).

Blue Mountain Operable Unit

An interim remedy for the Blue Mountain Operable Unit was established in September 1987. The selected remedy for this Operable Unit consists of using a mixture of sewage sludge and fly ash to vegetate the defoliated areas of Blue Mountain. The remedial action presented in the ROD for the Blue Mountain Operable Unit includes the following activities:

- Constructing access roads in areas targeted for revegetation.
- Spraying areas targeted for revegetation with lime and potash.
- Spraying targeted areas with a sludge-fly ash mixture.
- Applying a mixture of grass or tree seeds to the targeted area. If the tree seed will not germinate, seedlings will be planted.
- Applying a mulch cover to protect the seeds and permit seed germination (Reference 2, page 14).

The cost to EPA for the above remedial action is minimal, provided it costs the municipalities less to spray the sludge than current sludge-disposal methods (Reference 2, page 13). The full cost to implement this remedial action has been estimated at \$2,750 per acre. The total cost to revegetate the 2,000 acres is approximately \$5,500,000 (in 1986 dollars) (Reference 4, page 7-20).

Cinder Bank Operable Unit

The interim remedial action for the Cinder Bank Operable Unit was selected in June 1988. The remedial action presented in the ROD for the Cinder Bank Operable Unit consists of the following activities:

- Contouring to stabilize the Cinder Bank slopes and areas targeted for revegetation
- Installing gas vents where necessary

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- Constructing surface-water channels to direct Blue Mountain water runoff away from the Cinder Bank area
- Constructing a collection and treatment system for Cinder Bank runoff until it is revegetated
- Establishing a vegetative cover over Cinder Bank
- Performing long-term inspections, monitoring, and maintenance of the site (Reference 1, pages 25 and 26).

The estimated present worth cost for this remedial action will be in excess of \$2,861,000; however, the exact figure will not be known until an agreement is reached on the extent of remediation during remedial design (Reference 1, Abstract, page 2).

CURRENT STATUS

According to the Acting Remedial Project Manager, RODs for the first two Operable Units have been signed by the EPA Regional Administrator. Operable Unit 1 (Blue Mountain) has started the construction phase (May 7, 1991). Operable Unit 2 (Cinder Bank) is currently in consent decree negotiation with the Potentially Responsible Party. Operable Unit 3 is in the Remedial Investigation/Feasibility Study stage. Operable Unit 4 will enter the Remedial Investigation/Feasibility Study stage in the summer of 1991.

REFERENCES

1. Record of Decision for Palmerton Zinc Pile, Pennsylvania: Second Remedial Action; James M. Seif, Regional Administrator, EPA Region III; September 1988.
2. Record of Decision for Palmerton Zinc Pennsylvania: Interim Remedial Measure; James M. Seif, Regional Administrator, EPA Region III; September 4, 1987.
3. Draft Remedial Investigation Report: The New Jersey Zinc Company, Palmerton, Pennsylvania; J.F. Griffen, EPA; July 8, 1987
4. Palmerton Zinc Superfund Site Blue Mountain Project; EPA Region III; April 1987.
5. Remedial Investigation Report: The New Jersey Zinc Company, Palmerton, Pennsylvania; EPA; November 20, 1987.

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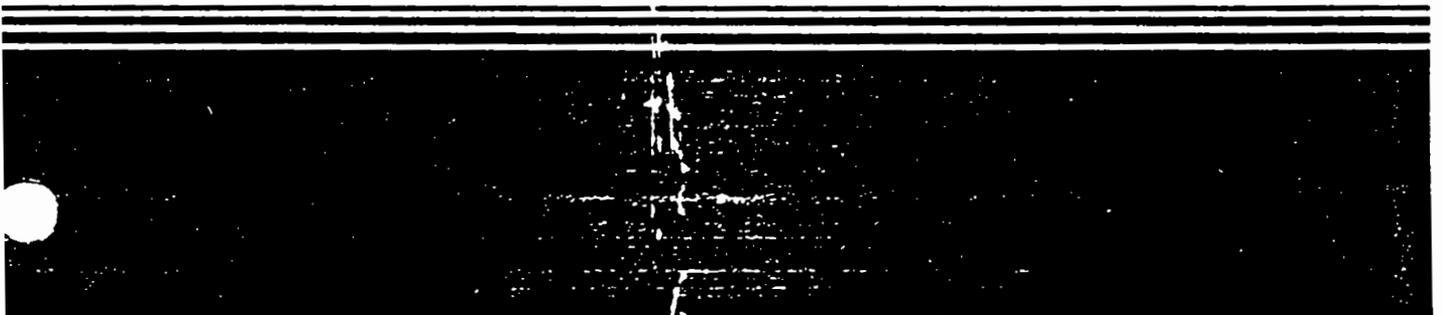
Reference 1

**Excerpts From Record of Decision for
Palmerton Zinc Pile, Pennsylvania: Second Remedial Action;
James M. Seif, Regional Administrator, EPA Region III;
September, 1988**



Superfund Record of Decision:

Palmerton Zinc Pile, PA



and Subject
ERPUND RECORD OF DECISION
Palmerton Zinc, PA
cond Remedial Action

1. Report Date **06/29/88**

7. Author(s) _____ 8. Performing Organization Rept No _____

9. Performing Organization Name and Address _____ 10. Project/Task/Work Unit No _____
 11. Contract(G) or Grant(G) No _____
 (C) _____
 (G) _____

12. Sponsoring Organization Name and Address
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

13. Type of Report & Period Covered
800/000

14. _____

15. Supplementary Notes

16. Abstract (Limit 200 words)
 The Palmerton Zinc site is composed of two locations in the Borough of Palmerton, Carbon County, Pennsylvania. Smelting operations have been conducted at two locations, a west smelter and an east smelter, flanking the Town of Palmerton, which is located at the confluence of the Lehigh River and Aquashicola Creek. Approximately 7,000 residents live in Palmerton, many of whom work at the smelting facility. Land use in the area is industrial, residential, and agricultural. The drainage pattern in the site area is toward Aquashicola Creek, designated a warm water fishery by the State of Pennsylvania, which flows into Lehigh River. Smelting operations were conducted in the west plant from 1898 to 1987, and in the east plant from 1911 to present. The site has had three owners, including the current operator, Zinc Corporation of America, and historically has produced zinc and other metals for a variety of products. Primary smelting of concentrated zinc sulfide ores, conducted until December 1980, resulted in the emission of large quantities of zinc, lead, cadmium, and sulfur dioxide. This air pollution caused defoliation of over 2,000 acres of vegetation in the vicinity of the east smelter. Between 1898 and 1987 process residue and other plant wastes (as well as municipal waste until 1970) were disposed of on Cinder Bank, a 2.5-mile, 2,000-acre waste pile located behind the east plant at the base of the Blue Mountains. Cinder Bank (See Attached Sheet)

17. Document Agency & Description
Record of Decision
Palmerton Zinc, PA
Second Remedial Action
 Contaminated Media: gw, sw, sediments
 Key Contaminants: cadmium, lead, zinc

a. Identifiers/Open-Ended Terms

c. COSATI Field/Group

Validity Statement	19. Security Class (This Report)	21. No of Pages
	None	60
	20. Security Class (This Page)	22. Price
	None	

EPA/ROD/R03-88/063
Palmerton Zinc, PA
Second Remedial Action

16. ABSTRACT (continued)

contains approximately 27.5 million tons of leachable metals including lead, zinc, and cadmium, as well as carbonaceous material. Large blocks of residue crack and break off, allowing rapid infiltration of runoff during periods of rain and snow melt, resulting in contaminated leachate percolating down to the ground water and seeping out of Cinder Bank. This remedial action addresses Cinder Bank. Additional areas of contamination as well as ground water and surface water contamination will be addressed in subsequent remedial actions. The primary contaminants of concern affecting the sediments, ground water, and surface water are metals including cadmium, lead and zinc.

The selected remedial action for this site includes: slope modification, capping, and application of a vegetative cover on Cinder Bank; construction of surface water diversion channels; surface water and leachate collection and treatment using lime-activated filtration lagoons and/or constructed wetlands; implementation of an inspection, monitoring, and maintenance plan; and wetlands restoration measures, if necessary. The estimated present worth cost for this remedial action will be in excess of \$2,861,800; however, the exact figure will not be known until agreement is reached on the extent of remediation during remedial design.

: - :
Palmerton Zinc Site
Operable Unit II
Cinder Bank

I. Introduction

The Superfund investigation of the Palmerton Zinc smelter focuses on four problem areas which are each being studied as individual units: first, the deposition of heavy metals, mainly cadmium, lead, and zinc, throughout the valley as a result of air emissions from the smelter; second, the Cinder Bank, approximately 2.5 miles long, which consists of an estimated 33 million tons of slag; third, the defoliated portions of Blue Mountain next to the smelter; and fourth, the overall site groundwater and surface water contamination. The investigation of the Cinder Bank, which is located on the smelter property and at the base of Blue Mountain, is the subject discussed herein. The Blue Mountain unit has recently entered the design phase, while the Valley and groundwater/surface water units are in the Remedial Investigation and Feasibility Study phase.

II. Site Name, Location and Description

The Palmerton Zinc Superfund Site is located in the Borough of Palmerton, Carbon County, Pennsylvania as shown on Figure 1. The town is situated at the confluence of the Lehigh River and Aquashicola Creek, just north of the Lehigh Water Gap. Land uses in the area include industrial sites, forest lands, residential communities and agricultural farmlands. Approximately 7,000 residents live within the town which has historically provided a majority of the workforce at the smelter. From 1898 to 1967 the smelter was privately owned by the now defunct New Jersey Zinc Company. It was then sold to Gulf & Western Inc. which operated the facility until 1981, when it was purchased by its current owner Zinc Corporation of America.

The topography surrounding the site is mountainous, lying in a deep valley within the Appalachian Mountains between Blue Mountain (elevation 1,500 feet) and Stony Ridge (elevation 900 feet). The Appalachian Trail runs along the top of Blue Mountain.

The smelting operations are located at two separate locations, a west smelter and an east smelter. Both smelters are located at the base of Blue Mountain (see Figure 2).

The major watercourse in the project area is the Lehigh River. The drainage pattern of the study area is toward Aquashicola Creek, a tributary of the Lehigh River. Aquashicola Creek flows through a buried valley, between Blue Mountain on the south and Stony Ridge on the north. The creek flows southwesterly and is joined by Buckwha Creek about one-half mile upstream of Harris Bridge and by Mill Creek near the east plant's main gate (See Figure 2). Aquashicola Creek flows into the Lehigh River approximately 1.5 miles southwest of the east plant.

The reach of Aquashicola Creek in Palmerton is classified as a warm water fishery and is stocked for trout by the Pennsylvania Department of Environmental Resources. According to the criteria of water uses in this classification, the creek should maintain stocked trout from February 15 to July 31. It should also maintain and propagate fish species and additional flora and fauna that are indigenous to a warm-water habitat.

A water intake is located on the Aquashicola Creek near the Field Station Bridge. This intake pumps water from the stream for industrial use at the east plant. Water from Aquashicola Creek is also pumped from an intake located between the Main Gate Bridge and the Sixth Street Bridge during times of emergency need for industrial process water.

Groundwater in the site vicinity occurs in both the unconsolidated deposits and the underlying bedrock. The shallow aquifer is classified as a Class 3 aquifer and the deep aquifer is classified 2a as determined by EPA Groundwater Classification Guidelines.

At the foot of Blue Mountain, the Palmer Water Company, which supplies water to the towns of Palmerton and Aquashicola, has as its water source four production wells, ranging in depth from about 200 feet to more than 400 feet, drawing ground water from bedrock. The yield of these wells reportedly ranges from 115 to 130 gallons per minute.

III. Site History

The Zinc Corporation of America currently operates one zinc smelter in Palmerton, referred to as the east plant, which opened for operation in 1911. Another smelter located in the west plant had operated between 1898 and 1987 at which time it was shut down. The Palmerton Zinc facility historically has produced zinc and other metals for machinery, pharmaceuticals, pigments, and many other products.

Primary smelting of concentrated zinc sulfide ores, which was the main source of air pollution, was stopped in December of 1980. However, until then the smelters had emitted large quantities of zinc, lead, cadmium and sulfur dioxide which caused the defoliation of many acres of land including approximately 2,000 acres on Blue Mountain, located adjacent to the east smelter. Aerial photography of the site taken from 1938 to 1985 shows the various stages of damage to vegetation. Vegetation damage is defined as areas of exposed rock and soil where the original vegetation, as seen on a 1938 aerial photograph, has been destroyed as a result of the smelter's emissions.

Vegetation damage first appeared on a 1951 aerial photograph as isolated patches on the steep, north-facing slope of Blue Mountain, located immediately south of the Palmerton Zinc east plant. During the 1938-1985 period of analysis, the vegetation damage progressed and additional areas of damage appeared. By 1985, vegetation damage appeared as a continuous, widespread area with barren, eroded land visible in aerial photographs.

The disposal of plant waste since the smelter operations began at Palmerton in 1898 has enabled the Cinder Bank to be built to its present dimensions of 2.5 miles and 33×10^6 tons. It contains large amounts of leachable lead, zinc, cadmium, and other metals.

IV. Enforcement History

Past zinc smelting operations have created widespread heavy metal contamination both on and off the Palmerton Zinc plant property. The contaminated areas have been divided into four distinct areas by EPA and are referred to as the Blue Mountain Project, the Cinder Bank, the Valley Contamination and overall groundwater and surface water contamination. An RI/FS for the Cinder Bank has recently been completed by the Zinc Corporation of America who, as the current owner of the facility is a potentially responsible party (PRP) at this site. The Valley Contamination Study is currently being performed under a Consent Order by Gulf and Western, the other PRP associated with this site. Both PRPs declined participation in the Blue Mountain RI/FS which was completed by EPA in April, 1987.

In a letter dated June 13, 1987, EPA gave the PRPs notice of their potential liability with regard to the implementation of the Blue Mountain Project remedial action. Enclosed with this letter was a copy of the completed RI/FS and a copy of EPA's proposed remedial alternative. The PRPs were extended the opportunity to present a good faith proposal to conduct

the Remedial Action to the Agency within sixty (60) days of receipt of the June 10, 1987 notice letter. EPA received a proposal from ZCA and completed successful negotiations in which ZCA, by means of a Consent Decree agreed to implement the Blue Mountain ROD. Gulf and Western Inc. again declined participation in this project.

V. Site Characteristics

A. Geology/Hydrogeology

1. SURFACE WATER

The drainage pattern of the study area is toward Aquashicola Creek, a tributary of the Lehigh River. Aquashicola Creek flows through a buried valley, between Blue Mountain on the south and Stony Ridge on the north. The creek flows southwesterly and is joined by Buckwha Creek about one-half mile upstream of Harris Bridge and by Mill Creek near the east plant's main gate. Aquashicola Creek flows into the Lehigh River approximately 1.5 miles southwest of the zinc plant.

The reach of Aquashicola Creek in Palmerton is classified as a trout-stocking stream by the Pennsylvania Department of Environmental Resources.

A water intake is located on the Aquashicola Creek near the Field Station Bridge. This intake pumps water from the stream for industrial use at the east plant. Aquashicola Creek water is also pumped from an intake located between the Main Gate Bridge and the Sixth Street Bridge during times of emergency need for industrial process water.

2. GROUND WATER

Groundwater in the site vicinity occurs in both the unconsolidated deposits and the underlying bedrock. The glacial outwash deposits in the stream valley contain significant variability typical of this type of deposit.

Bedrock in the site area also contains significant quantities of groundwater. The intense deformation of the bedrock is expected to occur through interconnected fractures and in related solution openings in the limestone formations. The degree of interconnection between the unconsolidated and bedrock aquifers and their relationship to nearby surface waters has not been defined to date, but is being investigated.

At the foot of Blue Mountain, the Palmer Water Company, which supplies water to the towns of Palmerton and Aquashicola, has as its water source four production wells, ranging in depth from about 200 feet to more than 400 feet, which draw groundwater from the bedrock aquifer. The yield of these wells reportedly ranges from 115 to 130 gallons per minute.

The depth to groundwater in the valley is reported to be about 5 feet. The flow directions of shallow groundwater are expected to be controlled by local topography and by Aquashicola Creek. Shallow groundwater may flow north from Blue Mountain to the creek. Wells installed in the unconsolidated deposits near Aquashicola Creek may receive substantial recharge from the creek. Deeper groundwater flow may be influenced primarily by both structural and stratigraphic relationships. Furthermore, deep groundwater will likely flow from the site toward the Lehigh River, to the west-southwest. The groundwater flow patterns are also being investigated.

3. Soils

The bedrock of Blue Mountain is Silurian-aged Shawangunk Conglomerate, ranging from a quartzitic sandstone to a coarse conglomerate. To the south is the Ordovician Martinsburg Shale, and, to the north, are red siltstones and shales interbedded with limestone and sandstone in the Bloomsburg (Cayuga) formation.

All of Carbon County was glaciated by the Kansan Glacier. The second, or Illinoian, glacier extended into the valleys to the north and south of Blue Mountain, but apparently did not cover the ridge itself.

The periglacial frost action during the Illinoian and Wisconsin glacial periods resulted in shallow channery soils on most ridges with deep deposits of colluvial material at the bases.

B. Extent of Contamination

1. Cinder Bank

A. Nature of Cinder Bank Wastes

Much of the Cinder Bank residue is in the form of briquettes from the vertical retorts and contains residual metals and carbonaceous material. As a result of either incomplete quenching or spontaneous combustion large portions smolder continuously and several of these areas are posted as "Fire Areas." In areas that have not been physically disturbed, large cracks form in the surface roughly parallel to the outer edge.

Occasionally large blocks of partially consolidated residue come off of the main mass of the Cinder Bank and tumble down the steep north slope towards Aquashicola Creek. As the cracks develop, steam and smoke issue from them leaving sublimated yellowish deposits on the adjacent surfaces. These cracks and resulting broken rough surfaces provide avenues for rapid infiltration and percolation of rain and snow melt, and facilitate leaching of soluble constituents from the Cinder Bank.

In 1981 approximately 1,800 linear feet of residue in the Palmerton cinder bank was sampled and analyzed. The purpose of the project was to define as accurately as possible the recoverable values in this waste pile.

Twenty-seven holes were drilled by the New Jersey Zinc Company in a more or less random pattern into the seven zones which comprise the residue bank. If there was any bias in selecting the locations to be investigated, it was that the drilling areas were chosen where the expectation of high metallic values was greatest. Approximately 200 samples were taken and analyzed.

The results of the drilling program, which analyzed for specific metals, are summarized below and as a whole, the bank can be said to contain the following:

27,500,000 Tons of Residue
16% Carbon
2.7% Zinc
0.025% Cadmium
0.36% Lead
0.33% Copper
0.6 Oz./T Indium

The Cinder Bank has been the repository of process residues and other wastes from the Palmerton operations for the past 65 years. It is located behind the East Plant and stretches approximately two and one-half miles along the base of Blue Mountain, covering about 200 acres of the lower slope. Until 1970, all of Palmerton's municipal waste was disposed by burying it in the residue. As of December 1987 the Cinder Bank ceased to be used as a depository for plant waste material.

An estimated 25-30 million tons of various materials are deposited over this area in irregular piles and ridges. Some segregation by type has been practiced in recent years with the objective of potential reclamation. During the past 30 years, considerable quantities of material suitable for aggregate and anti-skid uses have been removed by private contractors.

B. Cinder Bank Runoff and Seepage

Much of the Cinder Bank residue is in the form of briquettes from the vertical retorts and contains residual metals and carbonaceous material. As a result of either incomplete quenching or spontaneous combustion large portions smolder continuously and several of these areas are posted as "Fire Areas". In areas that have not been physically disturbed, large cracks form in the surface roughly parallel to the outer edge. Occasionally large blocks of partially consolidated residue come off of the main mass of the Cinder Bank and tumble down the steep north slope toward Aquashicola Creek. As the cracks develop, steam and smoke issue from them leaving sublimated sulfurous deposits on the adjacent surfaces. These cracks and resulting broken rough surfaces provide avenues for rapid infiltration and percolation of rain and snow melt and facilitate leaching of soluble constituents from the Cinder Bank. In addition, the Cinder Bank has been contoured to a slope approaching 2 to 1 which is unstable.

Evidence of mineral leachate from the Cinder Bank is abundant. Zinc concentrations in waters passing over or through the Cinder Bank increased significantly, especially in the area east of NEIC Station 69 (NJZ Station 10A) (see Figure 4). In this area, zinc concentrations increased from background levels ranging from 0.27 to 0.67 mg/l to values generally greater than 17 mg/l and as high as 230 mg/l in Cinder Bank run-off and seepage. Increase cadmium concentrations in the Cinder Bank run-off were also highest in this area.

The high concentrations of zinc in run-off and seepage from the east end of the Cinder Bank contributes to significant increases of zinc in Aquashicola Creek. About one-half of the total zinc load to the creek entered upstream of the Field Station Bridge (see Figure 2).

Cadmium and zinc were detected in all samples from seeps and springs near the base of the Cinder Bank. The average concentration of dissolved cadmium in samples from the seeps and springs at the base of the Cinder Bank was 0.118 mg/l or about 10 times higher than the run-off not influenced by the Cinder Bank. The average of all dissolved zinc concentrations in samples of seeps and springs at the base of the Cinder Bank was 35 mg/l or about 24 times greater than background.

The highest concentrations of cadmium and zinc observed were in samples from seeps and springs along the eastern 0.6 mile at the base of the Cinder Bank. These samples also exhibited low pH values from 4.3 to about 6 standard units.

Data from samples of seeps and springs at the base of the Cinder Bank show clearly that cadmium and zinc are being leached from the Cinder Bank and contribute to the contamination of Aquashicola Creek and the area groundwater.

Average annual precipitation in the vicinity of Palmerton is about 46 in. (117 cm) of which about 49% falls during the growing season (May to September); average annual runoff is about 24 in. (61 cm). The drainage area directly above Aquashicola Creek to the crest of Blue Mountain in the reach spanned by the NJZ East Plant and the Cinder Bank is about 1,100 acres (4.5 x 10⁸ sq m). Therefore, the average annual run-off to Aquashicola Creek from the Cinder Bank and Blue Mountain is about 2,200 acre-ft. Assuming that run-off and seepage flows and metals concentrations during the surveys were representative of average conditions, the average annual loads of cadmium and zinc contributed to Aquashicola Creek in the reach between the east end of the Cinder Bank and the 6th Street Bridge would be estimated at about 0.48 tons/yr and 110 tons/yr, respectively.

During periods of run-off, contaminated storm water percolates through the Cinder Bank to the groundwater. The groundwater recharges the creek and also seeps out through the Cinder Bank. The Company has attempted to isolate Blue Mountain runoff from the Cinder Bank with little success. Pipes were placed at the surface discharges of two rills to convey this water over the Cinder Bank. The pipes on top of the Cinder Bank froze, split and were not repaired. As a result, the water flows into the Cinder Bank.

2. Surface Water

There are significant contributions of zinc, cadmium and manganese to Aquashicola Creek in the reach from Harris Bridge to the 6th Street Bridge, located just downstream from the East Plant. Zinc and cadmium loads each increased about thirty times in this reach, while manganese increased sevenfold. No increases in metals above that which was found in the reach of the Aquashicola Creek from the Harris Bridge to the 6th Street Bridge were noted between the 6th Street Bridge and the Tatra Inn Bridge at the confluence of Aquashicola Creek and the Lehigh River.

Based on five-day average data, most of the zinc and cadmium load was contributed to Aquashicola Creek by groundwater and run-off sources:

Source	Zinc	Cadmium
Non-point contribution between Harris and Field Station Bridges (%)	50	13
Non-point contribution between Field Station and 6th Street Bridges (%)	32	79
Total of non-point contribution between Harris and 6th St. Bridges (%)	82	92
East Plant Discharges (%)	18	8
Total (%)	100	100

Most of the zinc enters the creek upstream of the Field Station Bridge. However, most of the cadmium enters the creek between the Field Station and 6th Street Bridges in the reach directly adjacent to the plant.

Cross-sectional concentration data at three stations in the Harris Bridge to 6th Street Bridge reach showed generally higher zinc and cadmium levels on the Cinder Bank side of the creek. No significant metal concentrations were found in Mill Creek, indicating that the run-off and groundwater from the drainage area on the left side of Aquashicola Creek are relatively metal-free.

Particulate erosion from the Cinder Bank adds to the contamination of Aquashicola Creek. Sediment analyses for cadmium, zinc, manganese, lead, and copper from Aquashicola Creek stations adjacent to the Cinder Bank showed increases above nearby background stations of 32, 26, 17, 11, and 10 times, respectively.

Metals released to Aquashicola Creek in the reach adjacent to the Cinder Bank had a negative impact on water quality, resulting in imbalanced aquatic communities. Benthic macroinvertebrate and periphyton numbers and diversity were reduced, as was the survival of test fish.

3. Sediment Quality

Zinc concentrations in sediments from the background Stations (27, 99 and 30) ranged from 420 mg/g to 840 mg/g and averaged 620 mg/g. The stations (25, 24, 23, 22, 21, and 20) adjacent to the Cinder Bank, East Plant and downstream on Aquashicola Creek to its confluence with the Lehigh River ranged from 6,200 mg/g to 42,000 mg/g and averaged 19,900 mg/g. This is 32 times the average of the background stations.

Cadmium concentrations in sediments from the background stations ranged from 2 to 13 mg/l and averaged 6 mg/l. The Stations (25, 24, 23, 22, 21, and 20) adjacent to the Cinder Bank, East Plant and downstream on Aquashicola Creek to its confluence with the Lehigh River ranged from 39 mg/l to 420 mg/l and averaged 157 mg/g. This is 26 times the average of the background stations.

Similarly, manganese, lead, and copper, as compared to the background stations, showed corresponding increases adjacent to the Cinder Bank and East Plant areas of 17%, 11% and 10%, respectively.

Background concentrations of zinc in stream sediments in southeastern Pennsylvania are generally less than 200 parts per million (ppm). The high concentrations of metals in Aquashicola Creek and in the Lehigh River sediment are attributed to discharges including erosion from the Cinder Bank.

A. Benthic Macroinvertebrates

Both Aquashicola Creek and the Lehigh River are characterized by a well-entrenched channel, moderate gradient and frequent large cobble-filled riffles over a hard-rock bottom. Throughout the study area, including reference (control) sites, benthic macroinvertebrate population levels were low (44 to 1851/m²) indicating that both Aquashicola Creek and the Lehigh River are not highly productive.

In Aquashicola Creek at Station 27, the reference station, the benthos reflected good water quality. The 29 kinds of organisms collected were well distributed among the forms present. Conditions began to deteriorate at the next two downstream sites, stations 32 and 25, where a 40% reduction in the number of kinds and 45% reduction in numbers/m² occurred. This reach of the stream is influenced by run-off from the NJZ Cinder Bank and changes in the benthos population are attributed to the high heavy metal concentrations in the run-off.

Conditions found in the Lehigh River, both upstream and downstream of Aquashicola Creek, reflect typical conditions for large, organically enriched, eastern U.S. rivers. No apparent effect of Aquashicola Creek on the river was observed.

B. Periphyton

Periphyton communities reflected the influence of the Palmerton Zinc Site in several ways. Attached algal populations responded to the toxicity of Cinder Bank run-off and seepage by decreasing from about 40,000 organisms per cm² at reference Station 27 to about 20,000 and 5,000/cm² in the reach adjacent to the Cinder Bank. This toxicity-induced decrease was also reflected in low chlorophyll concentrations of 69 and 27 ug/cm².

It appears that wastes carried by Aquashicola Creek did not influence Lehigh River periphyton significantly; communities were similar in numbers and composition upstream and downstream from the creek confluence.

C. Fish Survival

Mortalities among in-situ test fish occurred at six of eleven exposure sites. Significant mortality (greater than the 10% allowable for the control group) only occurred at Stations 20, 21, 22, and 23; this is the reach of Aquashicola Creek extending from the mouth to approximately 3 river kilometers upstream. This stretch of the creek receives Cinder Bank run-off and seepage.

There appears to be a correlation between total zinc concentration and mortality. At Station 24, the average total zinc concentration during the exposure period was 3.49 mg/l and no mortality of test fish was recorded. Station 21 had an average total zinc concentration of 0.87mg/l, and produced the highest mortality of any site (40%). At Station 20, near the confluence of Aquashicola Creek, total zinc concentration was somewhat lower at 0.71 mg/l and 20% mortality occurred.

3. Groundwater Quality

Specific conductivity of groundwater samples from seven wells on the East Plant site ranged from 130 to 800 micromhos per centimeter. Calculated total dissolved solids concentrations ranged from 35 mg/l to 520 mg/l. Generally, waters of this quality are considered acceptable for public drinking water supply. However, zinc concentrations in groundwater ranged from 0.003 mg/l to 3.2 mg/l and cadmium concentrations ranged from 0.002 mg/l to 0.024 mg/l. Zinc was detected in all seven wells sampled and cadmium was detected in four of the seven wells sampled. Higher levels of zinc and cadmium were detected in the two wells designated as Stations 93 and 94. These wells are located on the east side of the field Station between the Cinder Bank and raw materials storage area on the south and Aquashicola Creek on the north. Because of its location and the presumed direction of natural groundwater flow from south (Blue Mountain) to north (Aquashicola Creek), it is likely that the high metals concentrations in the wells resulted from leachate originating in the Cinder Bank. Pumping of the wells in this well field induces groundwater flow toward the well field from the Creek. The dilution of the groundwater provided by this infiltration results in metals concentrations somewhat lower than would be expected in the shallow aquifer if no pumping and induced infiltration were occurring.

Station Nos. 96, 97 and 98 are wells at the west end of the East Plant area on the lower flank of Blue Mountain near the Palmer Water Company maintenance building and a railroad switching yard. These wells are referred to by the Palmer Water Company as "deep wells," ranging in depth from about 200 ft (60 m) to more than 400 ft (120 m). The aquifers tapped by these wells are bedrock aquifers of small yield and have little or no direct contact with surface waters or the shallow alluvial aquifer. A small amount of cadmium was detected in Station No. 98 and low concentrations of zinc were detected in each of these three wells.

C. SUMMARY OF SITE RISKS

As required by the Superfund Amendments and Reauthorization Act (SARA) of 1986, EPA asked the U.S. Public Health Service, Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate the health threat posed by the defoliated portions of Blue Mountain. In a February 6, 1987 memorandum, ATSDR found that there is potential risk in human exposure through consumption of fish.

Erosion and run-off from the Cinder Bank have contributed to high metal levels in fish. The levels of lead and cadmium in the fish present a potentially significant health threat to persons who regularly consume fish from area streams. It is ATSDR's opinion that ". . . consumption of fish from the area streams presents a potential health threat and . . . the public should be advised to consume fish from the immediate area streams on a limited basis only (no more than once per week)."

Rainwater infiltration and surface water infiltration (Blue Mountain runoff) are leaching metals from the Cinder Bank and contributing to contamination of Aquashicola Creek. Low pH values assist in the leaching of metals from certain sections of the Cinder Bank.

The easternmost portion of the Cinder Bank appears to have the greatest impact on water quality with the zinc concentrations averaging 40 to 80 times greater than background zinc concentrations and cadmium concentrations averaging 10 times greater than background cadmium concentrations.

If average metal concentrations obtained from ZCA'S two-sampling events in 1986 are assumed for the entire Cinder Bank, then these values, along with run-off and drainage area calculations from NEIC's 1979 investigation, indicate that the Cinder Bank may contribute 283 lbs. of cadmium, 622 lbs. of copper, 90 lbs. of lead, 296 lbs. of manganese, and 117,051 lbs. of zinc to Aquashicola Creek each year.

Non-point sources, such as groundwater discharge, are responsible for between 80 and 95 percent of metals loading to Aquashicola Creek.

VI. Community Relations History

The community has generally been concerned about the environmental devastation and the negative image a barren mountain projects. The action being considered at this time deals only with the Cinder Bank, however, there are two other major contamination problems which are of public concern: 1) widespread soil contamination which exists because of the deposition of heavy metals from past air emissions from the smelter, and 2) significant groundwater and surface water contamination on and near the smelter property.

The public has been concerned about the potential health effects of the soil and groundwater contamination and also about the potential financial impact on the Zinc Corporation of America of any remedial action. An RI/FS on the widespread soil contamination is being completed by the previous owners of the smelter, Gulf & Western, Inc. pursuant to a consent order with EPA. The report will be available for public review and comment in the coming months. A separate RI/FS for the overall surface water and groundwater is also underway.

VII. Remedial Alternative Objectives

The major objectives of remedial actions to be taken at the Palmerton Zinc Superfund Site include (1) minimize direct contact with the Cinder Bank (2) reduce volume of run-off, (3) reduce contamination in run-off, (4) reduce the volume of run-off, (5) collect and treat leachate, (6) reduce wind-borne contaminated emissions and (7) reduce particulate erosion.

Based on the above objectives, numerous source control and mitigation control technologies were screened to provide a limited number of technologies applicable for remedial actions at the Site. Some of these technologies were removed from further consideration based on site specific information and other comparative criteria listed in Table 1.

guidelines require that soil pH be adjusted to 6.0 in the first year, up to pH 6.5 by the second year and maintained at 6.5 for 2 years following application. With joint applications of lime and fly ash, these levels should be attainable. A protective erosion and sedimentation plan will be developed and implemented.

It may be technically impossible to meet some of the guidelines (i.e. sludge application and 2 foot municipal landfill soil cover) because of the terrain on the Cinder Bank. Specifically, the steep terrain prevents incorporation of the sludge/fly ash into some areas of the cinders as preferred by the guidelines; the slopes of the Cinder Bank are in excess of the 20% maximum recommended by the guidelines. To overcome these problems, the project can be implemented to minimize any erosion caused by the steep slopes and the inability to incorporate the sludge. Consideration of Wetland and Floodplain Regulations will be incorporated into the final plans when making decisions on slope contours.

Overland movement of the sludge/fly ash mixture was nonexistent during the field tests. The long term effectiveness of the alternative can be monitored through soil and water sampling. Vegetative growth and metals uptake by the plants can also be easily monitored.

Operation and maintenance will be necessary to control erosion of the soil amendments and insure the integrity of the vegetative cover. Because the pH of the rainfall in Palmerton is acidic, it is anticipated that over several years the Site could begin to reacidify. This can be easily monitored through routine soil testing and top-dressings of lime can be applied as needed.

All remedial action on surface water and groundwater beyond controlling Cinderbank Run-on and run-off will be handled under Palmerton Zinc Operable Unit 4.

The costs to implement this alternative are calculated to be approximately \$4,500,000 which includes some slope contouring and placement of 2 foot soil cover on 25% of the Cinderbank (this percentage is for costing purposes only).

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Alternative 3 - Collection and Treatment of Runoff and Run-on

This alternative would consist of using a combination of lime activated filtration lagoons and/or constructed wetlands as a treatment for the collected run-off. These systems should precipitate or bioaccumulate any metals that remain in the run-off. Laboratory tests and field studies have demonstrated that both of these technologies are technically feasible. The exact design and procedures will be based on further laboratory and field tests.

This alternative will be effective in both the short-term and the long-term for the lime filtration lagoons, and in the long-term for the constructed wetlands, following the establishment of the vegetation. This alternative will reduce the toxicity and mobility of the the hazardous substances on site.

This alternative meets all seven of the remedial action objectives. In addition, it meets the Clean Water Act requirements of BMP to reduce surface water discharges.

The vegetation in the wetlands will reduce the toxicity, mobility and volume of metals in the run-off by bioaccumulation. As the vegetation in the wetlands becomes saturated with metals, it can be harvested and run through the kiln.

The lime in the filtration lagoons will reduce the toxicity, mobility and volume of metals in the water being treated by chemical precipitation of the metals. As the lime becomes saturated with metals, it can be replaced with fresh lime, and the old material can be run through the kiln and regenerated. The short-term technical and administrative feasibility is very good. It is technically feasible to install constructed wetlands and lime-activated filtration lagoons. The materials and equipment needed are available or could be purchased. The cost of this alternative is approximately \$2,861,800.

The long-term effectiveness of this alternative can be monitored through water, plant, and soil sampling. Operation and maintenance should be limited to harvest of the above-ground portions of the wetland plants on an infrequent basis and replenishment of the lime in the filtration lagoons as needed. Some routine maintenance such as keeping water dispersion structures operational will be needed periodically.

The goal of this alternative is to treat Cinder Bank leachate and potentially treat Blue Mountain run-off and reduce metal levels to surface water background comparable to areas not impacted by the Palmerton Zinc Site.

Alternative 4- Capping Using Soil and Vegetation

This alternative would consist of contouring the Cinder Bank and applying a cap on the Cinder Bank. This cap would prevent water from infiltrating the cinders and will consist of an initial placement of 6 inches of soil and bentonite mixture covered by 18" of soil. Over the cap, there will be a cover of soil into which there may be incorporated wastewater treatment sludge, lime potash, and fly-ash, or some combination of these materials, to aid in establishing a vegetative cover of shortrooted grasses for erosion control.

The alternative will meet remedial action objectives. The toxicity and mobility of the hazardous substances will be reduced, although, because no cinders will actually be removed from the Cinder Bank, the volume of hazardous substances at the site will not be reduced.

The remedy is protective of human health and the environment, as it will eliminate access to the hazardous substances by direct contact, prevent water and wind from moving the hazardous substances, and, ultimately, will reduce metal-contaminated water from entering either groundwater or surface water.

Finally, the remedy satisfies the statutory preferences for maximum use of alternative technology and for permanence. While the remedy is innovative and practical, it is not experimental, but rather comes from a proven method for dealing with large piles of waste materials. The method's dependability also insures that it will permanently work to eliminate access to the hazardous substances by water, wind, animals, and humans. The cost of this alternative, assuming contouring 25% of the Cinder Bank to a 30% grade, then placing the cap on 50% of the Cinder Bank, is approximately \$5,500,000 (listed percentage for slope contour and cap placement are for costing purposes only). Operation and maintenance costs and technical considerations

XI. Documentation of Significant Changes

No significant changes to the preferred alternative presented in the proposed plan have occurred with the exception of being more specific in addressing the required ARAR base covers prior to the placement of the sludge-flyash mixture and vegetation.

XII. Selected Remedial Alternative

A. Description and Performance Goals

Section 121 of SARA and the current version of the National Contingency Plan (NCP) (50 Fed. Reg. 47912, November 20, 1985) establish a variety of requirements pertaining to remedial actions under CERCLA. Applying the current evaluation criteria in Table 1 to the four remaining remedial Alternatives, we recommend that Alternative 3 be implemented. In addition, on areas of the Cinder Bank which contain RCRA listed waste Alternative 4 is recommended, otherwise, in the areas not containing RCRA listed waste, Alternative 2 will be implemented. Prior to implementation of any remediation alternatives, both EPA and PADER will be in complete agreement with the remedial design for the remediation.

This is an interim remedy for the site. When the RI/FS for the other Operable Units are completed by the responsible parties, RODs will be issued to address all aspects of the site. This interim remedy will not, however, be inconsistent with a final comprehensive remedy for the Site. This interim remedy attempts to ensure compliance with all ARARs for this Operable Unit and will be consistent, to the extent practicable, with those ARARs addressed herein.

The general procedures for the above described remediation will be as follows:

Step 1: Contour Slopes of Cinder Bank

Slope modification is required to enhance precipitation run-off from the Cinder Bank and reduce the amount of precipitation infiltration and particulate erosion. Heavy equipment will be used to modify slopes targeted for vegetation. Excessively steep or otherwise unstable slopes may be built-up from the toe of the slope. Gas vents will be installed, if necessary. The Remedial Design generated prior to the implementation of this interim remedial action will provide grading specifications necessary to ensure success in the final cap placement.

Step 2: Construction of Surface Water Diversion Channels

Surface water diversion channels will be constructed, which will assure the water run-off from Blue Mountain will be diverted away from the Cinder Bank area. During construction of the remediation action, surface water run-off from Blue Mountain will be diverted through channels away from the Cinder Bank and to a treatment system if warranted. Leachate from the Cinder Bank will be collected by channels and diverted to the treatment system. Initially, lagoons in compliance with RCRA standards, will be utilized for the temporary storage of collected surface water.

Step 3: Construction and Cap

A cap consisting of a minimum of 18" of soils and 6" of clay or soil/bentonite mixture will be placed over the Cinder Bank to prevent: 1) leaching of heavy metals into the groundwater; and 2) seeps contaminated with heavy metals from exiting the toe of the Cinder Bank. (See Alternative selection for further discussion.)

Step 4: Vegetative Cover

A stabilizing vegetative cover will be applied over the cap. The cover may be comprised of a wastewater treatment sludge/flyash mixture, or conventional mulching, fertilization and seeding. The purpose of the vegetative cover will be to stabilize the slopes, prevent erosion, and control surface water movement.

Step 5: Long-Term Activities

An inspection, monitoring, and maintenance plan to assure effectiveness of the remedy will be implemented.

Reference 2

**Excerpts From Record of Decision for
Palmerton Zinc Pennsylvania: Interim Remedial Measure;
James M. Seif, Regional Administrator, EPA Region III;
September 4, 1987**

1356



Superfund Record of Decision:

Palmerton Zinc, PA



TECHNICAL REPORT DATA
(Please read instructions on the reverse before completing)

1 REPORT NO EPA/ROD/R03-87/036		3 RECIPIENT'S ACCESSION NO	
4 TITLE AND SUBTITLE SUPERFUND RECORD OF DECISION Palmerton Zinc, PA Interim Remedial Measure		5 REPORT DATE September 4, 1987	
7 AUTHOR(S)		6 PERFORMING ORGANIZATION CODE	
9 PERFORMING ORGANIZATION NAME AND ADDRESS		8 PERFORMING ORGANIZATION REPORT NO	
12 SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency 401 M Street, S.W. Washington, D.C. 20460		10 PROGRAM ELEMENT NO	
		11 CONTRACT/GRANT NO	
		13 TYPE OF REPORT AND PERIOD COVERED Final ROD Report	
		14 SPONSORING AGENCY CODE 800/00	
15 SUPPLEMENTARY NOTES			
16 ABSTRACT <p>The Palmerton Zinc site is located in Carbon County, Pennsylvania. The New Jersey Zinc Company currently operates two zinc smelters in Palmerton at the base of Blue Mountain. These two smelters are referred to as the east and west plants. Since 1898, the New Jersey Zinc facility has produced zinc and other metals for machinery, pharmaceuticals, pigments and many other products. Primary smelting of concentrated zinc sulfide ores which was terminated in December 1980, is the main source of pollution. Prior to December 1980, the smelters emitted huge quantities of zinc, lead, cadmium and sulfur dioxide which led to the defoliation of approximately 2,000 acres on Blue Mountain, adjacent to the east smelter. Vegetation damage first appeared on a 1951 aerial photograph as isolated patches on the steep, north-facing slope of Blue Mountain located immediately south of the east plant. By 1985, vegetation damage progressed over a continuous widespread area leaving barren, eroded land visible. The primary contaminants of concern leading to the defoliation of Blue Mountain include: zinc, lead, cadmium and sulfur dioxide.</p> <p>The selected interim remedial measure focuses on the establishment of a natural eastern forest ecosystem and includes: onsite installation of a concrete pad with berms to mix offsite sewage sludge and fly ash; construction of access roads; application of lime (10 tons per acre) and potash (80 pounds actual potassium per acre) on areas (See Attached Sheet)</p>			
17 KEY WORDS AND DOCUMENT ANALYSIS			
a DESCRIPTORS		b IDENTIFIERS/OPEN ENDED TERMS	c COSATI Field Group
Record of Decision Palmerton Zinc, PA Interim Remedial Measure Contaminated Media: woods, soil, SW Key contaminants: zinc, lead, cadmium, sulfur dioxide, inorganics, heavy metals			
18 DISTRIBUTION STATEMENT		19 SECURITY CLASS (This Report) None	21 NO OF PAGES 34
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EPA/ROD/R03-87/036
Palmerton Zinc, PA
Interim Remedial Action

16. ABSTRACT (continued)

targeted for revegetation; application of fly ash and offsite sludge on target areas; application of grass seed or seedlings onto target areas; and application of mulch to protect the seed. The municipalities that may apply the sewage sludge and other amendments should do so at no cost to EPA, provided the cost of implementing the alternative is less than it costs the municipalities to dispose of the sludge. A minimal capital cost may be developed pending the outcome of municipality implementation issues. O&M will not be required.

The major watercourse in the project area is the Lehigh River. The drainage pattern of the study area is toward Aquashicola Creek, a tributary of the Lehigh River. Aquashicola Creek flows through a buried valley, between Blue Mountain on the south and Stony Ridge on the north. The creek flows southwesterly and is joined by Buckwha Creek about one-half mile upstream of Harris Bridge and by Mill Creek near the east plant's main gate. Aquashicola Creek flows into the Lehigh River approximately 1.5 miles southwest of the zinc plant.

The reach of Aquashicola Creek in Palmerton is classified as a trout-stocking stream by the Pennsylvania Department of Environmental Resources. According to the criteria of water uses in this classification, the creek should maintain stocked trout from February 15 to July 31. It should also maintain and propagate fish species and additional flora and fauna that are indigenous to a warm-water habitat.

A water intake is located on the Aquashicola Creek near the Field Stone Bridge. This intake pumps water from the stream for industrial use at the east plant. Aquashicola Creek water is also pumped from an intake located between the Main Gate Bridge and the Sixth Street Bridge during times of emergency need for industrial process water.

Ground water in the site vicinity occurs in both the unconsolidated deposits and the underlying bedrock. The glacial outwash deposits in the stream valley contain significant quantities of available ground water, as is typical of this type of deposit.

At the foot of Blue Mountain, the Palmer Water Company, which supplies water to the towns of Palmerton and Aquashicola, has as its water source four production wells, ranging in depth from about 200 feet to more than 400 feet, drawing ground water from bedrock. The yield of these wells reportedly ranges from 115 to 130 gallons per minute.

Site History

The New Jersey Zinc Company currently operates two zinc smelters in Palmerton, referenced to as the east and west plants, respectively. The west smelter began operations in 1898, and in 1911, the east plant opened for operation. The New Jersey Zinc facility has produced zinc and other metals for machinery, pharmaceuticals, pigments, and many other products.

Primary smelting of concentrated zinc sulfide ores, which is the main source of pollution, was stopped in December of 1980. However, up until then the smelters had emitted huge quantities of zinc, lead, cadmium and sulfur dioxide which has led to the defoliation of approximately 2,000 acres on Blue Mountain which is located adjacent to the east smelter. Aerial photography of the site taken from 1938 to 1965 has shown the various stages of vegetation damage. Vegetation damage is defined as areas of exposed rock and soil where the original vegetation, as seen on a 1930 aerial photograph, has probably been destroyed as a result of the smelter's emissions.

Vegetation damage first appeared on a 1961 aerial photograph as isolated patches on the steep, north-facing slope of Blue Mountain, located immediately south of the Palmerton Zinc smelter's east plant. During the period of analysis, the vegetation damage progressed and additional areas of damage appeared. By 1965, vegetation damage appeared over a continuous widespread area with barren, eroded land visible from aerial photographs.

Current Site Status

Surface soils samples were collected from the defoliated portions of Blue Mountain. Five sample sites from different locations of the mountain were selected and analyzed for the metals of concern. Recorded levels of cadmium ranged from a high of 1,300 ppm to a low of 364 ppm, lead from 6,475 ppm to 1,200 ppm, and zinc from 35,000 ppm to 13,000 ppm. The maximum levels are up to 2,600 times the typical regional background levels for cadmium, over 2,000 times the regional background levels for lead, and over 400 times the regional background levels for zinc. Depth profiles showed that most of the metal contamination is contained within the top 0 to 10 inches of soil. This is because the metals are bound in organic materials which prevent significant downward movement of metals.

Water flowing across the defoliated portions of Blue Mountain has eroded the surface and become contaminated with metals contained in the soil. The runoff and erosion has carried the metal laden soil into Aquashicola Creek.

The runoff has been sampled twice in recent years. In May of 1979, EPA sampled the runoff as part of a comprehensive study of the smelter. In March of 1966, Horsehead Industries sampled the runoff under a Superfund consent agreement with EPA. The levels obtained were compared to EPA's ambient water-quality criteria. At almost every sampling location, the criteria was exceeded; in some instances, the levels were 20 times higher than the criteria. The results of the sampling effort performed in 1986 by Horsehead Industries is presented in Table 1.

A 1984 study by the U.S. Fish and Wildlife Service found very high metal concentrations in fish taken from streams in the area. Although the major source of the metal contaminating the creek comes from the smelter property, the runoff from the mountain contributes to the contamination and, in turn, to high metal levels in the fish. Figure 3 is a summary of all fish-sampling results.

The environmental impacts of the metal contamination on the affected area of Blue Mountain are obvious to the naked eye. Besides the defoliated vegetation and erosion, a noticeable absence of microflora, lichens, arthropods and wildlife species has occurred. Researchers have studied this area extensively and have concluded that due to the impact on such a wide variety of organisms in the ecosystem, a comprehensive picture of the effects of poorly controlled metal emissions emerges.

the guidelines also require soil pH be adjusted to 6.0 in the first year, up to 6.5 pH by the second year and maintained at 6.5 for 2 years after application. With joint applications of limestone and fly ash these levels should be attainable. A protective erosion and sedimentation control plan will be developed and implemented.

It is technically impractical to meet some of the guidelines because of the terrain on Blue Mountain. Specifically, the rocky terrain prevents incorporation of the sludge into the soil as preferred by the guidelines; the slopes of the mountain are in excess of the 20 percent maximum recommended by the guidelines; and, there are bedrock outcrops on the mountain that the guidelines recommend be avoided. To overcome these problems, the project can be implemented to minimize any erosion caused by the steep slopes and the inability to incorporate the sludge. Overland movement of sludge was nonexistent during the field test. Application of the sludge on outcrops should cause no negative impacts and may improve water quality by reducing the amount of contaminated runoff entering the bedrock.

Operation and maintenance will not be necessary because the goal is to establish a natural eastern forest ecosystem. Consistent with Section 121 of the Superfund Amendments and Reauthorization Act of 1980 (SARA) (P.L. 99-499), the site would be revisited every five years to ensure continued effectiveness of the selected alternative.

The cost to implement the alternative would be minimal. The municipalities that may apply the sewage sludge and other amendments should do so at no cost to EPA, provided the cost of implementing the alternative is less than it costs the municipalities to dispose of the sludge.

Comparative Analysis

No environmental or public health benefits would result from implementing Alternatives 1 or 2. The reduction of existing or future health risks by preventing continued exposure to metals would not be addressed. Unlike Alternative 3, the metals would remain mobile and will continue to contaminate area surface waters by not minimizing runoff and erosion. This would not comply with the requirements of the Clean Water Act regarding Best Management Practices (BMP).

Addressing implementability, Alternative 1 does not require an implementability analysis since there is no implementation issues associated with taking no action. The effective implementation of Alternative 2 would depend on the property owners voluntary placement of restrictions in the deed. Based on the results of field test plots, Alternative 3 is implementable, provided there are reliable sources of sewage sludge to complete the revegetation of the defoliated areas.

There are no costs for Alternative 1 since this involves no action. The costs for Alternative 2 are minimal which should involve only small legal fees for the modification of deeds. Likewise, costs for implementing Alternative 3 would also be minimal, if the cost of applying the sewage sludge for municipalities is a cost effective means of disposal in lieu of their current practices.

Recommended Alternative

Section 121 of SARA and the current version of the National Contingency Plan (NCP)(50 Fed. Reg. 47912, November 20,1985) establish a variety of requirements relating to the selection of remedial actions under CERCLA. Applying the current evaluation criteria in Table 2 to the three remaining remedial alternatives, we recommend that Alternative 3 be implemented at the Palmerton Zinc Superfund Site.

This is an interim remedy for the site. When the RI/FS's for the other operable units are completed by the responsible parties, ROD's will be issued to address all aspects of the site. This interim remedy will not, however, be inconsistent with a final comprehensive remedy for the site. This interim remedy does not attempt to ensure compliance with all ARARS for the entire site, but as discussed above under Alternative 3, will be consistent, to the extent practicable, with those action specific ARARS addressing sludge application, the Clean Water Act and Best Management Practice requirements.

This alternative consists of using a mixture of sewage sludge and fly ash to revegetate the defoliated areas of Blue Mountain. Based on greenhouse studies and results of field test plots it appears that this technology is feasible.

Although changes may be made to application rates and/or sludge-fly ash ratios, it appears that a general outline of the procedures for the revegetation program would be as follows:

Step 1: Site preparation -- Heavy equipment (i.e., bulldozers) would be used to install access roads in the areas targeted for revegetation.

A concrete pad with reasonable berms would be installed to mix the sludge and fly ash on-site.

Step 2: Lime potash application -- Lime and potash would be sprayed on the areas targeted for revegetation. Lime would be applied at approximately 10 tons per acre and potash at 80 pounds actual K per acre.

Step 3: Sludge-fly ash application -- The sludge-fly ash mixture would be applied by spraying the mixture onto the target area. The sludge-fly ash ratio will be based on further analysis of the field test plots. The sludge will be obtained from the Town of Palmerton, Allentown, and, if necessary, Philadelphia.

Step 4: Plant target area -- Grasses would be planted by blowing a mixture of grass seed onto the target area. Studies are continuing on the feasibility of also blowing tree seed onto the area. It is not yet clear if tree seed will germinate on the site. If tree seed will not germinate, seedlings will be planted.

Step 5: Apply mulch -- To protect the seed and permit germination, adequate mulch will have to be applied. Mulching may be reduced or eliminated if spring oats are planted in the fall. This will provide winter cover that will die by spring. The target areas can then be seeded with the permanent plant species in the spring, and the spring oat stubble will serve as a protective "mulch" layer for the permanent species seed.

Schedule

The anticipated schedule is to continue with some limited design studies in the fall of 1987. Beginning as soon as possible, but probably not before the end of 1987, large scale, multi-acre revegetation will begin. It will take a number of years to complete the remedial action, the exact time depending on the amount of sludge available. EPA's goal is to complete the project in five years.

Responsiveness Summary

This responsiveness summary is divided into the following sections:

- Section I Overview. A discussion of EPA's preferred remedial alternative.
- Section II Background of Community Involvement and Concerns. A discussion of the community interest and concerns raised during remedial planning activities at the Palmerton Zinc Superfund Site.
- Section III Summary of Major Comments Received During the Public Comment Period and Agency Responses. A summary of comments and responses received by the general public and potentially responsible parties.

I. Overview

The proposed remedial action is to revegetate the defoliated areas of Blue Mountain using a mixture of sewage sludge and fly ash. An RI/FS report discussing the environmental and public health problems associated with the defoliated portions of Blue Mountain was prepared by EPA. The report also examined potential methods to address these problems. Based on the information in the report, the revegetation program is recommended.

The RI/FS report and a description of the recommended alternative was released for public review and comment on May 22, 1987, a public meeting was held on June 18, 1987 and the comment period closed on July 6, 1987. A total of five written comments were received.

II. Background of Community Interest and Concerns

The community has generally been concerned about the environmental devastation and the negative image the barren mountain projects. The action being considered at this time deals only with the mountain, however, there are two other major contamination problems which have been of public concern. Widespread soil contamination exists because of the deposition of heavy metals from past air emissions from the smelter. There is also significant ground water and surface water contamination on and near the smelter property.

The public has been concerned about the potential health effects of the soil and groundwater contamination and also about the potential financial impact on the zinc company of any remedial action. The current owners of the smelter, Horsehead Industries, are completing an RI/FS on the ground water and surface water problems on and near the smelter property. An RI/FS on the widespread soil contamination is being completed by the previous owners of the smelter, Gulf & Western Inc. These RI/FS's are being done under a consent order with EPA and the reports will be available for public review and comment in the coming months.

Reference 3

**Excerpts From Draft Remedial Investigation Report:
The New Jersey Zinc Company, Palmerton, Pennsylvania;
J.F. Griffen, EPA; July 8, 1987**

75-2-1000

REMEDIAL INVESTIGATION REPORT

1.0 - Introduction

1.1.1. Background Information

The New Jersey Zinc Company is located in the Borough of Palmerton which is situated along the southern boundary of Carbon County, Pennsylvania. The Borough lies in a narrow valley bounded on the south by the Blue Mountain and on the north by Stoney Ridge, in the vicinity of Lehigh Gap on the Lehigh River (see Figure 1.1). The New Jersey Zinc Company occupies approximately 267 acres in the Borough and consists of two (2) plants - the West Plant in the western end of the Borough on the northern bank of the Lehigh River and the East Plant and Cinder Bank in the eastern end of the Borough on the southern side of the Aquashicola Creek and at the foot of the north side of the Blue Mountain.

Construction of the West Plant was started in early 1898 with the first zinc oxide produced from zinc silicate, ores mined in New Jersey. Zinc metal was produced from the same ores in the first quarter of 1900. The zinc silicate ores were relatively pure in that they were free of lead and cadmium. Construction of the East Plant was started in 1910 for the treatment of zinc sulphide ores which contained small amounts of lead and cadmium. The process consisted in crushing the ores, removing the sulfur by burning which replaced the sulfur in the ore with oxygen to produce a low grade, crude zinc oxide and sulfur dioxide. The crude zinc oxide was further treated by sintering (forming lumps), mixing with coal and converted to either a relatively pure zinc oxide (American Process) or zinc metal. The sulfur dioxide was converted to sulfur trioxide and absorbed in a weak sulfuric acid to produce merchantable quality sulfuric acid. These processes started operation in 1913.

Just prior to World War II (September 1941), the employment reached a high of 3,600. Maximum annual production reached was approximately 134,000

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net tons of zinc metal, 93,000 net tons of zinc oxide, 157,000 tons of sulfuric acid, 40,000 tons of anhydrous ammonia, 6,600 tons of rolled zinc products and miscellaneous by-products.

Shutdown of the basic zinc metal circuit in 1980 due to foreign imports, depressed prices and high cost of environmental controls reduced the employment to approximately 630 in 1982. As of mid-1986, 550 were employed.

Cinders (residues) from the production facilities of both the East and West Plants have been stocked in designated areas (based on metal values) along the base of the north side of the Blue Mountain, south and east of the East Plant since 1913. The Cinder Bank is now approximately 2.5 miles long, between 500 and 1,000 feet wide at the base and the top up to 100 feet above the mineral soil layer. At the time of a bank drilling program in 1981, it was estimated that 27,500,000 tons of material were stored. Updating this to December of 1986, indicated that 28,300,000 tons were stored at that time. The designated areas are generally divided into boiler house and gas producer ash from anthracite coal, horizontal retort, vertical retort, traveling grate furnace (high and low zinc areas) and Waelz kiln residues, slags and town refuse.

Residue from the operations was normally quenched in water directly from the processes, loaded into railroad cars and/or trucks, and transported to the designated storage area. Here, the material was spread, by locomotive crane originally and later by front-end loader with compaction originally by settlement only and later by traveling across the area with the front-end loaders.

Generally, the major portion of the Cinder Bank is stable. However, occasionally steam and smoke is seen in certain areas of the bank and minor subsidences have occurred.

Analyses prior to and during stocking of residues, along with the drilling program carried out in 1981, indicates the greater percentage of

the refuse to be ash and carbon with small amounts of metals of which zinc is the greatest - averaging 2.7% (see Appendix 1-2). The New Jersey Zinc Company has performed many investigations on their own volition, as well as those suggested, requested or demanded by various State and Federal agencies.

The Environmental Protection Agency National Enforcement Center EPA-330/2-79-022 issued a report "Evaluation of Runoff and Discharge from New Jersey Zinc Company, Palmerton, Pennsylvania" dated December 1979. Plant discharges to the Aquashicola Creek and the Lehigh River are covered by NPDES Permit No. PA-0012751.

The New Jersey Zinc Company is an unincorporated division of Horsehead Industries, Inc., 204 East 39th Street, New York, NY 10016. The properties were purchased from Gulf + Western Industries, Inc. on September 30, 1981.

The site shown on Figure 1.1 is located in a narrow valley with the Stoney Ridge on the north and the Blue Mountain on the south in the south side of the Borough of Palmerton, as previously noted. The Cinder Bank is located south of the Aquashicola Creek along the base of the north side of the Blue Mountain. Elevation at the base of the Cinder Bank is approximately 500 feet above mean sea level and the top of the mountain at approximately 1500 feet above mean sea level. Photogrammetric maps are attached - Plates 4-1, 4-2, and 4-3. Prevailing winds in the area are generally westerly, parallel to the valley.

The Borough of Palmerton is on more than ten tracts of land purchased and sub-divided by The Palmer Land Company, a subsidiary of the original New Jersey Zinc Company, starting in late 1898. The majority of the population of the Borough, until the late sixties, was made up of families of employees of The New Jersey Zinc Company. The community population was 5,455 at the time of the 1980 census.

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of two to four vertical retorts. Initially, leach tests of these residues determined that they were not hazardous. However, later it was found that some of these residues failed the toxicity test. The operation was shut down October 11, 1985. The entire 15,000 N.T. will be recycled through the Waelz kilns and the area closed as per a closure plan submitted to Mr. Patrick McManus (3HW11), U.S. EPA Region III. (Copy attached marked Appendix 3-2.)

3.2 Materials Component Characteristics and Behavior

As a whole, the bank was reported to contain 27,500,000 estimated total tonnage in aforementioned drilling report containing approximately: 16% Carbon, 2.7% Zinc, 0.025% Cadmium, 0.36% Lead, 0.33% Copper, 0.6 Oz/T Indium, Remainder Ash.

Practically all of the above are in the form of oxides and are contained in materials ranging in size of fine powders through the original two inch square and two inch by four inch loaf briquets to lumps and layers of material too hard and/or heavy to be moved with a large bulldozer.

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Reference 4

**Excerpts From Palmerton Zinc Superfund Site Blue Mountain Project;
EPA Region III; April 1987**

4. PUBLIC HEALTH AND ENVIRONMENTAL IMPACTS

4.1 ENVIRONMENTAL IMPACTS

The environmental impacts of the metal contamination on the affected area of Blue Mountain are obvious to the naked eye. Vegetation is absent, and the soil is completely eroded. A number of articles, cited in this chapter, appeared in scientific journals documenting the environmental damage caused by the contaminants under study.

4.1.1 Reduction In Microflora

Reduced microbial activity can be seen throughout the defoliated portions of Blue Mountain. Tree trunks that fell 10 to 20 years ago have not decayed, as would occur in areas with normal bacterial activity. The wood here has the appearance of dry, weathered driftwood, rather than of decayed wood commonly found in forested areas.

The absence of microbial activity was documented by researchers in 1975 (Jordan and Chevalier 1975). The researchers concluded that "over the approximately 40-year period of accelerating vegetation damage, increasing denudation, and increasing soil zinc levels, it is inevitable that the microbial populations have undergone changes in the Lehigh Gap area. Zinc has affected the microbial populations by direct toxicity and by secondary environmental effects, such as destruction of vegetation, drought, high soil temperatures, elevated pH, loss of soil nutrients, and decreased input of fresh litter."

4.1.2 Reduced Lichen Growth

Lichens are sensitive indicators of environmental pollution. A study in 1972 (Nash 1972) estimated that, on the defoliated areas of Blue Mountain, the richness and abundance of lichen species were reduced by approximately 90 percent. The researcher concluded that the abnormally high concentrations of zinc in the defoliated areas are primarily responsible for the poor condition of lichen flora. Although the smelter was operating at the time of the lichen study, and sulfur dioxide (SO₂) was present in levels high enough to cause injury, the SO₂ was not detected at elevated levels at the periphery of the lichen-impooverished zone. Consequently, it was concluded that the extremely high soil concentrations of zinc were a more significant factor than SO₂ concentrations in causing the reduced lichen growth.

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4.1.3 Reduced Arthropod Growth

Leaf-litter arthropods are important organisms in the ecology of healthy forests. Arthropods break down organic matter (e.g., leaves and bark) and contribute to the normal flow of nutrients through a healthy forest. On Blue Mountain, and beyond, researchers have shown that metal contamination has severely affected the arthropod population.

In 1978, Strojan reported that total arthropod density was only 22 percent of that in an uncontaminated area (Strojan, Emissions, 1978). It was concluded that the cause of the decrease is the high levels of soil pollutants. In another article, Strojan presented data demonstrating that the reduction of arthropods is creating an abnormally thick layer of undecayed organic debris (Strojan, Decomposition, 1978).

In 1984, researchers Beyer, Miller, and Cromartie reported that the mortality rate of arthropods (woodlice) after 8 weeks was 84 to 87 percent in surface litter from Blue Mountain (Beyer et al. 1984). These researchers believe that the findings from this and previous studies demonstrate how the Palmerton smelters are changing the surrounding environment. The populations of soil organisms, the soil profile, and the nutrient flow through the ecosystem have been altered at sites near this smelter."

4.1.4 Significantly Reduced Vegetative Growth

The lack of vegetation in the affected area is obvious. The first systematic studies to document the role of metal contamination in this damage were undertaken in the early seventies. In an initial study, metal contamination of the vegetation on Blue Mountain was documented (Buchauer 1973). In a subsequent report (Jordan 1975), the effects of metal contamination on the vegetation were further documented, and a number of causes for the lack of vegetation were presented:

- . High soil zinc levels apparently inhibited seed germination and prevented reestablishment of vegetative cover.
- . In the absence of vegetative cover, soil erosion occurred, and eroded areas are even less likely to revegetate.
- . The lack of vegetative cover exposes the dark surface to solar radiation. The exposed surface may attain temperatures as high as 144°F, which can kill stems of tree seedlings.

of mulch, and other minor variables. At an average of \$25 per ton it will cost approximately \$2,750 per acre. The total cost to revegetate the 2,000 acres could be approximately \$5,500,000. The calculations made to derive these figures are provided in a letter from the City of Allentown to EPA dated December 29, 1986. This letter is provided in Appendix F.

It is anticipated that if Philadelphia sludge is used to expedite the project, similar cost savings will be available to Philadelphia. The Palmerton sludge would be delivered to the mountain by the Borough of Palmerton.

Costs that will be assumed by the EPA would be those associated with procuring experts to provide continuing design assistance on the project. Experts from Pennsylvania State University and SCS will be used to continuously refine the design of the project. For example, sludge-fly ash mixtures, plant species, and other parameters may have to be refined as the project proceeds. It is anticipated that these design-assistance costs should not exceed \$50,000 per year. These costs would (funded through inter-agency agreements) include travel, salary, and analytical costs associated with vegetation, soil, and water analysis.

Replacement costs are nil because the project can only have a net benefit. Currently, the high metal levels and absence of nutrients preclude any significant vegetation on the mountain. Application of the sewage sludge and the other amendments can only serve to benefit Blue Mountain and would not have to be removed or replaced.

Reference 5

**Excerpts From Remedial Investigation Report:
The New Jersey Zinc Company, Palmerton, Pennsylvania;
EPA; November 20, 1987**

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Upon completion of monitoring well installation and well development, wells were surveyed to determine their locations and elevations. (Survey criteria were within 0.01 feet vertically and ± 1 foot horizontally.) Monitoring well elevations are included on the lithologic and well construction logs in Appendix 4-1.

4.2.2 Supervision, Sample Collection, and Record Keeping

All drilling activities and well construction activities were supervised by REWAI's on-site project geologists, who were in constant contact with NJZ's project coordinator and REWAI's project manager. Lithologic samples were collected from bailed cuttings every five feet and stored in clean glass jars for future reference. These collected samples are being stored by NJZ at their East Plant facility. Sample jars were clearly labeled with the job number, well number, and sample depth intervals. All observations made by REWAI's project geologists are included on the lithologic and well construction logs in Appendix 4-1.

4.3 Groundwater Sampling Procedures

Upon completion of the unconsolidated aquifer monitoring well installations, two complete rounds of groundwater sampling were conducted by REWAI. The first round occurred the week of August 18, 1986, and approximately corresponded with the August surface water sampling event. The second round occurred the week of March 23, 1987, which corresponds seasonally with the March 1986 surface water sampling event. This sampling was not conducted in 1986 because monitoring wells were not installed at that time.

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5.0 INTRODUCTION

In compliance with the U. S. Environmental Protection Agency (EPA) Administrative Order by Consent (AOC) dated September 24, 1985, two (2) required surface water samplings were conducted on behalf of the New Jersey Zinc Company (NJZ), by R. E. Wright Associates, Inc. (REWAI). All work associated with the collection and analysis of surface water samples was completed as specified by the Task VI Site Operations Plan (SOP), approved by EPA Region III on March 6, 1986.

Five (5) distinct sampling areas at and around the NJZ East Plant site were included in these sampling events. These areas were:

- o Runoff from Blue Mountain (seeps and springs).
- o Runoff from the Cinder Bank (seeps).
- o Permitted discharges (NPDES) to Aquashicola Creek.
- o Water and sediment samples from Aquashicola Creek.
- o Water and sediment samples from the Lehigh River.

The REWAI field sampling crew was on-site between March 10, 1986 and March 14, 1986 and then again between August 11, 1986 and August 15, 1986 to conduct all fieldwork associated with these sampling events. Flows in both the Aquashicola Creek and Lehigh River during the March sampling period were high due to precipitation and snowmelt, thus characterizing conditions during the "wet season." Flows during the August sampling period were much lower, and thus characterized the "dry season."

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Mining Waste NPL Site Summary

**Sharon Steel/Midvale Tailings Site
Midvale, Utah**

**U.S. Environmental Protection Agency
Office of Solid Waste**

June 21, 1991

FINAL DRAFT

Prepared by:

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DISCLAIMER AND ACKNOWLEDGEMENTS

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract Number 68-W0-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Sam Vance of EPA Region VIII [(303)293-1523], the Remedial Project Manager for the site, whose comments have been incorporated into the report.

SHARON STEEL/MIDVALE TAILINGS SITE

MIDVALE, UTAH

INTRODUCTION

The Site Summary Report for Sharon Steel/Midvale Tailings is one of a series on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining waste program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information from EPA files and reports and on a review of the summary by the EPA Region VIII Remedial Project Manager for the site, Sam Vance.

SITE OVERVIEW

The Sharon Steel/Midvale Tailings site is the milling portion of a former milling and smelting operation originally owned and operated by U.S. Smelting (later renamed U.S. Smelting, Refining and Mining Company). Operations involved the milling and smelting of lead, copper, and zinc. The Mill site is approximately 260 acres, and is located in the City of Midvale, Utah, which is 12 miles south of Salt Lake City. The Mill site is bordered by streets to the north, northeast, and southeast and by the Jordan River to the west and south. Directly north of the site, where the smelter operations were conducted, a slag pile from smelting operations was generated, which constitutes the Midvale Slag NPL site. A separate NPL Site Summary Report has been completed for that site.

The Sharon Steel/Midvale Tailings Mill site includes the tailings source area, tailings piles, Mill buildings, and wetlands (Reference 1, page 1-4; Reference 2, page 2; Reference 3, pages 1-4 and 1-5). Figure 1 depicts the approximate boundaries of the Mill site as well as the more expansive study area for the Remedial Investigation/Feasibility Study. Approximately 14 million cubic yards of tailings were generated from past milling operations on the site (Reference 3, page 1-1). The 1990 estimated population within 2 miles of the site was 43,911 people. In the City of Midvale (less than 1 mile from the tailings piles), the 1990 estimated population was 12,085 (Reference 1, page 4-7). The site was proposed for the NPL in 1984, and added to the list in August 1990 (55 Federal Register 35502; Reference 3, page 1-10). The Remedial Investigation was conducted from July 1987 to 1988. The Feasibility Study was published in June 1989; in July 1989, the EPA Region VIII Superfund Program Proposed Plan was issued for the entire site. After extensive public comment on the Proposed Plan, EPA decided to postpone the Record of Decision (ROD) for a year and divide the site

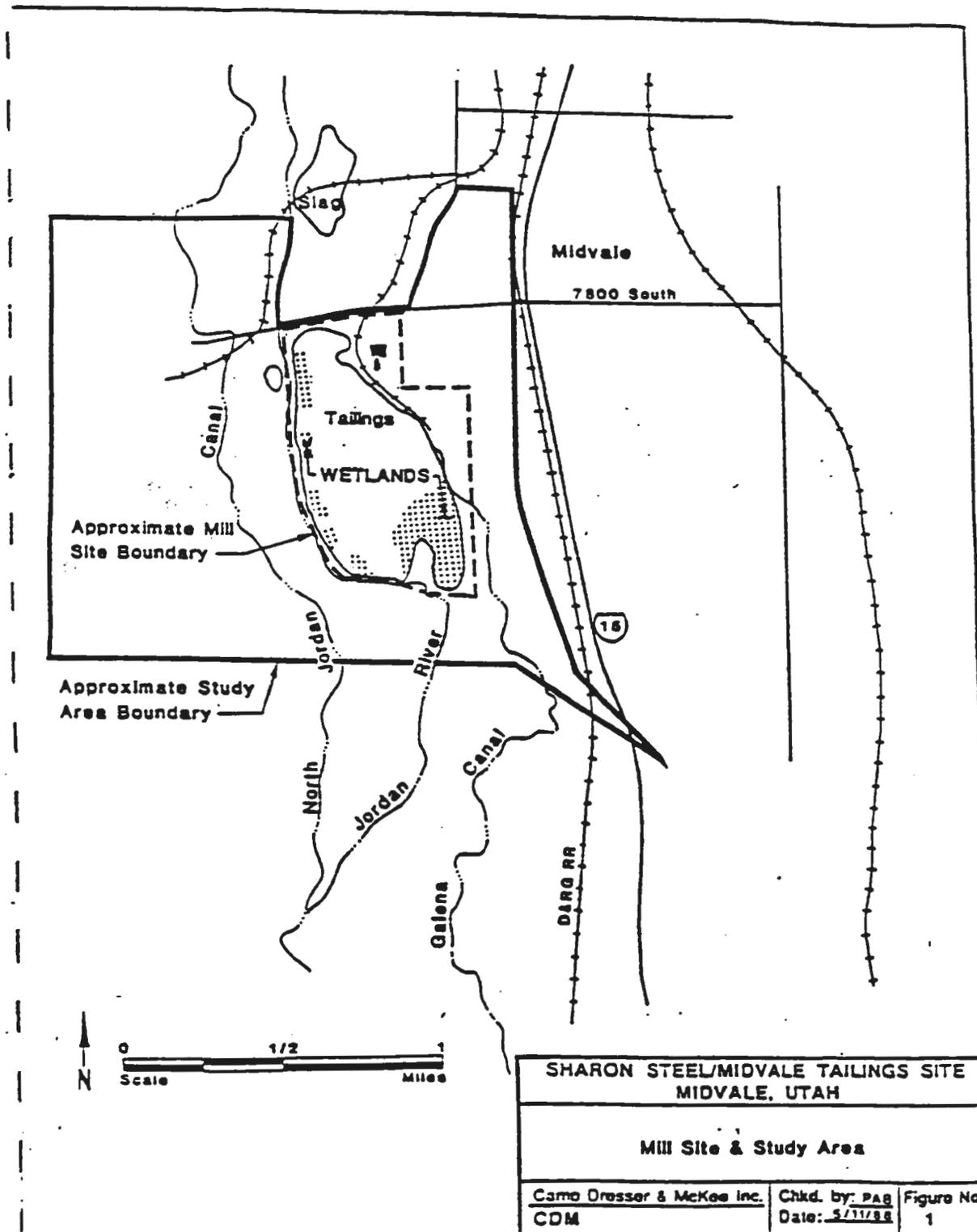


FIGURE 1. MILL SITE AND STUDY AREA

into two Operable Units for further Remedial Investigation/Feasibility Study investigations (Reference 8, page 2).

Operable Unit 1 is the Mill site, including tailings and ground water; Operable Unit 2 consists of the "study area" in Figure 1 (excluding the Mill site area). Operable Unit 2 includes offsite soils, residential areas, and public-use areas adjacent to the mill; (Reference 3, page 1-7; Reference 4, page 1). The primary constituents of concern in the soil are arsenic, cadmium, and lead (Reference 1, page 2-13). The primary constituent of concern in the ground water is arsenic (Reference 10, Appendix A, page 5-1).

The ROD for Operable Unit 2 was signed on September 24, 1990. The selected remedial action includes excavation of the contaminated soils from the residential areas and the temporary storage of these soils at the Mill site. The estimated remediation cost for Operable Unit 2 [capital and Operation and Maintenance (O&M) costs] is approximately \$20 million (Reference 4, page 16). The Feasibility Study and the Proposed Plan for Operable Unit 1 were released for public comment on October 5, 1990 (Reference 3, page 1-1). The ROD for Operable Unit 1, estimated to be completed in December 1991, will address remediation of the residential soils stored at the Mill site, tailings present at the Mill site, and contaminated ground water underlying the Mill site (Reference 4, Abstract, page 1; Reference 9).

OPERATING HISTORY

U.S. Smelting conducted both milling and smelting operations at the site. The milling portion of the facility operated from 1910 to 1971. In 1971, UV Industries bought U.S. Smelting. The smelter, located to the north of 7800 South Street (see Figure 1), is on the Midvale Slag Superfund Site, and was closed in 1958. Sharon Steel acquired the Mill and tailings site in 1979. The original operations involved receiving lead, copper, and zinc ores; extracting sulfide concentrates of these metals in the milling operation; and smelting these concentrates to extract the metals in purer form. The facility also operated as a custom mill, receiving ores and concentrating and extracting metals. The wastes from the milling operations were disposed of in unconsolidated tailings piles. The Mill site includes several Mill buildings and approximately 12 to 14 million cubic yards of tailings in uncovered piles (Reference 1, page 1-4; Reference 3, pages 1-8 and 1-9; Reference 6, page 14).

In June 1982, wind-blown tailings were sampled and found to have high concentrations of arsenic, cadmium, chromium, copper, lead, and zinc (Reference 3, page 1-9). A 6-foot chain-link fence was erected by Sharon Steel along the northern boundary of the property to prevent direct contact with the tailings piles. The fence, however, did not prevent the tailings from blowing down the embankment

Sharon Steel/Midvale Tailings Site

of a highway right-of-way (Reference 3, page 1-12). On September 17, 1982, the Utah State Bureau of Air Quality issued a request for a compliance plan to control the fugitive dust emanating from Sharon Steel (Reference 7, page 4; Reference 3, page 1-9). Sharon Steel Corporation responded to this request in October of that year with a proposal to use water flooding to suppress the dust. The State withdrew initial approval of the plan, and ordered Sharon Steel to design an alternative plan. Ultimately, a dust-mitigation program (using a chemical polymer dust suppressant) was implemented in May and June of 1988 (Reference 3, pages 1-9 and 1-13).

Also in 1988, a slope-stabilization and river bank-restoration plan was implemented. Where the berm bordering the site had been washed out by high river flows, it was reconstructed to serve as a buffer zone between the tailings and the River. Rehabilitation involved removing all tailings from the berm where it had been washed out. These tailings were placed on existing piles away from the River, and embankments were sloped at a ratio of approximately 3 to 1 in a horizontal to vertical configuration. In addition, stream-bank areas requiring repair were filled with gravel material, compacted, and covered with a graded rip-rap. Debris and sediments that were directing River flow into the tailings side of the River were also removed and the River channel was "cleaned" so that River flow would be redirected away from the bank bordering the tailings (Reference 3, pages 1-13 and 1-14).

SITE CHARACTERIZATION

The Mill site has three small offices, a bunkhouse, a machine-storage shed, and three Mill buildings. A 22-acre wetlands area and several small ponds are also located on the Mill site, along with the tailings piles. The sources of contamination at the site are the tailings piles (Reference 2, page 2). Descriptions of each potentially contaminated medium are presented below.

Ground Water

The original Remedial Investigation/Feasibility Study for the Sharon Steel Mill site, completed in June 1989, provided a general background on the ground-water system and its quality underlying the site. In response to public comment on the original Proposed Plan and Remedial Investigation/Feasibility Study, a ground-water/geochemistry Remedial Investigation Addendum was begun in November 1989, and completed in May 1990. This in-depth study was conducted to understand, in further detail, the geology, hydrologic system, and geochemistry of the site.

Four aquifers comprise the ground-water system at the Mill site. Two of these hydrologic units are regional aquifers: the Deep Principal Aquifer and the Upper Sand and Gravel Aquifer. They are

similar in their regional extent, composition, and depositional history. Two local aquifers were identified: the Perched Terrace Aquifer and the Saturated Tailings Zone (Reference 9, page 4-1).

The Deep Principal Aquifer, composed of unconsolidated clay, silt, sand, and gravel deposits, is confined by a thick (6.5 to 24.1 feet at the site) clay, silt, and fine-sand layer in the central part of the Valley and is generally unconfined along the perimeter of the Valley (the recharge area of the Aquifer) (Reference 9, pages 3-1 and 3-9). Beneath the Mill site, ground-water flow in the Aquifer is to the northeast toward pumping centers (Reference 9, page 4-1). During most of the year, the Aquifer displays artesian conditions in the site study area; however, high rates of summer pumping may reverse this gradient, as was observed in the summer of 1990 (Reference 9, page 3-11). The Remedial Investigation cautioned that this reversal could become more persistent if pumping were to continue year-round at rates similar to those occurring during the summer (Reference 9, page 4-1).

The Upper Sand and Gravel Aquifer is similar in composition to the underlying Deep Principal Aquifer. Overlying the Upper Sand and Gravel Aquifer is a discontinuous clay and silt layer that separates this Aquifer from the tailings at the Mill site (Reference 9, Executive Summary, page 6). Beneath the Mill site, ground-water flow in the aquifer is to the northwest most of the year; however, later in the summer, the flow direction has been observed to change to a northern direction (Reference 9, Executive Summary, pages 6 and 7; Reference 9, page 3-8). The onsite upward head difference between the Deep Principal Aquifer and the Upper Sand and Gravel Aquifer indicates that upward leakage from the Deep Principal Aquifer is occurring. However, locally, slight downward gradients exist, perhaps related to recharge from overlying units or from pumping of large municipal wells completed in the basal portion of this Aquifer and the Deep Principal Aquifer (Reference 9, page 3-9).

The two local hydrologic units present in the study area, the Perched Aquifer and the Saturated Tailings Zone, lie laterally adjacent to each other. The Perched Aquifer is located on the east side of the Mill tailings in the ancient Lake Bonneville clay, silt, and fine-sand deposits that form a terrace above the Jordan River (Reference 9, Executive Summary, page 7 and page 3-3). In general, recharge into this Aquifer percolates into the underlying Upper Sand and Gravel Aquifer; however, water may become perched above impermeable layers. In addition, some ground water flows from the Perched Aquifer into the Saturated Tailings Zone (Reference 9, page 3-4). The Saturated Tailings Zone is comprised of fine-grained metalliferous sand and silty sand and interbeds of slimes (low-permeability silts/clays) hydraulically deposited into tailings ponds constructed on the River's floodplain. At some locations, the tailings directly overlie the Upper Sand and Gravel Aquifer at what may be the pre-1951 channel of the Jordan River. In the 1950's, the Jordan River was diverted west to increase the area available for tailings disposal. Ground water is generally found in the lower portion of the tailings; flow is both lateral and downward through Jordan River overbank deposits, or

the buried Jordan River channel (Reference 9, pages 3-4 through 3-6). Some water remains above the slime interbeds. In November 1987, water levels indicated a fairly uniform ground-water gradient to the west; however, June 1990 measurements indicated different flow paths. Ground-water flow was determined to be to the north in the northwest part of the tailings and to the east and northeast in the western portion of the tailings (Reference 9, page 3-6). Overall, ground-water levels are decreasing in the tailings due to the discontinuation of dust-suppression activities (Reference 9, page 3-6).

The Deep Principal Aquifer is the primary drinking-water source in the Salt Lake Basin, serving 300,000 people. The nearest operating municipal supply well is approximately 1.5 miles north (downgradient) of the site. According to the State of Utah, the present allocation of water rights exceeds Aquifer recharge potential (Reference 3, pages 1-15 and 1-24). Both the Deep Principal Aquifer and the Upper Sand and Gravel Aquifer are potential sources of drinking water for Salt Lake County, which is north of the site (Reference 1, page 4-2). In the study area, two large-volume public supply wells pump water from the lower Upper Sand and Gravel Aquifer and the Deep Principal Aquifer (Reference 3, pages 1-15, 1-23, and 1-24; Reference 10, Executive Summary, page 6).

The location of the tailings provides the potential for the migration of contaminants to the unconsolidated deposits of the Jordan River Valley. Of 14 tailings samples, 10 were reported as exceeding Extraction Procedure (EP) toxicity test limits for lead, and 3 exceeded EP toxicity test limits for cadmium. One soil sample collected from the Mill site also exceeded the EP toxicity criteria for lead (specific levels were not provided) (Reference 3, page 1-23).

Chemical analyses of solid materials and water from below the tailings confirm that contaminants are migrating from the tailings into these materials. Onsite sampling concluded that contaminant concentrations decrease with depth in materials immediately below the tailings.

Wells completed in the tailings have the highest arsenic [average value 920 micrograms per liter ($\mu\text{g/l}$)] and Total Dissolved Solids (TDS) values (Reference 9, pages 3-23, 3-24, 4-2, and 4-3). Perched Aquifer ground-water samples collected from both onsite wells and wells in the vicinity of the site have arsenic concentrations ranging from 4.2 to 31.6 $\mu\text{g/l}$. The 31.6 $\mu\text{g/l}$ sample was collected from a well on the site (Reference 9, page 3-24). Ground-water samples from the upper portion of the Upper Sand and Gravel Aquifer show concentrations of arsenic ranging from less than 1 to 288 $\mu\text{g/l}$, with an average of 68 $\mu\text{g/l}$. TDS values ranged from 1,530 to 2,420 milligrams per liter (mg/l). Arsenic concentrations detected in upgradient wells are generally 1 $\mu\text{g/l}$ (Reference 9, pages 4-2 and 4-3). Concentrations of arsenic and TDS in the upper portion of the Upper Sand and Gravel Aquifer suggest a mixing of water in the upgradient Aquifer with water from the tailings.

Three wells completed in the Deep Principal Aquifer beneath the tailings site have very low arsenic concentrations (generally below detection limits) and low TDS values. Ground-water samples of private wells completed in this Aquifer show the same analytical results. These values suggest that arsenic has not yet migrated to the Deep Principal Aquifer, or that dilution has taken place (Reference 9, pages 3-23, 3-24, 4-3, and 4-4). The geometric mean of ground-water (and other media) contaminant concentrations are presented in Table 1 (Reference 10, page 1-17).

Soils

Soils in the Midvale area vary with the three local land features: the Jordan River floodplain; terraces from the Great Salt Lake/Lake Bonneville system; and artifacts of the mining industry (tailings dumps and man-made fill) (Reference 3, page 1-16, Reference 1, page 4-3). Levels of metals found in the soils and tailings are presented in Table 1. The mean lead concentration at the Mill site, for example, was 2,100 milligrams per kilogram (mg/kg), and in residential soils it was 722 mg/kg, with no samples for either location below 150 mg/kg lead (Reference 3, pages 1-28 and 1-29). Results of a geochemistry study completed by Drexlor in 1989, which was reported in the 1990 Baseline Risk Assessment, suggest that both the tailings and slag sites have contributed to lead levels in the soil (Reference 1, pages 2-8 and 2-9). The geometric mean of soil (and other media) contaminant concentrations are presented in Table 1.

Surface Water

Some of the sites, including most of the tailings piles, lie in the floodplain of the Jordan River. At one time, the River flowed through the Mill site, but was later relocated to the west of the site to facilitate tailings deposition. The tailings piles, which form an embankment on one side of the Jordan River, lack any provisions for containment or diversion of surface-water runoff or runoff (Reference 1, page 4-3).

Water-quality data suggest that the dissolution of metals from the tailings to the aqueous phase is occurring; but, it is not significant. This could be a result of: (1) low fluvial transport of sediment or tailings material, as indicated by low Total Suspended Solids (TSS) values (59 to 61 mg/l) or (2) high pH values (7.5 to 7.8) in the Jordan River, which would cause metals to remain bound to the sediments (Reference 3, page 1-40).

TABLE 1. GEOMETRIC MEAN OF CONTAMINANTS OF CONCERN IN VARIOUS MEDIA

Element	Local Background ¹ Soil		Contaminated Surface Soil				Tailings		
	Terrace	Floodplain	Terrace	Floodplain	Residential	Mill Site	Surface (Oxidized)	Surface (Dunes)	Subsurface (Unoxidized)
	(mg/kg)								
Aluminum	13,669.0	7,283.0	12,461.0	10,883.0	9,560.0	9,267.0	3,982.0	3,270.0	3,002.0
Antimony	6.1	< 5.5	6.4	8.8	5.7	72.7	73.5	16.0	17.0
Arsenic	15.2	5.7	31.5	40.7	65.5	158.0	425.1	320.2	411.2
Cadmium	3.2	2.0	5.4	7.1	12.5	27.6	46.8	37.3	36.4
Chromium	18.0	11.9	17.8	18.6	15.8	29.8	25.4	17.0	18.3
Copper	81.4	40.7	160.6	344.6	195.1	324.1	298.5	760.2	578.1
Lead	97.0	78.6	373.2	536.8	722.0	2,100.0	6,278.0	5,470.0	5,209.0
Manganese	454.3	249.5	466.0	452.8	508.9	833.7	1,199.0	1,497.0	2,032.0
Silver	1.4	< 1.4	1.9	2.8	3.0	10.4	26.9	24.9	27.1
Thallium	BDL	BDL	BDL	1.6	1.4	2.0	3.3	3.2	8.0
Zinc	124.3	100.3	320.8	537.4	591.8	2,143.0	4,821.0	6,048.0	6,372.0
n	4.0	5.0	23.0	17.0	22.0	31.0	13.0	22.0	4.0

n - Number of samples

BDL - below detection limit

¹"Local Background" as defined in the Remedial Investigation (CDM, 1988b). It was referred to as "ubiquitous contamination" in the Feasibility Study.

²No samples were collected from the deep confined aquifer because previous research showed no contamination.

³Geometric mean exceeds Maximum Containment Level (MCL) for drinking water.

Source: Reference 3, page 1-28

ENVIRONMENTAL DAMAGES AND RISKS

An environmental health problem was first suspected in June 1982 when the Utah State Department of Health was notified that citizens were gathering wind-blown tailings for sandboxes and gardens. Sand and wind-blown tailings were sampled by the State. High concentrations of arsenic, cadmium, chromium, copper, lead, and zinc were found (Reference 1, 1-4; Reference 2, page 2; Reference 7, page 1; Reference 3, page 1-9). A sample of "sand" analyzed by the State contained 4,000 parts per million (ppm) of lead (Reference 6, page 14).

The City of Midvale, less than 1 mile away, has a population of 12,085, and within 2 miles of the site there are 43,911 people. The Jordan River is classified for recreational use, excluding swimming, cold-water game fishing, and agriculture (Reference 1, page 4-3).

Contaminants of concern in the Mill tailings are aluminum, antimony, arsenic, cadmium, chromium, copper, lead, manganese, silver, thallium, and zinc. Arsenic, cadmium, and lead are likely to be of greatest potential concern to human health, as discovered in the Endangerment Assessment performed as part of the Remedial Investigation (Reference 1, page 6-3).

The exposure pathways evaluated for current and potential future use conditions are:

- Direct ingestion of site tailings or contaminated surface soils
- Ingestion of contaminated ground water
- Inhalation of tailings-contaminated dust
- Ingestion of home-grown produce by nearby residents
- Dermal adsorption of tailings or contaminated surface soils
- Ingestion/contact with contaminated surface water and sediments (Reference 1, page 6-3; Reference 3, pages 3-21 and 3-22; Reference 10, page 3-3).

In the Baseline Risk Assessment, arsenic is the only carcinogen evaluated for all exposure pathways except inhalation. For the inhalation pathway, both arsenic and cadmium are carcinogenic. The excess upperbound lifetime cancer risks for all current use exposure pathways combined is 5×10^{-4} , primarily from exposure to arsenic from ingestion of tailings in sandboxes and ingestion of indoor dust (note that the ground-water pathway is currently incomplete). However, "public information efforts by the State of Utah and EPA have generally eliminated the route of exposure involving

efforts by the State of Utah and EPA have generally eliminated the route of exposure involving tailings ingestion from sandboxes." Noncarcinogenic effects can also result from exposure to arsenic and cadmium through the evaluated pathways (Reference 1, page 5-2).

The overall excess upperbound cancer risk for all exposure pathways, except ground water, under future use conditions is 1×10^{-3} , resulting primarily from exposure to arsenic through indoor dust and tailings ingestion. Noncarcinogenic adverse effects could also occur due to exposure to arsenic and cadmium (Reference 1, page 5-2).

Of greatest concern is the ingestion of lead from the tailings study area that can cause noncarcinogenic adverse effects. Exposure of young children to lead may cause cognitive dysfunction and reduced growth, and in adults, hypertension may result from high lead-blood levels (Reference 1, page 5-8; Reference 3, page 1-25).

Assessment of the ground-water pathway is currently incomplete at the site; however, a future use and hypothetical current use scenario was examined in the Baseline Risk Assessment for ground water (Reference 10, Appendix A, page 5-1). Arsenic is the only contaminant of concern identified for the ground-water pathway.

Current domestic ground-water usage from hypothetical onsite and offsite (downgradient) wells completed in the upper portion of the Upper Sand and Gravel Aquifer would result in potential upperbound excess cancer risks of 4.4×10^{-3} and 1.2×10^{-3} , respectively (Reference 10, Appendix A, page 5-1). In addition, there would be a potential for noncarcinogenic adverse health effects from the use of ground water produced from the onsite well. A future use scenario (arsenic concentrations were determined with a ground-water quality model) suggests that potential upperbound excess cancer risks for the years 2020 and 2090 would range from 5.6×10^{-3} to 8.8×10^{-3} for an onsite domestic-use well and 1.2×10^{-4} to 5.6×10^{-3} for an offsite well. Noncarcinogenic adverse health effects are likely for the onsite domestic well; but, they are unlikely for the offsite domestic well (Reference 10, Appendix A, pages 5-4 and 5-5).

The combined risk from all pathways, including ground water, was determined for two future use scenarios based upon current water quality, hypothetical onsite residential use, and the offsite residential use. The excess upperbound lifetime cancer risk resulting from all exposure pathways for an onsite resident is 5.4×10^{-3} . The excess upperbound lifetime cancer risk resulting from all exposure pathways for an offsite resident is 1.7×10^{-3} (Reference 10, Appendix A, pages 6-1 through 6-3). In addition, adverse noncarcinogenic health effects are likely for each residential scenario.

TABLE 1. GEOMETRIC MEAN OF CONTAMINANTS OF CONCERN IN VARIOUS MEDIA (Continued)

Element	Sediment		Jordan River Surface Water		Ground Water ²		Air Data From December 1987 Event	
	Upstream	Downstream	Upstream	Downstream	Perched in Tailings	Shallow Unconfined	Upwind	Downwind
	(mg/kg)		µg/l					
Aluminum	1,492.0	3,365.0	1,010.0	1,030.0	60.0	54.0	--	--
Antimony	< 29.0	< 34.0	< 60.0	< 60.0	73.0	62.0	--	--
Arsenic	1.5	16.1	14.0	10.0	109.0 ³	29.0	314.0	438.0
Cadmium	< 1.5	2.2	0.36	0.44	< 3.0	5.0	< 3.0	25.2
Chromium	3.8	7.3	< 3.0	< 3.0	< 3.0	< 3.0	8.4	108.0
Copper	4.0	151.0	7.0	10.0	3.5	7.1	24.0	787.0
Lead	5.8	115.0	6.0	11.0	6.4	5.3	37.0	3,865.0
Manganese	38.2	128.9	53.0	53.0	305.0	79.4	--	--
Silver	< 2.0	3.0	< 0.2	< 0.2	< 4.0	< 4.0	--	--
Thallium	BDL	BDL	< 10.0	< 10.0	BDL	BDL	--	--
Zinc	16.0	331.0	19.0	20.0	62.0	195.0	90.0	5,422.0
n	3.0	3.0	1.0	1.0	7.0	7.0	2.0	5.0

n - Number of samples
BDL - below detection limit

¹"Local Background" as defined in the Remedial Investigation (CDM, 1988b). It was referred to as "ubiquitous contamination" in the Feasibility Study.

²No samples were collected from the deep confined aquifer because previous research showed no contamination.

³Geometric mean exceeds MCL for drinking water.

Source: Reference 3, page 1-28

Sharon Steel/Midvale Tailings Site

None of the surface-water sample analyses found metals to be in excess of the criteria for protection of aquatic life, except for the seep along the side slope of the tailings above the Jordan River. Despite high metal concentrations in the seep, River-water quality does not appear to be adversely affected. The geometric mean of sampling results is presented in Table 1 (Reference 3, pages 1-28, 1-40, and 1-41).

Sediment

The Sharon Steel/Midvale Tailing site is located in the Jordan Valley, which is a flat, sediment-filled Valley separated by fault-block mountains. The Valley has been filled with lacustrine sediments deposited in ancient Lake Bonneville, interlayered with coalescing alluvial fans derived from the adjoining mountains (Reference 1, page 4-2; Reference 3, page 1-14). Sediment data indicate that tailings are migrating from the Mill site into the Jordan River due to either ongoing erosion or previous slope failures. However, as previously stated, such migration is not causing significant dissolution in the aqueous phase. In addition, these data indicate that wetland sediments contain tailings. Sediment data are presented in Table 1 and the attached references (Reference 3, pages 1-40 through 1-42).

Air

During dry, windy periods in mid- to late-summer, contaminants may be transmitted through the air, causing inhalation exposure. This may also occur during off-road vehicle use at the Mill site, and to a lesser extent, during removal or stabilization as part of a potential site remedial action (if protective measures are not taken). The effect on health from inhalation exposure depends on the proximity of individuals to the site and particle size. Small particles (less than 10 microns), which may be carried farther than larger particles, could potentially affect more people; however, only a small proportion of the tailings particles are that small (Reference 3, page 1-23). Therefore, only nearby exposure may cause threats to human health. No indication of the exposure level was provided.

Air samples were taken in December 1987. Downwind concentrations of lead and zinc were at very high levels (3,865 and 5,422 $\mu\text{g}/\text{l}$, respectively). Other metal concentrations found in these samples are presented in Table 1 (Reference 3, page 1-23). Further details of the type of air sampling (i.e., particle size) or distance of downwind samples from the source were not provided in the Feasibility Study (Reference 3).

Modeled future ground-water quality was also investigated to determine human health risks for future use scenarios (for both onsite and offsite residents). Health risks for these scenarios are predicted to increase over time due to the increased degradation of ground-water quality, as calculated by ground-water quality modeling (Reference 10, Appendix A, pages 6-3 and 6-4).

Potential threats to environmental receptors including vegetation, aquatic life, and wildlife were also evaluated. Soil lead levels as low as 100 ppm are known to be phytotoxic. The geometric mean contamination level of lead in residential soils was found to be 722 mg/kg (see Table 1), far above the phytotoxic level (Reference 3, page 1-26 through 1-28). Aquatic life can be exposed to contaminants in both surface water and sediments. Of greatest concern are the high levels of metals in the sediments (see the previous section), which may act as a reservoir that can supply metals to the water column or be directly consumed by benthic organisms. Wildlife in the wetlands may be exposed to site-related contaminants through direct contact with surface waters or sediments or through the food chain. Among the metals present at the study area, lead has been shown to bioconcentrate in insects, small mammals, and songbirds (that may then be consumed by larger animals). While the potential of adverse effects due to lead exposure exists, it is presently unknown whether wildlife is being adversely affected by the metals found in the study area (Reference 3, page 1-27).

REMEDIAL ACTIONS AND COSTS

The October 1990 EPA Region VIII Superfund Program Proposed Plan announced EPA's preferred site remediation for Operable Unit 1. The preferred remedial action was listed as site capping, ground-water treatment, and institutional controls. However, EPA is continuing to evaluate the reprocessing of tailings as an alternative for remediation at Operable Unit 1. The U.S. Bureau of Mines is currently conducting a two-phase study to characterize the tailings and evaluate methods for their beneficiation. The preferred remedy outlined in the Proposed Plan includes the following activities:

- Installing a multi-layer vegetated soil cap over tailings and soils that exceed the action levels established for residential soils at Operable Unit 2.
- Pumping and treating contaminated ground water to reduce arsenic concentrations to action levels. The Feasibility Study for Operable Unit 1 specifies an ion-exchange treatment for the remedy that was selected; however, the Proposed Plan did not state the specific treatment to be used.
- Diverting storm water from the site through a drainage system.

Sharon Steel/Midvale Tailings Site

- Regrading the tailings bordering the Jordan River to prevent erosion.
- Excavating contaminated wetland sediments and placing them on tailings prior to capping; and restoring wetlands.
- Decontaminating, (possibly) demolishing, and disposing of Mill facility and support buildings offsite.

The 30-year present worth capital and O&M costs for the selected remedy are estimated to be \$43,138,000 (Reference 10, Appendix C, pages 8 through 10). EPA will continue dust-suppression activities until final implementation of a remedy.

The remedy selected in the 1990 ROD for Operable Unit 2 (offsite residential soils) includes the following activities (Reference 4, pages 17 and 18):

- Testing soils on each property prior to any action.
- Offering relocation during construction activities if testing of the hazards associated with construction at a vacant, contaminated lot in Midvale shows that relocation is advisable because of violations of the National Ambient Air Quality Standards.
- Removing contaminated household dust from residences when lead concentrations in the dust are greater than 500 ppm.
- Removing existing garden soils down to 18 inches (for soils with concentrations of lead greater than 200 ppm and arsenic greater than 70 ppm). Institutional controls will be employed to regulate the installation of new gardens.
- Removing contaminated soils that are not covered by pavement or structures that contain concentrations greater than 500 ppm lead and 70 ppm arsenic. The depth of excavation, based on data gathered during the Remedial Investigation, is not expected to exceed 24 inches.
- Replacing excavated areas with clean fill (up to the original grade).
- Revegetating the soil to initial conditions.
- Temporarily storing contaminated soils at the Mill site (Operable Unit 1), separating them from the tailings, and placing them where they will be included in the final remedy for Operable Unit 1.
- Installing a plastic liner under (and over) the excavated soil which will be stored at Operable Unit 1. This liner will prevent redispersal of the soils before remediation of Operable Unit 1.

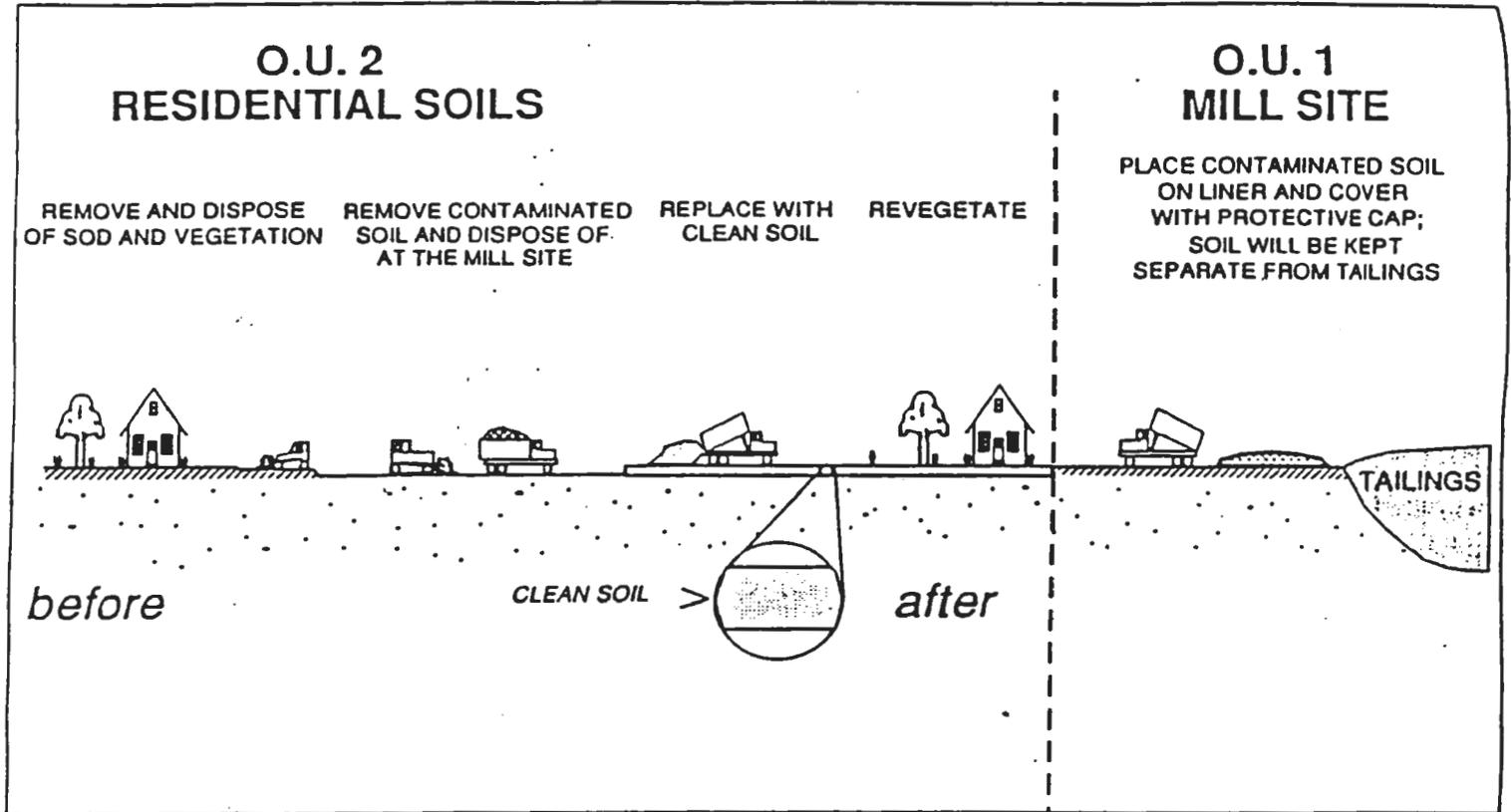


FIGURE 2. SOIL EXCAVATION AND DISPOSAL

- Implementing institutional controls to require building permits prior to construction during removal or replacement of pavements or foundations. Such activities may expose contaminated soils left in place by remediation and such activities will require special precautions. A "citizens repository" may be created to provide a place for residents to dispose of soils during future activities.

The 30-year present worth capital and O&M costs for the selected remedy are estimated to be \$22,650,000 (Reference 4, Table 7). Figure 2 is a graphical depiction of the selected remediation activities for residential soils.

CURRENT STATUS

The site was listed on the NPL on August 30, 1990 (55 Federal Register 35502). The ROD for Operable Unit 2 was signed on September 24, 1990. According to EPA Region VIII, the State of Utah is leading the Remedial Design Phase for Operable Unit 2. A final Remedial Design was expected by the end of May 1991. The Remedial Investigation/Feasibility Study and the Proposed Plan for remediation for Operable Unit 1 were released for public comment on October 5, 1990. The associated ROD is projected for completion in December 1991 (Reference 5).

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4. Declaration for Record of Decision - Sharon Steel (Operable Unit 2) Residential Soils, Midvale, Utah; EPA Region VIII and the Utah Department of Health; September 24, 1990.
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Reference 1

**Excerpts From Interim Baseline Risk Assessment
for the Sharon Steel/Midvale Tailings Site, Midvale, Utah, Draft;
EPA; April 23, 1990**

INTERIM BASELINE RISK ASSESSMENT
FOR THE
SHARON STEEL/MIDVALE TAILINGS SITE
MIDVALE, UTAH

DRAFT

April 23, 1990

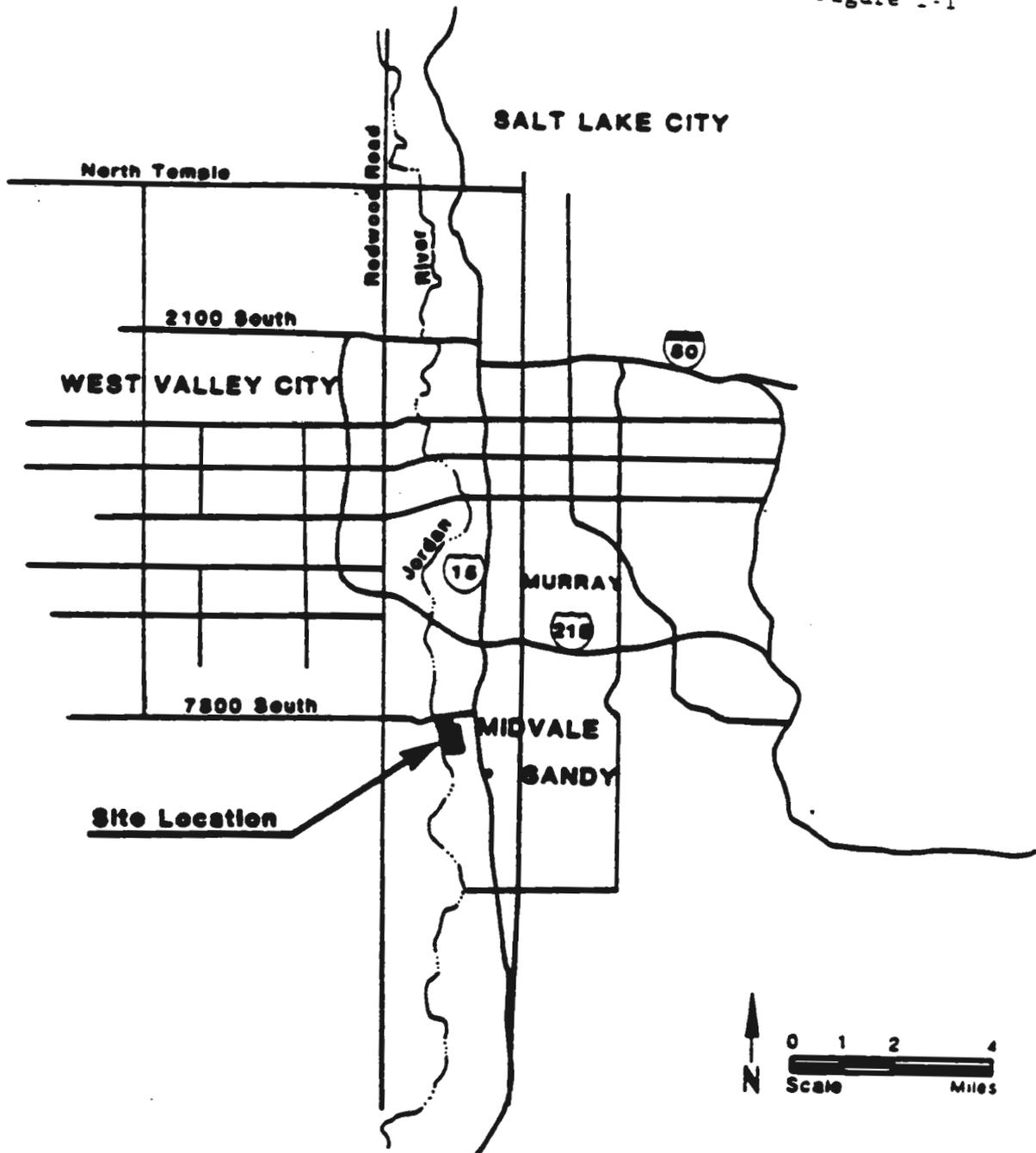
Steel/Midvale Tailings Study Area prepared by Camp Dresser & McKee (1988)
Information obtained from other sources is referenced accordingly

The Sharon Steel/Midvale Tailings study area is located in the town of Midvale, Utah, approximately 12 miles south of Salt Lake City (Figure 1-1). The study area includes the region from which samples were collected during the Remedial Investigation (RI). The mill site is defined as the tailings source area, including the tailings piles and mill buildings. It is bordered by 7800 South Street on the north, South Holden Street and Lennox Street on the northeast, South Main Street on the southeast, and the Jordan River on the west and south (Figure 1-2). The western border does extend, however, to include a smaller tailings pile on the western side of the Jordan River.

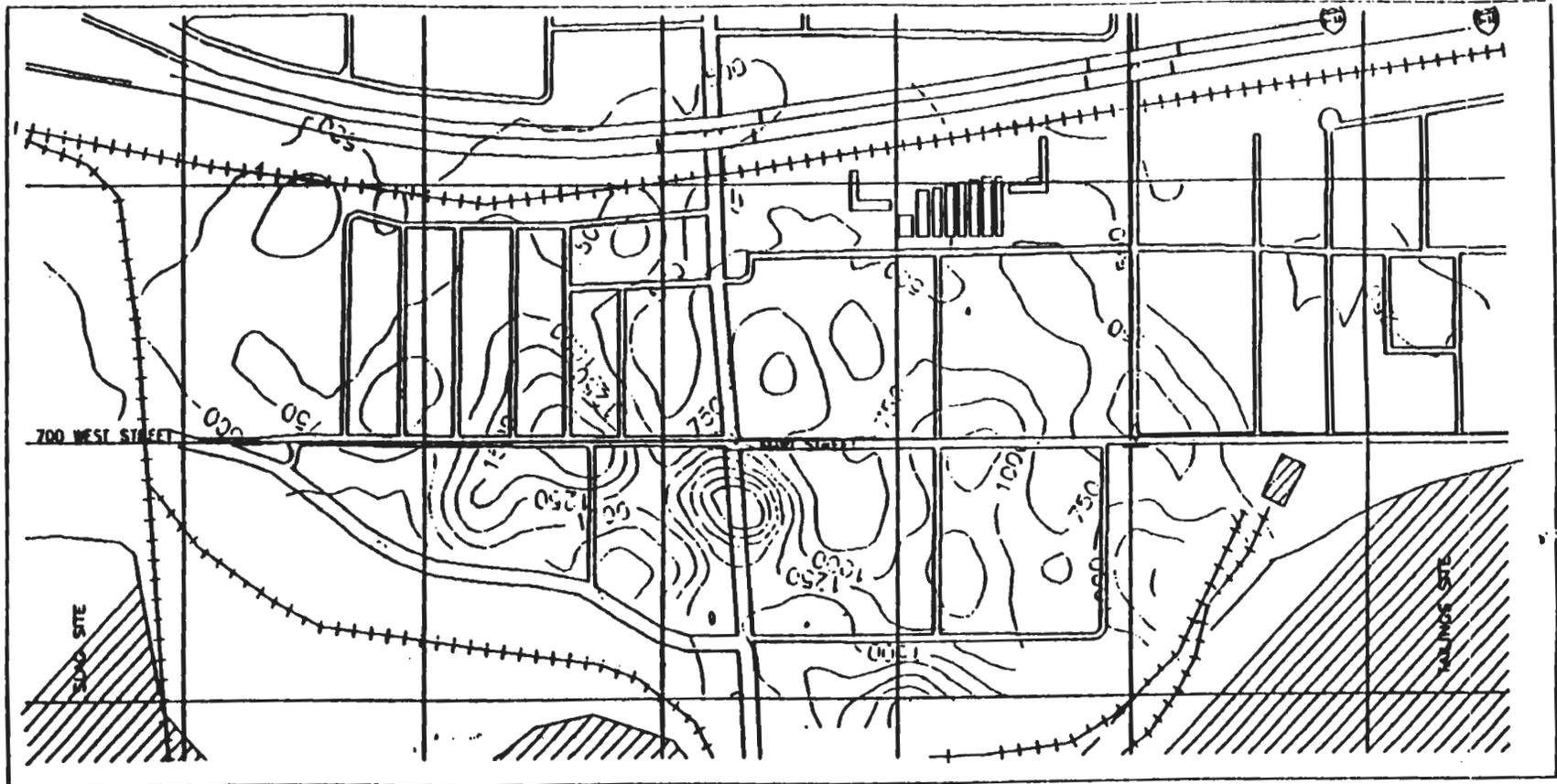
The site comprises the milling portion of a former milling and smelting operation originally owned and operated by U.S. Smelting (later U.S. Smelting, Refining and Mining Company) and is approximately 260 acres in size. The milling facility operated for a period of about 61 years (from 1910 to 1971); the smelter, located to the north of 7800 South Street, closed in 1958. The original operations involved receiving lead, copper, and zinc ores; extracting the sulfide concentrates of these metals in the milling operation; and smelting these concentrates to extract the metals in purer form. The facility also operated as a custom mill, receiving ores from many clients and concentrating and extracting a variety of metals to their specifications. The wastes from the milling operations were disposed of in unconsolidated tailings piles at the present site. The mill site includes several mill buildings and approximately 12-14 million cubic yards of tailings in uncovered piles up to 50 feet deep in places.

An environmental health problem was first suspected in June 1982 (UDOH 1982a), when the Utah State Department of Health was notified that citizens were gathering windblown tailings along the 7800 South Street right-of-way and utilizing them in sandboxes, gardens, and similar areas. The Utah Department of Health analyzed a sample of the sand, and found that it contained 4,000 mg/kg of lead. In August 1982, the State of Utah sampled the windblown

Figure 1-1



SHARON STEEL/MIDVALE TAILINGS SITE MIDVALE, UTAH	
Site Location	
Camp Dresser & McKee Inc. CDM	Chkd. by _____ Date _____



LEGEND

CONTOUR INTERVAL = 250 mg/kg

SHARON STEEL/MIDVALE TAILINGS SITE

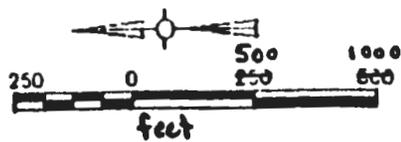
**MIDVALE SOILS
Pb 0-2 INCHES
(mg/kg)**

CAMP DREDDER & MOORE INC.

SHEET NO.

CDM

2-4



The quality of the residential soils data is discussed in detail in CDM (1990). Data quality relative to sample splits, blanks, rinseates, and performance evaluation samples appears to be excellent.

2.1.3 Surface Water and Sediments

Water samples from the Jordan River were collected both upstream and downstream of the mill site as described in the Final Draft RI (CDM 1988). In the EA, Table 2-9 summarizes the concentrations of dissolved metals at these two locations. Table 2-10 presents the results of samples taken from surface water bodies other than the Jordan River. Table 2-11 presents the results of sediment analyses for both the Jordan River and other surface water bodies.

2.1.4 Geochemistry Study

A limited geochemistry study of the soil and waste materials associated with the Sharon Steel/Midvale Tailings site was conducted by Drexler (1989). This study examined 15 samples including two tailings, one slag, one baghouse dust, nine soil, and one dross samples. Some of these samples are more associated with the adjacent Midvale Slag site. The methodology used was electron microprobe utilizing energy dispersive, wave length dispersive, and backscatter detectors. Details including quality assurance (quality control) may be found in Drexler (1989).

The results of four of these analyses are reported in Table 2-3. In general there is considerable variability in the sample results. Both the tailings and slag sites appear to have contributed to the soil lead. The results also indicate that other sources of lead (e.g., automobile exhaust or paint) are unlikely to be significant contributors to the soil lead burden. The wide variability and matrix complexity of lead associations suggests the potential for a wide variation in bioavailability and, potentially, toxicity.

4.0 EXPOSURE ASSESSMENT

This section addresses the potential pathways by which human populations could be exposed to contaminants at, or originating from, the Sharon Steel/Midvale Tailings site and study area. In identifying potential pathways of exposure, both current and likely future land-use of the site and surrounding area are considered.

Important steps in identifying exposure pathways are to characterize the site setting and consider mechanisms of migration for the selected chemicals in the environment. Accordingly, Section 4.1 presents a brief summary of information characterizing the site study area including hydrogeology, hydrology, soils and climatology. Mechanisms of migration were discussed in the EA and Section 3 of the Draft Final RI (CDM 1988), and are also briefly summarized here in Section 4.1. In Section 4.2, demographic information for the Midvale area is presented, potential exposure pathways are discussed, and those selected for detailed evaluation are identified. In Section 4.3, chemical concentrations at potential exposure points are provided and human exposure estimates for the selected pathways are presented. Section 4.4 summarizes uncertainties in the Exposure Assessment.

4.1 CHARACTERIZATION OF SITE SETTING

The following sections provide background information on hydrogeology, hydrology, soils, and climatology of the site study area. This information was also provided in the Draft Final RI. In addition, a brief summary of key mechanisms of migration at the site is provided in Section 4.1.5.

4.1.1 Site Hydrogeology

The information in this section may be revised pending receipt of the results of current groundwater monitoring studies.

The Sharon Steel/Midvale Tailings study area is located in the Jordan River Valley, which is a flat, sediment-filled valley separated by fault-block mountains typical of the Basin and Range physiographic region. The valley is bounded on the east by the Wasatch Mountains, on the west by the Oquirrh Mountains, on the north by the Great Salt Lake, and on the south by the Transverse Mountains. The valley has been filled with lacustrine sediments deposited in ancient Lake Bonneville, interlayered with coalescing alluvial fans derived from the adjoining mountains. Sediments are estimated to exceed 2,000 feet in thickness.

The groundwater system in the Jordan Valley consists primarily of a shallow unconfined aquifer overlying a deep confined aquifer. In addition, a localized shallow perched zone has been identified above the unconfined aquifer.

Regional and local studies of groundwater movement have been conducted and provide information pertinent to the site (Hely et al. 1971, Seiler and Waddell 1984, Earth Fax Engineering 1987). Section 7 of the Final Draft RI (CDM 1988) presents a detailed discussion of the site hydrogeology. Recently, however, a very extensive additional ground water investigation has occurred at the site which will allow a much more definitive description of site-specific hydrogeological conditions. Reports detailing the methods and results of this investigation and potential risks associated with ground water will be available in the Fall of September 1990. The degree and extent of interconnection between the two aquifers at the site will also be discussed in the groundwater report.

Both the deep and shallow aquifers are a source of drinking water for Salt Lake County. Municipal supply wells operated by Murray, Midvale, Sand City, and the Salt Lake Water Conservancy District are located within three miles of the Sharon Steel/Midvale Tailings study area. The direction of groundwater flow for the deep confined aquifer is believed to be westerly, toward the Jordan River.

TABLE 2-4

PARTICLE SIZE DISTRIBUTION DATA FROM TAILINGS SAMPLES^a

Sample	Percent ≥ 10 μm	Percent < 10 μm
Sample A:		
Total Mass	73.1	26.9
lead	29.0	71.0
zinc	52.4	47.6
copper	38.9	61.1
Sample B:		
Total Mass	77.6	22.4
lead	28.6	71.4
zinc	47.4	52.6
copper	31.5	68.5
Sample C:		
Total Mass	84.0	16.0
lead	42.0	58.0
zinc	57.0	43.0
copper	62.6	37.4
Sample D:		
Total Mass	82.1	17.9
lead	38.0	62.0
zinc	48.1	51.9
copper	54.7	45.3

^a Source: Montgomery (1989b).

that there were two distinct populations of soils data (CDM 1988). The population with the lower mean metal concentrations was considered to represent local background conditions (CDM 1988). The results for the metals of concern in soil for this BRA are summarized in Table 2-5. Some of the values estimated to represent local background conditions in Table 2-5 are slightly greater than the values for U.S. background soils summarized in Table 5-1 in the Final Draft RI (CDM 1988). It is likely, however, that historical mineral processing and smelting activities in the valley have contributed to a general increase in local background metal concentrations in soils. Alternatively, local background values could be representative of lithologic differences in the sediments deposited in the study area. Analysis of the over 180 soil sample results in the Final Draft RI generally indicated that the concentration separating local background soil samples from contaminated soil samples is approximately 150 mg/kg for lead (CDM 1988). For arsenic, the data indicated an upper limit of approximately 20 mg/kg for background concentrations (CDM 1988).

2.3 SUMMARY OF CHEMICALS OF CONCERN

Results of the previous EA, data quality considerations, and estimated background soil concentrations support the focus of this assessment on arsenic, cadmium, and lead as the primary chemicals of concern.

4.1.2 Site Hydrology

Portions of the Sharon Steel/Midvale Tailings mill site, including most of the tailings piles, lie in the floodplain of the Jordan River. The Jordan River flows northerly from Utah Lake to the Great Salt Lake. Historically, the Jordan River flowed through the mill site, but was relocated to the west of the site to facilitate tailings deposition. The eastern part of the site lies on a terrace above the floodplain. The tailings piles currently form an embankment on the east side of the Jordan River. The tailings lack any provisions for containment or diversion of surface water runoff or runoff.

The Jordan River, where it passes the mill site, is classified by the state of Utah for the following uses: recreation, excluding swimming (Class 2B); cold water game fish (Class 2A); and agriculture (Class 4). Ten irrigation intakes from the Jordan River lie within three miles of the site and irrigate approximately 160 acres. Use classifications upstream and downstream of the mill site differ from the classifications of the river where it passes the site. The site hydrology is discussed in more detail in Section 6 of the Draft RI Report (CDM 1988).

4.1.3 Soils

The soils in the Midvale area occur on three different land features with the soils on each feature very closely related. The soils located on each feature are markedly different from the soils on the other two features. The first feature is the floodplain which is composed of Bramwell, Chipman, and Magna soils, and mixed alluvial land and sandy alluvial land units. The floodplain is the area along the Jordan River between the North Jordan canal and Galena canal (Figure 2-2). The second feature is composed of the terraces from the Great Salt Lake/Lake Bonneville system, with Taylorsville, Hillfield, Kidman, Welby, Parleys, and Harrisville soils. The third feature is made up of artifacts of the mining industry, namely tailings dumps and man-made fill.

Residential units in Midvale are on terrace and mining industry artifacts. A complete description of the floodplain and terrace soils and the mining industry artifacts (e.g., old equipment) is presented in Section 5 of the Final Draft RI Report (CDM 1988). During the recent off-site residential soils investigation, a narrow "black layer" was identified in some of the residential soil samples. The potential origin of this layer is discussed in detail in the off-site soils report (CDM 1990).

4.1.4 Climatology

The site vicinity is generally classified as mid-latitude semi-arid, indicating an area of high summer temperatures, cold winters, and sparse rainfall. Mean maximum temperatures for the years 1951-1980 range from 42 degrees Fahrenheit (°F) in January to 93°F in July; mean minimum temperatures are 22°F in January and 66°F in July. The mean number of days with air temperatures at or lower than freezing is approximately 65 days/year (NOAA 1988).

The mean annual precipitation for the years 1951-1980 in the vicinity is 22.5 inches per year, with highest precipitation in April (3.0 inches) and lowest precipitation in July (0.7 inches).

The climate along the Wasatch Front is strongly influenced by elevation and topography. Wind flows, in particular, are influenced by surrounding terrain. Site-specific meteorological data collected during the RI showed that the predominant wind directions were from the south (39 percent) and south-southeast (11 percent).

4.1.5 Summary of Mechanisms of Migration

As described in the EA, a number of inorganic contaminants are present at elevated concentrations in the soils and mill tailings, air, ground water, and surface water or sediments at the Sharon Steel/Midvale Tailings study area.

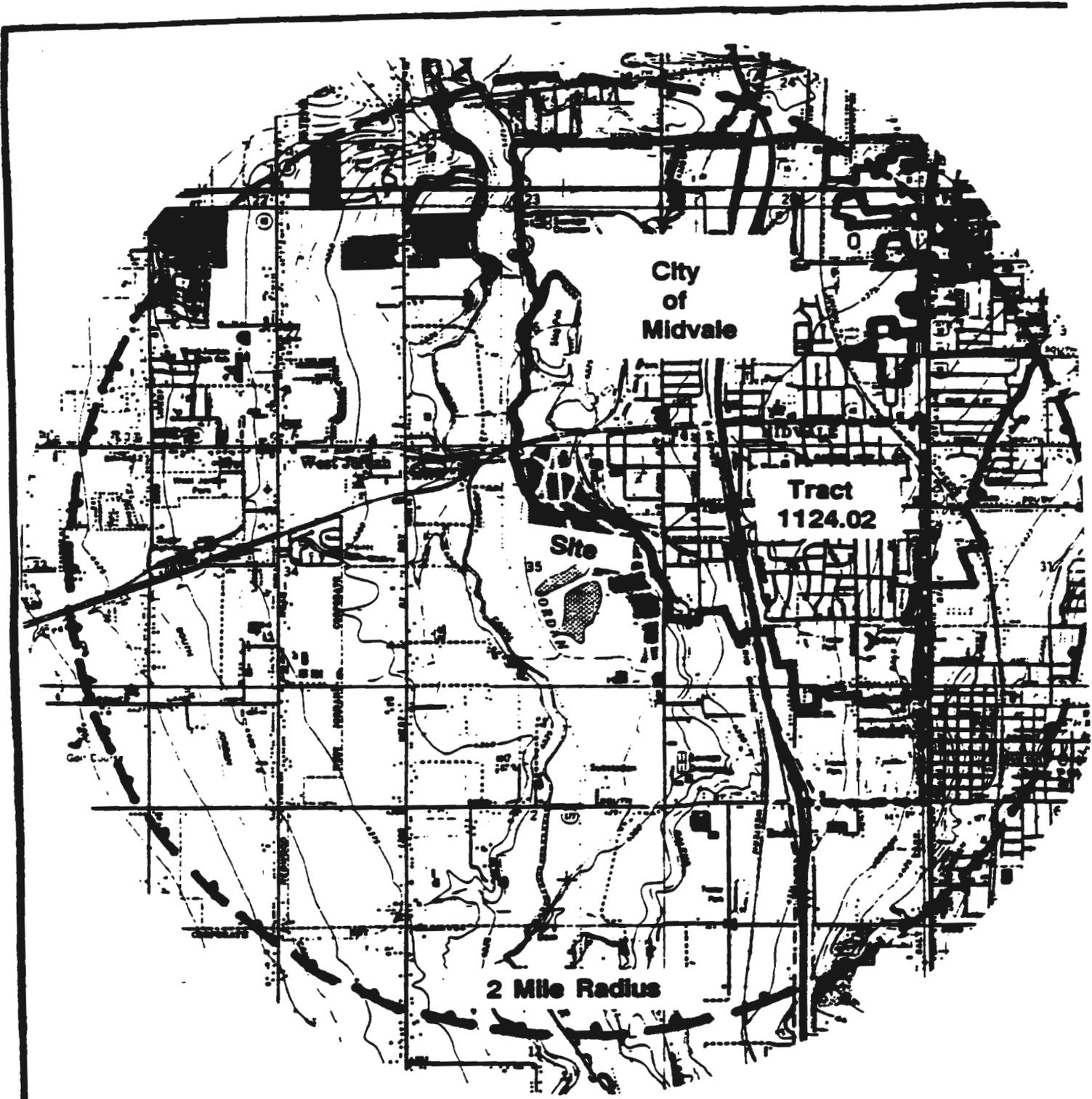
4.2.1 Site Demographics

The City of Midvale is located adjacent to the mill site and to the east. Producing agricultural lands are located across the Jordan River to the west of the mill site. Occupied residential and commercial areas lie immediately adjacent to the mill site on the east.

For the purposes of this project, demographic statistics were obtained for three areas surrounding the site (CACI 1990): within 2 miles, for the City of Midvale, and for Census Tract 1124.02 (see Figure 4-1 for delineation of these areas). The results of the survey are provided in Tables 4-1 through 4-3. As can be seen from these tables, the 1990 estimated population for the three areas is 43,911, 12,085, and 6,716, respectively. The average per capita income for the three areas is reported to be \$9,849, \$10,151, and \$10,730, respectively. The national average per capita income in the U.S. is \$12,121 (1989 estimate) (CACI 1990). The age distributions indicate that from 36-39% of these populations are from 0-16 years of age, 48-49% are from 17-54 years, and from 11-16% are over 54 years. Individuals who are members of low socioeconomic groups (i.e., below average per capita income) are more likely to be subject to nutritional deficiencies and have less access to health care delivery systems. The large proportion of children in the population indicates that a high degree of exposure associated with childhood behavior patterns such as mouthing of objects may also be experienced by the Midvale population. Taken together, the low income and large proportion of children constitute a sensitive subgroup which should be considered in setting remedial goals at the site.

4.2.2 Potential Exposure Pathways Under Current Use Conditions

Sampling data generated during the RI (CDM 1988) and subsequent efforts (CDM 1990) suggest that there is a potential for exposures to occur through contact with contaminated soil, air, groundwater and surface water under current use conditions of the mill site and surrounding area. The primary receptors of



SCALE:

1 MILE

-  = City of Midvale Boundary
-  = Census Tract Boundary
-  = 2 Mile Radius Boundary

FIGURE 4-1

Demographic Areas Examined
for the Shar Site

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Environmental and Health Sciences

5.0 RISK CHARACTERIZATION

This section presents quantitative risk estimates for the exposure pathways and chemicals examined in this assessment. To calculate risks, the chronic daily intakes estimated for each chemical of potential concern were combined with health effects criteria (RfDs and cancer slope factors). In the case of lead, the blood lead levels estimated in Section 4 were compared to blood lead levels considered to be of concern to human health. In Section 5.1 below, risks associated with current land and site use conditions are presented for arsenic and cadmium. In Section 5.2, risks associated with future site and land use conditions are presented, also for arsenic and cadmium. Section 5.3 presents an evaluation of the potential for adverse effects from lead exposure, both under current and future land use conditions. In addition, Section 5.4 presents a review of recent risk characterization efforts at similar sites. Section 5.5 discusses uncertainties affecting the risk characterization. Section 5.6 summarizes the risk characterization for the Sharon Steel/Midvale Tailings site.

To evaluate risks associated with exposure to carcinogens (e.g., arsenic), the excess lifetime cancer risk was calculated by multiplying the CDI by the slope factor as follows:

$$\text{Excess lifetime cancer risk} = \text{CDI} \times \text{CSF}$$

where

- CDI - chronic daily intake of chemical (mg/kg/day), and
- CSF - cancer slope factor for chemical (mg/kg/day)⁻¹.

Potential risks for noncarcinogens with the exception of lead are presented as the ratio of the CDI to the reference dose (CDI:RfD). Ratios that are greater than one can indicate the potential for adverse effects to occur, ratios less than one indicate that adverse effects are unlikely to occur.

In accordance with USEPA's guidelines for evaluating the potential toxicity of complex mixtures (USEPA 1986b), the excess lifetime cancer risks and CDI:RfD

ratios are each summed. The sum of the CDI:RfD ratios is referred to as the hazard index. Values greater than one indicate that adverse effects could occur. In this assessment, however, the CDI:RfD ratios for arsenic and cadmium were not combined because these two chemicals affect different target organs (see Table 3-2). Specifically, arsenic exposure may result in hyperpigmentation and keratosis of the skin, as well as in adverse effects to the central nervous system. Cadmium exposure can result in adverse effects to the kidney, hypertension and immunosuppression. The CDI:RfD ratios were added across exposure pathways for each of these chemicals separately.

5.1 POTENTIAL RISKS UNDER CURRENT LAND USE CONDITIONS

Table 5-1 presents the results of the quantitative risk assessment for the exposure pathways evaluated under current use conditions. For all pathways except inhalation, arsenic is the only carcinogenic chemical evaluated. For the inhalation pathway, both arsenic and cadmium are carcinogenic. The excess upperbound lifetime cancer risks for all exposure pathways combined is 5×10^{-4} , primarily due to exposure to arsenic from ingestion of tailings in sandboxes and ingestion of indoor dust. It should be noted that public information efforts by the State of Utah and USEPA have generally eliminated the route of exposure involving tailings ingestion from sandboxes.¹

Table 5-2 summarizes the CDI:RfD ratios for the same exposure pathways (except inhalation for which both arsenic and cadmium are carcinogenic). Also shown is the overall hazard index for arsenic and cadmium (treated separately) across exposure pathways. As shown in this table, the hazard index for arsenic exceeds one, primarily due to exposure via tailings ingestion and indoor dust ingestion. For cadmium, the hazard index also exceeds one, due predominantly to exposure via indoor dust ingestion and soil ingestion.

¹ Symonik, D. Utah Department of Health. Personal communication. April 10, 1990.

TABLE 5-4
 POTENTIAL FOR ADVERSE NONCARCINOGENIC EFFECTS AT THE
 SHARON STEEL/MIDVALE TAILINGS SITE
 FUTURE SITE USE

Exposure Pathway/ Chemical	Chronic Daily Intake (mg/kg/day)	Reference Dose (mg/kg/day) [Uncertainty Factor] (a)	CDI:RfD Ratio
Tailings Ingestion			
Arsenic	1.12E-05	1.00E-03 [1]	1E-02
Cadmium	1.82E-06	1.00E-03 [10]	2E-03
Dust Ingestion			
Arsenic	3.22E-03	1.00E-03 [1]	3E+00
Cadmium	2.50E-03	1.00E-03 [10]	2E+00
Produce Ingestion			
Arsenic	5.45E-04	1.00E-03 [1]	5E-01
Cadmium	1.68E-03	1.00E-03 [10]	2E+00
Total Hazard Index			
Arsenic	---	---	4E+00
Cadmium	---	---	4E+00

(a) Uncertainty factors used to develop reference doses generally consist of multiples of ten (10), with each factor representing a specific area of uncertainty in the available data. Standard uncertainty factors include a factor of 10 to account for variation in sensitivity among members of the human population. Modifying factors may also be applied at the discretion of the reviewer to cover other uncertainties in the data.

Table 4-18 summarizes the calculated blood lead levels under both current and future use conditions for two combinations of exposure pathways, all of them combined and all except sandbox tailings ingestion and homegrown produce ingestion combined. As shown in this table, blood lead levels exceed 30 ug/dL, the highest value that can be reliably predicted using USEPA's model (i e., the relationship between lead intake and blood lead levels is nonlinear at blood lead levels above 30 ug/dl). Under current use conditions, this was the case for children assumed to ingest tailings in sandboxes and homegrown produce as well as not, except in the <500 mg/kg residential soil lead concentration band for a child assumed not to ingest sandbox tailings or homegrown produce (for which a blood lead level of 24 ug/dL was predicted). Table 5-5 summarizes the input parameters used to calculate lead intakes and ultimately blood lead levels.

Based on the estimated blood lead levels, adverse effects from exposure to lead could potentially occur to young children under both current and future use conditions at the Sharon Steel site. These effects in children could vary from blood disorders through cognitive dysfunction and reduced growth. Although blood lead levels in adults were not specifically calculated, it is also possible that exposures via the same pathways could potentially result in adverse effects; in adults these effects may be manifested as hypertension.

5.4 RISK CHARACTERIZATION EFFORTS AT SIMILAR SITES

To put the results of this assessment, specifically with respect to lead, into better perspective, information available from studies conducted at other mining/smelting site in the western United States can be useful. There are several studies that have been conducted in an attempt to relate blood lead and environmental lead levels. A review of all of these is beyond the scope of this single report, however, a few are discussed here to provide some information on the types of approaches that have been used and results observed. Studies at the Midvale site (Boernschein et al. 1989), the Helena site in Montana (MDHES 1986), the Bunker Hill site in Idaho (USEPA 1988c), and

6.3 EXPOSURE ASSESSMENT

Potential pathways by which humans could be exposed to arsenic, cadmium, and lead at or originating from the site under current or future use conditions were identified and selected for evaluation. The exposure assessment was performed in accordance with concepts on exposure advanced in the NCP (USEPA 1990a). The exposure pathways selected for evaluation in the BRA were as follows:

Current Use Conditions

- direct contact with and incidental ingestion of site tailings in sandboxes by children;
- direct contact with and incidental ingestion of residential area soils by an individual assumed to be exposed both as a child and subsequently as an adult (e.g., a gardener);
- inhalation of windblown particulates from the site by nearby residents; and
- ingestion of home-grown produce by nearby residents.

Future Use Conditions

- direct contact and incidental ingestion of site soils by an on-site resident assumed to be exposed both as a child and an adult;
- inhalation of windblown particulates from the site by an on-site resident; and
- ingestion of home-grown produce by an on-site resident.

To evaluate exposures for each pathway, concentrations to which individuals might be exposed were calculated based directly on site-specific sampling data or were predicted using environmental models. For the inhalation pathway, emission and dispersion models were used to estimate air concentrations. For the homegrown produce ingestion pathway, particle deposition and plant uptake models were used to predict concentrations in vegetables. The approach used to estimate these concentrations (and to calculate potential human exposures) followed recent USEPA guidance for Superfund site risk assessments, in which USEPA states that the baseline risk assessment should evaluate "reasonable maximum exposures" (RME) expected to occur under both current and future land use conditions. USEPA notes that "the intent of the RME is to estimate a

Reference 2

**Excerpts From Superfund Program Proposed Plan,
Sharon Steel/Midvale Tailings Site, Midvale, Utah;
EPA Region VIII; July 1989**

Superfund Program Proposed Plan

U.S. EPA Region VIII

Sharon Steel/Midvale Tailings Site

Midvale, Utah

July 1989

EPA ANNOUNCES PROPOSED PLAN

This Proposed Plan identifies the preferred option to remedy the threat posed by contaminated tailings, soil, and ground water at the Sharon Steel/Midvale Tailings Superfund site. This Plan also includes summaries of the other alternatives that were analyzed for this site. This document is issued by the U.S. Environmental Protection Agency (EPA), the lead agency for site activities. EPA will select a final remedy for the site "only after" the public comment period has ended and the information submitted during this time has been reviewed.

The EPA is using this Proposed Plan as part of its public participation responsibilities under sections 104 and 117(a) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). This document summarizes information which can be found in greater detail in the Remedial Investigation and Feasibility Study (RI/FS) reports and other documents contained in the administrative record file for this site. The EPA encourages the public to review these other documents for a more comprehensive understanding of the site and Superfund activities that have been conducted there. The administrative record file, which contains the information upon which the selection of the response action will be based, is available at the following locations:

Ruth Vine Tyler Library
315 Wood Street
Midvale, Utah
Hours: Mon - Thurs, 9:00am - 9:00pm
Fri - Sat, 9:00am - 5:30pm

and

U. S. EPA Library
EPA - Region VIII
999 18th Street, Suite 500
Denver, Colorado 80202
1-(800) 759-4372, ext. 1444
Hours: Mon - Fri, 8:00am - 4:30pm

The EPA may modify the preferred alternative, select another response action presented in this Plan and the RI/FS Report, or select a more appropriate alternative based on new information or public comments. Therefore, the public is encouraged to review and comment on all the alternatives identified here, as well as to provide any information not previously identified. More detailed information on all the alternatives can be found in the FS Report.

MARK YOUR CALENDAR

July 14 - August 21, 1989:

Public comment period on remedies to control contaminated soil and tailings at the Sharon Steel/Midvale Tailings Superfund site.

August 17, 1989:

Public meeting at the Midvale Bowery, Midvale City Park, 327 East 6th Avenue, Midvale, Utah at 7:00 pm.

September 30, 1989:

Record of Decision, which selects final remedial alternative for the Mill site.

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SITE BACKGROUND

The Sharon Steel/Midvale Tailings site is located in Midvale, Utah, approximately 12 miles south of Salt Lake City and west of Interstate 15. The 260-acre mill site was used by an ore refining company from 1905 to 1971. Generally, the mill site is bordered by 7800 South Street on the north, by Main Street on the east and the Jordan River on the west and south (see Figure 1, site location map).

Eight buildings are located on the mill site including three small offices, a bunkhouse, a machine storage shed, and three mill buildings. A 22-acre wetland and several small ponds are also located on the mill site. During milling activities at the site, metals such as lead, copper, and zinc were removed from crushed ore. Tailings remaining after metals had been extracted from the ore were deposited on the site. EPA estimates that 14 million cubic yards of tailings currently remain on the site.

An environmental health problem was first suspected in 1982 when the Utah State Department of Health learned that citizens were using windblown tailings from 7800 South Street in sandboxes and gardens. The State analyzed a sample of the "sand" and found that it contained unsafe levels of lead. Samples from the windblown tailings from locations along 7800 South Street showed elevated concentrations of arsenic, cadmium, chromium, copper, lead, and zinc.

Several sampling efforts revealed that contaminated soil, air and ground water were present. EPA proposed the mill site for listing on its National Priorities List (NPL) in 1984. The NPL is a nationwide list of sites that are eligible for investigation and cleanup under the Superfund program.

EPA's Remedial Investigation at the mill site began in July 1987 and continued through June 1988. The study was designed to:

- Identify the nature and extent of contamination related to the site;
- Determine whether current or future contamination from the site may threaten human health or the environment; and

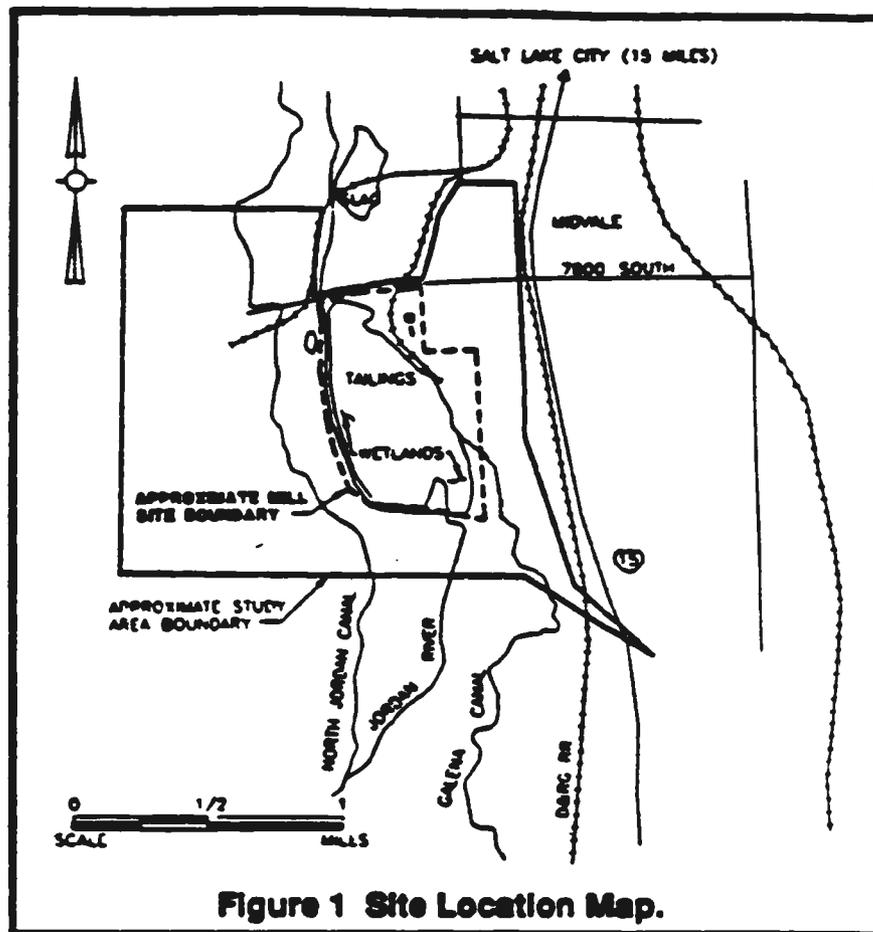


Figure 1 Site Location Map.

- Gather information needed to develop remedial options.

To determine if the site caused a contamination problem, EPA reviewed previous studies conducted near the mill site. EPA also collected samples from the tailings piles, soil, ground water, surface water, sediments, and air in the study area. An Endangerment Assessment (EA) was prepared by EPA to determine risks to human health and the environment resulting from exposure to site contamination.

The EA revealed that lead and arsenic contained in on-site tailings or windblown tailings dust may threaten human health if the tailings themselves or tailings dust are ingested. EPA also concluded that humans may be exposed to contaminants by eating vegetables grown directly on the tailings or in contaminated soil. The greatest risk lies in swallowing tailings and eating leafy and root crops grown in soils contaminated with the tailings. Children are especially at risk because during play it is possible for them to come into contact with dirt that may be contaminated.

Reference 3

**Excerpts From Final Feasibility Study Report
for the Mill Site Operable Unit 1 of the Sharon Steel/Midvale Tailings Site,
Midvale, Utah, and Appendices; Camp, Dresser & McKee;
July 14, 1989**

**FINAL
FEASIBILITY STUDY REPORT
FOR THE
MILL SITE OPERABLE UNIT #1
OF THE
SHARON STEEL/MIDVALE TAILINGS SITE
MIDVALE, UTAH**

JULY 14, 1989

**EPA Contract No.: 003-8140
Document Control No.: 7760-003-FS-BCBY**

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U.S. Environmental Protection Agency
999 18th Street
Denver, Colorado 80202**

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Denver, Colorado 80202**

1.0 INTRODUCTION

In July 1987, EPA initiated the Remedial Investigation/Feasibility Study (RI/FS) for the Sharon Steel/Midvale Tailings site. A Final Draft of the RI report completed in June 1988 (CDM 1988b) determined that past milling operations on the site generated approximately 14 million cubic yards of tailings which have contaminated local soils and ground water.

To ensure that remediation proceeds in a timely manner, EPA has divided the site into two operable units. An operable unit is a discrete portion of an entire site, which is addressed separately from other units. Operable Unit One is the mill site which is the primary source of contamination. Operable Unit Two is adjacent to the mill site and includes residential areas and other areas frequently used by the public which have been contaminated by tailings. This FS addresses only Operable Unit One, the mill site. The focus is on remediating the source of contamination. The FS for Operable Unit Two will be completed following signing of the Record of Decision (ROD) on Operable Unit One; the ROD is now scheduled for fall 1989.

This section includes a brief discussion of the purpose of the RI/FS (Section 1.1), a summary of activities completed during the RI (Section 1.2), a site description including the history of the site (Section 1.3), a summary of the nature and extent of contamination (Section 1.4) and an outline of the FS process (Section 1.5).

1.1 PURPOSE

EPA conducted the Sharon Steel/Midvale Tailings RI to determine the nature and general extent of the release of hazardous substances; the extent to which the release or threat of release may pose a threat to human health and the environment; the extent to which sources can be adequately identified; and to gather sufficient information to determine the necessity for remedial action.

The Endangerment Assessment (EA), completed as part of the RI, determined that under current land use conditions, carcinogenic and toxic (non-carcinogenic) risks exist for children and adults in the residential areas adjacent to the mill site as a result of exposure to arsenic (10^{-3} - 10^{-5} carcinogenic risk) and lead. Action levels appropriate for future land use scenarios at the mill site, including residential development and light industrial use, are developed in this FS. Potential risks to environmental receptors are discussed qualitatively in the EA. The risks include phytotoxicity and adverse effects to wildlife. These findings are discussed in more detail in Section 1.4. Arsenic and lead are the primary contaminants addressed in the FS.

The FS evaluates remedial action alternatives based on the data in the RI report and on supplemental investigations subsequent to the RI. A summary of RI activities is presented in Section 1.2 and the supplemental investigations are described in Section 1.3.2. The purpose of the FS for the Sharon Steel/Midvale Tailings site is to develop a list of alternatives (1) that are protective of human health and the environment, (2) that attain Federal and State requirements that are applicable or relevant and appropriate (ARARs), (3) that are cost-effective, (4) that utilize permanent solutions and alternative treatment technologies or resource recovery technologies, to the maximum extent practicable, and (5) that satisfy consideration of the preference for remedies with treatment.

The FS has been prepared in accordance with the provisions of the Superfund Amendments and Reauthorization Act of 1986 (SARA), CERCLA (42 U.S.C. 9601, et seq.) and the National Contingency Plan (NCP) (November 20, 1985), and the proposed NCP (December 21, 1988). The following EPA documents have also been followed: Guidance on Feasibility Studies Under CERCLA (EPA 1985) and Guidance for Remedial Investigations and Feasibility Studies Under CERCLA (October 1988).

Based on the evaluation of the alternatives identified in the FS, EPA has developed a Proposed Plan for remediating the mill site. The public is encouraged to review the FS and the Proposed Plan and to submit comments to EPA. A glossary of terms has been included as Appendix A to assist the reader in interpreting these documents. Based on the FS and the comments received by the public, EPA will develop a Final Plan for inclusion in the Record of Decision (ROD).

1.2 SUMMARY OF RI ACTIVITIES

Field investigations were performed from July 1987 through December 1987 and included the following activities:

- o Site surveying and mapping
- o Installation of nine monitoring wells on the mill site
- o Soil, tailings, and mill building sampling on the mill site
- o Soil sampling in residential and agricultural areas adjacent to the mill site
- o Surface water flow measurements
- o Surface water and sediment sampling
- o Ground water level monitoring
- o Ground water sampling
- o Air monitoring for three months at four air quality stations and for six months at two meteorological stations

The field activities were conducted utilizing the most recent EPA RI guidance which required the preparation of the following documents:

Final Work Plan for RI/FS, Sharon Steel/Midvale Tailings Site, Midvale, Utah (CDM 1987a).

Final Health and Safety Plan, Sharon Steel/Midvale Tailings RI/FS, Midvale, Utah (CDM 1987b).

Final Sampling and Analysis Plan, Sharon Steel/Midvale Tailings RI/FS (CDM 1987c).

Final Quality Assurance Project Plan, Sharon Steel/Midvale Tailings RI/FS (CDM 1987d).

Final Community Relations Plan, Sharon Steel/Midvale Tailings Site, Midvale, Utah (CDM 1988a).

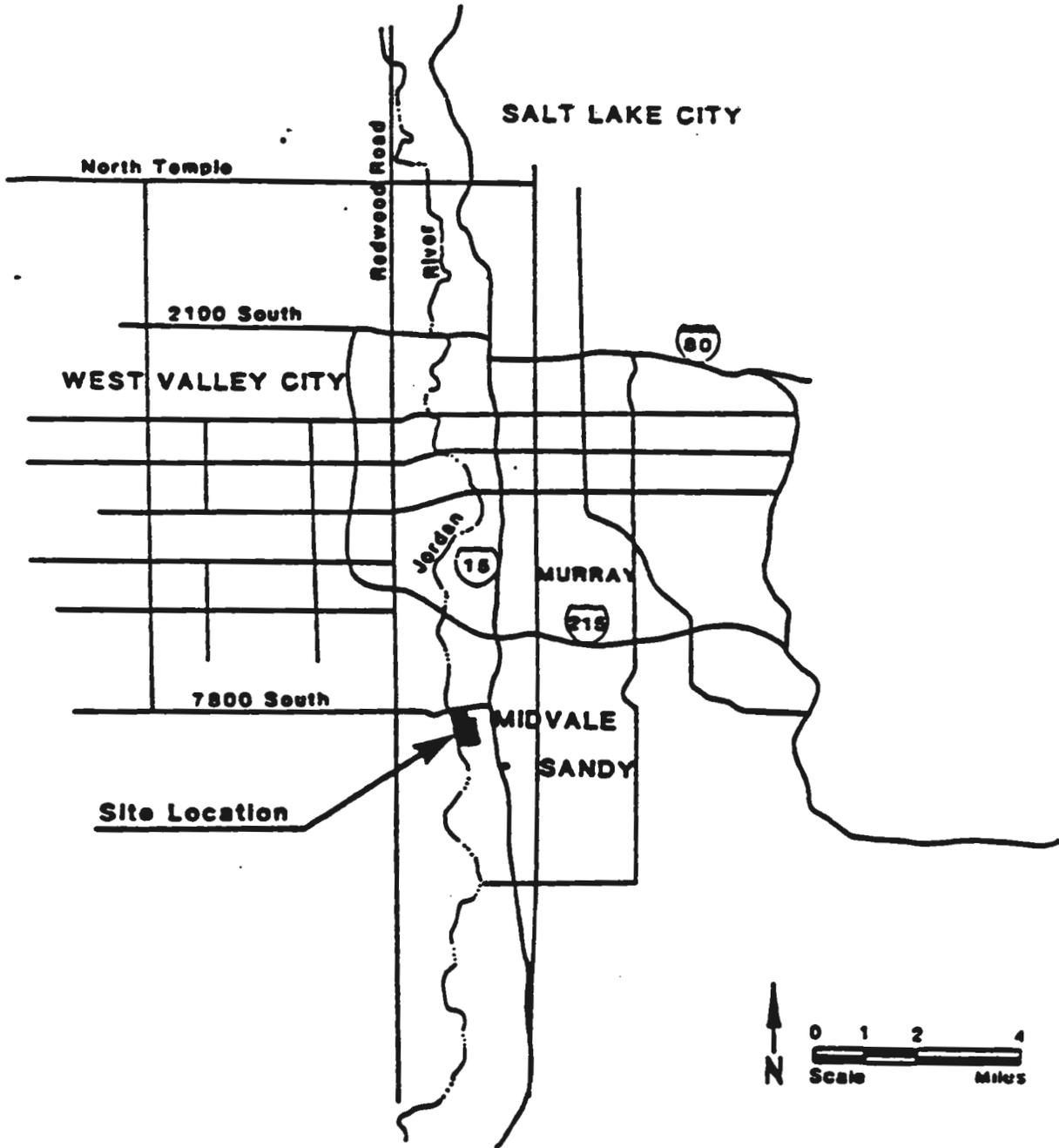
The data obtained during the field activities were compiled and summarized in the "Final Draft Remedial Investigation Report, Sharon Steel/Midvale Tailings Site, Midvale, Utah" (CDM, 1988b), which is used as the basis for conducting the PSs for both operable units.

In total, 531 samples were collected from the Sharon Steel/Midvale Tailings study area and analyzed by the Contract Laboratory Program (CLP). These samples included 15 surface water samples, 19 ground water samples, 97 tailings samples (44 surficial, 53 subsurface) from the mill site, 12 stream sediment samples, and 229 air samples. The results are of varying data quality in terms of Quality Assurance/Quality Control, and also address Operable Unit 2, off-site residential areas. In addition, field observations/measurements and screening analyses of 182 soil samples were performed. These included 34 soil samples from the mill site and 125 soil samples from residential and agricultural areas adjacent to the mill site. All sampling and analytical work was conducted using methods approved by EPA Region VIII.

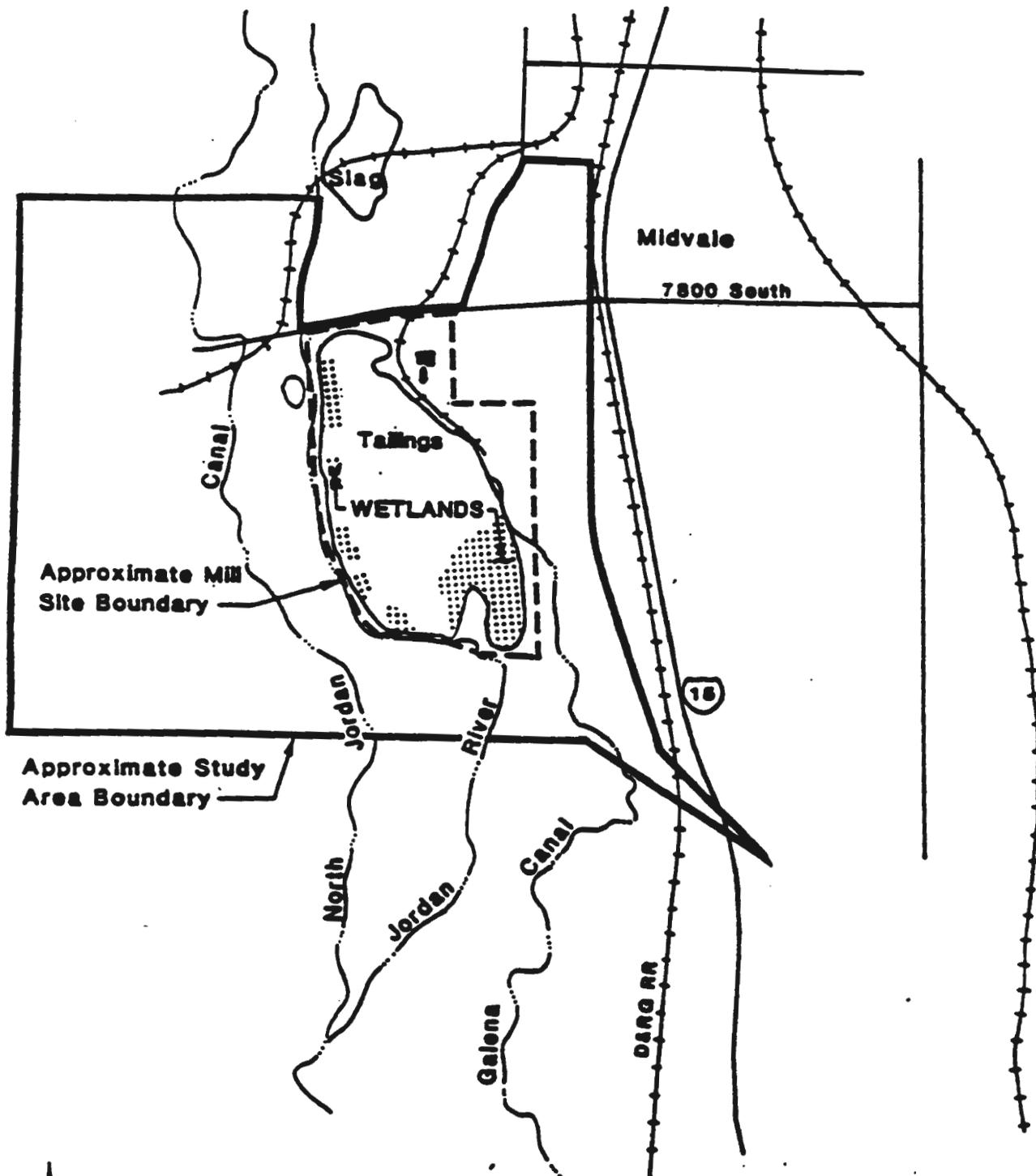
1.3 SITE DESCRIPTION

1.3.1 SITE LOCATION AND DESCRIPTION

The Sharon Steel/Midvale Tailings site is located in Midvale, Utah, approximately 12 miles south of Salt Lake City (Figure 1-1) and west of Interstate 15. The approximate study area is depicted on Figure 1-2 and includes the tailings, agricultural land to the west and south, the southwest portion of the Midvale community, and wetlands located to the south and east. The mill site area, which includes the tailings, mill



SHARON STEEL/MIDVALE TAILINGS SITE MIDVALE, UTAH		
Site Location		
Camp Dresser & McKee Inc. CDM	Chkd. by: PAB Date: 5/11/88	Figure No. 1-1



**SHARON STEEL/MIDVALE TAILINGS SITE
MIDVALE, UTAH**

Mill Site & Study Area

Camp Dresser & McKee Inc.
CDM

Chkd. by: PAB
Date: 5/11/88

Figure No.
1-2

buildings, and the wetlands, is located south of 7800 South Street, east of the Jordan River, and west of Main Street. The mill site boundary, as shown in Figure 1-2, was used as the site boundary when the site was nominated for placement on the NPL. Based on an estimated extent of contamination, RI investigations were conducted within the study area shown in Figure 1-2. Figure 1-3 illustrates the locations of ground water, surface water, and sediment sampling on the mill site.

To provide for timely selection of a remedy on at least one portion of the site, the study area was divided into two operable units, as noted previously. The mill site area comprises the original site boundary and is Operable Unit One (OU1). Operable Unit Two (OU2), hereafter referred to as off-mill site, encompasses the residential and high public use areas adjacent to the mill site. Its boundaries are subject to revision based on additional sampling which will be conducted as part of the FS for OU2. As illustrated in Figure 1-2, the entire study area covers approximately 830 acres, of which 260 acres comprise the mill site. Approximately 200 acres comprise the residential and high public use areas adjacent to the mill site. The remaining 370 acres comprise agricultural lands to the west, and light industrial and commercial lands to the south and east.

The site can be divided into two operable units, because the location and use of each pose varying risks to human health and the environment. OU1 has been defined as a "source area" and public access is restricted by a fence, security personnel, and locked gates; whereas OU2 has been defined as an "impacted area", and includes the community and other areas frequently used by the public.

1.3.2 SITE HISTORY

The Sharon Steel/Midvale Tailings mill site includes the milling portion of a former milling and smelting operation originally owned and operated by the U.S. Smelting, Refining and Mining Company (USSRM), later known as UV Industries, Inc. The operations were in effect from 1910 to 1971. The

smelter, which is located north of 7800 South Street, closed in 1958; the milling operation closed in 1971. Sharon Steel subsequently acquired the mill and tailings site in 1979. The smelter is located on the Midvale Slag Superfund site, and, therefore, was not investigated during the Sharon Steel/Midvale Tailings RI/FS (see Section 1.4.3 for detailed discussion). In the milling operation, sulfide concentrates of lead, copper, zinc, and other metals were extracted from ore. The facility operated as a custom mill, receiving ores from many sources for concentrating and extracting a variety of metals.

An environmental health problem was first suspected in June 1982, when the Utah State Department of Health was notified that one or more citizens had gathered windblown sand and tailings along 7800 South Street and was utilizing the material for sandboxes and gardens. The State Department of Health analyzed a sample of the "sand" (obtained from the citizen who had removed it near the site) and found that it contained 4,000 ppm of lead (UDE 1982a). In August 1982, the State sampled windblown tailings from nine locations along 7800 South Street (UDE 1982b). The analyses showed elevated concentrations of arsenic, cadmium, chromium, copper, lead, and zinc in the windblown tailings.

In 1982, Sharon Steel Corporation erected a fence along the northern boundary of its property. However, tailings have been blown by the wind through and over the fence and down the embankment of the highway right-of-way. In September 1982, the State Bureau of Air Quality requested that Sharon Steel Corporation submit a compliance plan for the control of fugitive dust from their tailings piles. Sharon Steel Corporation responded to this request in October 1982 with a proposal to use water flooding to suppress the dust. The State initially approved but subsequently withdrew approval of Sharon Steel's dust control plan and issued another order to Sharon Steel to suppress the dust. Subsequently, Sharon Steel implemented a dust mitigation program in May and June of 1988 using a chemical polymer dust suppressant (see Section 1.3.2.2).

In March 1983, the State of Utah and EPA completed a hazardous waste site preliminary assessment and site investigation of the Sharon Steel tailings. The results indicated that elevated concentrations of metals were present in the soil, air, and ground water (EPA 1984).

In 1983, the U.S. Geological Survey (USGS 1983) drilled wells at the northwest corner of the site, where 7800 South Street crosses the Jordan River. Samples from one of these wells contained concentrations of lead that exceed the Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs) standard for lead in drinking water.

In early 1984, EPA's Field Investigation Team (FIT) completed a documentation record and site assessment for the Sharon Steel/Midvale Tailings mill site (EPA 1984). This assessment documented elevated concentrations of arsenic, cadmium, lead, chromium, and iron in releases from the mill site to the air and, possibly, ground water. Releases to surface water and direct human contact with these contaminants were also considered possible. A score of 73.49 was assigned to the mill site. On October 15, 1984, EPA proposed the mill site for listing on the NPL under CERCLA. The current status of the mill site is "in rulemaking."

Studies completed in 1985 included a reprocessing study conducted for the State of Utah (Professional Mining Systems 1985) and a site investigation conducted by potentially responsible party (PRP) Sharon Steel (Montgomery Engineers 1985). Approximately 11 million tons of unconsolidated tailings from the milling operations were reported to be located at the mill site in uncovered piles from 10 up to 40-50 feet deep. Arsenic, cadmium, lead, chromium, copper, and zinc were identified in elevated concentrations in analyses of tailings samples (Montgomery Engineers 1985, Professional Mining Systems 1985).

After the site was proposed for listing on the NPL, the Utah Bureau of Solid and Hazardous Waste was given funding by EPA to conduct an RI/PS at the site. The State entered into a contract with Camp Dresser and McKee

Inc. (CDM) in December 1985 to provide support to the State in conducting these studies. Under the State RI/FS, CDM was to undertake field sampling and analysis of mill tailings, soils, surface water, air quality, and building samples in the site vicinity. Due to hazardous waste insurance and liability problems, CDM could not conduct the ground water portion of the RI/FS under the State's contract. In June 1986, to facilitate progress at the site, the State asked EPA to assume responsibility for the ground water portion of the RI/FS.

During 1986, EPA continued to negotiate with PRPs, including Sharon Steel. In February 1987, EPA decided to assume responsibility for the RI/FS in order to expedite the RI/FS investigation. EPA then tasked CDM to expand their ground water activities to include the full RI/FS for the site. The CDM team began a phased RI/FS in June 1987. The Phase I sampling plan was designed as a screening phase to determine the general extent of contamination. Any Phase I data that indicated contaminant migration into ground water or onto vicinity properties would then be used to design a Phase II sampling program that would allow site boundaries to be defined.

Phase I field studies for the RI were completed in December of 1987. A final draft of the RI was completed in June 1988. Preliminary work on the FS occurred between March 1988 and August 1988. During this time, the need for additional data resulted in further field investigations (similar to the previously planned Phase II studies) of tailings, reprocessing, and ground water. These investigations delayed the FS until the additional data could be collected. Results of a metals speciation study and an additional reprocessing study were available in March and May of 1989, respectively. Results from an additional ground water investigation were available in May 1989. It is estimated that results from an additional residential soil investigation will be available following the signing of the ROD for OUI in September 1989; these will provide data needed for the OUI FS to estimate the volume of residential property soils in need of remediation.

In addition, EPA's Emergency Response Team (ERT), in cooperation with Sharon Steel working pursuant to a consent order with EPA, completed interim activities including fencing, dust prevention, and slope stabilization of tailings piles during 1988 and the early part of 1989. Following is a summary of these activities:

1.3.2.1 Fencing

The construction of perimeter fencing as proposed by Sharon Steel and EPA was completed by Sharon Steel to limit site access. A fence was constructed on an existing berm located on the east bank of the Jordan River along the entire reach of the river bordering the west edge of the tailings. This fence connects with existing property boundary fencing.

The fencing is industrial grade, six-foot chain link topped with a 45° angle extension arm fitted with three strands of barbed wire angling outward from the site. An effort was made to place the fence on property lines but in some instances it was located back from the property line to provide a better fence base. The fencing encloses all the tailings but still allows limited public access to the Jordan River.

Setback locations include:

1. Along the west bank of the Galena Canal where, in order to avoid crossing the canal, the new fence was placed on the bank rather than on the east property line.
2. Along Main Street where approximately 1200 feet of existing fence was partially submerged in a ditch. The new fence was placed on the existing berm which was originally constructed as a starter dike when the river was rerouted to expand the tailings area.
3. Along 7800 South where a new fence was constructed approximately 21 feet from the edge of pavement to provide for the legal highway right-of-way. Tailings which had blown out on the shoulder of the road were removed and placed within the fenced boundary of the property.

Part of the security fence includes approximately 1,300 feet of existing chain link property boundary fence which had the 45° angle extension arm with three strands of barbed wire added. In addition, a three acre plot owned by Sharon Steel west of the Jordan River was fenced separately from the property east of the river.

1.3.2.2 Dust Prevention

A dust mitigation program was commenced by Sharon Steel on May 19, 1988 and completed on June 16, 1988 in response to a compliance order issued to Sharon Steel by the Utah Department of Health, Bureau of Air Quality (BAQ). Approximately 75 acres of tailings were stabilized by spray application of 9,000 gallons of a polymer dust suppressant mixed with water and 90,000 lbs. of wood mulch. A second polymer dust suppressant application, covering approximately 57 acres, was completed May 24, 1989. The polymer is designed to bind together the near surface soil or tailings particles, forming a wind erosion resistant crust. Previous experience at other sites has shown that such a crust remains intact for one to two years.

1.3.2.3 Slope Stabilization and River Bank Restoration

In approximately five locations, the berm bordering the site had been washed out by high river flows. This berm was rehabilitated and reconstructed to serve three primary purposes:

1. To serve as a platform for placement of the security fence.
2. To serve as a buffer zone between the tailings and the river.
3. To serve as an access road for construction and maintenance activity. This road has a width of approximately 10 feet.

All tailings were removed from the berm in these five locations as part of this rehabilitation effort. These tailings were placed on existing piles away from the river and embankments were sloped to approximately 3:1 (horizontal to vertical) configuration. This work was performed along 600

to 800 feet of the berm. All stream bank areas requiring repair were filled with gravel material, compacted and covered with a graded riprap. Steeper slopes remain on other portions of the embankment.

Existing obstructions in the river, including debris and sediment which were directing river flow into the tailings side of the river, have been removed and the river channel cleaned so as to redirect flow away from the east bank.

1.3.3 SITE GEOLOGY AND HYDROGEOLOGY

The Sharon Steel/Midvale Tailings study area is located in the Jordan River Valley, a flat, sediment-filled valley surrounded by fault-block mountains typical of the Basin and Range physiographic region. The valley is bounded on the east by the Wasatch Mountains, on the west by the Oquirrh Mountains, on the north by the Great Salt Lake, and on the south by the Transverse Mountains. The valley has been filled with lacustrine sediments deposited in ancient Lake Bonneville, interlayered with coalescing alluvial fans derived from the adjoining mountains. Unconsolidated sediments are estimated to exceed 2,000 feet in thickness; however, the exact depth of the sediments in the valley is unknown.

The ground water system beneath the Jordan River Valley underlying the mill site consists primarily of a shallow unconfined aquifer overlying a deep confined aquifer. The two aquifers are separated by deposits of clay, silt, and fine sand ranging from about 20 to 40 feet in thickness in the vicinity of the mill site. In some parts of the Salt Lake Valley, the shallow unconfined aquifer has a permeability only slightly greater than that of the underlying confining bed. The maximum thickness of the shallow unconfined aquifer is about 50 feet. This aquifer is composed of clay, silt, and fine sand. A portion of the tailings were deposited on the old river bed of the Jordan River, which was rerouted to the west, on its present course, at the level of the shallow unconfined aquifer.

The top of the confining bed below the shallow unconfined aquifer is generally 50 to 150 feet below ground surface (Hely et al. 1971). The confining bed is present at the site but its continuity throughout the site is unknown. The confining bed is absent along the margins of the valley where only a single unconfined aquifer exists.

The ground water units described in the literature have been identified at the site. The uppermost unit is a local perched zone of ground water which occurs within the tailings, and east of them in terrace deposits. The middle unit (shallow unconfined aquifer) underlies the tailings and terrace deposits, and is separated from these perched zones by a layer of clayey, unsaturated material. This unit is correlative to the diastem aquifer described in previous Sharon Steel/Midvale Tailings site reports. Ground water levels in this unit are closely related to the level of the Jordan River. In addition, the shallow unconfined aquifer appears to discharge to the Jordan River. Neither the perched zone nor the shallow unconfined aquifer are a current source of drinking water within the boundary of the Sharon Steel/Midvale mill site.

The lower unit is the deep principal aquifer. It underlies the shallow unconfined aquifer and is separated from it by 20 to 40 feet of clayey material. The deep aquifer is reported to be artesian in the mill site area, and appears to discharge upward to the overlying unit. There is some evidence, however, that heavy pumping of the deep aquifer could result in a reversal of artesian conditions in localized areas. Given the arid nature of the region, it is likely that pumping of the deep aquifer may increase in the future. The deep principal aquifer is a major source of drinking water in the Salt Lake Basin. The Utah Division of Water Rights has recently conducted hearings regarding limitations on withdrawals from this principal aquifer, to prevent infiltration of shallow ground water to this deep zone. Presently allocated water rights for the principal aquifer far exceed aquifer recharge, according to the State.

For a more simplified discussion of the ground water situation and probable contamination, see the text and diagram in Section 1.4.4.2.

1.3.4 SOILS

The soils in the Midvale area are closely related to each other and occur on three different land features: floodplain soils, terrace soils and mining industry artifacts. The Jordan River Floodplain lies along the Jordan River between the North Jordan and Galena canals. The floodplain includes Brawell, Chipman and Magna soils and mixed alluvial and sandy alluvial land units. The terraces are from the Great Salt Lake/Lake Bonneville system, with Taylorsville, Hillfield, Kidman, Welby, Portleys and Harrisville soils. The artifacts from the mining industry include dumps of tailings and made-land. Made-land is a miscellaneous land type consisting of areas covered with such material as gravel, rock, concrete blocks and non-organic material other than soil.

Different soil types occur in different portions of the study area, namely:

- o Silty soils on the terrace west of the mill site
- o Silty to sandy soils on the floodplain
- o Sandy soils on the terrace east of the mill site with primarily residential land use
- o Sandy and slag-contaminated soils on the mill site.

The mill site is located on floodplain soils, the residential area is on terrace soils and the agricultural area is on floodplain and terrace soils. Made-land has been observed at the site and the residential area.

1.3.5 SITE HYDROLOGY

Portions of the Sharon Steel/Midvale Tailings mill site, including most of the tailings piles, lie in the floodplain of the Jordan River which forms the western and southern boundaries for the mill site. The Jordan River

flows north from Utah Lake to the Great Salt Lake. Historically, the Jordan River flowed through the mill site, but it was relocated to the west of the site in the early 1950s to facilitate tailings deposition. Currently, the tailings form an embankment which limits flooding on the east side of the Jordan River. The tailings piles previously were contained by tailings dams, and remnants of these dams remain. Surface water run-on generally flows into low areas of the tailings, especially these vestiges of the old ponds. Runoff is generally uncontrolled, but appears minimal.

The Jordan River, in the reach bordering the Sharon Steel/Midvale Tailings mill site, is classified by the State of Utah for the following uses: recreation, excluding swimming (Class 2B); cold water game fish (Class 3A); and agriculture (Class 4) (UDH 1978). Ten irrigation intakes from the Jordan River lie within three miles downstream of the mill site and irrigate approximately 160 acres (EPA 1984). Stream classifications change approximately eight miles downstream from the mill site at the confluence with Little Cottonwood Creek. At this point, the fisheries classification becomes 3B which is protective of warm-water game fish; the other classifications remain the same.

Stream flow measurements from the Jordan River during the RI indicated average flow conditions for the month of August. With the exception of Bingham Creek which enters from the west, the quantity of flow coming from all other Jordan River tributaries in the vicinity of the mill site is insignificant when compared to the flow of the Jordan River. Flow data indicated Bingham Creek comprises 13 percent of the Jordan River flow at the downstream boundary of the mill site (7800 South). Perched water from the tailings discharge into the Jordan from a seep at a rate of approximately 0.0001 cfs. Channelization of the Jordan River in the vicinity of the mill site has resulted in some unstable banks, some of which were repaired by Sharon Steel during early 1989. There is evidence of past erosion along the east and west bank of the Jordan River as it passes by the mill site.

1.3.6 TAILINGS STABILITY

The stability of the tailings pile located adjacent to the Jordan River was evaluated during the RI in order to determine the potential for collapse of tailings into the river. The results of the slope stability analyses in the RI report (CDM 1988b) indicated that:

1. In its existing configuration, much of the tailings pile perimeter is unstable or marginally stable under static or pseudostatic loading conditions. Failures from either deep or shallow slip surfaces could adversely impact the Jordan River.
2. Flattened perimeter side slopes of 3:1 (horizontal to vertical) would stabilize the tailings pile for static loading conditions and pseudostatic loading conditions using seismic coefficients on the lower end of the 0.15g to 0.30g range. Most of the perimeter side slopes have not yet been sufficiently flattened.
3. Even flattened perimeter slopes will apparently not stabilize the tailings pile for pseudostatic loading conditions using seismic coefficients on the upper end of the 0.15g to 0.30g range.
4. Continued undercutting of the toe of the slope by the Jordan River may destabilize portions of the tailings pile which are currently stable or areas made stable by remediation. Areas of marginal and unstable slopes resulting from the evaluation are shown in Figure 1-4.

As described in Section 1.3.2.3, however, Sharon Steel has rehabilitated and reconstructed some of these slopes along a 600-800 foot reach of the Jordan River.

1.3.7 DEMOGRAPHY AND LAND USE

According to 1980 census data, approximately 1,440 people live within 0.25 mile of the mill site and 8,180 people live within one mile of the mill site. Occupied residential and commercial areas lie immediately adjacent to the mill site on the east. Producing agricultural lands are located immediately across the Jordan River on the west side of the mill site.

Wind patterns in the vicinity of the mill site increase the likelihood that populated areas nearby may be exposed to airborne contaminants.

The City of Midvale is located adjacent to the mill site to the east. Midvale currently has a population of about 12,200 with approximately 4,300 dwelling units and a land area of approximately 3.4 square miles (City of Midvale 1987). The city has a planning commission and has adopted a master plan and zoning ordinance. This has allowed the City of Midvale and Sharon Steel Corporation to explore alternatives with various parties for both recovery of metals from the tailings and reclamation of the mill site for commercial development.

The deep confined aquifer is a source of drinking water for Salt Lake County. Municipal supply wells operated by Murray, Midvale, Sandy City, and the Salt Lake Water Conservancy District are located within three miles of the Sharon Steel/Midvale Tailings mill site. The nearest downgradient municipal supply well currently in use is located approximately 1.5 miles north of the mill site in Murray. The direction of ground water flow for the deep confined aquifer is believed to be westerly, toward the Jordan River and then north, towards Great Salt Lake (Hely, et al 1971; Vaddell 1987b).

The following public water supply wells, located within a three-mile radius of the site, draw water from the deep confined aquifer. In addition, approximately 325 people are served by private wells from the deep aquifer in the same area.

<u>Location</u>	<u>Number of Wells</u>	<u>Population Served</u>
Salt Lake City	5 (part of blended system)	300,000
Sandy City	7	83,700
Midvale	5	10,000
Murray	1	28,000
Private Wells	Not Listed	325

1.4 NATURE AND EXTENT OF CONTAMINATION

This section reviews the nature and extent of contamination based upon RI data and some additional data available after the RI. One of the key factors in assessing the nature and extent of contamination is the degree of public health or environmental risk posed by the contaminants. For example, if there is no current or potential future migration pathway or receptor for a contaminant, then there is essentially no risk. The EA completed during the RI reviewed 11 potential contaminants of concern and reviewed the potential migration pathways and potential receptors for these contaminants to determine the degree of risk posed by the mill site.

The following three sections summarize the results of the EA regarding contaminants of concern (Section 1.4.1), potential migration pathways and receptors (Section 1.4.2), and the risks posed by the site (Section 1.4.3). Section 1.4.4 reviews the extent of the nature and extent of contamination.

1.4.1 CONTAMINANTS OF CONCERN

The EA included in the RI report (CDM 1988b) identified the following contaminants of concern in the mill tailings: aluminum, antimony, arsenic, cadmium, chromium, copper, lead, manganese, silver, thallium, and zinc. Based upon site-specific data, the EA determined that arsenic and lead pose the most significant threats to both human health and the environment. This FS focuses on reducing arsenic and lead exposures.

1.4.2 POTENTIAL MIGRATION PATHWAYS AND RECEPTORS

Under current and potential future land use conditions at the Sharon Steel/Midvale Tailings study area, the EA determined that the principal migration pathways by which human receptors could potentially be exposed to site contaminants are:

- o Direct ingestion of tailings or contaminated surface soils
- o Inhalation of tailings-contaminated dust
- o Ingestion of produce grown in home gardens located in the study area
- o Ingestion of contaminated ground water

Environmental receptors (aquatic life and wildlife) could be exposed via the same routes (except ground water) and, in addition, via ingestion of or contact with contaminated surface water and sediments. Environmental receptors include cold water game fish, migratory waterfowl, and terrestrial mammals. Ingestion of these receptors by humans is not considered to be a significant pathway due to low exposure rates. These receptors are discussed in more detail in the RI report. All potential receptors and exposure levels are discussed in more detail in the EA.

1.4.2.1 Soil/Tailings

Direct ingestion of tailings or contaminated soil is a potentially significant route of exposure. Young children (<6 years) constitute the most sensitive population, via the normal mouthing of soiled objects, their hands, or the actual consumption of dirt. Older children are less likely to eat soil or to mouth soiled objects, but they may still ingest dirt from their hands. Similarly, although adults may ingest small amounts of contaminated soil or tailings, they are less likely to be exposed by this route. Dermal absorption is a less important route of exposure, and generally limited to instances where exposed cuts or scrapes allow absorption through the skin. Such instances would occur when persons get dirt/tailings on their skin or clothes during work or play activities, or via exposure through clothes handling (e.g., laundry).

Tailings-contaminated soils on or near the mill site are also available for uptake by vegetation. Consumers of garden vegetation or produce in the area may be potential receptors.

1.4.2.2 Air

Air transmission of contaminants may occur during the windy, dry periods of mid to late summer. In addition, off-road vehicle use on the mill site may lead to inhalation exposures. Airborne release may also occur, to a limited extent, during removal or stabilization as a part of potential site remediation activities if protective measures are not taken. Migration pathways correspond to local wind-flow patterns. Inhalation exposure is contingent on the receptors being relatively close to the mill site, although small particles, less than 10 microns in size, may be carried great distances, but will usually be well-dispersed and in low concentrations. It is estimated, further, that only a small proportion of the tailings are less than 10 microns in size, adapting some previous RI data (CDM 1988b).

1.4.2.3 Ground Water

Ground water provides a pathway for transporting contaminants off the mill site. Specifically, saturated unconsolidated deposits in the Jordan River Valley may receive metals leached from the tailings. Laboratory tests were conducted to determine the potential leachability of metals from the tailings pile. The methodology used was the EP toxicity test (a leach with mild acetic acid). Results indicated that 10 of 14 tailings samples exceeded EPA leachability limits for lead and 3 of 14 for cadmium. One soil sample from the mill site also exceeded the leachability limit for lead (CDM 1988).

Three ground water sources are potentially subject to metals contamination from the mill site. The first is perched ground water within the tailings piles. This perched water, however, is limited in extent to within the tailings and would not be considered a viable source of drinking water. Some of this perched water currently seeps into the Jordan River, but no adverse impacts to river water quality were detected. There is some

indication, however, that this perched ground water discharges into the shallow unconfined aquifer described below (CDM 1988).

The second ground water source is a shallow unconfined aquifer that extends beyond the mill site. Regional wells in this aquifer have low metal concentrations but high average TDS (1,695 mg/L) and sulfate (2,130 mg/L). Downgradient of the mill site, this aquifer discharges to the Jordan River. This aquifer is not currently used as a drinking water source either on or downgradient from the mill site. According to EPA's ground water classification, this aquifer is 2B (potential drinking water source), and its future use will be addressed in this FS.

A deep confined artesian aquifer also occurs within the study area and is a primary drinking water source for the Salt Lake County Water Conservancy District, which serves 300,000 people. The nearest operating municipal supply well, downgradient of the mill site, is located approximately 1.5 miles to the north. Available data from this well indicate that the deep aquifer is not currently contaminated by metals. As noted previously, withdrawals from this deep aquifer are under study by the Utah Division of Water Rights. Also, see Section 1.4.4.1 for a diagram of the ground water situation.

1.4.2.4 Surface Water

The surface water system represents a potential route of exposure. Both the Jordan River and a 22-acre wetland on the mill site are subject to metal releases from the mill site. Dissolved and suspended metals may be released to, and transported by, the surface water system. Jordan River sediments and wetland sediments may currently act as a "sink" for metals from the site. These sediments may also be resuspended and diverted downstream during high flows.

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1.4.3 CURRENT RISK CHARACTERIZATION

1.4.3.1 Risk Characterization for Human Receptors

The greatest carcinogenic risk at the Sharon Steel/Midvale Tailings study area under both current and future use conditions is the direct ingestion of contaminated surface soil/tailings and the ingestion of leafy and root crops grown on contaminated soils.

Carcinogenic risks posed by ingestion are the result of exposure to arsenic. Under current use conditions, for the average case, children and adolescents living in residential areas are at the greatest risk (4×10^{-6} to 2×10^{-5}). For the reasonable maximum case, children playing in sandboxes containing tailings, anyone living in the residential area, and adults consuming leafy and root crops are at the greatest risk (2×10^{-3} to 1×10^{-3}). Remediation of these risks will be addressed in OU2.

Carcinogenic risks on the mill site (OU1) will be dependent on future land use of the mill site. For purposes of developing action levels (cleanup goals) for the mill site, two future land use scenarios have been considered. One scenario considered is residential development of the mill site. This scenario would allow for unrestricted use of the mill site in the future. The second scenario considered is light industrial development. Evaluation of this scenario considers potential exposures received by construction workers on the mill site. Appendix D describes these scenarios and the development of corresponding action levels in more detail.

Carcinogenic risks posed by inhalation of airborne contaminants are the result of exposure to arsenic and cadmium. Although these risks appear to be relatively low (4×10^{-6} to 4×10^{-5}), there is some evidence presented in the RI that the risks for inhalation exposure may be underestimated.

The greatest toxic (non-carcinogenic) risk at the Sharon Steel/Midvale tailings study area under both current and future use conditions is posed by the ingestion of lead. Under current use conditions for OU2 and the future residential use scenario for the mill site, children are at the greatest risk followed by adults consuming vegetables under reasonable maximum case assumptions. At this time, EPA has withdrawn the reference dose (RfD) for lead (previously known as the Acceptable Daily Intake (ADI)) and is reevaluating lead toxicity. Research indicates that lead may be more toxic than previously estimated. Specific health risks associated with lead exposure are further analyzed in Section 5.3 of the EA and in Appendix D of this PS.

1.4.3.2 Risk Characterization for Environmental Receptors

The potential threats to vegetation, aquatic life, and wildlife posed by the chemicals of concern at the Sharon Steel/Midvale Tailings area were considered. The major conclusions of this evaluation are summarized below.

Vegetation

Lead is known to be phytotoxic at soil levels as low as 100 ppm (Kabata-Pendias and Pendias 1984). Soil lead concentrations exceed this level over a large portion of the study area, especially on the mill site.

Aquatic Life

Aquatic life can be exposed to contaminants in both surface water and sediments. Under current conditions, one metal, zinc, is present in the river at unnaturally high concentrations downstream of the mill site, but the zinc concentration at this location (35 µg/L) is below the federal Ambient Water Quality Criterion (AWQC). The concentration of zinc in the river is, therefore, considered unlikely to adversely affect the fish population. Of greater significance are the unnaturally high concentrations of metals in the river sediments. These sediments may act as a

reservoir which supplies metals to the water column or may directly adversely affect benthic organisms.

Wildlife

Analysis of surface waters and sediments from the wetlands adjacent to the tailings piles indicates that zinc concentrations are unnaturally high in surface water and several metals are present at unnaturally high concentrations in sediment. Wildlife in the wetlands habitat may be exposed to site-related contaminants directly through contact with contaminated surface waters or sediments, through consumption of organisms living in the surface waters or sediments, or through consumption of larger insects or animals feeding on these organisms. Some metals are known to accumulate in animal tissues which may serve as a source of exposure for large predatory birds, such as the white-faced ibis or other terrestrial animals. Among the metals present at the study area, lead has been shown to bioconcentrate in insects, small mammals, and songbirds which may then be consumed by larger animals (Beyer et al. 1985). It is uncertain whether wildlife in the wetlands habitat is currently being adversely affected by the metals present at the study area; however, the potential does exist for wildlife exposures that may lead to adverse effects.

1.4.4 EXTENT OF CONTAMINATION

Table 1-1 lists the geometric mean for the contaminants of concern detected in the various media. Complete laboratory data results are reported in the RI (CDM 1988b). The following subsections describe the extent of contamination in soils, ground water, surface water, and sediments. The focus of this FS for Operable Unit 1 is on mill site contamination. Some references to off-site contamination are included in the following sections, but the full extent of off-site contamination will be described in detail in the FS for Operable Unit 2.

TABLE 1-1
 GEOMETRIC MEAN OF CONTAMINANTS OF CONCERN IN VARIOUS MEDIA

Element	Local Background ^a Soil		Contaminated Surface Soil				Tailings		
	Terrace	Floodplain	Terrace	Floodplain	Residential	Mill Site	Surface (Oxidized)	Surface (Dunes)	Subsurface (Unoxidized)
	(ug/Kg)								
Aluminum	13,669.0	7,283.0	12,461.0	10,883.0	9,560.0	9,267.0	3,982.0	3,270.0	3,002.0
Antimony	6.1	<5.5	6.4	8.8	5.7	72.7	73.5	16.0	17.0
Arsenic	15.2	5.7	31.5	40.7	65.5	158.0	425.1	320.2	411.2
Cadmium	3.2	2.0	5.4	7.1	12.5	27.6	46.8	37.3	36.4
Chromium	18.0	11.9	17.8	18.6	15.8	29.8	25.4	17.0	18.3
Copper	81.4	40.7	160.6	344.6	195.1	324.1	298.5	760.2	578.1
Lead	97.0	78.6	373.2	536.8	722.0	2,100.0	6,278.0	5,470.0	5,209.0
Manganese	454.3	249.5	466.0	452.8	508.9	833.7	1,199.0	1,497.0	2,032.0
Silver	1.4	<1.4	1.9	2.8	3.0	10.4	26.9	24.9	27.1
Thallium	BDL	BDL ^e	BDL	1.6	1.4	2.0	3.3	3.2	8.0
Zinc	124.3	100.3	320.8	537.4	591.8	2,143.0	4,821.0	6,048.0	6372.0
n ^b	4.0	5.0	23.0	17.0	22.0	31.0	13.0	22.0	4.0

Element	Sediment		Jordan River Surface Water		Ground Water ^c		Air Data From December 1987 Event	
	Upstream	Downstream	Upstream	Downstream	Perched In Tailings	Shallow Unconfined	Upwind	Downwind
	(ng/Kg)		(ug/L)					
Aluminum	1492.0	3365.0	1010.0	1030.0	60.0	54.0	-	-
Antimony	<29.0	<34.0	<60.0	<60.0	73.0	62.0	-	-
Arsenic	1.5	16.1	14.0	10.0	109.0 ^d	29.0	314.0	438.0
Cadmium	<1.5	2.2	.36	.44	<3.0	5.0	<3.0	25.2
Chromium	3.8	7.3	<3.0	<3.0	<3.0	<3.0	8.4	108.0
Copper	4.0	151.0	7.0	10.0	3.5	7.1	24.0	787.0
Lead	5.8	115.0	6.0	11.0	6.4	5.3	37.0	3,865.0
Manganese	38.2	128.9	53.0	53.0	305.0	79.4	-	-
Silver	<2.0	3.0	<0.2	<0.2	<4.0	<4.0	-	-
Thallium	BDL	BDL	<10.0	<10.0	BDL	BDL	-	-
Zinc	16.0	331.0	19.0	20.0	62.0	195.0	90.0	5,422.0
n	3.0	3.0	1.0	1.0	7.0	7.0	2.0	5.0

^a "Local Background" as defined in the RI (CDM 1988b). Referred to as "ubiquitous contamination" in the FS.

^b n = Number of samples

^c No samples were collected from the deep confined aquifer because previous research showed no contamination.

^d Geometric mean exceeds MCL for drinking water.

^e BDL = below detection limit.

In order to determine the extent of contamination, a base concentration level for each contaminant had to be established. Local background levels, as described in the RI, were used as the basis. Table 1-1 lists local background levels determined during the RI.

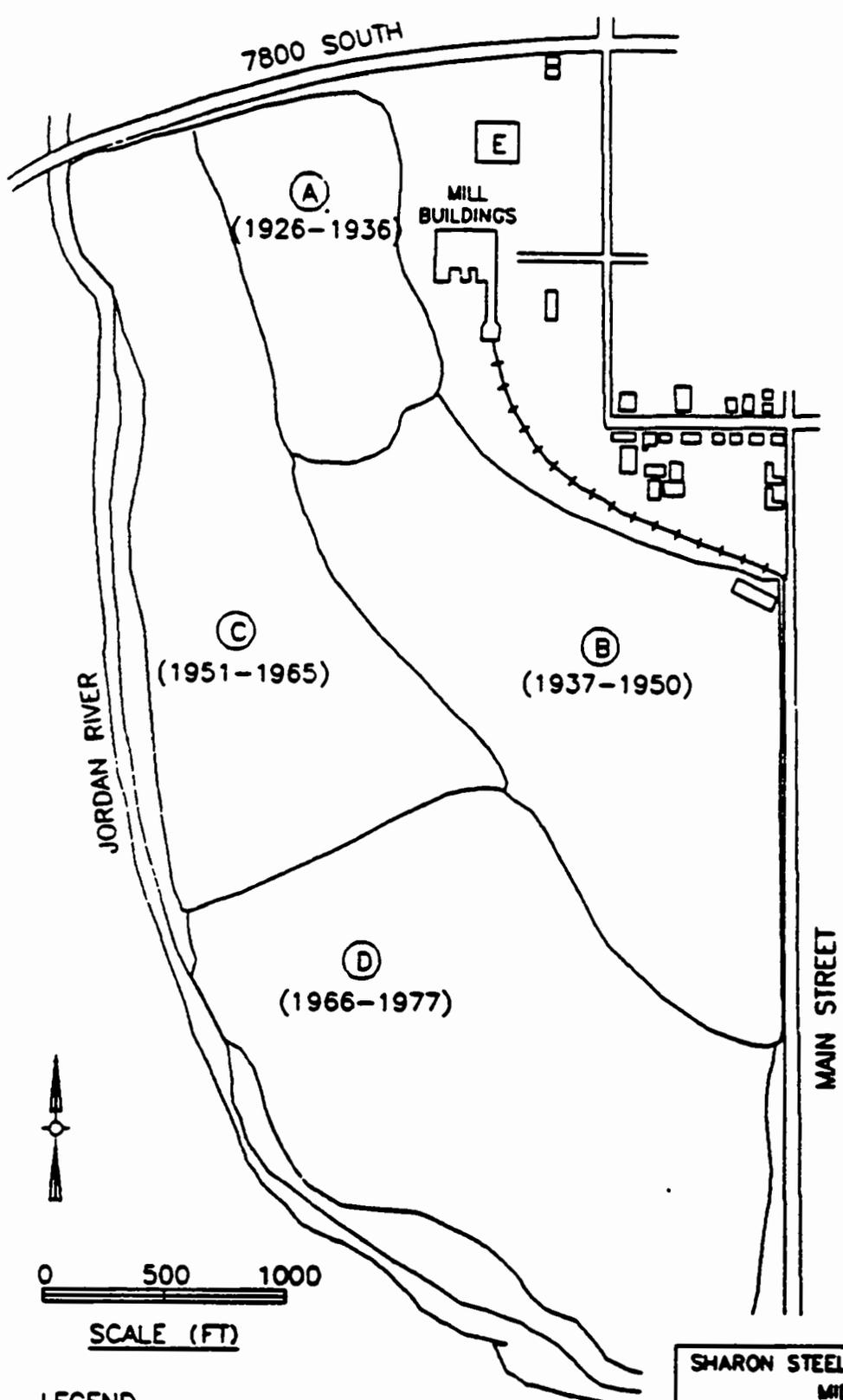
1.4.4.1 Soils and Tailings

Due to the history of smelting activity in the Salt Lake Valley, it was considered unlikely that we would find any uncontaminated soils in the area which could serve as an estimate of natural background. When analyzing the off-site soil data, however, it was apparent that the soil data followed a bimodal distribution with samples ≤ 150 mg/Kg forming one node and samples $\geq 500-700$ mg/Kg forming a second node. It is also apparent that the lower concentrations occur farther from the mill site than the higher concentrations.

No samples from the residential area or the mill site had lead values below 150 mg/Kg lead. Four samples from floodplain soils and 23 samples from terrace soils were below 150 mg/Kg for lead and were used to estimate background contamination levels for these soil types.

A suite of inorganic contaminants exist at high concentrations in the tailings; from high to low concentrations in mill site and off mill site soils; and in sediments of the Jordan River. The suite of contaminants includes antimony, arsenic, cadmium, copper, lead, silver, and zinc.

Figure 1-4 shows schematically the extent of tailings and soils on the mill site. Tailings cover 207 acres east of the Jordan River and an area 2.3 acres in size just west of the river (not shown in Figure 1-5). The main tailings pile has a weighted average depth of approximately 36 feet and the western area is estimated to be approximately 6 feet deep. In addition, a 6.5 acre area on the mill site is covered approximately 8 feet deep with concentrated pyrite materials. Two areas of surface soils also exist on the mill site: 41 acres in the vicinity of the mill buildings and 13.5 acres along the original channel of the Jordan River.



LEGEND

- D TAILINGS AREA DESIGNATION
 (1966-1977) YEARS OF TAILING DEPOSITION
- E ON-SITE SOIL AREA

SHARON STEEL/MIDVALE TAILINGS SITE
MIDVALE, UTAH

DESIGNATION OF TAILINGS/SOILS AREAS

CAMP DRESSER & GARDNER INC.

SHEET NO

CDM

1-5

spread of contamination to the deep confined aquifer (water supply aquifer) is unlikely to occur unless influenced by heavy pumping from water supply wells in the area. If the gradient is reversed due to heavy pumping, contaminated ground water could start to flow downward to the deep aquifer.

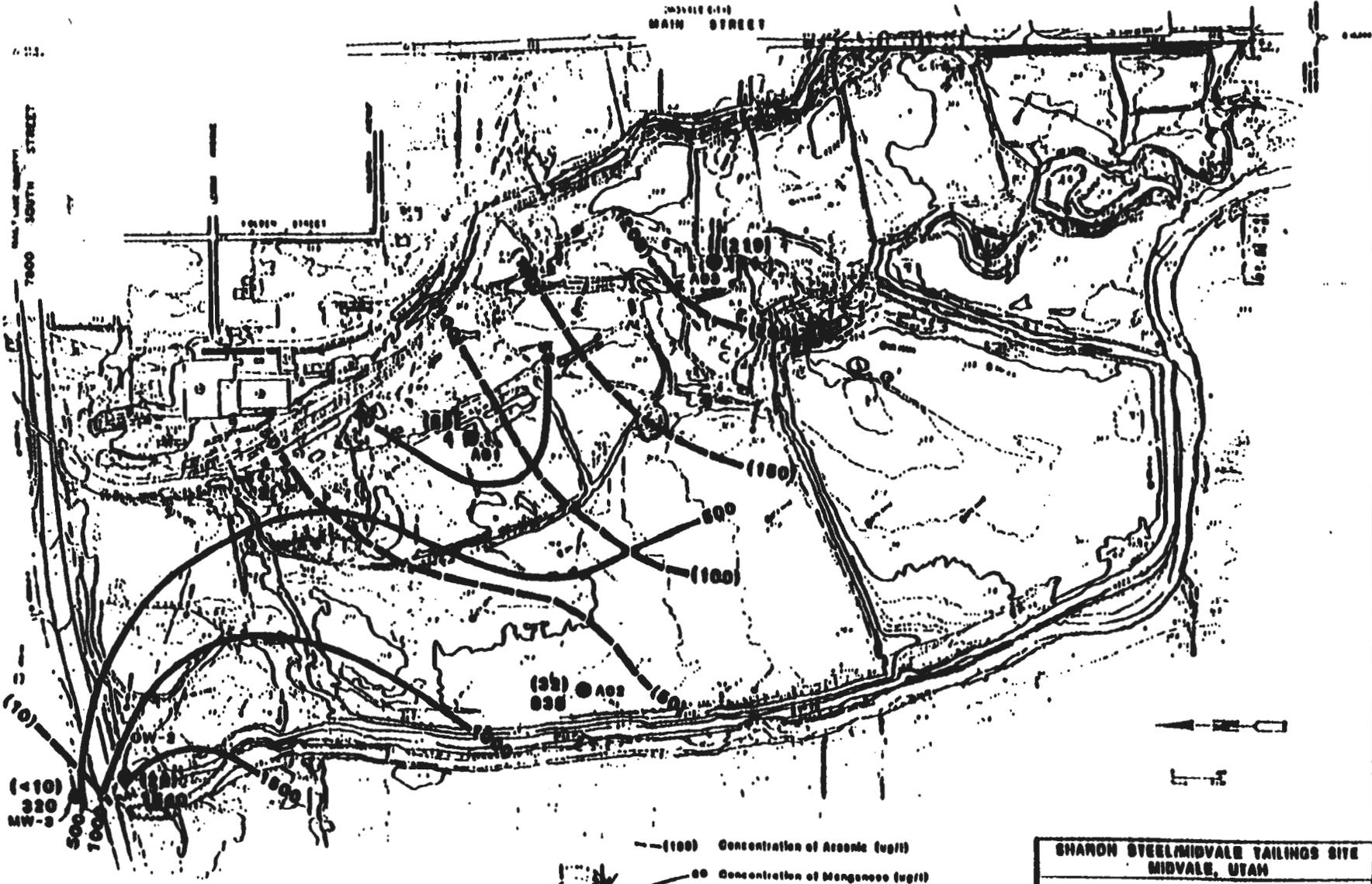
1.4.4.3 Surface Water and Sediments

Surface water and sediments samples were collected from upstream and downstream in the Jordan River and from accessible surface water on the mill site. Results for water and sediment samples are listed in Tables 1-3 and 1-4, respectively.

Sediment data indicate that tailings are migrating from the mill site into the Jordan River. This migration may be due to ongoing erosion or previous slope failures along the western boundary of the mill site. These data also indicate that wetland sediments contain tailings.

Water quality data suggest that in the Jordan River, dissolution of metals from transported tailings to the aqueous phase was not significant at the time of sampling. One factor potentially responsible for reduced dissolution of metals is the lack of significant fluvial transport of sediment or tailings material, as indicated by low TSS values (59 to 61 mg/L). A second factor could be the high Jordan River pH values (7.5 to 7.8). At these pH values, metals would tend to remain bound to the sediments.

With the exception of the seep visible along the side slope of the tailings above the river, none of the surface water samples exceeded metals criteria for the protection of aquatic life. Although metal concentrations were high in the seep, Jordan River water quality did not appear to be adversely affected. The potential exists for continued undercutting of the tailings piles by the Jordan River and related local slope failures which could increase metal concentrations in the river, however, recent slope stabilization activities (Section 1.3.2.3) have reduced this possibility.



- (100) Concentration of Arsenic (ug/l)
 - 00 Concentration of Manganese (ug/l)

SHARON STEEL/MIDVALE TAILINGS SITE
MIDVALE, UTAH
 Distribution of Arsenic and Manganese -
 Diatom Analyzer

12/28/77

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TABLE 1-3

SUMMARY OF SURFACE WATER CHEMISTRY DATA

Parameter	Units	Gardner SW-3	Bingham SW-4	Galena SW-5	Irrig. Drainage SW-6	Irrig. Culvert SW-7	Fonded Water SW-8	Galena Canal Trib. SW-9	Old Channel "Wetland" SW-11	Seep SW-12	Jordan River Upstream SW-1	River Downstream SW-1
General												
Temperature (field)	°C	27	20	24	22	20	19	22.9	23	24	14	10
pH (field)	S.U.	0.2	7.0	9.0	7.9	7.6	7.7	0.4	7.5	6.2	7.5	7.0
Dissolved Oxygen (field)	mg/L	10.2	7.9	9.0	5.2	6.4	7.9	0.9	7.6	—	7.0	7.7
Specific Conductivity (field)	umhos/cm	2,110	2,110	1,400	2,560	1,410	1,344	2,290	1,150	1,950	1,950	1,000
Acidity	mg/L	<5	<5	<5	<5	<5	<5	<5	<5	16	<5	<5
TDS	mg/L	970	1,300	700	1,440	100	763	1,230	794	4,020	1,100	1,140
TSS	mg/L	36	26	62	0	<4	13	61	<4	80	50	61
Anions												
Chloride	mg/L	220	200	100	290	21	100	260	100	270	200	230
Nitrate-Nitrogen	mg/L	1.0	2.6	0.1	1.2	0.79	0.10	0.60	<0.10	0.10	1.5	1.5
Bicarbonate	mg/L	240	310	130	440	120	190	230	190	9	290	200
Carbonate	mg/L	<5	<5	50	<5	<5	<5	10	<5	<5	<5	<5
Sulfate	mg/L	240	420	170	340	17	200	370	210	3,000	330	320
Fluoride	mg/L	0.5	0.5	0.5	0.0	0.1	0.5	0.6	0.6	2.9	0.6	0.5
Total Metals of Concern												
Aluminum	µg/L	930	633	322	362	13	260	444	47	2,120	1,010	1,030
Antimony	µg/L	<60	<60	<60	<60	<60	<60	<60	<60	69	<60	<60
Arsenic	µg/L	19	25	12	21	<4	10	10	20	160	14	10
Cadmium	µg/L	0.39	0.59	1.0	0.56	0.2	0.4	1.9	0.4	7.5	0.56	0.44
Chromium	µg/L	<3.0	<3.0	<3.0	3.3	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Copper	µg/L	13	17	13	17	10	13	13	17	97	7	10
Lead	µg/L	9	23	14	12	5	30	80	36	93	6	11
Nickel	µg/L	<14	<14	<14	<14	<14	<14	<14	<14	60	<14	<14
Silver	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	1.6	1.0	<0.2	<0.2
Zinc	µg/L	29	20	1,390	30	23	47	80	370	3,460	10	20

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TABLE 1-4
SUPPORT SEDIMENT CHEMISTRY DATA

Parameter	Units	Downstream				Upstream				Point Bar Below Soap	Bingham Creek	Old Channel "Wetland"	Surface Tailings
		SD-01A	SD-01B	SD-01C	Geometric Mean	SD-02A	SD-02B	SD-02C	Geometric Mean	SD-003	SD-004	SD-011	
Total Metals													
Aluminum	mg/kg	2,510	1,590	9,590	3,365	1,710	1,400	1,390	1,492	6,410	6,000	10,300	
Antimony	mg/kg	330 ^a	300	300	<10	290	310	200	<20	370	320	4730	
Arsenic	mg/kg	10	6.1	69	46.1	1.5JCB	1.2JB	2	1.5	26	25	306	
Barium	mg/kg	45	26	139	54.6	37	45	25	34.7	103	43	222	
Beryllium	mg/kg	1.10	1.00	1.30	<1.1	0.970	1.00	0.950	<0.97	1.20	1.10	1.50	
Cadmium	mg/kg	1.60	1.90	0.5	<2.2	1.50	1.50	1.40	<1.5	2.0	1.60	16	
Calcium	mg/kg	20,500	9,200	39,900	10,860	11,000	6,240	10,100	9,710	39,800	16,100	47,100	
Chromium	mg/kg	5.0	4.0	17	7.3	4.2	3.0	3.4	3.0	11	6.0	27370	
Cobalt	mg/kg	1.60	1.7	6.3	2.6	1.50	1.50	1.40	<1.5	4.3	3.0	7.7	
Copper	mg/kg	69	93	944	191	4.2	3.0	4.0	4.0	59	217	1,020	
Iron	mg/kg	3,400	3,430	17,400	6,090	3,000	2,620	2,340	2,640	12,000	10,000	48,200	
Lead	mg/kg	23	26	2,560	115	4.7	0.1	5.1	5.0	30	1,470	16,600	
Magnesium	mg/kg	6,500	4,390	7,610	6,010	3,920	3,920	3,440	3,750	6,450	2,060	10,000	
Manganese	mg/kg	116	71	260	129	42	39	34	30.2	222	94	2,150	
Mercury	mg/kg	0.10	0.10	0.14	<0.1	0.10	0.10	0.10	<0.1	0.10	0.10	0.67	
Molybdenum	mg/kg	1.00	1.00	0.0	<2.1	1.00	1.00	1.00	<1.0	1.3	1.0	7.6	
Nickel	mg/kg	7.60	7.10	12	<0.7	6.00	7.20	6.60	<6.9	0.70	7.50	23	
Potassium	mg/kg	934	177	2,500	633	537	473	436	400	1,730	1,250	2,230	
Selenium	mg/kg	0.0030	0.0030	3.5	<1.1	0.230	0.2030	0.2030	<0.2	1.030	0.030	6.030	
Silver	mg/kg	2.20	2.00	6.4	3.0	1.90	2.10	1.90	<2.0	2.50	5.7	5430	
Sodium	mg/kg	322	110	571	279	136	100	160	132	377	227	455	
Thallium	mg/kg	50	50	50	<5	50	50	50	<5.0	50	50	20	
Tin	mg/kg	13	100	130	<11.9	14	10	12	11.9	13	16	150	
Vanadium	mg/kg	7.5	5.2	20	9.0	9.3	6.4	5.6	6.9	16	11	39	
Zinc	mg/kg	203	110	1,520	331	15	23	12	16	240	406	6,240	

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^a U = Undetected
 J = Estimated
 S = Estimated due to spike recoveries outside limits.
 H = Estimated due to holding time violation.

Reference 4

**Excerpts From Declaration for Record of Decision - Sharon Steel
(Operable Unit 2) Residential Soils, Midvale, Utah;
EPA Region VIII and the Utah Department of Health;
September 24, 1990**

Administrative Record
S.F. File Number 4.2

DECLARATION FOR THE RECORD OF DECISION

Sharon Steel (Operable Unit O2)

Residential Soils

Midvale, Utah

September 24, 1990

U.S. Environmental Protection Agency Region VIII

Utah Department of Health

DECLARATION FOR THE RECORD OF DECISION

SITE NAME AND LOCATION

Sharon Steel (Operable Unit O2, Residential Soils), Midvale, Utah

STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected remedial action for the Sharon Steel, Operable Unit O2 (OU2) Site, in Midvale, Utah. The selected remedial action was chosen in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This decision is based on the Administrative Record (AR) for this Site.

The State of Utah concurs with the selected remedy, as indicated by cosignature.

ASSESSMENT OF THE SITE

Actual or threatened releases of hazardous substances at and from this Site, if not addressed by implementing the response action selected in this Record of Decision (ROD), may present an imminent and substantial endangerment to the public health, welfare, or the environment.

DESCRIPTION OF THE SELECTED REMEDY

The selected remedy for Sharon Steel OU2 addresses the soil contamination in the residential and commercial area immediately east of the Sharon Steel mill site (Operable Unit O1 (OU1)). These soils in OU2 are contaminated with tailings blown from the mill site and contain elevated levels of lead, arsenic, and cadmium.

The action described herein is the first part of a two-step remedy and addresses the most immediate threat to public health. It consists of excavation of the contaminated soil and placement of these soils from the residential areas, temporarily, at the mill site (OU1). A separate ROD will, at a later date, address the remedy for the tailings already present at the mill site and the contaminated residential soils temporarily placed there as a result of this initial action. The major components of the first phase of the remedy (OU2) include:

- o Removal of contaminated soils and associated vegetation, to the action level. The level of contamination which would trigger removal is 500 parts per million (ppm) lead and 70 ppm arsenic concentrations in the soil. Existing soils being used for gardening would be remediated to the action level of 200 ppm lead and/or 70 ppm arsenic.
- o The soils removed from this area will be transported to the mill site (OU1). The remedy selected for the mill site will address the tailings at the mill site and the contaminated soils from OU2, temporarily placed there as a result of this action.
- o Clean soil will replace the excavated soils back to the original ground surface.
- o Clean soils will be graded to the original contour and revegetated.

DECISION SUMMARY

**Sharon Steel Operable Unit O2
Residential Soils
Midvale, Utah**

September 24, 1990

**U.S. Environmental Protection Agency, Region VIII
Utah Department of Health**

DECISION SUMMARY

1. SITE NAME, LOCATION, AND DESCRIPTION

The Sharon Steel OU2 is located in Midvale, Utah, bounded on the west by Sharon Steel OU1 mill buildings, site, and tailings, on the north by 7200 South Street, on the east by a line one or two blocks east of Interstate Highway 15, and on the south by the newer residential and commercial area in south Midvale City. The exact boundaries of the site, however, are imprecise due to the widespread nature of the contamination. A map showing the approximate location of OU2 and its relationship to OU1 is given in Figure 1.

There are three main topographic and geologic features of the Sharon Steel site: Jordan River Floodplain, terraces from the Great Salt Lake/Lake Bonneville system, and artifacts from the mining industry. The tailings (OU1) from the mill are located on the Jordan River floodplain, and the mill site (OU1) and nearby residential area (OU2) are on the terraces. The terrace soils, having originated from the weathering of sedimentary and igneous rocks from the Wasatch Mountains, are generally well drained.

OU2 encompasses part of the City of Midvale, Utah and surrounding areas. Approximately 44,000 people live within a two mile radius of the mill site, 12,000 within the City of Midvale, 8,000 people live within one mile, and 1,400 people live within a quarter mile of the mill site. The age distribution is: 36 - 39% from 0 - 16 years; 48 - 49% from 17 - 54 years; and 11 - 16% over 54 years.

The land south and west of Midvale is used primarily for agricultural and commercial activities; the land north and east of Midvale is mostly urban. The entire area is drained by the Jordan River which provides cold water and warm water habitat for fish, but is more heavily used for agricultural irrigation. Adjacent to the Jordan River are wetlands, and potential wildlife habitat, but these features are not within OU2. The Salt Lake Valley has substantial ground water resources consisting of shallow and deep aquifers used for various domestic, agricultural and industrial applications. There are a number of public drinking water supply wells within a three mile radius of the Site, most of which use the deep aquifer. These serve approximately 440,000 people. Recent data suggests that the shallow and deep aquifers are hydraulically connected. However, the RI/FS shows that only the shallow aquifer directly under the mill site itself (OU1) has been contaminated. Ground water issues will be considered as part of the later OU1 remedy. To date, none of the public water supply wells have been contaminated.

2. SITE HISTORY AND ENFORCEMENT ACTIVITIES

The Sharon Steel Site includes a former milling operation originally owned and operated by the U.S. Smelting, Refining and Mining Company, later known as UV Industries, Inc. The mill operated from 1906 to 1971. During the milling operation, sulfide concentrates of lead, copper, and zinc were extracted from the ore by froth flotation. The facility operated as a custom mill, receiving ore from many sources, then concentrating and extracting a variety of metals. The tailings from the milling operations are located at the mill site (OU1) in uncovered piles up to 50 feet deep, and have an estimated volume of 14 million cubic yards.

The tailings are fine grained and the piles resemble sand dunes. Sharon Steel purchased the mill site in 1979.

An environmental health problem was first suspected in 1982 when the Utah Department of Health was notified that local citizens were gathering wind blown tailings and then using them for sandboxes and gardens. The tailings had high concentrations of lead, cadmium, and arsenic. A public education campaign was launched to warn residents about the dangers of this practice. In addition to the residential use of the tailings, an investigation in 1988 revealed that tailings and other dusts had been blown by the wind and had contaminated the soil with lead, cadmium, and arsenic, over a 571 acre area of the City of Midvale downwind of the mill site. Analysis of the contaminants in the soil strongly suggest that a major contributor to OU2 contamination is due to wind-blown tailings from the Sharon Steel mill site. Some of the contamination may also have originated from the smelter at an adjacent Superfund site (Midvale Slag). Of the 571 acre residential area contaminated by the tailings, further investigations have revealed that about a 142 acre area (with an estimated volume of 242,000 cubic yards) has soils which contain levels of lead and/or arsenic above the action level of 500 ppm lead and/or 70 ppm arsenic.

The Sharon Steel site, including both the mill site (OU1) and the "off-site" soils contaminated areas (OU2), was proposed for the Superfund National Priorities List (NPL) in 1984 and became final on August 28, 1990. The State of Utah was the lead agency for the Site between 1985 and 1987. Since 1987, the U.S. Environmental Protection Agency (EPA) has been the lead agency. The initial Remedial Investigation (RI) for the site was completed in June 1988. A Feasibility Study (FS) for the entire Site was published in June 1989, and a Proposed Plan issued in July 1989. A public hearing on this Proposed Plan was held in August 1989. As a result of extensive public comment, EPA decided to divide the Site into two operable units, with OU1 referring to ground water, the mill site, and its tailings, and OU2 referring to the residential soils contaminated by wind blown tailings. The decision to divide the Site into operable units was based on the endangerment presented by the residential soils and the need to further investigate the ground water beneath the mill site. Issuance of the ROD was postponed for one year to allow additional studies to answer questions posed by the public. Further RI/FS studies and reports concerning ground water and residential soils were completed during 1989 and 1990. The FS for OU2 was completed on June 6, 1990, and the Proposed Plan was issued on June 6, 1990. A public hearing was held on the Proposed Plan for OU2 on June 14, 1990, in Midvale, Utah.

While the Superfund process is underway, the State of Utah has been working with Sharon Steel to suppress the release of fugitive dust from the mill site to prevent further contamination of the residential soils and to prevent re-contamination after implementation of the remedy.

Three Potentially Responsible Parties (PRPs) have been identified at the Site. These include: (1) Sharon Steel Corporation - the current owner of the mill site; (2) UV Industries, Inc. and UV Industries, Inc. Liquidating Trust - the former owner and operator of the mill site; and (3) Atlantic Richfield Company - a generator of hazardous substances disposed of at the mill site and a potential former operator of the mill. General notice letters were sent to the PRPs on August 28, 1985; and requests for information were sent on May 12, 1988 (CERCLA 104e). No special notice letters have been sent. All of these parties have been named as defendants in

Criterion 4: Reduction of Toxicity, Mobility, or Volume Through Treatment

This is the anticipated performance of the treatment technologies a remedy may employ. Although containment options do reduce mobility, this is not "treatment" in the context of this criterion. This criterion reflects the statutory preference for treatment alternatives. Only two of the alternatives classify as treatment: Alternative 4 (stabilization) and Alternative 5 (soil washing). Alternative 4's treatment would decrease toxicity and mobility but increase volume. Alternative 5's treatment would reduce toxicity, mobility, and volume. Alternative 3c may meet this criterion if soils stored at OU1 receive treatment in the future.

Criterion 5: Short-term Effectiveness

This criterion addresses the period of time needed to achieve protection and any adverse effects on human health and the environment that may be posed during the construction and implementation period, until clean up goals are achieved. Because there is no construction required in Alternative 1, the "no action" alternative, there would be no risks in addition to those already present. Alternative 2 does not require any movement or transport of contaminated soils, therefore, fugitive dust from this source will be minimal. Alternatives 3 through 5 all require movement of contaminated soil, so there is some threat of exposure via fugitive dust emissions. Exposure via fugitive dust will be minimized for all these alternative by temporary relocation of the residents during construction, and by use of dust suppression methods.

Criterion 6: Implementability

Implementability addresses the technical and administrative feasibility of the remedy, including availability of materials and services needed to implement a particular option. Because Alternative 1 requires no action, it is easily implemented. Alternatives 2 through 5 use technologies and construction that are readily available. Alternatives 3 and 5 require disposal sites and therefore pose more difficulty, but nonetheless disposal capacity is available. Alternatives 3 and 4 require moderate coordination with local officials and Alternative 5 requires a high degree of coordination because of the production of soil washing effluents which will require disposal.

Criterion 7: Costs

Cost factors include estimated capital and operation and maintenance (O&M) costs, as well as present worth costs. Alternative 1, the "no action" alternative has little capital costs but does require monitoring and therefore O&M expenditures. It is obviously the least costly alternative. Alternatives 2, 3c, and 4 have moderate costs in the \$20 million range. Alternatives 3a, 3b, and 5 have substantially higher costs (\$70 - 90 million).

Criterion 8: State Acceptance

This criterion indicates the State's preferences regarding the various alternatives. The State of Utah supports Alternative 3c as evidenced by its testimony at various public meetings, and its written submittal during the comment period.

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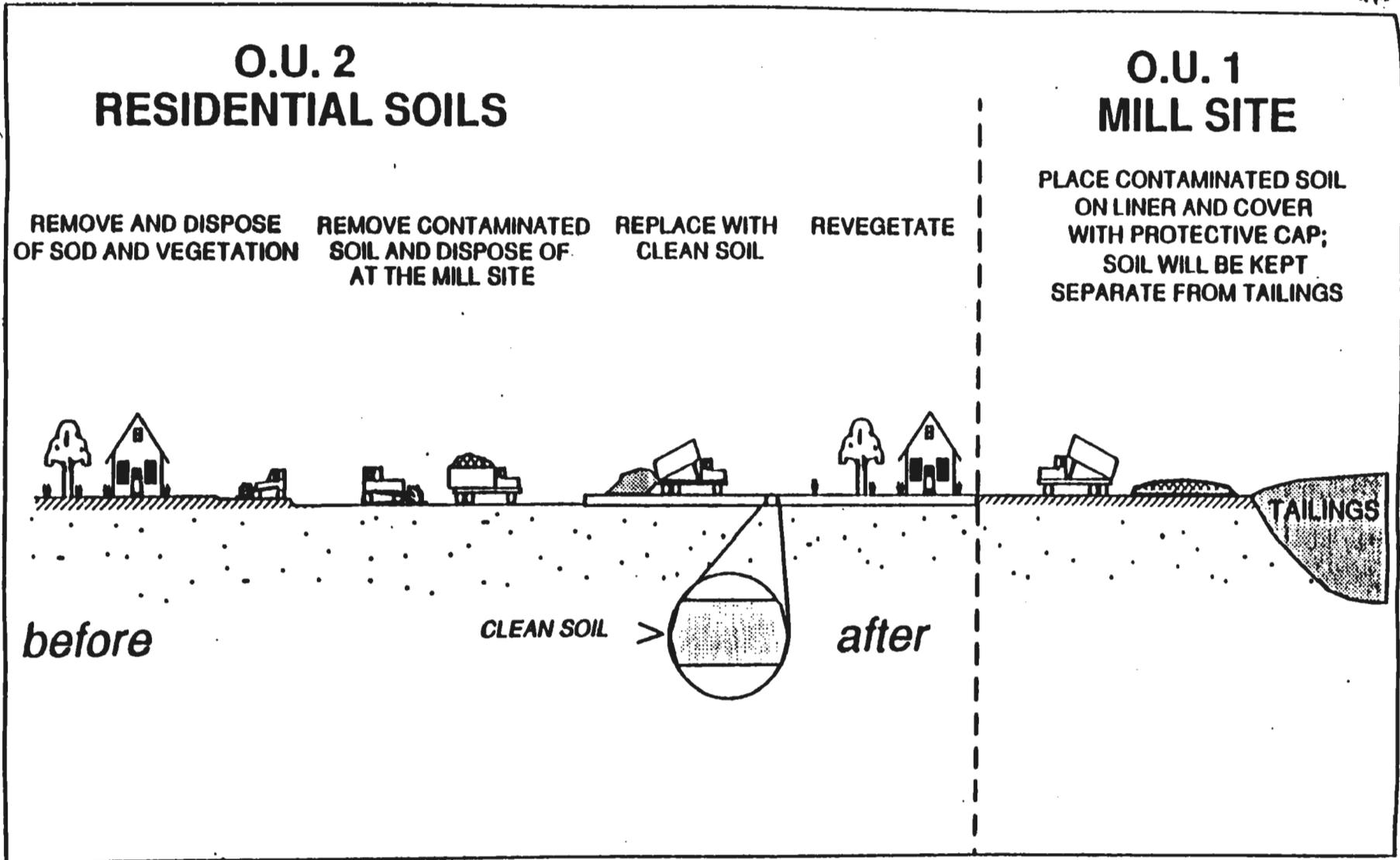


Figure 3
Alternative 3c: Soil Excavation and Disposal

Criterion 9: Community Acceptance

This criterion addresses the public's general response to the alternatives described in the Proposed Plan. Most of the residents interviewed and local political officials supported Alternative 3c.

Of the various alternatives proposed, Alternative 3c was the best overall in satisfying the nine remedy selection criteria of the NCP.

9. THE SELECTED REMEDY

EPA has chosen Alternative 3c as the selected remedy (illustrated in Figure 3) for the Sharon Steel Operable Unit O2. In summary, this alternative has the following components:

- A. Soils on each property will be tested prior to any action.
- B. If testing of the hazards associated with construction at a vacant contaminated lot in Midvale shows that relocation is advised, because the National Air Quality Standards may be violated, residents will be offered relocation during construction activities.
- C. Removal of contaminated household dust from residences when lead concentrations in the dust are above 500 ppm lead using field analysis.
- D. Removal of existing garden soils down to 18 inches for soils with concentrations of lead greater than 200 ppm and arsenic greater than 70 ppm. Institutional controls will be employed to regulate the installation of new gardens.
- E. Removal of contaminated soils, not covered by pavement or structures, containing concentrations greater than 500 ppm Pb and 70 ppm As. The depth of excavation, based on data gathered during the OU2 RI is not expected to exceed 24 inches.
- F. Replacement of excavated areas with clean fill up to the original grade.
- G. Revegetation to initial conditions.
- H. Temporary storage of contaminated soils at OU1, separate from the tailings and where they will be included in the final remedy for OU1.
- I. Installation of a plastic liner under and over the excavated soil which will be stored at OU1. This liner will prevent redispersal of the soils before remediation of OU1.
- J. Institutional controls to require building permits prior to construction during removal or replacement of pavements or foundations. Such activities may expose contaminated soils left in place by remediation and such activities will require special precautions. A "citizens repository" may be created to provide a place for residents to dispose of soils during these future activities.

- K. Detailed descriptions of institutional controls will be produced during RD, and they will be enacted by the appropriate local governments prior to implementation of RA.

The objective of the selected remedy is reduction of exposure of the residents of Midvale to the unacceptably high levels of lead and arsenic in their soils. The action levels based on health-based calculations are 500 ppm lead and 70 ppm arsenic for soils. Because home grown vegetables grown in contaminated soil can incorporate lead and thereby produce an additional exposure route, the action level for garden soils is 200 ppm lead and 70 ppm arsenic. When this remedy is implemented, the risks from cancer due to arsenic exposure will be reduced from current risks of 5×10^{-4} to 2.6×10^{-5} , the current hazard index due to arsenic exposure will be reduced from 2 to 0.44. The percentage of children predicted to have blood lead levels in excess of 10 ug/dL will be reduced from 85% to approximately 11% in areas of greatest contamination. In areas of intermediate contamination, the percentage will be reduced from 36% to 11%.

10. STATUTORY DETERMINATIONS

Protection of Human Health and the Environment.

The selected remedy meets the three goals for human health concerns to the maximum extent practicable: (1) it will reduce the blood lead level for most children 10 ug/dL or less; (2) it reduces the risk of cancer due to arsenic exposure to 2.6×10^{-5} , within the acceptable risk range; and (3) it reduces the chronic daily intake/reference dose for arsenic to 0.44, a value below the EPA goal of 1. The preferred goal of 10^{-6} excess risk of cancer due to arsenic exposure could not be reached at this Site because the concentration of arsenic in local background soils resulted in a slightly higher risk. Nonetheless, the risk does fall into the acceptable range for arsenic and meets the other goals.

In addition, short-term effects will be minimized during remedial action because, during the excavation process, the residents will be temporarily relocated if necessary and fugitive dust controls during transport of contaminated soils will be implemented. Therefore, there will be no unacceptable short-term risks or cross-media impacts caused by implementation of the selected remedy.

Compliance with ARARs

The selected remedy will comply with all Federal and State ARARs. A list of ARARs for the selected remedy is given in Table 8. Because the remedy involves excavation of contaminated soils from OU2 and placement of them into OU1, the ARARs affecting OU1 must be considered. Where Utah is authorized to implement Federal law, Federal standards have the force of Utah Law as well.

Cost Effectiveness

Of the two remedies in which the contaminated soils are transported away from the residences in OU2, the selected remedy is the most cost effective while still providing an equal level of protectiveness. It also compares favorably with alternatives where the wastes remain on Site.

TABLE 7

COMPARATIVE ANALYSIS OF FINAL ALTERNATIVES

Criteria	Alternative 1 No Action	Alternative 2 Capping	Alternative 3 Soil Removal/ Replacement	Alternative 4 In Situ Stabilization	Alternative 5 Soil Washing
OVERALL PROTECTIVENESS					
Human Health	No significant reduction in risk	Cap reduces direct contact with contaminant	Removal of contaminated soil reduces risk of direct contact	Immobilization of metals reduces risk of direct contact	Removal of contaminated soil and regulated disposal reduces risk of direct contact
Environmental Protection	Allows continued spread of contamination	Spread of contamination curtailed by cap, and vegetation layer	Migration potential minimized due to removal of accessible contamination	Migration potential minimized due to stabilizing of accessible contamination	See Alternative 3
COMPLIANCE W/ARARs					
Chemical Specific ARAR	Does not meet air or water release standards	Air and water protection standards are met	See Alternative 2	See Alternative 2	See Alternative 2
Location Specific ARAR	Not relevant	See Alternative 1	Operable Unit 1 location specific ARARs will be met	See Alternative 1	See Alternative 3
Action Specific ARAR	Would not meet ARARs	All Federal and State regulations are met by procedures incorporated during remediation	See Alternative 2	See Alternative 2	See Alternative 2
Other Criteria/Guidance	Allows soil ingestion exceeding 500 mg/kg Pb	Protects against soil ingestion to 500 mg/kg lead	See Alternative 2	See Alternative 2	See Alternative 2
LONG TERM EFFECTIVENESS & PERMANENCE					
Magnitude of Residual Risk	Source has not been Removed. Existing risk will remain.	Residual risk from potential breach in cap	Residual risk from contaminant below existing barriers	Residual risk from contamination below stabilized soil	See Alternative 3
Adequacy and Reliability of Controls	No controls over remaining contamination	Integrity of imported soil layer will be maintained by institutional control measures. Reliability questionable.	Institutional controls are designed to prevent exposure to contamination below existing barriers	Institutional controls are designed to prevent exposure to stabilized and contaminated soils. Reliability questionable.	See Alternative 3

TABLE 7 (cont.)

COMPARATIVE ANALYSIS OF FINAL ALTERNATIVES

Criteria	Alternative 1 NoAction	Alternative 2 Capping	Alternative 3 Soil Removal/ Replacement	Alternative 4 In Situ Stabilization	Alternative 5 Soil Washing
REDUCTION OF TOXICITY, MOBILITY, VOLUME					
Treatment Process Used	None	None used	3a, 3b - None used 3c - to be determined	Chemical and physical stabilization of contaminants	Contamination extracted from soil to solution
Amount Destroyed or Treated	None	None	None	242,00 CY	242,000 CY
Reduction of Toxicity, Mobility or Volume	None	No reduction in volume or toxicity. Mobility reduced by cap	3a, 3b, - No reduction in volume or toxicity. Mobility reduced by disposal location controls. 3c - to be determined	Mobility prevented by incorporation into soil matrix. Volume increased. Toxicity decreased.	Highly contaminated volume reduced to 2,000 CY. Mobility and toxicity of soils are reduced.
Irreversible Treatment	None	No treatment used	3a, 3b - No treatment used 3c - to be determined	Initially irreversible, long term unknown.	Irreversible
Type and Quantity of Residuals remaining after treatment	No treatment used therefore no residuals remain.	See Alternative 1	3a, 3b - See Alternative 1 3c - to be determined	280,000 CY of stabilized soil	240,000 CY washed soil and 2,000 CY of metal sludge
Statutory Preference for Treatment	Does not satisfy	See Alternative 1	See Alternative 1	Satisfies	See Alternative 4
SHORT TERM EFFECTIVENESS					
Community Protection	Risk not increased by remedy implementation	Residents relocated during implementation	See Alternative 2	See Alternative 2	See Alternative 2
Worker Protection	No risk to workers	Less risk because minimal dust generated, however Level C protection required.	Level C protection required.	See Alternative 3	See Alternative 3
Environmental Impacts	Continued impact from existing conditions	Dust generated during construction	See Alternative 2	See Alternative 2	See Alternative 2
Time Until Action is Complete	N/A	3 1/2 years	3 1/2 years	3 1/2 years	3 1/2 years

18)

TABLE 7 (cont.)

COMPARATIVE ANALYSIS OF FINAL ALTERNATIVES

Criteria	Alternative 1 No Action	Alternative 2 Capping	Alternative 3 Soil Removal/ Replacement	Alternative 4 In Situ Stabilization	Alternative 5 Soil Washing
IMPLEMENTABILITY					
Ability to Construct and Operate	No construction or operation required	Standard construction techniques required to operate and construct.	See Alternative 2	Technology readily available to construct and operate stabilization process	Technology readily available to construct and operate washing process
Ease of additional remediation if needed	If monitoring indicates more action is necessary, FS/ROD process may need to be done again.	Would destroy original remedy	See Alternative 2	See Alternative 2	See Alternative 2
Ability to Monitor Effectiveness	Soil monitoring will indicate increasing contamination	Ground water monitoring will give notice of failure before significant exposure occurs	See Alternative 2	See Alternative 2	See Alternative 2
Ability to obtain approval from other agencies	No approval necessary	Minimal coordination with local, state and federal agencies needed	Moderate level of coordination with local, state and federal agencies needed	See Alternative 3	High level of coordination with local, state, and federal agencies needed
Availability of Services and Capacities	No services or capacities required	Disposal not required	Disposal capacity available	See Alternative 2	Disposal capacities to be determined
Availability of Equipment, Specialists, Materials	None required	Typical construction equipment, material, specialist needed	See Alternative 2	See Alternative 2	Specialized equipment available
Availability Technology	None required	Cap technology readily available	Required technology readily available	See Alternative 3	See Alternative 3
COST					
Capital	150,000	16,680,000	a 97,340,000 b 72,490,000 c 21,910,000	24,010,000	91,520,000
First Year Annual O&M Cost	120,000	78,000	72,000	78,000	72,000
Present Worth Cost	1,380,000	17,483,000	a 98,080,000 b 73,230,000 c 22,650,000	24,813,000	92,260,000

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TABLE 7 (cont.)

COMPARATIVE ANALYSIS OF FINAL ALTERNATIVES

Criteria	Alternative 1 No Action	Alternative 2 Capping	Alternative 3 Soil Removal/ Replacement	Alternative 4 In Situ Stabilization	Alternative 5 Soil Washing
STATE ACCEPTANCE	Not preferred	Not preferred	Preferred alternative	Not preferred	Not preferred
COMMUNITY ACCEPTANCE	Minor faction supports	Not preferred	Major support of residents and political leadership. Some reprocessors expressed concerns that nature of soils with tailings might present problems for reprocessing options at OUI.	Not preferred	Not preferred

Reference 5

**Meeting Notes Concerning Sharon Steel/Midvale Tailings Site;
From Laurie Lamb, SAIC, to Sam Vance, EPA Region VIII;
March 26, 1991**

**MEETING
SUMMARY REPORT**

SAIC Contact: **Laurie Lamb**

Date: **3/26/91**

Time: **8:00 a.m.**

Meeting at SAIC **X** Meeting at EPA

Person(s) Contacted (Organization): **Sam Vance, EPA Region VIII Remedial Project Manager**

Subject: **Sharon Steel/Midvale Tailings Clean-up**

Summary: **Overall, Sam felt the NPL Site Summary for Sharon Steel was well written. It was simply lacking the most updated information for the site.**

Operable Unit 1 has a new Remedial Investigation/Feasibility Study and Proposed Plan which came out in October. (Perhaps that's why it didn't make it into our document?) The Proposed Plan is significantly different than the one proposed in 1989. The ground-water Addendum Remedial Investigation is approximately 1,800 pages - this document (study) provided a better understanding of the site hydrology.

The State is leading the Remedial Design for Operable Unit 2 with incremental funding from EPA. A draft Remedial Design work plan is expected by May. The final is expected at the end of May.

A ROD for Operable Unit 1 should be out in December 1991. The tailings reprocessing study is ongoing at the Salt Lake, Spokane, and Rolla offices of the U.S. Bureau of Mines.

Reference 6

**Excerpts From Report of the Preliminary Assessment/Site Inspection
of Sharon Steel Corp.; Prepared for EPA by Pat Ianni, Ecology and Environment,
Field Investigation Team;
March, 15, 1983**

CO1 0913

ADMINISTRATIVE RECORD
SF FILE NUMBER

1.4

REPORT ON THE
PRELIMINARY ASSESSMENT /SITE INSPECTION
OF
SHARON STEEL CORP.

TDD NO. R8-8301-03

Submitted to: Keith Schwab, EPA-RPO
Submitted by: Pat Ianni, E & E FIT VIII
Preparation Date: March 15, 1983

SHARON STEEL CORPORATION SITE

Sharon Steel Corporation owns 260 acres of land occupied by an old smelting/milling operation and several tailings ponds. This property is located in Midvale, Utah just south of 7800 South Street. Bordering the site is a railroad track, part of the Denver and Rio Grande Western Line, along the northeast side, and 700 West Street along the southeast side. The Jordan River flows along the south and west boundaries.

The site was originally owned and operated by U. S. Smelting (later known as U. S. Smelting, Refining and Mining Company) from approximately 1910 until 1971. The smelter was shut down in 1958 and the mill ceased operations in 1971. U. V. Smelting purchased U. S. Smelting in 1971 and also operated a smelter on the north side of 7800 South Street. In 1979, Sharon Steel purchased the land south of 7800 South Street. The northern parcel, containing black slag piles from the former smelting operation, was sold to Material Services, Inc.

The original on-site operations involved receiving lead, copper and zinc ores, extracting the sulfide concentrate of these metals, and then smelting these concentrates to extract the metals in a purer form. The primary source of the ores was the Lark Mine in Lark, Utah. The facility also operated as a custom mill, receiving ores from many sources and extracting a variety of metals. Thus, the wastes (mill tailings) produced varied depending on the specific ores and refining processes used. The wastes were disposed on-site in flotation ponds located to the south and west of the mill. Sharon Steel purchased the site with the intention of reclaiming precious metals from the mill tailings; however, their only activity to date has been selling ^{tailings for the pyrite} concentrate) which is stored on-site. Currently, ten million tons of tailings, approximately 40 to 50 feet deep in places, are piled on-site.

An environmental/health problem was first detected in June, 1982, when the Utah State Department of Health was notified that citizens were gathering wind-blown mill tailings along the 7800 South Street right-of-way, and using them for sand boxes, gardens, etc. At this time, the State analyzed a sample of the "sand" which had been removed by a citizen and found it contained 4000 ppm lead. In

Reference 7

**Excerpts From Potential Hazardous Waste Site Identification
and Preliminary Assessment, Sharon Steel Corporation;
Prepared for EPA by Ecology and Environment, Field Investigation Team;
March 14, 1983**

001 086

 ADMINISTRATIVE RECORD POTENTIAL HAZARDOUS WASTE SITE IDENTIFICATION AND PRELIMINARY ASSESSMENT SE FILE NUMBER 1.4	REGION 8	SITE NUMBER (to be assigned by HQ) 000001
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NOTE: This form is completed for each potential hazardous waste site to help set priorities for site inspection. The information submitted on this form is based on available records and may be updated on subsequent forms as a result of additional inquiries and on-site inspections.

GENERAL INSTRUCTIONS: Complete Sections I and III through X as completely as possible before Section II (Preliminary Assessment). File this form in the Regional Hazardous Waste Log File and submit a copy to U.S. Environmental Protection Agency; Site Tracking System; Hazardous Waste Enforcement Task Force (EN-335); 401 M St., SW; Washington, DC 20460.

I. SITE IDENTIFICATION					
A. SITE NAME Sharon Steel Corporation		B. STREET (or other identifier) 7800 South 700 West			
C. CITY Midvale		D. STATE Utah	E. ZIP CODE 84047	F. COUNTY NAME Salt Lake	
G. OWNER/OPERATOR (if known)					
1. NAME Paul Shank, Mgr. of Engineering - Sharon Steel				2. TELEPHONE NUMBER 801-355-5301	
H. TYPE OF OWNERSHIP					
<input type="checkbox"/> 1. FEDERAL <input type="checkbox"/> 2. STATE <input type="checkbox"/> 3. COUNTY <input type="checkbox"/> 4. MUNICIPAL <input checked="" type="checkbox"/> 5. PRIVATE <input type="checkbox"/> 6. UNKNOWN					

I. SITE DESCRIPTION Former milling/smelting operation with a disposal area for sulfide flotation mill tailings used from 1910 - 1971	
J. HOW IDENTIFIED (i.e., citizen's complaints, OSHA citations, etc.) Citizen's complaint about windblown "sand" along Sharon Steel roadside.	K. DATE IDENTIFIED (mo., day, & yr.) 6-11-82

L. PRINCIPAL STATE CONTACT	
1. NAME James Salmen / Dale Parker	2. TELEPHONE NUMBER 801-533-4145

II. PRELIMINARY ASSESSMENT (complete this section last)	
A. APPARENT SERIOUSNESS OF PROBLEM	
<input type="checkbox"/> 1. HIGH <input checked="" type="checkbox"/> 2. MEDIUM <input type="checkbox"/> 3. LOW <input type="checkbox"/> 4. NONE <input type="checkbox"/> 5. UNKNOWN	
B. RECOMMENDATION	
<input type="checkbox"/> 1. NO ACTION NEEDED (no hazard) <input type="checkbox"/> 2. IMMEDIATE SITE INSPECTION NEEDED a. TENTATIVELY SCHEDULED FOR _____ b. WILL BE PERFORMED BY _____	
<input checked="" type="checkbox"/> 3. SITE INSPECTION CONDUCTED: a. TENTATIVELY SCHEDULED FOR 2-17-83 b. WILL BE PERFORMED BY E+E FIT VIII	
<input checked="" type="checkbox"/> 4. SITE INSPECTION NEEDED (low priority) with further sampling of native soil, Jordan River and groundwater	

C. PREPARER INFORMATION		
1. NAME Pat Ianni / Mark Mullis	2. TELEPHONE NUMBER 303-757-4984	3. DATE (mo., day, & yr.) 3-14-83

III. SITE INFORMATION		
A. SITE STATUS		
<input type="checkbox"/> 1. ACTIVE (Those industrial or municipal sites which are being used for waste treatment, storage, or disposal on a continuing basis, even if infrequently.)		
<input checked="" type="checkbox"/> 2. INACTIVE (Those sites which no longer receive wastes.) accept for the current sale of pyrite concentrate piled on-site.		
<input type="checkbox"/> 3. OTHER (specify): (Those sites that include such incidents like "midnight dumping" where no regular or continuing use of the site for waste disposal has occurred.)		
B. IS GENERATOR ON SITE?		
<input checked="" type="checkbox"/> 1. NO Not anymore - Generator was present from 1910-1971		
<input type="checkbox"/> 2. YES (specify generator's four-digit SIC Code): _____		
C. AREA OF SITE (in acres)		
260		
D. IF APPARENT SERIOUSNESS OF SITE IS HIGH, SPECIFY COORDINATES		
1. LATITUDE (deg.-min.-sec.)		2. LONGITUDE (deg.-min.-sec.)
-		-
E. ARE THERE BUILDINGS ON THE SITE?		
<input type="checkbox"/> 1. NO <input checked="" type="checkbox"/> 2. YES (specify): office, mill operations (several), materials receiving (truss)		

001 1980

VII. PERMIT INFORMATION

APPLICABLE PERMITS HELD BY THE SITE.

- 1. DES PERMIT
- 2. SPCC PLAN
- 3. STATE PERMIT (specify) _____
- 4. AIR PERMITS
- 5. LOCAL PERMIT
- 6. RCRA TRANSPORTER
- 7. RCRA STORER
- 8. RCRA TREATER
- 9. RCRA DISPOSER
- 10. OTHER (specify) _____

3. IN COMPLIANCE?

- 1. YES
- 2. NO
- 3. UNKNOWN

4. WITH RESPECT TO (list regulation name & number) _____

VIII. PAST REGULATORY ACTIONS

- A. NONE
- B. YES (summarize below)

9-17-82 Utah State Bureau of Air Quality issued a request for a compliance plan to control the fugitive dust at Sharon Steel

IX. INSPECTION ACTIVITY (past or on-going)

- A. NONE
- B. YES (complete items 1, 2, 3, & 4 below)

1. TYPE OF ACTIVITY	2. DATE OF PAST ACTION (mo., day, & yr.)	3. PERFORMED BY (EPA/State)	4. DESCRIPTION
Preliminary Assessment/ Site Inspection	2-17-83	ET E FIT & EPA, City, State	Visual inspection

X. REMEDIAL ACTIVITY (past or on-going)

- A. NONE
- B. YES (complete items 1, 2, 3, & 4 below)

1. TYPE OF ACTIVITY	2. DATE OF PAST ACTION (mo., day, & yr.)	3. PERFORMED BY (EPA/State)	4. DESCRIPTION

NOTE: Based on the information in Sections III through X, fill out the Preliminary Assessment (Section II) information on the first page of this form.

Reference 8

**Excerpts From Proposed Plan for the Mill Site, Operable Unit No. 1,
Sharon Steel Site, Midvale, Utah; EPA Region VIII; October 1990**



Proposed Plan for the Mill Site Operable Unit No. 1

October 1990

Sharon Steel Site
Midvale, Utah

EPA ANNOUNCES PREFERRED ALTERNATIVE FOR THE MILL SITE AND TAILINGS

The U.S. Environmental Protection Agency (EPA) has announced its preferred alternative to address contamination of *tailings*¹ and *ground water* at the Sharon Steel/Midvale Tailings Superfund site (Sharon Steel site) in Midvale, Utah. EPA is the lead agency for the cleanup at the site.

The preferred remedy for the mill site (*Operable Unit 1*) is to implement Alternative No. 4, capping with ground water treatment. However, EPA will also establish a process to continue evaluating *reprocessing* as a potential remedy. EPA will continue dust suppression activities until final implementation of a remedy is initiated. For more details about this alternative, see page 8.

The Proposed Plan

This Plan presents EPA's preferred alternative for remediating Operable Unit 1 (OU1) at the Sharon Steel site. It includes the mill site, surrounding tailings, and contaminated residential soils (from OU2) that EPA plans to incorporate into the mill site remedy.

MARK YOUR CALENDAR: OPPORTUNITIES FOR PUBLIC INVOLVEMENT

Public Meeting

January 9, 1991, 7:00 p.m.
Midvale Middle School
138 Pioneer Street
Midvale, Utah 84047

Ruth Vine Tyler Library
315 Wood Street
Midvale, Utah 84047
Hours: Mon-Thurs: 9:00 am-9:00 pm
Fr-Sat: 9:00 am-5:30 pm

Public Comment Period

October 9, 1990 to January 15, 1991

City of Midvale
City Hall
80 East Center Street
Midvale, Utah 84047
Hours: Mon-Fri: 8:00 am-5:00 pm

Send comments to

Sam Vanca, Remedial Project Manager
U.S. Environmental Protection Agency
999 18th Street
Denver, Colorado 80202

Utah Department of Health
Bureau of Environmental Response and Remediation
288 North 1460 West, Fourth Floor
Salt Lake City, Utah 84116
Hours: Mon-Fri: 8:00 am-5:00 pm

Record of Decision

March 31, 1991

EPA Superfund Records Center
999 18th Street
Denver, Colorado 80202
Hours: Mon-Fri: 8:30 am-4:30 pm

Information Repositories

The Proposed Plan, the *Remedial Investigation and Feasibility Study (RI/FS)* reports, and other documents in the *Administrative Record* are available at information repositories at the following locations (see next column):

¹ Words shown in bold italics on the first mention are defined in the glossary at the end of this Proposed Plan.

PUBLIC INVOLVEMENT PROCESS

Residents and other interested parties are encouraged to read and comment on this Proposed Plan and the Remedial Investigation and Feasibility Study (RI/FS) Reports, prepared by EPA in cooperation with the Utah Department of Health (UDOH). These documents describe site conditions and all the cleanup alternatives considered during studies conducted at the mill site.

EPA will make its final selection of an alternative only after considering State and community comments. EPA may modify the preferred alternative, select another alternative presented in this plan, or select a more appropriate alternative based on new information or public comments. Therefore, the public is encouraged to review and comment on all the alternatives identified here, as well as to provide any new information for EPA's consideration. More detailed information on all the alternatives can be found in the Mill Site Feasibility Study (FS) Report. By March 31, 1991, EPA will publish a *Record of Decision (ROD)* that responds to State and community comments and documents the rationale for its decision. This will be the second ROD for the site. The first ROD was issued on September 24, 1990 and addressed contaminated *residential soils*, Operable Unit 2 (OU2).

This Proposed Plan is prepared in fulfillment of EPA public participation responsibilities under Section 117 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986.

Comments on the Proposed Plan and FS Report may be submitted either orally or in writing at a public meeting, or you can send EPA written comments postmarked no later than January 15, 1991.

This Proposed Plan Covers

Public Involvement Process	p. 2
Site Background	p. 3
Risk Evaluations	p. 4
Cleanup Evaluation Criteria	p. 5
Summary of Alternatives	p. 5
Preferred Alternative	p. 6
Comparison of Alternatives	p. 7
Reprocessing	p. 8
Glossary	p. 9

Reference 9

**Excerpts From Remedial Investigation Addendum
for Sharon Steel/Midvale Tailings Site, Midvale, Utah,
1989-1990 Ground-water/Geochemistry Data Report;
Prepared for EPA by Camp, Dresser & McKee;
Undated**

REMEDIAL PLANNING ACTIVITIES AT
SELECTED UNCONTROLLED HAZARDOUS
SUBSTANCES DISPOSAL SITES IN A ZONE
FOR EPA REGINS VI, VII, & VIII

U S EPA CONTRACT NO. 68-W9-0021

REMEDIAL INVESTIGATION ADDENDUM FOR
SHARON STEEL/MIDVALE TAILINGS SITE
MIDVALE, UTAH

1989-1990 GROUND WATER/GEOCHEMISTRY
DATA REPORT

VOLUME I - TEXT

Work Assignment No. 003-8L40
Document Control No . 7760-003-RI-BLRT

Prepared for:

U S Environmental Protection Agency

Prepared by:

CDM Federal Programs Corporation
8215 Melrose, Suite 110
Lenexa, KS 66214

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EXECUTIVE SUMMARY

Editor's Note: This Executive Summary provides a general overview of the Remedial Investigation Addendum. The reader should note that, in simplifying the language and generalizing the conclusions for this summary, nuances that are important to the scientific reader are lost. For this reason, the body of this report is written for the scientific community and should be consulted by those readers. If any confusion between the content of this summary and the content of the final Remedial Investigation Addendum is apparent, the confusion is interpreted in accordance with the report.

1.0 INTRODUCTION

The Sharon Steel/Midvale Tailings Superfund Site (the Site) is located in Midvale, Utah, approximately 12 miles south of Salt Lake City. The study area includes: the Sharon Steel mill tailings, agricultural lands that lie to the west and south of the mill site, the southwest portion of the Midvale community, and wetlands located to the south and east of the mill tailings pile.

The Sharon Steel/Midvale Tailings Site has been divided into two Operable Units by the Environmental Protection Agency (EPA). Operable Unit One (OU1) is the Sharon Steel property, which includes the mill buildings, wetlands and tailings piles. These features were used to define the site boundary during nomination for placement on EPA's National Priorities List (NPL) as a Superfund site. Operable Unit Two (OU2) includes the residential and high public use areas in Midvale adjacent to the Sharon Steel property. OU2 boundaries were first defined by the EPA in 1988, but have been revised based on the additional sampling described in the 1990 Soils Remedial Investigation (RI) Addendum, and in the Feasibility Study (FS) for Operable Unit Two (see Volume III of the FS). The site was officially listed on the NPL in August 1990.

The 1990 Remedial Investigation Addendums (Soil and Ground Water/Geochemistry) and Feasibility Study were conducted by the EPA in response to a request by local citizens and officials from the local and State governments for a study which had more detail than the 1988 RI and FS conducted by EPA. This report presents the results of the additional ground water, ground water geochemistry, and subsurface soils chemistry studies conducted in and near the community of Midvale, Utah from

November 1989 through May 1990. The primary objectives of the ground water/geochemistry investigation are:

- To further describe the ground water system underneath the Sharon Steel/Midvale Tailings Site.
- To further describe ground water quality at the site and the extent of ground water contamination.
- To use the above information to predict the movement of contaminants, particularly arsenic, in the ground water system beneath OU1.

Figure ES-1 conceptually depicts the site and lists the major objectives for the ground water and geochemistry studies. To describe these studies, the report is divided into four sections: Introduction, Methodology, Results and Interpretation, and Summary of Results. In addition, several data appendices are included which contain results of analyses and supporting data developed during the course of the investigation.

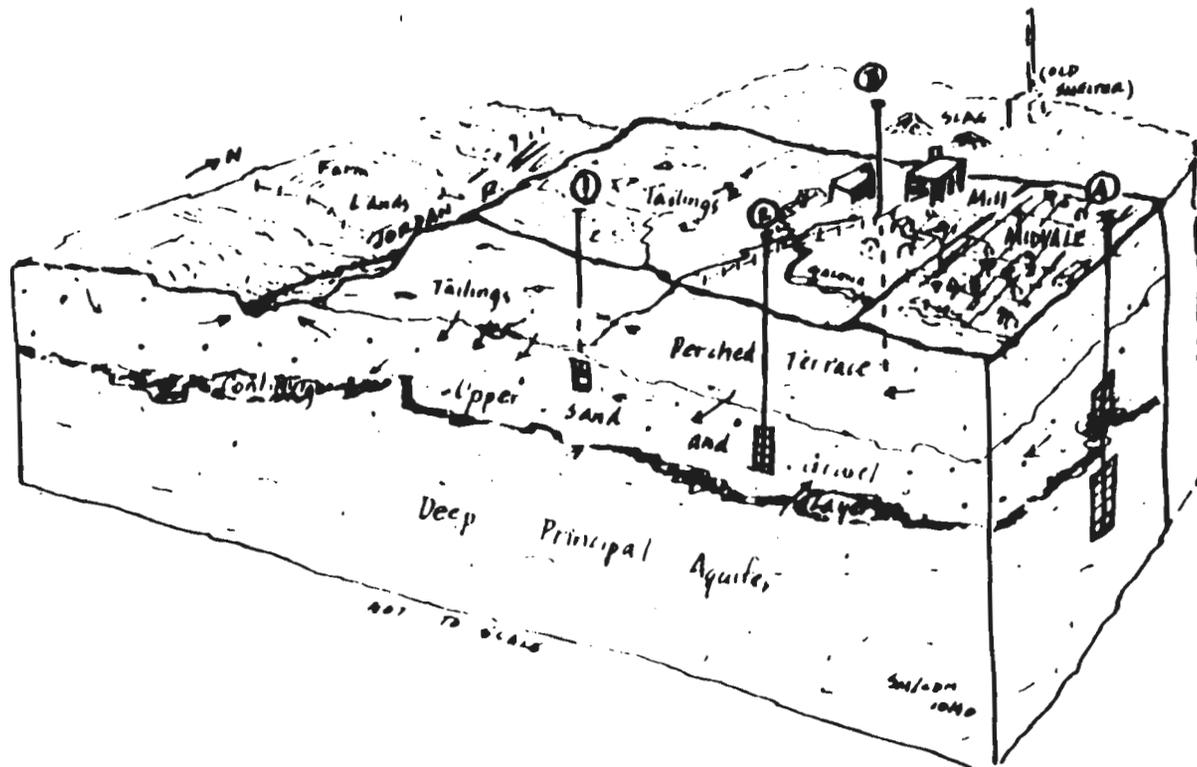
Several previous field studies have been conducted at the site (including EPA's 1988 RI); data and information from these studies have been incorporated in the current study and reported herein.

2.0 METHODOLOGY

EPA is required to document the methods and procedures to be used in data gathering prior to the field study. Often the methods are modified or changed in the field because on-site conditions are found to be different than expected. The methodology section describes the procedures that were actually used in the study.

Sixteen wells were completed to evaluate the soils and tailings of the Site study area during this investigation. The purpose of the wells was to determine subsurface geology, to provide a monitoring device for recording changes in ground water levels, and to obtain subsurface soils and ground water samples for chemical analysis. The wells were drilled and completed in a manner to preclude any cross-contamination between foreign substances and the soil and water in the drilled hole and subsequently completed well.

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THE EPA 1989-90 STUDY INCLUDED:

CONTAMINATED GROUND WATER PATHWAYS

- NW —> RIVER
- N —> SLAG (SITE BOUNDARY OR 1/4 MI OFFSITE)
- INF —> OAK ST WELL
- INCREASED PUMPING EFFECTS - MIDVALE WELLS

- 1. TO THE GROUND WATER TABLE IN THE UPPER AT
- 2. TO TAILINGS, WITH INTO UPPER SAND AND GRAVEL (U.S.G.) AQUIFER
- 3. TO THE BOUNDARY WELL INTO U.S.G. AQUIFER
- 4. TO WELL 1, 1/4 MI NORTH OF THE BOUNDARY INTO U.S.G.
- 5. TO OAK ST WELL INTO DPA, WITH INCREASED PUMPING.

Figure ES-1 - Ground Water/Geochemistry Study Summary

Subsurface geology was determined by geologists present during the well drilling. The on-site geologist described the subsurface soils as they were extracted from the drill hole. Later, geologic logs for each hole were written and compiled into a geologic cross-section which represented the subsurface geology of the site.

Subsurface soils extracted from the drill holes were recorded and sent to storage; some samples were divided, with portions sent to EPA-approved laboratories for both chemical and physical analyses. Extreme care was taken to ensure that the soils were representative of subsurface conditions and were not cross-contaminated by foreign substances.

When the target depth for a particular hole was reached, the drill tools were removed and the hole was completed as a monitoring well. Upon completion, the well was developed by surging and removing water until the well water quality stabilized.

Ground water levels were monitored periodically. The levels were measured using electronic devices that were checked for accuracy. All monitoring devices were decontaminated before and after placement in a well.

Ground water samples were obtained using pumps designed to extract water which were representative of the ground water found at the well location. Care was taken to insure that the sampling method did not influence the chemistry of the water.

A Quality Assurance (QA) program was conducted throughout the course of the study to ensure that collected samples were representative of the site. The QA program included: collecting duplicate and triplicate sample sets during the same sampling event; collecting samples (ground water) at the same monitor well during different sampling events; and creating blank samples. These procedures allowed the study team to evaluate the sampling program with respect to accuracy and precision of the results.

A long-term aquifer test was performed on a well centrally located on the mill tailings. The purpose of the test was to determine the hydraulic properties of the aquifer directly beneath the tailings. The test was conducted for 14 days, seven days of pumping and observation and seven days of observation.

only. Water pumped from the well during the test was continually monitored for water quality to ensure that no contaminants were distributed to the surface.

Laboratory, or analytical, methods were used to analyze both subsurface soil samples and ground water samples collected during the investigation. The procedures used in the analyses were developed for the EPA's Contract Lab Program (CLP), in order that the analyses provide the most accurate results possible. In addition to the CLP analyses, analyses for stable and radioactive isotopes of oxygen, hydrogen, and sulfur were performed by non-CLP laboratories. These other laboratories used procedures equally as rigorous as the CLP laboratory. Quality Control (QC) programs were required for all laboratories used in this study. QC programs are used to detect flaws in the analytical procedures so that the procedures can be amended and results of the analyses qualified.

Understanding the interactions of soils with contaminated ground water can help determine the ultimate fate of the contamination at the Site. Laboratory tests were performed by the U.S. Bureau of Reclamation (USBR) Research Center in Denver, Colorado to determine the interactions between arsenic-contaminated water from the tailings and noncontaminated subsurface soils found at the site. The laboratory tests entailed shaking a mixture of tailings water and subtailings soils together for an extended period (batch tests) and percolating tailings water through the subtailings soils (column tests). The test procedures included precautionary measures intended to mimic conditions found at the Site.

The data and results from the above analyses and studies were used in computer models which were designed to aid EPA in determining the hydrologic and geochemical characteristics of the Sharon Steel/Midvale Tailings Site. These computer programs aided in determining such characteristics as the amount of water flowing through the tailings pile and into the subsurface soils beneath; the direction and speed with which the regional ground water flows around and under the site; the chemical form which the arsenic takes in the tailings and subtailings water and soil, and finally, the expected behavior of the arsenic contamination in the ground water beneath the site.

3.0 RESULTS AND INTERPRETATIONS

3.1 HYDROGEOLOGIC INVESTIGATION

The aim of the hydrogeologic investigation at the Sharon Steel/Midvale Tailings Site was to determine the subsurface geology, hydrology and geochemistry of the Site. The information gathered was used to characterize the physical parameters of the aquifers of interest and the magnitude and direction of ground water flow. These results, in turn, were used in the computer modeling of regional ground water flow, and along with the results of the geochemical investigation, were used in the computer modeling of contaminant transport in the ground water.

Four hydrologic units or aquifers at the Sharon Steel/Midvale Tailings Site are recognized: two regionally extensive aquifers, the Deep Principal Aquifer and the Upper Sand and Gravel Aquifer, which are similar in extent, composition, and depositional history; and two local aquifers, the Perched Terrace Aquifer and the Saturated Tailings Zone.

The Deep Principal Aquifer is the main source of ground water in the Salt Lake Valley. The aquifer is composed of clay, silt, sand, and gravel deposits resulting from erosion of the Wasatch Front. The Deep Principal Aquifer is generally unconfined along the perimeter of the valley, the recharge area for the aquifer. In the central part of the valley the Deep Principal Aquifer is confined which causes the aquifer to become artesian in this region. The confining layer consists of a relatively impermeable deposit of clay, silt, and fine sand which ranges from 40 to 100 feet in thickness. The confining layer at the Sharon Steel/Midvale Tailings Site is an effective barrier to the rapid exchange of water between the Deep Principal Aquifer and the overlying Upper Sand and Gravel Aquifer. Ground water flow in the Deep Principal Aquifer beneath the site is in a northeast direction.

The Upper Sand and Gravel Aquifer has a depositional history and composition similar to the underlying Deep Principal Aquifer. Ground water usage in this upper aquifer is primarily by small domestic wells; however, in the study area some large volume public water supply wells pump water from this aquifer. At the Sharon Steel Midvale Tailings Site, the Upper Sand and Gravel Aquifer is overlain by the Perched Terrace Aquifer (described below) and the Saturated Tailings Zone (described below). A discontinuous clay and silt layer, referred to in this report as the subtailings unit, separates

the Upper Sand and Gravel Aquifer from the overlying tailings material. Ground water flow in this aquifer beneath the site is in a northwest direction, with the Jordan River being a point of discharge for the ground water.

The Perched Terrace Aquifer is composed of sediments that were deposited during a period of time when the Salt Lake Valley was covered by ancient Lake Bonneville. These lake sediments are comprised mainly of clay and silt with thin interbeds of fine sand. These sediments have been eroded in the central portion of the Salt Lake Valley by the Jordan River and form a terrace above the river. Water from precipitation will, in general, percolate through sediments and into the underlying Upper Sand and Gravel Aquifer; but sometimes, water will stop flowing and accumulate above an impermeable layer, such as a clay layer. This water is described as being "perched". Some ground water flow is into the Saturated Tailings Zone that lies in a lateral position to the Perched Terrace Aquifer (see Figure ES-1).

The Saturated Tailings Zone, which currently contains water, consists of mill tailings deposited during the refining operations of the Sharon Steel mill. Different types of ores were refined at the mill at different times; therefore, the tailings produced were of varying composition and characteristics. In general, the tailings are composed of fine grained sands and silts with interbeds of slimes (low permeability deposits produced by the refining operations). Ground water flow in the Saturated Tailings Zone is similar to the Perched Terrace Aquifer in that the water flows laterally and downward into the Upper Sand and Gravel Aquifer, with some water remaining perched above the slime layers.

3.2 QUALITY CONTROL AND QUALITY ASSURANCE (QA/QC) RESULTS

The results of QA/QC program for the study indicated that the sampling program provided samples that were usable for purposes of supporting the investigative efforts. With few exceptions, the sampling and laboratory analyses were consistent and reliable. The exceptions were not used in any subsequent analyses.

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3.3 EVALUATION OF ANALYTICAL RESULTS

3.3.1 Subsurface Soils

Results from laboratory analyses of the subsurface soils showed that metal concentrations were highest in the mill tailings, lower in the subtailings unit, and background levels in the Upper Sand and Gravel Aquifer. It appears that the metals are being leached from the tailings by ground water percolating downward. When the metal-laden ground water reaches the subtailings unit, the chemical conditions found in that unit promote the precipitation of minerals that contain the metals and sulfur. Most of the remaining metals will be adsorbed to the aquifer matrix or coprecipitate when the percolating tailings water reaches the Upper Sand and Gravel Aquifer. An exception to this scenario is arsenic. Arsenic does not appear to precipitate as a mineral in the Upper Sand and Gravel Aquifer.

3.3.2 Ground Water

The chemistry of the ground water at the Site uniquely reflects the particular aquifer in which it is found. As expected, the water in the Saturated Tailings Zone has high concentrations of metals, including arsenic; furthermore, the water has high concentrations of total dissolved solids (TDS). The ground water in the Upper Sand and Gravel Aquifer east-southeast (hydraulically upgradient) of the Site and at depth beneath the tailings in the Upper Sand and Gravel Aquifer has no detectable concentrations of arsenic and lower concentrations of TDS than in the Saturated Tailings Zone. The ground water in the Upper Sand and Gravel Aquifer immediately beneath the tailings has detectable concentrations of arsenic (over 200 parts per billion (ppb)) and TDS concentrations that are intermediate to concentrations found in the tailings water and the ground water upgradient of the Site and at depth beneath the tailings. The water chemistry of the ground water found beneath and in close proximity to the tailings reflects that tailings water is mixing with ground water immediately beneath the tailings, adversely affecting the water quality of the Upper Sand and Gravel Aquifer. The analyses of the stable isotopes of oxygen and hydrogen also reflect the mixing of tailings water and ground water immediately beneath the tailings

3.0 RESULTS AND INTERPRETATION

3.1 HYDROGEOLOGY

3.1.1 REGIONAL HYDROGEOLOGY

The regional basin-wide ground water system in the Salt Lake Valley is an important water resource to many users and consequently has been the subject of extensive study. References which have been reviewed to gain insight into the relationship between the local hydrologic conditions observed at the Sharon Steel/Midvale Tailings Site and the regional hydrologic system include Dames and Moore (1988), Hely (1971), Jensen (1985), Kennecott (1984), Marine (1964), Miller (1980), Morrison (1965), Taylor (1949), U.S.G.S. (1983b), and Waddell (1987a, 1987b)

The regional, basin-wide ground water system is generally characterized as consisting of two major hydrogeologic units within the Quaternary age valley fill in the Salt Lake Valley: the Shallow Unconfined Aquifer and the Deep Principal Aquifer. These hydrogeologic units are separated by a regionally extensive confining unit. Within the regional system, the Shallow Unconfined Aquifer is described as being comprised of clay, silt, and fine sand and less than 50 feet in thickness. The aquifer is generally reported to yield poor quality water slowly to wells. The base of the Shallow Unconfined Aquifer is marked by relatively impermeable deposits of clay, silt, and fine sand, separating it from the confined, underlying Deep Principal Aquifer. The confining layer ranges from 40 to 100 feet in thickness and generally lies between 50 and 150 feet below the ground surface (Hely, 1971).

The Deep Principal Aquifer is the main source of ground water produced by wells in the Salt Lake Valley area. The aquifer consists of both an unconfined portion, generally located at the edges of the valley near the mountain fronts, and a confined portion in the central part of the valley. Similar to the Shallow Unconfined Aquifer, the matrix of the Deep Principal Aquifer is comprised of clay, silt, sand, and gravel deposits (Hely, 1971)

Older Tertiary age deposits of claystone and mudstone underlie the Deep Principal Aquifer. These deposits consist of hard, sticky clay, clayey gravel, and thin interbeds of gravel (Dames and Moore, 1988). Although these materials are generally of lower permeability and yield, they are utilized

locally for ground water production. Hely (1971) included these deposits with the Deep Principal Aquifer for his studies. Other investigations have not included these materials with the Deep Principal Aquifer because they are considered to be relatively impermeable when compared to the overlying material (Dames and Moore, 1988). A review of well completion records from the study area shows that fewer wells have perforated zones within the underlying than overlying material

3.1.2 LOCAL HYDROGEOLOGIC SYSTEM

The local hydrogeologic system under investigation in this RI Addendum comprises a subset of the basin-wide, regional system, briefly described in the previous section. The areal extent of the local system includes the Sharon Steel/Midvale Tailings Site (the Site) itself in addition to that area within an approximate two mile radius around the Site. Available data from well boring logs were used for a fairly detailed conceptualization of the hydrogeology of the local system (see Plates 3.1-1 and 3.1-2)

Site specific investigative activities were performed in areas both on and immediately adjacent to the tailings site, providing more detailed hydrogeologic and geochemical data than previously provided in the original RI (CDM 1998). These additional focused investigative activities allowed for further, more detailed characterization and analysis of the local ground water system and provided a conceptual model by which to predict potential impacts to the local system from the tailings site.

As a result of the additional efforts, an understanding of the geology and hydrogeology as previously described in the original RI is superseded by this discussion of the local hydrogeologic system.

Four separate ground water zones have been identified and differentiated at and in the vicinity of the Sharon Steel/Midvale Tailings Site: the Perched Terrace Aquifer, the Saturated Tailings Zone, the Upper Sand and Gravel Aquifer and the Deep Principal Aquifer. The Perched Terrace Aquifer occurs within the upper portion of the lacustrine deposits that underlie the terrace area east of the tailings site. The Saturated Tailings Zone is comprised of saturated tailings in the old tailings disposal area. Both the Perched Terrace Aquifer and the Saturated Tailings Zone are underlain by the Upper Sand and Gravel Aquifer. In the original RI (CDM 1988), the Upper Sand and Gravel Aquifer was called the Diastem Aquifer, but has been renamed for this document. As described for the regional system, the Deep Principal Aquifer underlies the Upper Sand and Gravel Aquifer and is separated

from it by a confining layer. The following sections discuss the hydrogeologic characteristics of these units in detail.

Plate 3.1-1 shows the location of wells utilized in the local hydrogeologic and stratigraphic analysis. A fence diagram shown on Plate 3.1-2 illustrates the areal and vertical relationship between these units in the study area. This diagram was developed from driller's logs of water wells on file with the Utah Division of Water Rights (UDWR, 1986, UDWR, 1990b). Plate 3.1-3 depicts additional detailed geologic cross sections of the Sharon Steel/Midvale Tailings Site.

Additional information concerning the hydrologic properties of these materials is also presented in Sections 3.4 and 3.6.

3.1.2.1 Perched Terrace Aquifer

The Perched Terrace Aquifer occurs within the terrace on the east side of the Jordan River Valley. The terrace which abuts the east side of the mill tailings is comprised of native lake sediments deposited in the ancestral Great Salt Lake. The lake sediments consist of clay and silt with interbeds of fine-grained sand. The log for borehole MW-401 provides a detailed lithologic description of this unit (see Appendix B). Table 3.1-1 summarizes the results of geotechnical tests performed on selected terrace materials from borehole MW-401. These tests show that clay/silt size material of low plasticity comprises all of the samples analyzed. Visual observations of the samples in MW-401 indicate that fine-grained sand and silty sand comprise some intervals. In some cases, the sand was thinly interbedded with the silt/clay materials. The thickness of these deposits range up to 67.4 feet (MW-401) and 68.0 feet (MW-13). Thin remnants of the lake sediments are also present at some locations on the margins of the Jordan River floodplain, ranging up to 5.7 feet in thickness (A02). Fine-grained overbank deposits from the Jordan River also comprise portions of the Jordan River floodplain.

Ground water within the lacustrine deposits is most commonly associated with the sandy interbeds. Five wells (MW-403, MW-404, OW-1, MW-1 and 004) are completed in this unit. Logs from these wells indicate that a high degree of stratification exists within the lake sediments. Figure 3.1-1 is a hydrograph comparing water levels in wells MW-404, MW-403 and MW-402 which are completed in a nested fashion into the shallow lake sediments, deep lake sediments, and Upper Sand and Gravel

Aquifer (immediately underlying the lake sediments), respectively. This figure illustrates the different potentiometric levels existing within different horizons of the lake sediments and the presence of a downward hydraulic gradient. Available data indicate that ground water flow within this Perched Terrace Aquifer is generally to the west, discharging to ground surface along the exposed valleywall-forming erosional flanks of the terrace materials or discharging into the mill tailings which abut the terrace on the east side of the mill site. A minor component of discharge is also downward to the Upper Sand and Gravel Aquifer to the extent permitted by the lacustrine clay/silt layers. Recharge of the perched zone is reported to occur largely by infiltration of water from irrigation activities -- especially as a result of seepage from irrigation canals constructed within the lacustrine deposits (Hely, 1971). Water level data (Figure 3.1-2) from well 004 shows a close correlation between the presence of water in the adjacent Galena Canal and fluctuations in ground water levels. The hydrograph for well MW-404 which is screened across the upper terrace materials (Figure 3.1-1) also exhibits a rise in water table in May 1990 that could correspond with the onset of irrigation activities. Similar increases are also apparent in wells MW-1 and OW-1.

3.1.2.2 Saturated Tailings Zone

The Saturated Tailings Zone is comprised of fine-grained, metalliferous sand and silty sand generated by ore processing operations and deposited hydraulically into settling ponds constructed upon the Jordan River channel and its adjacent floodplain. In the 1950s, the Jordan River was diverted to the west to increase the area available for tailings disposal. Slime interbeds comprised of silty/clay material are present in varying amounts throughout the tailings. Table 3.1-2 summarizes the results of grain size analyses performed on tailings slime samples. The slimes consist of 80-100 percent silt/clay fines of low plasticity. Previous analyses on the sandy fraction of the tailings (CDM, 1988) show this fraction consists of 45 to 79 percent fine and very fine sand with 19 to 53 percent silt/clay fines. Coarser material comprises only 0 to 5 percent of the material. Slime interbeds range from less than 0.01 feet up to several feet in thickness.

The tailings range in thickness up to 61.6 feet (MW-752), depending upon the area of deposition. Figure 3.1-3 provides an isopach map showing the tailings thickness over the Sharon Steel/Midvale Tailings Site. The base of the tailings generally lies between 4280 and 4290 feet elevation in the Jordan River Valley. Figure-3.1-4 is a contour map showing the elevation of the base of the tailings deposit.

The tailings are usually underlain by organic-rich clay, silt, and fine sand representing overbank deposits derived from the Jordan River. Remnants of the lake sediments are believed to be present at some locations along the valley margins where stiff clay/silt is found (well 004). Up to 6.1 feet (MW-601) of subtailings material was encountered beneath the tailings. At some locations (SRK-10, MW-200 series and MW-750 series wells) the tailings directly overlie the , indicating that these wells may have intercepted the pre-1951 channel of the Jordan River. As detailed below, the subtailings unit was penetrated by drilling at eight locations during the remedial investigations.

<u>Well(s)</u>	<u>Subtailings Thickness (feet)</u>	<u>Notes</u>
001/A01	3.9	Organic rich
002/A02	5.7	Upper 0.8 feet organic rich
003/A03	3.6	Sulfur odor, upper 1.7 feet organic rich
MW-201/202	0	Subtailings absent
MW-301/302	2.35	Organics near contact
MW-601	6.1	Sulfur odor, upper 0.6 feet organic rich
MW-751/752	0	Subtailings absent
SRK-10	0	Subtailings absent

In addition, 60 boreholes drilled during the reprocessing investigations (JMM, 1989) encountered this subtailings horizon. Of these 60 boreholes, seven boreholes penetrated this horizon, indicating that at locations A-3, B-3, B-7, B-9, B-13, B-16, C-1, C-9, C-10, and C-18 the subtailings were apparently absent. One of the areas exhibiting the lack of low permeability subtailings material was east of well A-03, and MW-601.

Table 3.1-3 summarizes the results of geotechnical tests performed on the floodplain deposits which form the subtailings unit. In all cases, the materials tested were classified as clays, CL or CH, according to the Unified Soil Classification System (USCS).

Ground water generally occurs in the lower portion of the tailings deposits. At some locations -- generally where the tailings deposit is thin -- little or no ground water accumulation was observed. Thin zones of saturated materials were also observed locally, perched atop some slime layers. As much as 24 feet of saturated thickness has been observed (well 003). Drilling conducted in the Cell "D" area in 1987 did not encounter saturated tailings. Since August 1987, declining water levels

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have been observed in each of the tailing wells; this trend appears to be continuing. Figure 3.1-5 is a hydrograph of 001 which illustrates this trend. Table 3.1-4 summarizes this decline for each of the wells in the tailings. This trend is probably a result of reduced infiltration to the tailings from the surface and may be associated with the discontinuation of dust suppression efforts by water flooding the tailings surface.

Water levels in November 1987 indicated a fairly uniform ground water gradient in a general westerly direction (CDM, 1988). Figure 3.1-6 provides a water level contour map based on June 1990 measurements from the tailings monitoring wells. These recent data indicate a much different flow path within the tailings, by the presence of a steep gradient to the west between well 003 and wells 001 and SRK-10. A discontinuity or barrier within the tailings deposit, such as a buried access road or sedimentation control dike is believed to be responsible for this phenomenon. In the northwest part of the tailings the gradient becomes flatter and turns to a northerly direction. Near the west edge of the tailings, the gradient is to the east and northeast. The contours imply that a point of discharge exists near or north of well MW-754 and could be associated with the absence of subtailings materials in the area of the original Jordan River channel. This area has been the target of detailed studies to characterize the hydrologic relationships at this interface.

Figures 3.1-7 and 3.1-8 are comparative hydrographs for wells MW-201/MW-204 and MW-301/MW-303, respectively. These nested well pairs are completed in the upper and lower portions of the saturated tailings. The hydrographs indicate that a downward gradient exists within the tailings at both locations, suggesting that leakage through the subtailings material takes place.

3.1.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer occurs in the upper portion of alluvial valley fill deposits which underlie the lake sediments and tailings/subtailings material. These deposits are interpreted to be alluvial fan materials deposited by streams entering the Salt Lake Valley from the adjacent mountains prior to the rise in level of the ancestral Great Salt Lake. These deposits are present throughout the study area and generally correspond to the basin-wide, regional upper Shallow Unconfined Aquifer as described in Section 3.1.1. More recent alluvial fan materials and deltaic materials deposited within the ancestral Great Salt Lake may also be included in this unit in some locations near the perimeter

the study area. Recent Jordan River Valley alluvial sands and gravels may also be present and are included in this unit.

The Upper Sand and Gravel Aquifer at the site ranges in thickness from 118 feet (MW-651) up to 158 feet (MW-401 – see Plate 3.1-3). The aquifer is mantled by floodplain deposits and/or remnants of lake sediments over much of the Jordan Valley, but is exposed at several locations along the river channel. The base of the unit is marked by a confining layer of clay and silt which represents a significant hydrologic control at the site.

The Upper Sand and Gravel Aquifer consists of a heterogeneous mixture of fine to very coarse-sand and gravel with cobbles in some intervals. Grain size analyses (Table 3.1-5) of samples obtained from this unit show gravel content ranges up to 64 percent. More gravel may be present in some intervals, but sampling retrieval efforts were frequently unsuccessful in the more gravelly zones. Many intervals contain a significant silt/clay fraction, which in some cases appears to be of depositional origin and, in others, related to the in-place weathering of the gravels. The grain size analyses also show that the percentage of fines ranges between 3 and 34 percent. In addition, interbeds of clay, silt, fine sand, and silty sand occur within the unit. These layers usually contain more than 85 percent fines. Figure 3 1-9 shows the geotechnical test results plotted with depth to illustrate the variability of material encountered at MW-401. These interbeds are probably lenticular and discontinuous since they do not appear to significantly influence hydrologic conditions at the site. They may, however, be an important factor concerning the movement of ground water on a localized basis. The clay interbeds are interpreted to represent gaps in the deposition of high energy sediments resulting either from natural areal migration of stream channels or changes in the depositional environment, such as intervals between the episodic periods of mountain building at the margins of the valley.

Twenty-one of the ground water monitoring wells at the Sharon Steel/Midvale Tailing Site are completed in the Upper Sand and Gravel Aquifer. Most wells monitor the upper $20 \pm$ feet of the unit. Three wells (OW-3, MW-202, and MW-752) are installed deeper into the unit and are nested with shallower completions. Figures 3 1-10, 3 1-11, 3.1-12, and 3.1-13 are potentiometric contour maps developed from water levels measured in the upper portion of the aquifer in April, May, June, and July 1990, respectively. During the period April through June, 1990, the maps indicate a west to

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west-northwesterly flow direction. Contours based on the July 1990 measurements show a more northerly flow except near the eastern portion of the tailings area where flow is to the northeast

Water level measurements on a variable subset of available wells are available extending back to October 1987. The gradient on the average planar surface describing the configuration of the potentiometric surface can be determined using statistical methods to remove subjective interpretation. This best fit planar slope can be utilized in conjunction with hydraulic conductivity information to estimate ground water flow rates and velocities. The statistical method selected consisted of a least squares fit of the observed potentiometric surface elevations to the following equation:

$$z_{\text{pred}} = a + bx + cy$$
$$z_{\text{resid}} = z_{\text{obs}} - z_{\text{pred}}$$

z_{resid} minimized using least squares method

where

- z_{pred} - Least squares predicted potentiometric surface elevation
- z_{resid} - Least squares difference between predicted and observed potentiometric surface elevation
- z_{obs} - Observed potentiometric surface elevation
- a,b,c - Coefficients of plane equation
- x - Local northing coordinate of observation point
- y - Local easting coordinate of observation point

The statistical plane fits were conducted on available data with the results summarized in Figure 3.1-14 for available periods where flow was toward the Jordan River. An average gradient of 0.0024 feet/foot was calculated for all periods in the record except the July 1990 set, since use of a simple plane to describe flow direction for this set is inappropriate. This average gradient may be somewhat high, since it does not consider the reversal in flow occurring at the peak of summer pumping. A weighted average of 10 months at the 0.0024 feet/foot and 2 months at 0.001 feet/foot was used to develop the average year-round gradient of 0.0022 feet/foot.

Table 3.1-6 compares water levels measured in April, June and July 1990. In each of the wells installed in the Upper Sand and Gravel Aquifer, a decline in the potentiometric surface is exhibited. The greatest decline occurred in MW-402 (6.64 feet), with declines of greater than 2 feet at A-01, A-

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on these materials. Blebs (blisters or air bubbles) of carbonaceous and limy mottling (spotting and streaking) are commonly observed and could indicate some soil development at this horizon. The material ranges from moderately stiff to hard and contains beds and concretions cemented with calcium carbonate. Evidence of soft sediment erosion and deposition in the form of angular clasts of sediment embedded in the matrix was also observed locally.

Water level data collected at the Sharon Steel site indicates that the confining unit maintains a significant head differential between the over- and underlying sand and gravel formations. This unit appears to correlate with the regional confining layer identified in the USGS studies (Waddell, 1987b)

Based on the results of low permeability column testing (see Section 3.5.2) of similar material from the Upper Sand and Gravel Aquifer, the hydraulic conductivity of the confining unit is estimated to be less than 2.3×10^{-4} ft/day.

3.1.2.5 Deep Principal Aquifer

The Deep Principal Aquifer is also comprised of alluvial fan material similar to that which forms the Upper Sand and Gravel Aquifer, but is separated from it by the clayey confining unit described in the previous section. Only the upper 15-20 feet of the Deep Principal Aquifer has been explored at the Sharon Steel/Midvale Tailings Site. Available regional data indicate that the unit ranges from approximately 100 to 400 feet in thickness (Waddell 1987b). The base of the unit is formed by claystones and mudstones reported to be of Tertiary age (Dames and Moore, 1988).

Locally at the site, the Deep Principal Aquifer consists of sand, gravel, and clayey sand and gravel. Although no grain size analyses were performed on these materials, results would be expected to be much the same as for the Upper Sand and Gravel Aquifer. Water well logs from nearby areas indicate clayey interbeds are also common within the unit. Such layers may also constitute additional confining layers to underlying sands and gravels.

Three ground water monitoring wells (MW-401, MW-651 and MW-701) are completed in the Deep Principal Aquifer at the Sharon Steel/Midvale Tailings Site. Wells MW-651 and MW-701 flow 20-25 gpm at the ground surface under natural artesian pressure. While drilling MW-401, a 2-3 feet rise in

03, MW-451, MW-601, MW-2, and MW-13. The smallest declines were observed in wells closest to the Jordan River. These water level changes are the result of increased pumping at large capacity municipal supply wells located east and/or southeast of the site in Midvale and Sandy City. These municipal wells are known to have production zones that cross the regional confining zone, producing a portion of their discharge from the Upper Sand and Gravel Aquifer.

A comparison of water levels between nested wells MW-203 and MW-202 (Figure 3.1-15), as well as MW-751 and MW-752 (Figure 3.1-16), indicates that a slight downward gradient exists within the Upper Sand and Gravel Aquifer. An upward gradient exists between OW-3 and OW-2 (Figure 3.1-17) adjacent to the Jordan River. Upward leakage is known to take place based on the onsite upward head difference between the Deep Principal Aquifer and the Upper Sand and Gravel Aquifer. Since the Jordan River acts as the regional discharge point, an upward gradient would also be expected to exist at well nests MW-203/202 and MW-751/752. However, localized recharge from rainfall and snowmelt and seepage from the Perched Terrace Aquifer and Saturated Tailings Zone may account for the observed very slight downward gradient. Pumpage from large municipal supply wells could also be a factor in creating this gradient, since most of these wells pump only from the basal portion of the Upper Sand and Gravel Aquifer and the Deep Principal Aquifer.

3.1.2.4 Confining Unit

The base of the Upper Sand and Gravel Aquifer is marked by a zone of fine-grained sediment. At the site, this zone was observed to range in thickness from 6.5 feet at MW-401 to 24.1 feet at MW-651. Drillers' logs from water wells in the site study area show the presence of similar material, which appears to correlate to this unit. Plate 3.1-4 shows interpreted extent and thickness of these materials. The unit may be comprised of several coalescing layers or from a single quiescent episodic deposition of fine-grained material. Whichever, the unit influences ground water movement by creating a local aquitard, or confining unit, between the Upper Sand and Gravel Aquifer and the Deep Principal Aquifer. This confining unit appears to roughly correspond to the regionally extensive confining unit (see Section 3.1.1) although, locally, it is thinner than expected based on the regional information.

As observed in the exploratory borings at the Sharon Steel site, the confining unit consists of clay, silt, and silty/clayey sand and gravel. Table 3.1-7 presents the results of geotechnical tests performed

Although these studies did not differentiate ground water usage by aquifer, they indicated that the Shallow Unconfined Aquifer is seldom used for water supply because of poor water quality and small yields to wells. In contradiction, within the local Sharon Steel/Tailings Site study area, the Upper Sand and Gravel Aquifer is utilized to a significant extent due to the aquifer's high permeability and good water quality. A number of municipalities, including Midvale and Sandy City, have wells that produce from both zones, the Upper Sand and Gravel and Deep Principal Aquifers. Regionally, the most productive wells are reported to be located in the unconfined part of the Deep Principal Aquifer near the mountains, where the aquifer is comprised of thick, coarse-grained deposits.

To characterize local ground water use in the Sharon Steel/Midvale Tailings Site study area, records from the Utah Division of Water Rights were reviewed in an area extending three miles north (generally down gradient) and two miles east, south, and west of the site (UDWR, 1990a). A listing of underground water rights is included in Appendix G. A total of 625 ground water appropriations have been listed for this area. Of these, 587 are for wells and 38 for underground drains, springs, and sumps. Some wells are suspected of having multiple water right numbers and multiple listings under different, inaccurate, or preliminary locations. Additional wells may also exist which are not included in the State records. Some wells represent appropriated water which has not yet been developed by the water right holder. Other wells listed may now be out of service or abandoned. No inventory has been made to identify these situations in the field in the Midvale vicinity.

These records do not identify the aquifer from which the wells produce ground water. However, boring logs available for some of the wells usually denote the perforated intervals. Upon review many of the shallower wells and some of the deep supply wells produce ground water, at least in part, from intervals correlating to the Upper Sand and Gravel Aquifer. USGS modeling estimates that annually 89 percent of the ground water production is from the Deep Principal Aquifer. During summer months, when production is increased due to irrigation and domestic demands, approximately 84 percent is produced from the Deep Principal Aquifer. Many of the municipal wells are operated only during the summer months to supply the increased demands upon the municipal systems (Goodyear, 1990).

Table 3.1-9 provides a summary of the State records by location and well use. The largest number of wells are located in Sections 18, 19, and 30 of Township 2 South, Range 1 East (the southwest part of Murray City). Most of these wells are relatively shallow (less than 150 feet deep), small-capacity

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the water level was also observed in the borehole when this unit was penetrated indicating a strong upward gradient occurs across the confining unit. Figures 3.1-18, 3.1-19, and 3.1-20 are potentiometric surface contour maps based on water levels collected from these monitoring wells in April, May, and June 1990, respectively. Each map shows a gradient to the northeast at about 0.004 feet per foot. Figure 3.1-21 provides a comparable map presenting water levels measured in July 1990. This figure shows the gradient to be in a more easterly direction and steeper at 0.014 feet per foot.

The ground water in the Deep Principal Aquifer occurs under generally confined conditions. The hydrographs in Figures 3.1-22, 3.1-23, and 3.1-24 indicate the presence of an upward gradient from the Deep Principal Aquifer to the Upper Sand and Gravel Aquifer in all of the nested well pairs except at MW-401/MW-402 in July 1990. At this location, the potentiometric level in well MW-401 has declined 13.31 feet between April 29 and July 7, 1990 with 10.27 feet of the decline occurring since June 12. The water level in MW-402, completed in the Upper Sand and Gravel Aquifer, has also declined 6.19 feet between April 29 and July 7 with 4.88 feet of the decline occurring since June 11. The July data show that a downward gradient existed between MW-402 and MW-401 at that time. This gradient reversal is probably a result of increased pumping by high capacity public water supply wells located east and southeast of the site.

3.1.3 GROUND WATER USE

Detailed U.S. Geological Survey (USGS) studies have been performed to estimate ground water use in the Salt Lake Valley, notably those by Hely (1971) and Waddell (1987b). Figure 3.1-25 displays these estimates by type of usage on a yearly basis between 1969-1982. Ground water production by wells has ranged from approximately 105,000 acre-feet in 1970 to 130,000 acre-feet in 1980. Hely and Waddell's estimates show the largest increase in usage to be for public supply and institutional purposes. Field inspection in 1983 by Waddell indicated that 15 percent fewer wells were in use in 1983 than in 1968. Changing land use patterns manifested by the replacement of individual household wells used for domestic and other purposes by public water supplies was cited as the cause for this reduction (Waddell, 1987b). Table 3.1-8 summarizes the average annual ground water usage of the Salt Lake Valley from 1964-1968 and 1969-1982. This table shows that an average 117,000 acre-ft/year of ground water were produced from the Salt Lake Valley between 1969 and 1982. Production for this period was approximately 9 percent higher than for the period 1964 through 1968

The three wells completed in the deep portion of the Upper Sand and Gravel Aquifer beneath the tailings site have arsenic concentration values (Figure 3-3-7c) which are very low and are generally below the detection limit of the instruments used to measure them (see Section 2.9.2.1). It is apparent from these values that the arsenic release has not reached this zone or that the arsenic concentrations have been diluted to values below the detection limit.

Wells completed in the Upper Sand and Gravel Aquifer upgradient of the tailings pile indicate little to no arsenic concentrations (Figure 3-3-7d).

Water from wells completed in the Perched Terrace Aquifer have arsenic concentrations ranging from 4.2 $\mu\text{g/l}$ to 31.6 $\mu\text{g/l}$ (Figure 3-3-7e). The latter value is from OW-1 which is located on the Sharon Steel/Midvale Tailings Site and could possibly have been influenced by the distribution of tailings on the property.

Water from private wells and wells completed in the Deep Principal Aquifer show little to no arsenic concentrations (Figure 3.3-7f).

3.3.2.2 Total Dissolved Solids

Values for total dissolved solids (TDS) for all samples obtained during 1990 from ground water monitoring wells are found in Figures 3-3-8a through 3.3-8f. In general, the tailings waters (Figure 3-3-8a) have the highest TDS values and the waters from the private wells and the Deep Principal Aquifer (Figure 3.3-8f) have the lowest TDS values. Waters from wells completed in the Upper Sand and Gravel Aquifer just beneath the tailings pile (Figure 3.3-8b) have TDS values that are slightly higher than both the wells completed in deeper zones beneath the tailings (Figure 3.3-8c) and wells upgradient from the tailings (Figure 3.3-8d). The Perched Terrace Aquifer wells have similar TDS values (Figure 3.3-8e) to the other upgradient wells with the exception of MW-1, which has an exceptionally high TDS value.

3.3.2.3 Trilinear Diagrams

Trilinear diagrams permit the cation and anion compositions of many samples to be represented on a single graph by which major groupings or trends in the data can be discerned visually. The SDS data

Concentrations of arsenic for waters sampled in the different aquifers is of interest in this study. Arsenic concentrations and concentrations of total dissolved solids (TDS) are discussed in the Sections 3.3.2.1 and 3.3.2.2, respectively.

Graphical and statistical evaluations have been employed to interpret the standard chemical analyses. The graphical methods were used to group the waters by plotting the major ions on trilinear diagrams. (Section 3.3.2.3) and plotting iron and arsenic species on Eh vs. pH diagrams (Section 3.3.2.6). Statistical methods were also used to group the waters by employing cluster and factor analyses (Section 3.3.2.4). The results of isotope analyses of the ground waters are discussed in Section 3.3.2.5.

3.3.2.1 Arsenic Concentrations in Ground Waters

Arsenic concentrations are summarized in Table 3.3-1 and in Figures 3.3-7a through 3.3-7f. These tables and figures list all samples collected from monitoring wells (filtered through 0.45 micron filters) and the associated arsenic values measured by the CLP laboratory in 1990. Arithmetic means are presented in Table 3.3-1 for wells with multiple arsenic values and for each aquifer. Means were calculated on a conservative basis with values in the data set below detection set to the detection limit for the computations. The aquifer means are calculated using the well means. Arithmetic means are used here for strictly qualitative comparison purposes, since the sample populations rarely follow a normal distribution.

The wells completed in the Saturated Tailings Zone have the highest values for arsenic concentrations, with an average value of 920 $\mu\text{g/l}$ (Figure 3.3-7a).

The wells completed in the shallow portion of the Upper Sand and Gravel Aquifer beneath the tailings (also described using the term, subtailings) have arsenic concentrations that range from less than 1.0 $\mu\text{g/l}$ to 288 $\mu\text{g/l}$, with an average value of 68 $\mu\text{g/l}$ (Figure 3.3-7b). The arsenic concentrations are highest at MW-601 and A-03 which are in close proximity to one another. If only one value of arsenic concentrations for both wells is used then the average value for the shallow wells is 49 $\mu\text{g/l}$. These values are significantly higher than any of the upgradient wells, indicating release to the aquifer from the tailings.

normalized (see Table 3.3-3). A cluster analysis was performed on this subset and is presented in Figure 3.3-10a. Another cluster analysis was performed on a second subset of the SDS data containing log normalized values of all major metals with data consistently above the detection limit. Table 3.3-2 lists the metals data used before they were log normalized. The results of the metals data cluster analysis are presented in Figure 3.3-10b.

The dendrograms from both cluster analyses places the chemical analyses of samples obtained from Saturated Tailings wells (Group 1) and the Upper Sand and Gravel Aquifer below the tailings (shallow completion - Group 2) wells in closer relationship to each other than chemical analyses from other wells. This suggests a chemical relationship between waters in the tailings and waters in the Upper Sand and Gravel Aquifer just below the tailings, with a possibility that the water in the Upper Sand and Gravel just below the tailings may be a result of mixing between the tailings water and water from the Upper Sand and Gravel Aquifer upgradient of the tailings area.

Factor analysis is a mathematical method which reduces multivariables of a problem to a manageable size. In this study, factor analysis was used to consolidate the relationships of the log normalized SDS major ion data (Table 3.3-4) into four factors (Table 3.3-5), with similar data having similar factor values. All major ions were chosen because they were thought to have the greatest variability between samples. A plot of the values from the first factor (Figure 3.3-11) indicates a close relationship among the wells in Group 1 and Group 2.

3.3.2.5 Stable Isotopes and Tritium

Elemental isotopes in the environment (Table 3.3-6) may act as indicators of the source and history of the material being studied. The isotopes of oxygen and hydrogen are used in ground water studies as indicators of the source of the water. Sulfur isotopes are used as indicators of either a mineralogical or biological source of the sulfur in the water. In general, isotopic fractionation occurs during several different kinds of chemical reactions and physical processes:

- Isotopic exchange reactions involving the redistribution of isotopes of an element among different molecules containing that element.
- Unidirectional chemical reactions in which reaction rates depend on isotopic compositions of the reactants and products. Examples of unidirectional reactions are precipitation and dissolution of minerals and biological reduction of elements.

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from this study are plotted in Figures 3.3-9a through 3.3-9f. The TDS values shown on the figure are calculated TDS values vs. the actual measured values. Figure 3.3-9a has plotted, in addition to the compositions of the Saturated Tailings waters, the outlines of the groupings from the other diagrams.

The results from the trilinear diagrams indicate that there are three groups of waters at the Sharon Steel/Midvale Tailings Site:

- Group 1 - Saturated Tailings. The ground water in the mill tailings aquifer are classified as CaSO_4 type waters.
- Group 2 - Upper Sand and Gravel Aquifer beneath tailings (shallow completions). This water is classified as a calcium-sodium sulfate water.
- Group 3 - Upper Sand and Gravel Aquifer beneath tailings (deep completions), Perched Terrace Aquifer and Upper Sand and Gravel Aquifer upgradient of site (background). This water is classified as a calcium-sodium chloride-sulfate water, but generally does not have a dominant anion or cation.

The water sampled from the Deep Principal Aquifer is scattered on the diagram and does not group together, but generally falls in the same area as the non-tailings waters (Figure 3.3-9a).

It appears from the diagrams that the water from Group 2 has a major anion-cation composition intermediate to the Group 1 and the Group 3 waters.

3.3.2.4 Statistical Evaluations

Two statistical evaluations were performed on the ground water data: cluster and factor analyses. The geologic applications and mathematical basis of these techniques are described in Davis (1973). In essence, cluster analysis places objects (in this case the water sample analyses) into more or less homogeneous groups such that the relation between the groups is revealed. The result of cluster analysis using the SDS data from this study are shown on two dendrograms (Figure 3.3-10a and 3.3-10b).

The cluster analysis was performed on two subsets of the SDS data. The first subset contained all parameters except those that were consistently below the detection limits. The data set was then log

- The extremely low vertical hydraulic conductivity of the aquitard separating the Deep Principal and Upper Sand and Gravel Aquifers limits movement of water, even under gradient reversal conditions
- Aquifer testing at the Site indicates that the Upper Sand and Gravel Aquifer responds as a non-leaky system and does not show recharge boundary effects from the Jordan River for durations of pumping of a least a week. Hydraulic characteristics of the Upper Sand and Gravel Aquifer at the site indicate that the aquifer has a hydraulic conductivity of 135 to 208 ft/day and responds as an aquifer which is transitional between semi-confined and unconfined.
- The Saturated Tailings Zone overlies low permeability clays or slimes, except where it overlies the buried channel of the Jordan River. The tailings are currently draining and are anticipated to stabilize at a level that will allow discharge of all water percolating from the surface to the Upper Sand and Gravel Aquifer. Steady state discharge from the tailings to the Upper Aquifer is estimated to be 0.08 feet/year with the current surface management practices

4.2 GEOCHEMISTRY

- The migration of contaminants from the tailings into the subtailing soils and aquifer materials is shown by chemical analyses of solid materials and water from below the tailings. Contaminants (including arsenic, lead, and zinc) have migrated from the tailings into the material below the tailings
 - This contaminant migration is shown by analyses of solid samples in 003/A03, MW-201/202, MW-301/302, MW-751 and MW-601. Samples from these borings showed elevated concentrations of the contaminants in samples immediately below the tailings with concentrations decreasing with depth below the tailings. At MW-201/202, the contamination is contained in a mixed zone of native materials and tailings. At MW-601, MW-301/302, and 003/A03 the subtailings material is a low permeable layer including an organic-rich, reducing zone at the top of the layer. In

4.0 SUMMARY OF RESULTS

This section provides a summary of results of studies described in earlier sections.

4.1 HYDROGEOLOGY

- Four zones of hydrologic significance are present at the Site in the subsurface:
 - the Deep Principal Aquifer
 - the Upper Sand and Gravel Aquifer
 - the Perched Terrace Aquifer
 - the Saturated Tailings Zone

- An areally extensive aquitard separates the Deep Principal Aquifer and the Upper Sand and Gravel Aquifer

- Ground water in the Deep Principal Aquifer flows toward pumping centers to the northeast of the site

- The Upper Sand and Gravel Aquifer is used for drinking water supply in the area east and southeast of the site. production from this aquifer reaches a peak during peak summer pumping periods. Throughout most of the year, ground water in the Upper Sand and Gravel Aquifer beneath the site flows west to northwest and discharges into the Jordan River; during the peak summer pumping season, the flow changes to a more northerly and easterly direction

- An upward gradient exists from the Deep Principal Aquifer to the Upper Sand and Gravel Aquifer at most locations and times of the year near the Site. An exception to this was observed at the MW-401/MW-402 site, where a significant downward gradient developed due to peak summer pumping from surrounding municipal supply wells. Future increase in pumping may lead to a more widespread gradient reversal.

upgradient wells. This result suggests that the water below the tailings in the Upper Sand and Gravel Aquifer resulted from mixing of tailings and upgradient water.

- Factor analyses using a combination of the concentrations of all major anions and cations result in distinctly different factor scores for water from wells completed upgradient of the site in the Upper Sand and Gravel Aquifer and for water from wells completed in the Saturated Tailings Zone. Waters from the shallow portion of the Upper Sand and Gravel Aquifer below the tailings have factor scores between the upgradient and tailings waters. This evaluation supports that waters in the shallow portion of the Upper Sand and Gravel Aquifer wells result from mixing of tailings and upgradient type waters
- Cluster analyses using metal concentrations and all parameters with detectable concentrations indicate that waters from the tailings wells and waters from the upgradient Upper Sand and Gravel Aquifer cluster into distinct groups. Waters from the upper portion of the Upper Sand and Gravel Aquifer below the tailings also cluster together in a group between the upgradient and tailings groups. Waters from the lower portion of the Upper Sand and Gravel Aquifer below the tailings group cluster with the upgradient waters from the Upper Sand and Gravel Aquifer.
- Evaluation of the results from analyses of hydrogen and oxygen isotopes (δD and $\delta^{18}O$) indicate that waters from the tailings and waters from the Upper Sand and Gravel Aquifer upgradient from the Site are distinctly different. Waters from the upper portions of the Upper Sand and Gravel Aquifer below the tailings have δD and $\delta^{18}O$ between the tailings and upgradient waters.
- Analyses of arsenic(III) by differential pulse polarography indicates that the majority of the arsenic (90 to 100 percent) in the water from the tailings wells is arsenic(III). The majority of arsenic (67 to 79 percent) in well MW-601 completed in the upper portion of the Upper Sand and Gravel Aquifer below the tailings is arsenic(V). Most waters from the shallow portion of the Upper Sand and Gravel Aquifer have a higher percentage of arsenic (V) than the tailings wells. The measured values are not consistent with

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this reduced zone, sulfides have precipitated. At MW-201/202 and MW-751, the low permeable zone is not present and contaminants migrate directly into the Upper Sand and Gravel Aquifer.

- Contaminants (including TDS, arsenic, and zinc) have migrated from the water in the tailings through the subtailings material or directly into the water contained in the Upper Sand and Gravel Aquifer.
 - Elevated concentrations of these parameters are observed in selected wells completed in the upper portion of the Upper Sand and Gravel Aquifer below the tailings. These wells include OW-2, A01, A03, MW-601, A02, MW-302, MW-203, MW-751, and MW-753. Concentrations of arsenic ranged from $< 1 \mu\text{g/L}$ in 203 to $288 \mu\text{g/L}$ in 601 in selected samples. Wells besides those representing the low and high values of arsenic concentrations (MW-203, MW-302 and A03, MW-601 respectively) typically ranged from 10 to $70 \mu\text{g/L}$. TDS values ranged from 1,530 mg/L to 2,420 mg/L. The concentrations of arsenic currently observed at selected wells below the tailings are elevated above levels in water from wells upgradient of the tailings site completed in the Upper Sand and Gravel Aquifer (wells MW-402, MW-451, MW-501, MW-551, MW-552, and MW-702). All these upgradient wells have arsenic concentrations at or near the detection limit (usually $1 \mu\text{g/L}$).
- The observed values of arsenic and TDS in the shallow portion of the Upper Sand and Gravel Aquifer below the tailings suggest that the waters at these locations resulted from the mixing of water from the Upper Sand and Gravel Aquifer (originally represented in quality by upgradient wells) with tailings water. Other evaluations which support this conclusion are summarized below:
 - Construction of trilinear diagrams for major cations and anions indicates that the waters from the upgradient wells completed in the Upper Sand and Gravel Aquifer and waters from wells completed in the Saturated Tailings Zone plot in different fields. Water wells completed in shallow portions of the Upper Sand and Gravel Aquifer below the tailings plot in a field between the fields of the tailings and

thermodynamic calculations, indicating an incomplete thermodynamic data base, high measured Eh values or nonequilibrium conditions. However, the concentrations of iron(II) and iron(III) generally agree with thermodynamic predictions.

- Batch test results using contaminated water from the tailings (arsenic concentrations = 1,035 $\mu\text{g/L}$) and non-contaminated soil indicates that the arsenic adsorption properties are quite variable for the different materials at the site.

4.3 MODELING

- The results of the solute transport modeling effort demonstrate that concentrations of arsenic in the shallow portion of the Upper Sand and Gravel Aquifer beneath the tailings and downgradient of the tailings have already or will reach the MCL in the future.
- Scenarios for hypothetical receptor wells located on-site indicate that the arsenic MCL has already been reached. This agrees with the arsenic concentrations found in waters from wells completed in the shallow subtailings portion of the Upper Sand and Gravel Aquifer
- Scenarios for hypothetical receptors under conditions of a northerly hydraulic gradient indicate that
 - Arsenic concentrations for waters in a receptor well at the northern edge of the Site will reach the MCL before the year 2000.
 - For a receptor 1,000 feet north of the Site, the arsenic MCL will be reached in approximately 10 years after the onset of the northerly hydraulic gradient.
- A receptor well located in-line with the Oak St. well will have concentrations of arsenic at or above the MCL in approximately 425 years after the time that the hydraulic gradient reverses and the Jordan becomes a losing river.

See

Reference 10

**Excerpts From Feasibility Study Operable Unit 1, Mill and Tailings Site,
Sharon Steel/Midvale Tailings Site, Midvale, Utah, Volumes I and II;
Prepared for EPA by Camp, Dresser & McKee;
October 1990**

REMEDIAL PLANNING ACTIVITIES AT
SELECTED UNCONTROLLED HAZARDOUS
SUBSTANCES DISPOSAL SITES IN A ZONE
FOR EPA REGIONS VI, VII, & VIII

U.S. EPA CONTRACT NO. 68-W9-0021

DRAFT FINAL

VOLUME I

FEASIBILITY STUDY INTRODUCTION

SHARON STEEL/MIDVALE TAILINGS SITE
MIDVALE, UTAH

Work Assignment No.: 003-8L40
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Prepared for:

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This document has received internal technical review by EPA, CDM/FPC, and the Sharon Steel/Midvale Technical Advisory Committee. Their comments and revisions are incorporated in this copy. This document is therefore termed Draft Final, and will be finalized following public review and comment.

- o Direct ingestion of tailings or contaminated surface soils
- o Dermal absorption of tailings or contaminated surface soils
- o Ingestion of contaminated ground water
- o Ingestion/contact with contaminated surface water and sediments
- o Inhalation of tailings-contaminated dust
- o Ingestion of produce grown in contaminated soils or irrigated with contaminated ground water

The following sections describe these pathways of exposure.

Direct Contact

Direct contact with tailings and soil is probably the most common exposure route for the chemicals at the Sharon Steel/Midvale Tailings site. Direct contact through ingestion may result from the actual consumption of tailings and soil or through mouthing of soiled objects or extremities. Dermal absorption is also a direct contact pathway; but is limited to instances when exposed cuts or scrapes allow absorption through the skin. Absorption of the contaminants of concern through unbroken skin is not considered significant.

Ground Water

Ground water also provides a pathway for the transportation of contaminants leached from the soil or tailings. Receptors using the ground water as a drinking water supply or for crop irrigation would then be exposed to risk.

Surface Water and Sediments

The surface water system represents a potential route of exposure. Both the Jordan River and a 22-acre wetland on the Sharon Steel property are subject to metal releases from airborne tailings and soil, as well as the shallow unconfined aquifer. Dissolved and suspended metals would,

REMEDIAL PLANNING ACTIVITIES AT
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DRAFT FINAL

VOLUME II
FEASIBILITY STUDY - OPERABLE UNIT 1

MILL AND TAILINGS SITE

SHARON STEEL/MIDVALE TAILINGS SITE
MIDVALE, UTAH

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Element	Local Background ^a Soil		Contaminated Surface Soil				Tailings		
	Terrace	Floodplain	Terrace	Floodplain	Residential	Hill Site	Surface (Oxidized)	Surface (Dunes)	Subsurface (Unoxidized)
	(mg/Kg)								
Aluminum	13,669.0	7,283.0	12,461.0	10,883.0	9,560.0	9,267.0	3,982.0	3,270.0	3,002.0
Antimony	6.1	<5.5	6.4	8.8	5.7	72.7	73.5	16.0	17.0
Arsenic	15.2	5.7	31.5	40.7	65.5	158.0	425.1	320.2	411.2
Cadmium	3.2	2.0	5.4	7.1	12.5	27.6	46.8	37.3	36.4
Chromium	18.0	11.9	17.8	18.6	15.8	29.8	25.4	17.0	18.3
Copper	81.4	40.7	160.6	344.6	195.1	324.1	298.5	760.2	578.1
Lead	97.0	78.6	373.2	536.8	722.0	2,100.0	6,278.0	5,470.0	5,209.0
Manganese	454.3	249.5	466.0	452.8	508.9	833.7	1,199.0	1,497.0	2,032.0
Silver	1.4	<1.4	1.9	2.8	3.0	10.4	26.9	24.9	27.1
Thallium	BDL ^d	BDL	BDL	1.6	1.4	2.0	3.3	3.2	8.0
Zinc	124.3	100.3	320.8	537.4	591.8	2,143.0	4,821.0	6,048.0	6372.0
n	4	5	23	17	22	31	13	22	4

Element	Sediment		Jordan River Surface Water		Perched in Tailings	Ground Water ^c		Air Data From December 1987 Event	
	Upstream	Downstream	Upstream	Downstream		Upper Sand & Gravel/Shallow	Deep Princ. Aquifer/ Residential Wells	Upwind	Downwind
	(mg/Kg)				(ug/L)		(mg/Kg)		
Aluminum	1492.0	3365.0	1010.0	1030.0	27.0	25.84	26.15	-	-
Antimony	<29.0	<34.0	<60.0	<60.0	<28.0	30.18	29.59	-	-
Arsenic	1.5	16.1	14.0	10.0	7.63	28.14	1.64	314.0	438.0
Cadmium	<1.5	2.2	.36	.44	3.0	3.0	3.0	<3.0	25.2
Chromium	3.8	7.3	<3.0	<3.0	5.0	5.0	5.67	8.4	108.0
Copper	4.0	151.0	7.0	10.0	6.24	5.93	8.08	24.0	787.0
Lead	5.8	115.0	6.0	11.0	1.78	1.19	1.28	37.0	3,865.0
Manganese	38.2	128.9	53.0	53.0	163.79	218.65	9.16	-	-
Silver	<2.0	3.0	<0.2	<0.2	5.0	5.23	5.16	-	-
Thallium	BDL	BDL	<10.0	<10.0	4.81	8.17	2.89	-	-
Zinc	16.0	331.0	19.0	20.0	7.38	49.96	8.26	90.0	5,422.0
n	3	3	1	1	8	9	5	2	5

^a "Local Background" as defined in the RI (CJM 1988b).

^b n = Number of samples

^c Samples were collected other locations within the upper sand and gravel aquifer. See Table 1.7.

^d BDL = below detection limit.

APPENDIX A

**BASELINE RISK ASSESSMENT
FOR GROUND WATER
SHARON STEEL/MIDVALE TAILINGS SITE
MIDVALE, UTAH**

OCTOBER 1990

5.2 FUTURE MODELED WATER QUALITY SCENARIOS

Table 5-3 summarizes carcinogenic risks from arsenic in ground water for the future on-site and downgradient domestic well scenarios at years 2020 and 2090. The on-site well scenario and downgradient domestic well (3) have risks ranging from 4×10^{-3} to 9×10^{-3} associated with them for the years 2020 and 2090 respectively. These risks exceed EPA's allowable risk range of 10^{-6} to 10^{-4} . The downgradient domestic well (5), however, has a risk of approximately 1×10^{-4} for the years 2020 and 2090 which falls within EPA's allowable risk range.

Table 5-4 summarizes the CDI:RfD ratios for arsenic for future scenarios. The ratio ranges from 2.3 - 5.0 for the on-site domestic well and the downgradient domestic well (3). The ratio associated with ingestion of ground water from downgradient domestic well (5), however, is less than one, indicating that adverse noncarcinogenic health effects are unlikely to occur as a result of this exposure.

5.3 UNCERTAINTIES ASSOCIATED WITH RISK CHARACTERIZATION

The uncertainties associated with the risk characterization information presented above are limited. For noncarcinogenic effects, the CDI:RfD ratios are within the same order of magnitude as or greater than the RfD safety factor of one. This indicates that there is only a small degree of uncertainty surrounding the potential for noncarcinogenic adverse effects from exposure to arsenic calculated according to the exposure scenario defined in this RA. Although the arsenic RfD is currently under review by EPA, its safety factor of one indicates that because the study was based on a human epidemiological study on a large population, relatively little uncertainty exists.

EPA has calculated a CPF for ingested inorganic arsenic of 1.75 based on long term epidemiological data on a large population in Taiwan. There is data which suggests, however, that at low doses, inorganic arsenic

5.0 RISK CHARACTERIZATION

This section provides quantitative risk estimates for the ground water ingestion pathway. Both carcinogenic and noncarcinogenic risks from arsenic are evaluated. Carcinogenic risks are calculated for each scenario by multiplying the CDI by the cancer slope factor (CSF) for arsenic as follows:

Excess lifetime cancer risk = CDI x CSF

Where

CDI = Chronic daily intake (mg/kg/day)

CSF = $1.75 \text{ (mg/kg/day)}^{-1}$

Noncarcinogenic risks are evaluated by the ratio of the CDI to the reference dose (RfD) for arsenic. The RfD for arsenic, 1×10^{-3} mg/kg/day (USEPA 1990b), has recently been withdrawn but will be utilized here for purposes of comparison with the soil/tailings RA. Ratios which exceed one indicate that adverse health effects may occur. Ratios less than one suggest that adverse health effects are unlikely to occur.

5.1 CURRENT WATER QUALITY SCENARIOS

Table 5-1 summarizes carcinogenic risks from arsenic in ground water for the on-site and downgradient domestic well scenarios. Both the on-site scenario at 4.4×10^{-3} and the downgradient scenario at 1.2×10^{-3} exceed EPA's allowable risk range of 10^{-6} to 10^{-4} .

Table 5-2 summarizes the CDI:RfD ratios for the current water quality scenarios. The hazard index for arsenic is 2.5 for the on-site well and 0.7 for the downgradient well.

6.0 INTEGRATION OF GROUND WATER PATHWAYS WITH OTHER PATHWAYS

The soils/tailings RA (Volume III, Appendix B) characterized risks associated with ingestion of contaminated soils, tailings, dust, and produce as well as inhalation of contaminated airborne particulates under both current and future land use scenarios. To accurately evaluate total potential future risk, it is necessary to combine the risk from soils/tailings pathways with the risk from the ground water pathway for the future land use scenarios.

Future site use scenarios in the soils/tailings RA assume future residential use of the millsite. These future site use risks are most appropriately combined with the ground water risk estimated for an on-site domestic well.

6.1 CURRENT SCENARIOS

Table 6-1 summarizes the risks from all pathways for the current scenarios. The on-site residential scenario assumes residential use of the millsite including construction of a shallow domestic well. The off-site residential scenario assumes ground water exposure from a shallow domestic well near the site boundary, downgradient of the site and soils/tailings exposure from off-site residential areas. For the on-site residential scenario, the CDI:RfD ratio of 7 exceeds one and the excess upperbound lifetime cancer risk of 5×10^{-3} exceeds EPA's allowable risk range of 10^{-6} to 10^{-4} . For the off-site residential scenario, the risks are less. The CDI:RfD ratio of 3 still exceeds one, however, and the excess upper bound lifetime cancer risk of 2×10^{-3} still exceeds EPA's allowable risk range.

To put these risk numbers in perspective, it is worth noting that the current drinking water MCL for arsenic (0.05 mg/L), using the same intake assumptions as this RA, results in a CDI:RfD ratio of 2 and an excess

TABLE 5-3

POTENTIAL UPPERBOUND EXCESS LIFETIME CANCER RISKS
FROM GROUND WATER FOR FUTURE MODELED WATER QUALITY SCENARIOS

Scenario	CDI (mg/kg/day)	Slope Factor ₁ (mg/kg/day) ⁻¹	Excess Upperbound Lifetime Cancer Risk
<u>On-Site Domestic Well</u>			
Drinking Water			
Year 2020	3.4 x 10 ⁻³	1.75	5.6 x 10 ⁻³
Year 2090	5.0 x 10 ⁻³	1.75	8.8 x 10 ⁻³
<u>Downgradient Domestic Well (3)^a</u>			
Drinking Water			
Year 2020	2.3 x 10 ⁻³	1.75	4.0 x 10 ⁻³
Year 2090	3.4 x 10 ⁻³	1.75	5.6 x 10 ⁻³
<u>Downgradient Domestic Well (5)^b</u>			
Drinking Water			
Year 2020	7.1 x 10 ⁻⁵	1.75	1.2 x 10 ⁻⁴
Year 2090	7.1 x 10 ⁻⁵	1.75	1.2 x 10 ⁻⁴

^a Assumes that current summer pumping rates and patterns occur year round.

^b Assumes increased pumping at the Oak Street Well in Midvale such that a reversal of the current hydraulic gradient occurs.

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upperbound lifetime cancer risk of 1×10^{-3} . The present MCL for arsenic (0.05 $\mu\text{g/L}$) was actually established in 1942 by the U.S. Public Health Service to protect the public from acute health effects. At that time, adverse health effects from chronic exposure had not been investigated and were not understood. As an interim measure, EPA has continued to use 0.05 $\mu\text{g/L}$ as the MCL. Currently, however, EPA is re-evaluating the MCL, as well as the recently withdrawn reference dose (RfD), based on more recent toxicological and epidemiological data. Additional considerations regarding the MCL may include the natural background concentrations of arsenic in many municipal water systems and technological problems associated with removing arsenic from these water systems.

From a remedial perspective, if remediation activities substantially reduced or eliminated risks from the soils/tailings pathway for the current off-site scenario, the remaining ground water risk would be equivalent to the risk associated with the MCL for arsenic. In the future, however, the ground water risk would increase due to the predicted increased concentrations of arsenic in ground water.

6.2 FUTURE MODELED WATER QUALITY SCENARIOS

Table 6-2 summarizes the risks from all pathways for the future scenarios based on ground water quality modeling results. The on-site residential scenario assumes future residential use of the mill site including construction of a shallow domestic well. The off-site residential scenario assumes future ground water exposure from a shallow domestic well near the site boundary, downgradient of the site, and soils/tailings exposure from off-site residential areas.

For the on-site residential scenario, total risks would continue to increase due to the predicted increased degradation in ground water quality such that in 30 years the CDI:RfD ratio would be 7 and the excess upperbound lifetime cancer risk would be 7×10^{-3} . In 100 years, the CDI:RfD ratio would be 9 and the excess upperbound lifetime cancer risk would be 1×10^{-2} .

2/3/6

TABLE 6-1

SUMMARY OF RISK CHARACTERIZATION RESULTS FOR
SOILS/TAILINGS PATHWAYS AND GROUND WATER PATHWAY
FOR FUTURE LAND USE SCENARIOS BASED UPON CURRENT WATER QUALITY

Exposure Scenario	CDI:RfD Ratio for Arsenic	Excess Upperbound Lifetime Cancer Risk
On-Site Residential		
Soils/Tailings Pathways	4	1.0×10^{-3}
Ground Water Pathway	2.5	4.4×10^{-3}
TOTAL:	<u>6.5</u>	<u>5.4×10^{-3}</u>
Off-Site Residential^a		
Soils/Tailings Pathways	2	5.0×10^{-4}
Ground Water Pathway	0.7	1.2×10^{-3}
TOTAL:	<u>2.7</u>	<u>1.7×10^{-3}</u>

^a This scenario assumes ground water exposure from a shallow domestic well near the site boundary, downgradient of the site, and soils/tailings exposure from off-site residential areas.

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Filename: ALT4A.WK1

SCREENING OF REMEDIAL ACTION ALTERNATIVES
 COST ESTIMATING WORKSHEET DATE: 02-Oct-90 01.12 PM
 (+50% to -30% Level) BY: SLK

PROJECT: SHARON STEEL/MIDVALE TAILINGS SITE
 FEASIBILITY STUDY - OPERABLE UNIT ONE

ALTERNATIVE 4: CAPPING

DESCRIPTION: Construction of a multi-layered soil cap,
 groundwater control with extraction, treatment and Jordan River disposal,
 mill facility demolition and debris disposal.

DIRECT CAPITAL COSTS
 (Includes Labor, Equipment & Materials, Unless Otherwise Noted)

	COST COMPONENT	UNIT	QUANTITY	UNIT COST	CAPITAL COST
1.	Excavation				
	a. Mill Facility Area (Excav & Spread)	CV	132000	\$8	\$1,070,000
	b. Wetlands Remove/Restore	CV	43600	\$10	\$436,000
	c. Tailings West of Jordan (Excav & Spread)	CV	22300	\$8	\$182,000
2.	Surface Water Control				
	a. Regrading (includes 1b, OU2 soils)	CV	640100	\$1	\$640,000
	b. Galena Canal Rehab	LF	3950	\$75	\$296,000
	c. Slope Stabilization (Soil Cement)	LF	8600	\$671	\$5,771,000
3.	Capping (incl mill facility area)				
	a. 12" Gravelly Sand	CV	400100	\$10	\$3,941,000
	b. 24" Vegetation Layer	CV	800200	\$8	\$6,498,000
	c. Revegetation	AC	240	\$633	\$157,000
4.	Groundwater				
	a. Groundwater Extraction Wells	EA	27	\$16,500	\$446,000
	b. On-site Treatment	LS	1	\$805,000	\$805,000
	c. Pumping/Discharge to Jordan River	LS	1	\$397,400	\$397,000
	d. Interceptor Trench	LF	5550	\$62	\$344,000
5.	Mill Facility				
	a. Facility Demolition	LS	1	\$873,600	\$874,000
	Disposal at USPCI	LS	1	\$2,285,000	\$2,285,000
	b. UGT Removal	EA	2	\$17,370	\$35,000
	c. Asbestos Pipe Disposal	LF	8000	\$3	\$21,000
	d. Liquid Disposal	GAL	10000	\$2	\$18,000
		CV	500	\$47	\$24,000
					\$140,000

APPENDIX C
COSTS

Costs for each alternative were developed as follows. Direct capital costs include materials, labor and equipment costs for the remedial action items in each alternative. The one time cost involve in the institutional control of deed, well permit restrictions and re-zoning ordinance, is also included here. Indirect capital costs were established as percentages of direct capital costs, and include Engineering and Design costs, contingency allowances to cover costs related to unforeseen circumstances, other direct costs such as legal and regulatory fees, and mobilization/demobilization costs incurred by the construction crews.

Annul O&M costs are post-construction costs which include the costs for yearly site reviews and an estimate of remediation activities as a result of those reviews. Administration costs related to those remedies, and administering deed and permit restrictions on the site were also included.

Costs were evaluated over a 30 year period (unless noted otherwise) presented as a Present Worth Total Cost.

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SCREENING OF REMEDIAL ACTION ALTERNATIVES
 COST ESTIMATING WORKSHEET
 (-50% to -30% Level)

DATE: 02-Oct-90 01:12 PM
 BY: SLK

PROJECT: SHARON STEEL/MIDVALE TAILINGS SITE
 FEASIBILITY STUDY - OPERABLE UNIT ONE

ALTERNATIVE 4. CAPPING

DIRECT ANNUAL/PERIODIC COSTS							PRESENT	WORTH
COST COMPONENT	UNIT	FREQUENCY	QUANTITY (PER YEAR)	UNIT COST	DIRECT ANNUAL COST	LIFE OF ITEM (YEARS)	ANNUAL COSTS	PERIODIC COSTS
DIRECT ANNUAL/PERIODIC COSTS								
1. Cap								
a. Inspection	EA	ANNUAL	1	\$2,000	\$2,000	30	\$21,000	n/a
b. Mowing & Revegetation	EA	ANNUAL	1	\$55,200	\$55,200	30	\$567,000	n/a
c. Cap Repair & Maintenance	EA	ANNUAL	1	\$10,000	\$10,000	30	\$103,000	n/a
2. Groundwater								
a. Replace Groundwater Extraction Wells	EA	ONE EVERY YEAR	1	\$16,500	\$16,500	30	\$170,000	n/a
b. Well O&M	LS	ANNUAL	1	\$40,000	\$40,000	30	\$411,000	n/a
c. Treatment Plant O & M	LS	ANNUAL	1	\$83,500	\$83,500	30	\$850,000	n/a
d. Pumping/Discharge to Jordan O&M	LS	ANNUAL	1	\$55,100	\$55,100	30	\$666,000	n/a
TOTAL DIRECT ANNUAL COSTS:					\$262,000			
TOTAL PRESENT WORTH OF DIRECT COSTS:							\$2,696,000	
TOTAL PRESENT WORTH OF DIRECT PERIODIC COSTS:								\$0
TOTAL PRESENT WORTH OF DIRECT ANNUAL/PERIODIC COSTS:								\$2,696,000
INDIRECT ANNUAL/PERIODIC COSTS (Percentage of Total Direct Annual Costs):								
Administration (10%)	LS	ANNUAL	1		\$26,200	30	\$269,000	n/a
Maintenance Reserve & Contingency Costs (25%)	LS	ANNUAL	1		\$65,500	30	\$673,000	n/a
TOTAL PRESENT WORTH OF INDIRECT ANNUAL/PERIODIC COSTS:								\$942,000
TOTAL PRESENT WORTH (Capital & Annual/Periodic) COSTS:								\$4,138,000

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SCREENING OF REMEDIAL ACTION ALTERNATIVES
COST ESTIMATING WORKSHEET
(+50% to -30% Level)

PROJECT: SHARON STEEL/MIDVALE TAILINGS SITE
FEASIBILITY STUDY - OPERABLE UNIT ONE

ALTERNATIVE 4. CAPPING

INDIRECT CAPITAL COSTS (% of Direct Capital Costs)

1. Engineering & Design (15%)	\$3,704,000
2. Contingency Allowance (25%)	\$6,173,000
3. Other Indirect Costs	
A. Legal (5%)	\$1,230,000
B. Regulatory (5%)	\$1,230,000
C. Mobilization/Demobilization (10%)	\$2,469,000

TOTAL INDIRECT CAPITAL COSTS	\$14,810,000
TOTAL CAPITAL COSTS (DIRECT + INDIRECT)	\$39,500,000

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Mining Waste NPL Site Summary Report

**Silver Bow Creek/Butte Area Site
Butte, Montana**

**U.S. Environmental Protection Agency
Office of Solid Waste**

June 21, 1991

FINAL DRAFT

Prepared by:

**Science Applications International Corporation
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DISCLAIMER AND ACKNOWLEDGEMENTS

The mention of company or product names is not to be considered an endorsement by the U.S. Government or the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in the partial fulfillment of EPA Contract Number 68-W0-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Russ Forba, Sara Weinstock, Ron Bertram, Mike Bishop, and Scott Brown of EPA Region VIII [(406) 449-5414], the Remedial Project Managers for the site, whose comments have been incorporated into the report.

SILVER BOW CREEK/BUTTE AREA SITE

BUTTE, MONTANA

INTRODUCTION

The Site Summary Report for Silver Bow Creek/Butte Area is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of the summary by the EPA Region VIII Remedial Project Managers for the site, Russ Forba, Sara Weinstock, Ron Bertram, Mike Bishop, and Scott Brown.

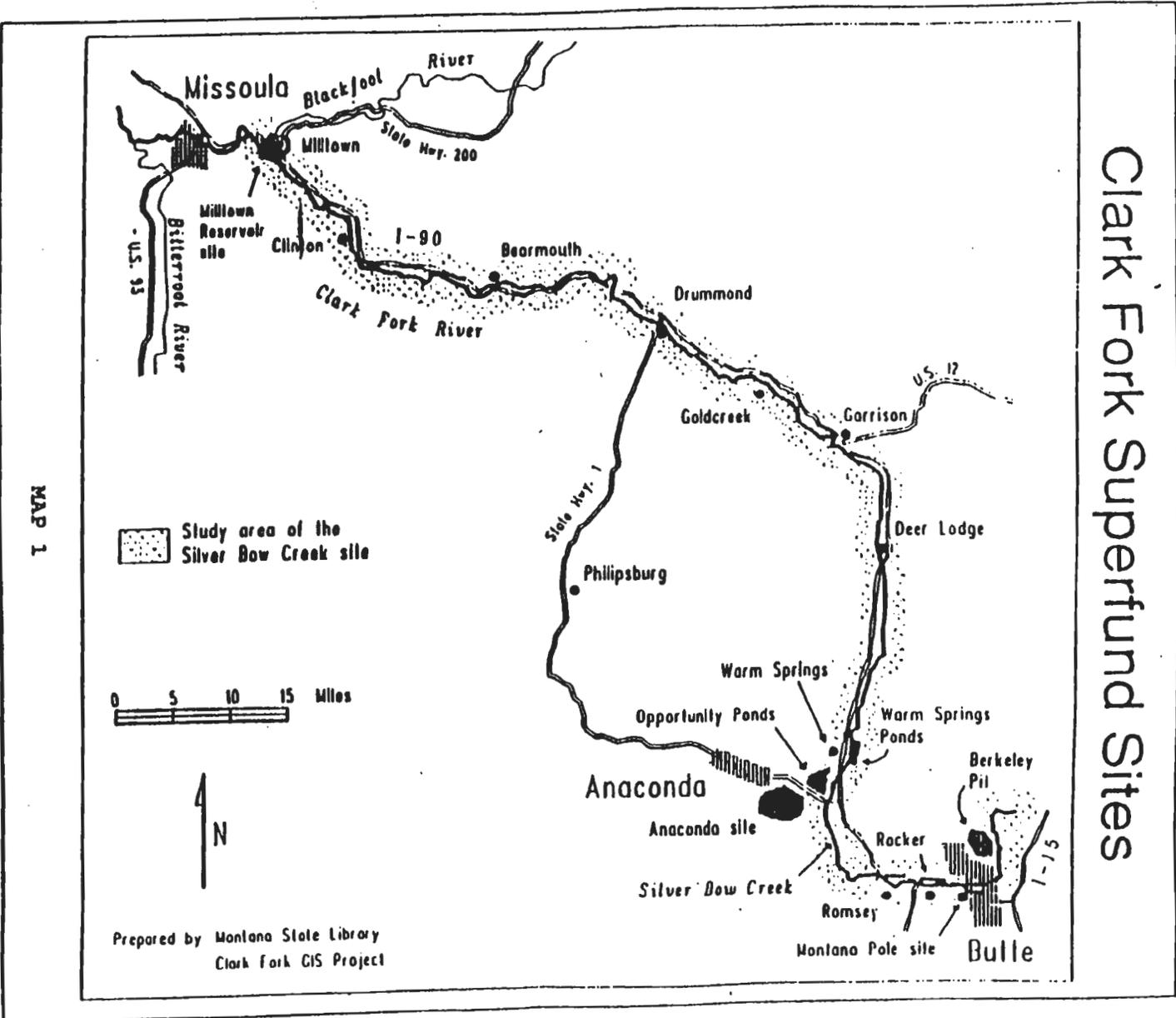
SITE OVERVIEW

The Silver Bow Creek/Butte Area site is one of four separate but contiguous Superfund Sites located along the course of the Clark Fork River in southwestern Montana. The four sites, known collectively as the Clark Fork Superfund Sites, are the Anaconda Smelter site, the Milltown Reservoir site, the Montana Pole site, and the Silver Bow Creek/Butte Area site (see Figure 1). All four sites have the potential to contaminate Silver Bow Creek and/or the Clark Fork River (Reference 1, page 4). Also, Milltown Reservoir has the potential to contaminate the sole-source aquifer below Missoula. The Superfund effort in the Clark Fork Basin encompasses the largest geographic area of all Superfund assignments in the United States. Except for the Montana Pole site, contamination at the sites is primarily mining wastes and heavy metal-laden soils and water. The Montana Pole site, which lies adjacent to the Silver Bow/Butte Area site, is contaminated with wood-treating wastes (Reference 1, pages 3 and 4).

The Silver Bow Creek/Butte Area Superfund Site is the largest and most complex of the four sites. Silver Bow Creek has historically received discharge from mining, smelting, wood treating, and other industrial sources for over 110 years (Reference 5, page 1).

The Silver Bow Creek/Butte Area site includes the Cities of Butte and Walkerville (population 38,000), the Berkeley Pit (a nonoperating open-pit copper mine); numerous underground mine works (operated by New Butte Mining, Inc.); the Continental Pit (operated by Montana Resources); Silver Bow Creek; Warm Springs Ponds (mine tailings); and Rocker Timber Framing and Treating Plant. The approximate size of the Silver Bow Creek/Butte Area site is 450 acres.

Clark Fork Superfund Sites



The Silver Bow Creek site was added to the NPL in September 1983. Originally, the site encompassed the Silver Bow Creek floodplain from Butte (downstream) to Warm Springs Ponds. Remedial Investigations were initiated in this area in 1985. In November 1985, the site boundaries were expanded to include Butte (Reference 1, page 4).

In October 1988, EPA and the Montana Department of Health and Environmental Sciences (MDHES) released the first Clark Fork Superfund Master Plan to coordinate remedial activities of all four sites in the Clark Fork Basin. Since February 1990, EPA has assumed the lead role on most of the Silver Bow Creek/Butte Area Operable Units, except for streamside tailings (which are under the lead of the MDHES (Reference 2, page 2). At present, there are seven Operable Units within the Silver Bow Creek/Butte Area site. These units will be discussed in the next section.

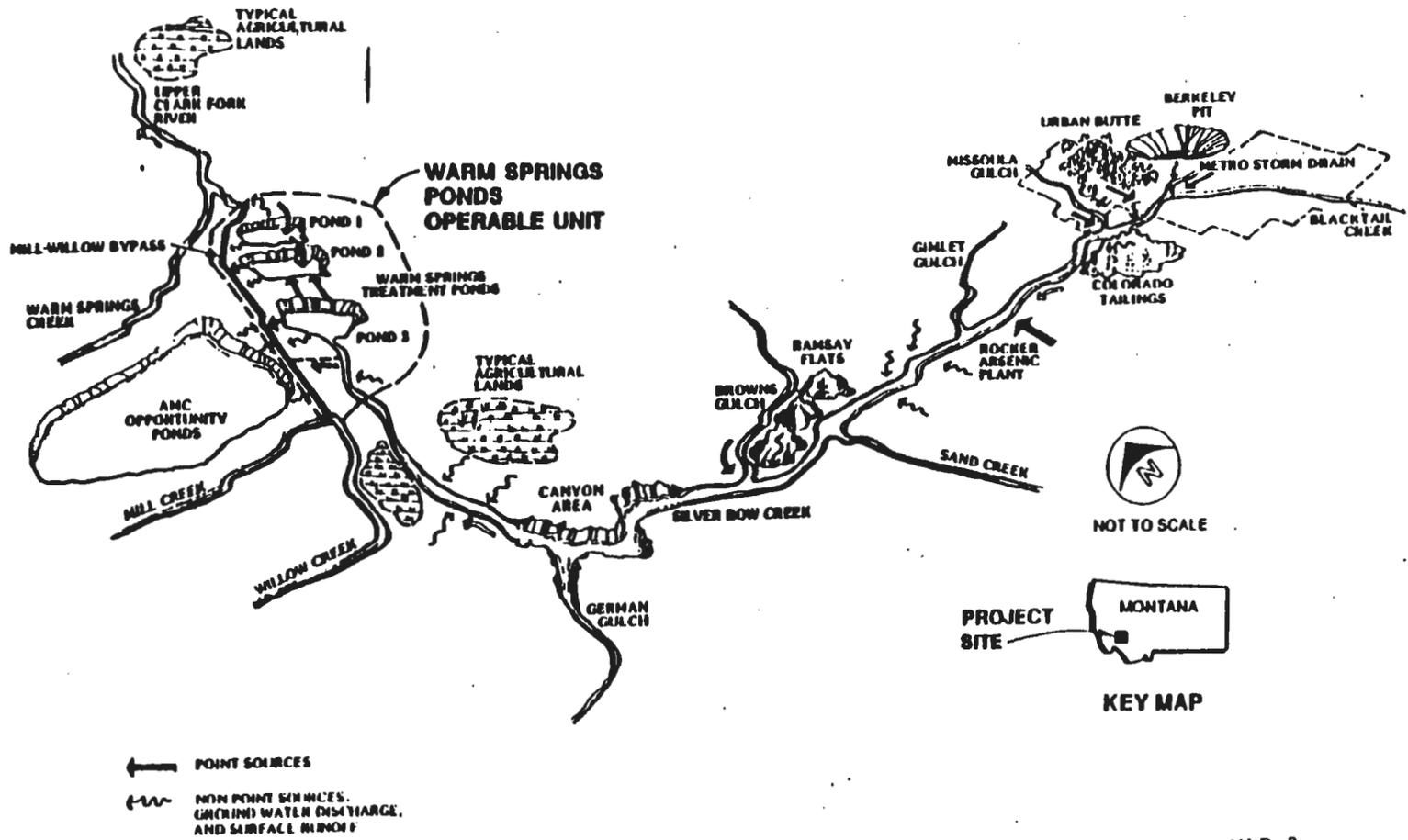
A Phase II Remedial Investigation for the Warm Springs Ponds Operable Unit was completed in May 1989 (see Figure 2). The Record of Decision (ROD) for this Operable Unit was signed in September 1990. According to EPA, the selected remedial alternative, which is designed to control contamination associated with pond-bottom sediments, surface water, mine tailings, contaminated soils, and ground water is currently being implemented. In addition, three removal actions are underway (Mill Willow Bypass, Travona/West-Camp Pond, and Butte Priority Soils). Remedial Investigations are underway for the Streamside Tailings, Rocker Timber Plant, and Butte Mine (Berkeley Pit and underground mines) Operable Units. The Butte Mine Feasibility Study is scheduled to be completed by 1993 (Reference 11, page 1).

OPERATING HISTORY

In the years following the discovery of gold (in 1864), the Butte area became an internationally recognized mining center with over 300 combined copper and silver mines and 8 smelters in operation by 1884. The Butte area has been mined almost continuously for 110 years (Reference 1, page 4). Most of the ore mined in Butte was shipped 26 miles west to the smelting complex in Anaconda, Montana (a separate Superfund Site); however, ore was also smelted in any of eight smelters in the Butte area. Smelting continued in the Butte area until the Washoe Smelter became operational in Anaconda in 1902 (Reference 8, page 3). By the 1950's, the Anaconda Company (purchased by Atlantic Richfield Company in 1979) had consolidated all mining activity in the area.

Copper, silver, gold, zinc, lead, manganese, and molybdenum have been mined by both underground (vein) mines and open-pit mines in the Butte area. Major underground mining activity took place from the late 1880's through 1960. Over 3,500 miles of underground workings exist in the area; some of the vein mines reached over 5,000 feet in depth (Reference 1, page 4). The Berkeley Pit, an

FIGURE 2. SILVER BOW CREEK SITE SCHEMATIC



MAP 2

**SILVER BOW CREEK
SITE SCHEMATIC
WARM SPRINGS PONDS
FEASIBILITY STUDY**

open-pit mine, operated from 1955 to 1982. It is estimated that over 3,500 miles of underground mine workings are interconnected with the Berkeley Pit. The pit is over 1 mile deep and 1.5 miles wide at the rim. Mining companies installed a pumping system to dewater the underground mines and the Berkeley Pit during active mining. In the 1950's, bulkheads were installed underground to inhibit the flow of water between mines and the pits and create two underground flow systems, the east camp (includes the Berkeley Pit) and the west camp (see Figure 3). These bulkheads were installed to improve the efficiency of pumping operations (Reference 1, page 4).

In 1964, a mill was constructed in Butte to concentrate the copper sulphide ore from the Butte mines. High-grade ore was processed through the mill and smelter, while lower-grade ores were leached with acid water from the mines in large leach dumps located near the tailings disposal area. The mill tailings were impounded behind a 2-mile-long dam northeast of the mining operation (Yankee Doodle Tailings Pond). Prior to 1911, when pollution control measures were first initiated, all mining, milling, and smelting wastes were discharged directly to Silver Bow Creek (Reference 9, page ES-1; Reference 10, page 2).

The first pollution control measures consisted of ponds created by dams built to trap and settle the mining wastes (sediments, tailings, and sludges). In 1911, a 20-foot high dam was erected on Silver Bow Creek, creating Warm Springs Pond 1. Another dam, 18 feet high, was erected on the creek in 1916, creating Warm Springs Pond 2. (This dam was extended to a height of 23 feet.) A third dam, 28-feet high (built between 1954 and 1959), was primarily for sediment control. This dam was eventually raised to 33 feet. In 1967, Pond 3 was converted to treat mill losses, precipitation plant spent solution from Butte operations, and overflow from the Opportunity Ponds. Treatment consisted of adding a lime/water suspension to raise the Ph of the surface water in Silver Bow Creek and precipitate heavy metals in Pond 3. The three ponds are currently used to physically, chemically, and biologically treat Silver Bow Creek surface water through sedimentation and chemical and biological precipitation of heavy metals (Reference 10, page 3).

Mining activity in the Butte area continued until 1982, when the Berkeley Pit was closed (Reference 9, page ES-1). At this time, the pumps dewatering the mine were shut down and the underground mines began to flood. As the water levels reached the bottom of the Berkeley pit, it began to fill (Reference 5, page 1). In 1986, mining activity resumed, although on a smaller scale. The Continental Pit, operated by Montana Resources, produces approximately 50,000 tons per day of copper/molybdenum ore; New Butte Mining, through its underground operation, produces approximately 500 to 1,000 tons per day of silver, lead, and zinc ore. Montana Resources operates an onsite mill to concentrate its ore, discharging the tailings to the Yankee Doodle Tailings Pond area; New Butte Mining ore is shipped offsite for milling and smelting.

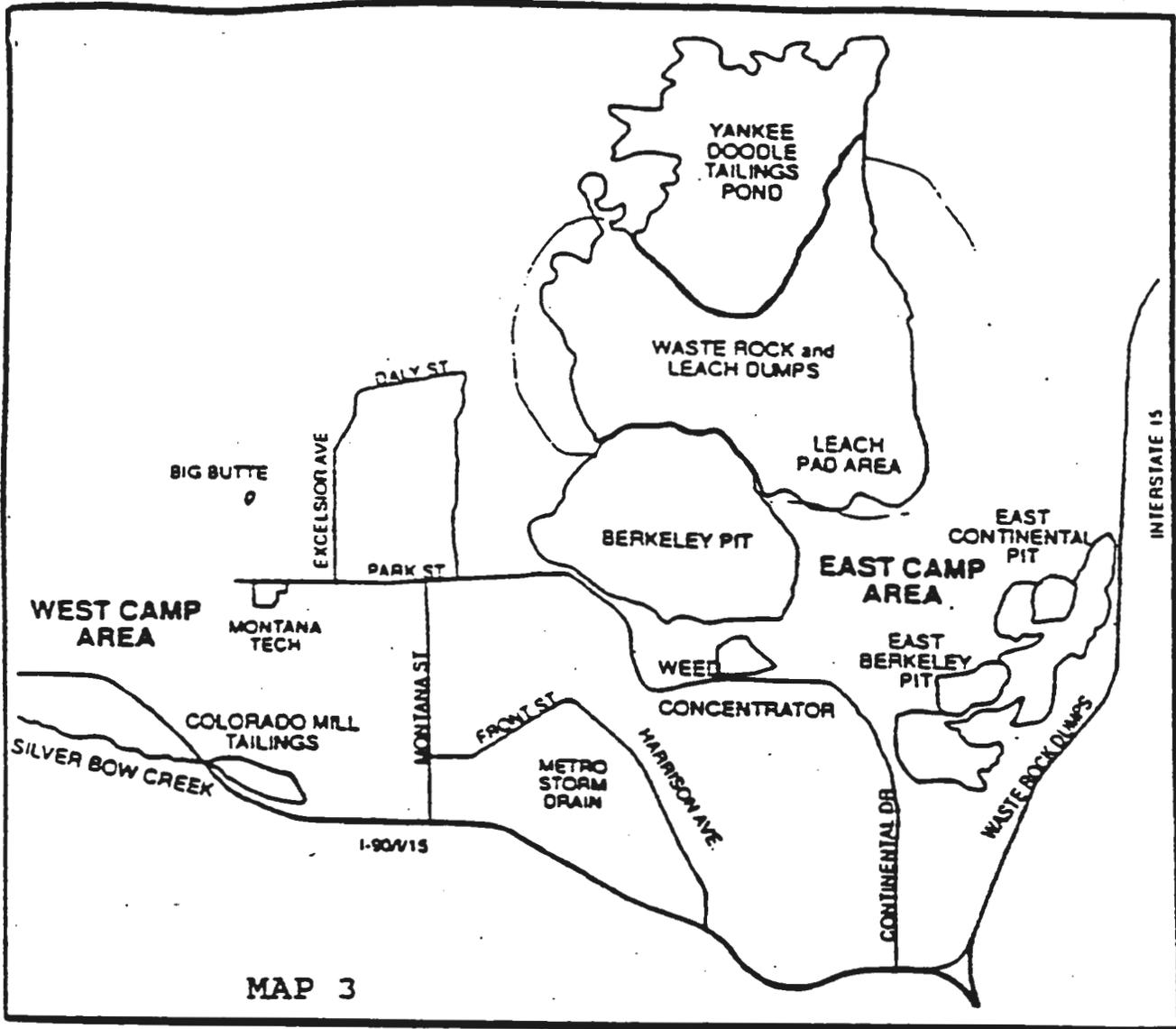


FIGURE 3. BUTTE AREA

SITE CHARACTERIZATION

The wastes generated by mining, milling, and smelting activities are sources of contamination for soils, surface water, and ground water. Contamination is occurring through blowing dust, contaminated runoff and contaminants leaching through the soil into the ground water (Reference 1, page 4). The Silver Bow Creek/Butte Area site is divided into seven Operable Units. The Operable Units are:

- Warm Springs Ponds - Three settling ponds were built in 1911, 1916, and 1959 for the purpose of trapping mining wastes in Silver Bow Creek before the contaminated water reached the Clark Fork River (Reference 2, page 2). The ponds (still in use) operate by settling out tailings particles and other solids and reducing the concentrations of the dissolved metals. They now cover an area of approximately 4 miles square and contain 19 million cubic yards of submerged and unsubmerged heavy metal contaminated sediments and tailings (Reference 9, page ES-2; Reference 10, page 2).

The Mill-Willow Bypass, a subunit of Warm Springs Operable Unit, is a diversion ditch that routes water around the ponds and into the Clark Fork River. Tailings and contaminated soils wash into the bypass during summer storms, carrying heavy metals into Clark Fork River. These heavy metals are suspected to have caused fish kills in the bypass and upper Clark Fork River (Reference 2, page 2).

- Streamside Tailings - Mine tailings have been deposited on the banks of Silver Bow Creek between the Colorado Mill Tailings Pile and the Warm Springs Ponds. Vegetation is absent in these areas, making the tailings susceptible to wind and water erosion (Reference 2, page 2).
- Rocker Timber Plant - The Rocker Timber Framing and Treatment plant was in operation from the early 1900's to 1956. The plant treated mine timbers with a preservative containing arsenic. In addition, creosote was used at this plant to treat poles and to lubricate skids for mine timber loading and unloading. Waste material from the pressure treatment was dumped along the banks of Silver Bow Creek. Surface soils at the plant were found to have high levels of arsenic (Reference 12, page 18).
- Butte Mine Flooding - The areas included in this Operable Unit are the Berkeley Pit and the underground mines. The mines are flooding and the pit is filling with acidic mine water containing heavy metals, sulfates, and arsenic. If left unchecked, the mine water may discharge to shallow ground water and surface water (Reference 2, page 3). In 1989, EPA began pumping water from the Travona Mine shaft to prevent it from flooding basements and running into Silver Bow Creek (Reference 2, page 3). Elevated levels of arsenic and other heavy metals were detected in ground-water samples taken from the Travona Mine Shaft (Reference 3, page 1).

Silver Bow Creek/Butte Area Site

- **Butte Priority Soils** - This Operable Unit includes 36 contaminated soil sites in Butte that pose a potential threat to human health and the environment. Contaminants include lead, zinc, copper, cadmium, and arsenic. The soil areas vary in size, location, and composition. The sources of contamination are being addressed in this Operable Unit. Sources include waste rock dumps, smelter wastes, or tailings piles. This Operable Unit includes the Colorado Tailings Area along Silver Bow Creek and the Butte Reduction Works (Reference 2, pages 3 and 4).
- **Nonpriority Soils** - This Operable Unit includes potential human health risks from contaminated soils in the nonresidential areas of Butte (Reference 7, page 36).
- **Active Mining Area** - This Operable Units includes the active mining operations in the Butte area. The problem areas include fugitive dust emission sources; source areas of acid mine drainage discharge to the Berkeley Pit; impacts on wildlife from exposure to mining waste; and potential human exposure to contaminated soils (Reference 7, page 36).

Soils

Soil sampling indicates that the soils at the site contain elevated levels of lead, arsenic, copper, cadmium, and mercury (Reference 6, page 1). Soil contamination in the Silver Bow Creek/Butte Area Superfund Site is concentrated in two areas. The first area of contamination is the alluvial soil along the Silver Bow Creek floodplain between Butte and the Warm Springs Ponds. This area is defined as the Streamside Tailings Operable Unit. The tailings that cover the soil occur primarily on lower terrace levels along the stream channel, where they have undergone active erosion and redeposition. The second area of soil contamination involves surface soils and sediments (in areas farther removed from the stream banks) contaminated by mine and mill tailings and acid mine-water discharges. These areas are the Warm Springs Ponds, the Rocker Timber Plant, and the Butte Priority Soils Operable Units.

In May 1988, EPA and MDHES completed the Butte Area Soils screening study. The study showed metal levels to be highest at old mill sites and mine waste dumps. Residences located near mine wastes tended to have higher metals levels in their soils, than those in other parts of the city. A Butte Priority Soils Study was then conducted, which covered 36 areas of Butte that pose a potential threat to human health and the environment due to the high concentrations of arsenic, cadmium, copper, lead, mercury, and zinc in the soils (Reference 1, page 5). Two subunits within the Butte Priority Soils Operable Unit, Walkerville (residential area) and Timber Butte Mill, were found to have mercury and lead contamination. In Walkerville, mercury vapor was found in residential basements. At the Timber Butte Mill, high levels of lead were found in the soil (Reference 4, page 6).

Surface Water

Contaminated soils and tailings pile leachates from the Warm Springs Ponds, Streamside Tailings, Rocker Timber Plant, and Butte Priority Soils Operable Units have contributed to the surface-water contamination of Mill Creek, Willow Creek, the Mill-Willow Bypass, Silver Bow Creek, and the Clark Fork River (Reference 11, pages 2-23 through 2-28). Results from the Phase I and Phase II Remedial Investigations (conducted in 1987 and 1989, respectively) indicated that concentrations of heavy metals in Mill, Willow, and Silver Bow Creeks exceed State water-quality standards (Reference 10, page 5). It is possible that these exceedances are a result of three sources (ground-water inflow, surface-water inflow, and mobilization of mine wastes deposited in the streambed). Ground-water inflows have contributed to the contamination of Silver Bow Creek at the reach between Montana Street and the Colorado Tailings Pile. Large increases in copper, zinc, sulfate, arsenic, and cadmium loads are apparent in this reach of the Creek (Reference 12, page 27).

Monitoring data for the Warm Springs Ponds shows that the ponds provide 50 to 90 percent removal of metals from the pond influents. Despite this removal/treatment, sampling performed in 1987 and 1988 indicated that the pond effluents frequently exceeded Ambient Water Quality Standards for cadmium and iron. Ambient Water Quality Standards for copper, lead, and zinc were also occasionally exceeded in the pond effluents, particularly during the winter months. It should be noted that no sampling was conducted during high runoff events, which cause inflows to be diverted around the pond system (Reference 11, pages 2-12 through 2-14).

Warm Springs Ponds pose a further risk to the Clark Fork River because they are susceptible to flood and earthquake damage, which potentially could release millions of cubic yards of tailings, contaminated sediments, and metal precipitates into the River. The Ponds are not strong enough to withstand a moderate earthquake, and a 100-year flood could seriously damage the berms supporting the ponds.

Ground Water

Ground-water studies involve the Butte Mine Flooding and the Warm Springs Ponds Operable Units. The first Operable Unit 14 is miles square and includes the Berkeley Pit, the Yankee Doodle Tailings Pond, the Montana Resources Leach Dumps, the Weed Concentrator, all mine workings, and all surface areas draining into the mine workings (Reference 5, page 1). EPA is concerned with the Butte Mine Flooding Operable Unit because the flood waters are highly acidic and contain high concentrations of copper, iron, manganese, lead, arsenic, cadmium, zinc, and sulfates. If the water continues to rise in the Berkeley Pit, contaminated water may eventually flow into shallow ground

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Silver Bow Creek/Butte Area Site

water (alluvial aquifer) and to Silver Bow Creek, creating the potential for significant environmental impacts and human health problems (Reference 5, page 1).

Shallow ground water in the area of the underground mines was tested in 1986 and 1987, and was found to contain arsenic, cadmium, and other contaminants (Reference 10, page 6). During the Phase I Remedial Investigation (1987), it was found that Federal Drinking Water Standards (DWSs) were exceeded for arsenic, cadmium, copper, iron, zinc, and sulfate at several domestic wells (Reference 12, page 27 and page 32).

An additional ground-water problem exists below Warm Springs Pond 1 and in the area of the Mill-Willow Bypass. Monitoring data collected from the shallow aquifer below Pond 1 and the bypass indicates exceedances of Montana's Maximum Contaminant Levels (MMCLs) for cadmium, manganese, iron, and sulfide. The MMCL for arsenic was also exceeded in the shallow aquifer below Pond 1. Monitoring data for deep wells at both locations demonstrate exceedances of MMCLs for manganese and sulfide. The MMCL for iron was also exceeded in the deep wells below Pond 1 (Reference 11, pages 2-17 through 2-19).

Air

Mine-waste dumps and dried-tailings piles are susceptible to wind-blown erosion, and pose a threat to air quality in the area. Potential exposure pathways are inhalation of contaminants from wind-blown dust and direct contact with contaminated soils.

ENVIRONMENTAL DAMAGES AND RISKS

Investigations into the environmental problems associated with mining activity in the Upper Clark Fork area were conducted first by the Potentially Responsible Party (PRP) (Anaconda Minerals Company) from 1966 to 1982. EPA initiated the Remedial Investigation/Feasibility Study process in 1983. An Initial Remedial Investigation for the Silver Bow Creek site prior to inclusion of the Butte area was completed in 1987.

EPA established priorities to ensure the most serious problems were dealt with first (i.e., areas involving potential human health risks were given a higher priority than environmental risks). The four Operable Units at the Silver Bow Creek/Butte Area Superfund Site which are considered high priorities are: (1) Warm Springs Ponds; (2) Rocker Timber Plant; (3) Butte Mine Flooding; and (4) Butte Priority Soils. The Streamside Tailings Operable Unit is considered an intermediate priority (Reference 1, page 5).

The ROD for the Warm Springs Ponds Operable Unit identified the following risks to human health:

- Workers at the Ponds face an increased cancer risk estimated to be 2×10^{-4} (2 chances in 10,000) due to incidental ingestion of arsenic in contaminated soils, sediments, and tailings. People at the site for recreational purposes (e.g., hunters, fishermen, bird watchers, etc.) also face increased cancer risk from exposure to arsenic.
- Workers and people at the site for recreational purposes face additional cancer and noncancer health risks due to ingestion of lead and other hazardous substances in the contaminated soils, sediments, and tailings.
- Current residents adjacent to the Ponds face actual or potential risks from contaminated soils, sediments, and tailings becoming windborne.
- The contaminated ground water below Pond 1 poses a potential threat to ground-water users.
- The berms protecting the Ponds fail to meet current dam safety standards. Their failure (in flood or earthquake) could result in catastrophic consequences (Reference 11, pages 2-23 through 2-27).

The following environmental risks were also identified for the Warm Springs Operable Unit:

- Periodic fishkills have occurred in the Mill-Willow Bypass and the Clark Fork River, which were likely due to copper and zinc released from the tailing deposits. Contaminated soils, sediments, and tailings also pose an unquantifiable chronic risk to aquatic life and wildlife, both within the Operable Unit and downstream.
- Aquatic life water-quality criteria have been exceeded in water discharged from the Ponds and water diverted around the Ponds without treatment.
- Berm failure could result in significant environmental consequences for the Clark Fork River (Reference 11, pages 2-27 through 2-28).

Ground-water infiltration into underground mines and the Berkeley Pit could potentially contaminate the shallow ground-water aquifer and surface water if the water in Berkeley Pit rises beyond 5,410 feet. As of February 27, 1990, the water level was 4,975 feet, and has not, therefore, reached the critical level. The contaminants of concern are arsenic, cadmium, lead, copper, zinc, iron, manganese, and sulfates (Reference 5, pages 4 and 5). Wells for domestic-water consumption are located in the vicinity of the Silver Bow Creek site and draw water from the shallow aquifer.

Silver Bow Creek/Butte Area Site

Surface water in Silver Bow Creek was sampled to determine levels of heavy metals and the results were reported in the 1987 Remedial Investigation. For the protection of aquatic life, the concentrations of total recoverable arsenic, cadmium, copper, lead, and zinc in surface water should not exceed specific criteria. When these heavy metals were measured, concentrations did exceed the standards for protection of aquatic life in Silver Bow Creek (Reference 12, page 33).

The West Camp/Travona underground mine-flooding discharges could contaminate Silver Bow Creek through direct discharge of ground water into Missoula Gulch, which joins Silver Bow Creek. When pumps for the West Camp mines were shut off in 1965, ground water began to flood basements in the residential areas south of the mine shafts. An intercept well was drilled in 1965. From 1965 to 1969, water flowed from this well into Missoula Gulch, and then, into Silver Bow Creek (Reference 3, page 2).

Agricultural soils and crops were also affected by the mine wastes from the Silver Bow Creek site. Circumstantial evidence exists that approximately 5,400 acres of land have been contaminated by heavy metals to varying degrees, by using Silver Bow Creek or the Upper Clark Fork River water for irrigation (Reference 12, page 37).

Fish and water fowl were also studied during the 1987 Phase I Remedial Investigation. There is evidence that fish, particularly Rainbow Trout, are receptors of heavy metals within the study area. It was also found that arsenic concentrations in fish tissue were below U.S. Department of Agriculture (USDA) food standards (Reference 12, page 46).

REMEDIAL ACTIONS AND COSTS

Remedial actions for each Operable Unit are described below.

Warm Springs Ponds Operable Unit

As described in the 1990 ROD, the selected remedy for the Warm Springs Ponds Operable Unit includes controlling contamination associated with pond bottom sediments, surface water, mine tailings, contaminated soils, and ground water within the boundaries of the Operable Unit. The following actions are required:

- Allow Ponds 2 and 3 to continue to function as treatment ponds until upstream sources of contamination are cleaned up. Increase the capacities of Ponds 2 and 3 to receive and treat flows up to the 100-year flood. Provide for flows greater than the 100-year flood to be routed

around the ponds. Wet portions of Pond 1 will be dewatered, and the pond will be covered and revegetated.

- Raise and strengthen all pond berms according to specific criteria, which will protect against dam failure during earthquakes or floods.
- Remove all remaining tailings and contaminated soils from the Mill-Willow Bypass and consolidate them over existing dry tailings and contaminated soils within Pond 1 (prior to its closure) and Pond 3. Reconstruct the Mill-Willow Bypass to safely route flows up to half the probable maximum flood.
- Construct intercept trenches to collect contaminated ground water from below Pond 1 and pump the water to Pond 3 for treatment.
- Establish surface and ground-water monitoring systems.
- Implement controls to prevent future residential development, swimming, and fish consumption.
- Delay (for no more than 1 year) decisions related to remediation of contaminated soils, tailings, and ground water below Pond 1 (Reference 11, pages 1-2 through 1-4).

The estimated cost of these remedial measures is \$57,037,000 (for construction) and \$379,000 annually (for operation and maintenance) (Reference 11, pages 2-50 and 2-82).

Streamside Tailings Operable Unit

The Phase I Remedial Investigation was initiated by MDHES to evaluate levels of contamination in soils/tailings, ground water, surface water and aquatic animals and plants in Silver Bow Creek (along with the Warm Springs Ponds). Phase II Remedial Investigation/Feasibility Study activities, which are building on the initial investigations, are currently ongoing and include a site-wide assessment of health and environmental risks; evaluation of possible remedies for streamside tailings along Silver Bow Creek; and additional investigations and remedy evaluations for other Operable Units of the Silver Bow Creek site.

Butte Priority Soils Operable Unit

EPA replaced heavy metal-contaminated soils with clean soils from 23 homes in Walkerville during 1988. In addition, the PRPs (Atlantic Richfield, New Butte Mining, and the City of Walkerville) removed and regraded several old mine dumps in preparation for reseeding and fencing. Removal

actions were completed at Walkerville (a residential area) in 1988 and Timber Butte Mill in 1989, after the Butte Priority Soils Study indicated high concentrations of heavy metals (Reference 4, page 6).

Butte Mine Flooding Operable Unit

A PRP-sponsored Remedial Investigation/Feasibility Study for the Berkeley Pit began in 1990. The Remedial Investigation/Feasibility Study will be completed in 2 to 3 years, after which clean-up will be performed. A likely solution is a treatment system for water in the Berkeley Pit and other underground mine runoff.

In 1989, PRPs began pumping rising water from the Travona mine to prevent contaminated water from flooding residential basements and entering Silver Bow Creek. Water was discharged (in 1989) to the Butte Metro Treatment Plant, and was required to meet State water-quality standards and drinking-water standards for arsenic. Pumping continued through May 1990, and it is still done on an occasional basis to control the water level in the mine (Reference 3, page 2).

Rocker Timber Plant Operable Unit

The Remedial Investigation/Feasibility Study was initiated during 1990. Approximately 1,000 cubic yards of arsenic contaminated soils and wood chips were removed in 1989 (Reference 7, page 37).

CURRENT STATUS

Remedial measures began in 1990 at the Warm Ponds Springs Operable Unit. Specifically, the Mill-Willow Bypass removal action began. According to EPA, a Remedial Investigation/Feasibility Study is currently being conducted at the Butte Mine Flooding Operable Unit by the PRP. An expedited response action has been implemented at the Travona Mine site. The response entails pumping of contaminated ground water from the mine shaft to a Publicly Owned Treatment Works for treatment. Under the Butte Priority Soils Operable Unit, three soil removal actions have been completed. A removal is currently underway at the Streamside Tailings Operable Unit. A Remedial Investigation and Feasibility Study is underway at the Rocker Operable Unit.

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Silver Bow Creek/Butte Area Site

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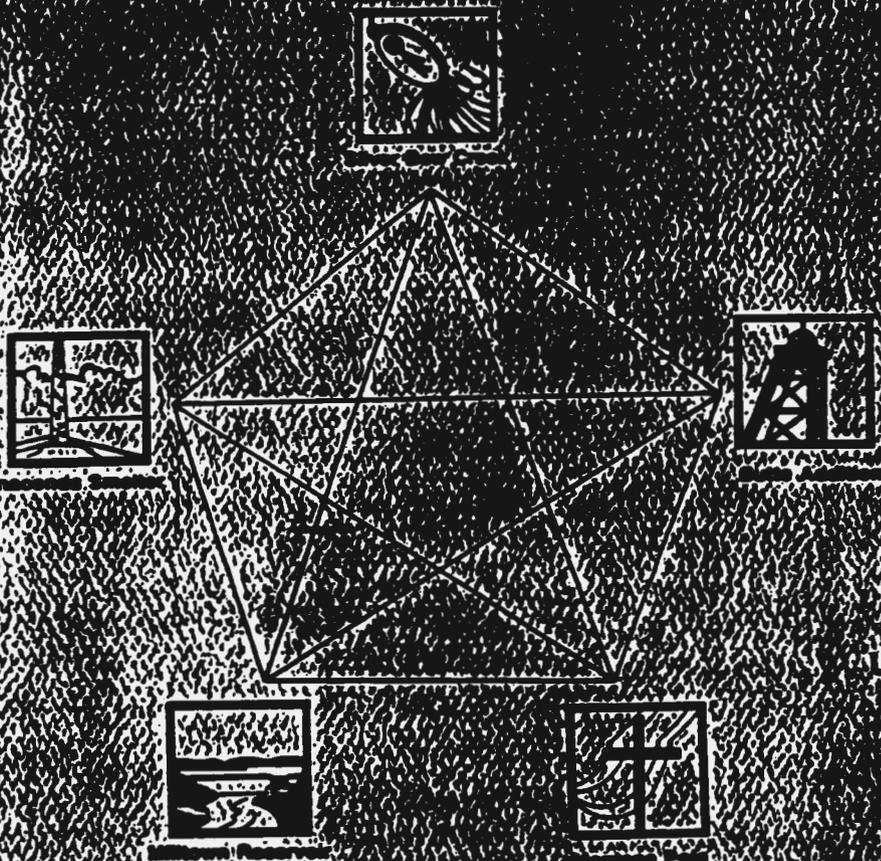
Reference 1

**Excerpts From Clark Fork Superfund, Master Plan;
EPA and MDHES; October 1988**

CLARK FORK SUPERFUND

Ref #1

MASTER PLAN



U.S. Environmental Protection Agency
and
Montana Department of
Health and Environmental Sciences

October 1988

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PREFACE

This Master Plan has been developed by the U.S. Environmental Protection Agency (EPA) and the Montana Department of Health and Environmental Sciences (MDHES). It describes the overall general approach being used to address concerns regarding hazardous substances, pollutants, and contaminants at the Superfund sites in the Clark Fork Basin. The detailed technical approaches being used at specific Superfund sites are described in site-specific workplans which are available to the public at Superfund document repositories throughout the Clark Fork Basin. The coordination of these technical approaches is accomplished through active communication among all Superfund project managers and the Superfund Coordinator.

The scope of Superfund problems and specific human health and environmental concerns associated with each site are discussed in Section 2 and the Appendix of the Master Plan. The Superfund effort in the Clark Fork Basin encompasses the largest geographic area of all Superfund assignments in the United States. The number and complexity of existing and potential human health and environmental problems in the basin require that priorities be set for response actions. The approach that EPA and MDHES have used to prioritize response actions is explained in Section 3. This prioritization process has resulted in identification of three broad categories of Superfund problem areas: problems primarily related to human health, problems which primarily affect the quality of Silver Bow Creek, and problems which relate primarily to the Clark Fork River and adjacent areas. The technical and legal interrelationships among these categories and among sites are discussed in the Master Plan. Section 3 also summarizes the major accomplishments of the Superfund program at the Clark Fork sites.

Federal laws governing Superfund response actions require that technical and legal issues be addressed in a well documented and consistent manner at all sites. The Superfund process is outlined and mechanisms available to implement interim and final response actions are described in Section 4. The influence of site interrelationships on the process and schedule is discussed in light of the need for effective, coordinated response actions. A schedule for addressing Superfund problem areas, which is based on information currently available to EPA and MDHES, is presented in Section 5. This Master Plan will be updated periodically as cleanup activities progress. EPA and MDHES welcome public comments on the information presented in this Master Plan.

1.0 INTRODUCTION

1.1 GOALS AND OBJECTIVES

This Master Plan has been prepared for public distribution by the U.S. Environmental Protection Agency (EPA) and the Montana Department of Health and Environmental Sciences (MDHES) to provide a better understanding of the overall approach being used to manage Superfund activities in the Upper Clark Fork Basin of southwestern Montana. These activities are being conducted under authority of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) or "Superfund" which was passed by Congress in 1980 and amended in the Superfund Amendments and Reauthorization Act of 1986. Appropriate state authorities are also utilized in the Superfund process.

Superfund activities in the Clark Fork Basin are focused on reducing risks to human health and the environment from the release or threatened release of hazardous substances, pollutants, or contaminants primarily from past mining and smelting activities.

Other Federal, State, and local agencies are also conducting natural resource investigations in the Basin. These investigations have been summarized in a report prepared by the Governor's Clark Fork Basin Project (Johnson and Schmidt, 1988). In addition to integrating appropriate information from these investigations, Superfund activities in the Basin must be conducted in a specified manner as required by CERCLA and the National Contingency Plan (NCP)¹ which guides technical implementation of Superfund activities.

To ensure that effective response actions are achieved, Superfund activities must be coordinated so that the technical and legal requirements of CERCLA and the NCP are met. In addition, consistent approaches to response actions must be followed since study results and response actions at one location will affect these activities at other contaminated sites. To assist in coordinating response actions in a technically and legally-consistent manner, EPA has developed guidance for the Superfund program throughout the country. Interpretation and application of this guidance to achieve appropriate consistency among sites is achieved through active communication among the Superfund project managers, the Superfund coordinator, and other staff.

This Master Plan was developed to aid the public in understanding how requirements of the Superfund process relate to response actions which are being planned or implemented at the Superfund site. Some specific objectives of the Master Plan are to:

- identify, prioritize, and coordinate inter-site activities to achieve the most rapid and effective investigation and where necessary, remediation of the Clark Fork Superfund sites as possible;

¹ Terms which appear in bold face type on first mention are defined in the glossary on page 11 of this document.

- coordinate Superfund activities with other environmental improvement programs.
- provide for consistent approaches to response actions for all sites.
- communicate information on Superfund activities to all interested parties

A projected schedule for addressing contamination problem areas is included in this Master Plan. This schedule will, of necessity, be modified and updated as new information becomes available and major decisions are made.

1.2 HISTORICAL BACKGROUND

The EPA and the State of Montana are working together in the Superfund program to seek solutions to the impacts from hazardous substances (primarily metals) left by over 100 years of mining and processing operations, as well as other industrial activities. The area of concern includes the Upper Clark Fork Basin above Warm Springs Creek and the main stem of the Clark Fork River to the Bitterroot River below Missoula, Montana.

Investigations in the upper Clark Fork area, initiated by EPA in 1982, resulted in the establishment of four separate but contiguous Superfund sites. The sites are the Milltown Reservoir site, the Anaconda Smelter site, the Montana Pole site, and the Silver Bow Creek/Butte Addition site (See Map, page 2). EPA and MDHES initially identified 77 existing or potential contamination problems at the sites. As described in Section 3, these problems have been consolidated where possible for more efficient responses. EPA has provided funds to MDHES to take the lead for investigations at the Silver Bow Creek site, the Montana Pole site, and the Milltown Reservoir site. The Atlantic Richfield Company (ARCO) is conducting investigations at the Anaconda Smelter site and may undertake work at other sites. EPA also intends to offer the opportunity to potentially responsible parties to conduct the investigations for the Butte Addition to the Silver Bow Creek site under an enforcement agreement (see Section 4.4 Superfund Enforcement Authorities). EPA is managing response actions for the Butte Addition.

In an effort to develop an integrated approach for addressing these sites, EPA, MDHES, the Montana Governor's office, representatives from the communities of Butte and Anaconda, and the Atlantic Richfield Company (ARCO) have provided input to this Master Plan to help define investigation and remedial priorities and establish a schedule for coordinated action.

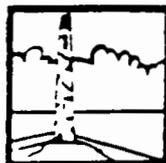
2.0 PROBLEM AREA DEFINITION

Each Clark Fork Superfund site is comprised of several existing or potential contamination problems. The most important problems are summarized for each site in the Appendix. The history and interrelationships of problems among sites are described further in the narrative below. The major corrective actions that have already been taken at each site are described in Section 3.3.



2.1 MILLTOWN RESERVOIR SITE

Milltown Reservoir is located adjacent to Milltown, Montana at the confluence of the Blackfoot and Clark Fork Rivers. Milltown Reservoir was created in 1907 as part of a hydroelectric power generating facility which has been owned and operated since 1929 by Montana Power Company. The reservoir has accumulated 6.5 million tons of sediments transported by the Clark Fork River and its tributaries (Woessner et al., 1984). Unusually high concentrations of arsenic, lead, zinc, cadmium, and other metals have been found in reservoir sediments. These contaminants have been transported from the reservoir sediments into the shallow ground water that provided drinking water for Milltown residents. The reservoir was designated a Superfund site in September 1983.



2.2 ANACONDA SMELTER SITE

The Anaconda Smelter is located at the southern end of the Deer Lodge Valley approximately 25 miles northwest of Butte. Ore from the Butte area mines was transported to Anaconda and processed at various locations (Old Works, Arbitr Plant, and Smelter Hill) from 1884 to 1980. Ore processing wastes, including about 185 million cubic yards of tailings, about 27 million cubic yards of furnace slags, and about 250,000 cubic yards of flue dust (CH2M Hill, October 1984), are contained within an area of more than 6,000 acres and contain elevated concentrations of copper, cadmium, arsenic, lead, and zinc. The Anaconda Smelter area was designated as a Superfund site in September 1983.

Tailings were typically deposited in ponds where solids were allowed to settle before the wastewater was recycled or released into nearby watercourses. These ponds (Anaconda Opportunity, Bradley, and Iron) were created by a series of dikes which have left mounds of tailings as deep as 90 feet. These ponds contain various wastes which have led to ground water and surface water quality degradation. Additionally, emissions from the smelter stack have resulted in soils contamination throughout a broad area of the upper valley.



2.3 MONTANA POLE SITE

The Montana Pole site encompasses approximately 40 acres immediately south of Silver Bow Creek at the southwest edge of Butte. From 1947 to 1983 the Montana Pole Treating

Company treated poles with pentachlorophenol (PCP) and creosote at this site. In 1983, seepage of these wastes from the Montana Pole site into Silver Bow Creek was estimated to be two to five gallons per day. The site was designated a Superfund site in November 1986.



2.4 SILVER BOW CREEK/ BUTTE ADDITION SITE

Following the discovery of gold in 1864, the Butte area became an internationally



recognized mining center with over 300 combined copper and silver mines, 9 silver mines, and 8 smelters in operation during 1884. In 1955, excavation of the Berkeley Pit began and mining continued until 1977. Silver Bow Creek has historically received discharge from mining, smelting, wood treating, and other industrial sources for over 100 years.

The Silver Bow Creek site was designated a Superfund site in September 1983. The original site encompassed the floodplain of Silver Bow Creek from Butte downstream to the Warm Springs Ponds. Remedial investigations were initiated within this area during 1985. In November 1985, the boundaries of the site were expanded to include the Butte area. Downstream portions of the Clark Fork River floodplain from Warm Springs Ponds to Milltown Reservoir were identified as an expanded study area.

Today mining, milling, and smelting wastes exist as sources of soil, water, and air contamination throughout the Butte area. Contaminated surface water runoff from the Butte area discharges directly to Silver Bow Creek. In addition, underground mines in the area are filling and generating acid water as water levels rise. During active mining, these mines were dewatered by a network of pumps with some water being recycled and some being discharged to Silver Bow Creek. It is estimated that over 3,500 miles of underground mine workings are interconnected with the Berkeley Pit. These mines contain approximately 11.2 billion gallons of acid mine water (CDM 1988). Initial investigations suggest that within eight years at the earliest, water in the Berkeley Pit may rise to a level where acid mine drainage could contact the bedrock/alluvium interface with the possibility for contamination of Silver Bow Creek.

In addition to contaminants from the Butte area, the Montana Pole and Ricker wood treating sites contribute to the contaminant load of Silver Bow Creek. Continuous deposits of metals-laden sediments and tailings lie within the floodplain and con-

taminate surface and ground water along Silver Bow Creek and the Upper Clark Fork River. The Anaconda Smelter site also has contributed contamination to the Clark Fork River.

2.5 INTERRELATIONSHIPS AMONG SITES

Geographic, technical, and legal interrelationships among Superfund sites in the Clark Fork Basin dictate that close coordination will be required during implementation of this Master Plan. Due to their geographic proximity, all Superfund sites are sources of contamination to Silver Bow Creek and/or the Clark Fork River. As a result of this interrelationship, response actions need to be coordinated so that downstream, down-gradient, or downwind sites are not recontaminated, following cleanup, by upstream, upgradient, or upwind sites. Another similarity among these sites is the problem of dealing with large volumes of mining wastes which contain similar metallic contaminants. The sites also share similar pathways through which human health and the environment are adversely affected. Due to geographic proximity and similarities of waste characteristics, response action criteria which are established for these sites will be closely related. For the same reason, response actions appropriate at one mining waste site may also be appropriate at other sites.

All of these interrelationships among Superfund sites in the Clark Fork Basin require that response actions are carefully coordinated to ensure that effective solutions are identified and implemented in an appropriate sequence. The overall purpose of this continuing master planning effort is to ensure that activities being conducted at individual sites complement each other and lead to the most efficient response possible.

3.0 ADDRESSING OPERABLE UNITS

In order to manage the interrelated problems identified at the four Clark Fork Superfund sites, EPA and MDHES have consolidated the 77 potential contamination problems into 25 **Operable Units**. An operable unit is a clearly defined, smaller portion of the overall work to be completed at a Superfund site. Each operable unit is generally investigated and remediated on an individual basis. The criteria used to designate operable units are:

- Areas with similar contaminated media (soils, flue dust, ground water, etc.);
- Areas within a similar geographic area;
- Areas that will be remediated using similar techniques;
- Areas that will be remediated within a similar time frame and
- Areas that can be managed and addressed as an individual RI/FS.

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These 25 operable units are subject to change as more information becomes available. For example, it may be possible to further consolidate operable units if additional similarities between individual units are identified, or further investigation may show that the consolidated operable units must be broken back down into smaller, more manageable units to carry out appropriate remedies.

3.1 CRITERIA FOR ESTABLISHING PRIORITIES

Since there are so many Superfund problems to be addressed, priorities are established to ensure the most serious problems are dealt with first. The EPA and MDHES have identified high, medium, and low priority operable units according to the sequencing criteria listed in Table 1.

Table 1: Criteria for Establishing Priorities for Operable Units	
High Priority Sequencing Criteria:	
1.	High potential human health exposure
2.	High potential environmental exposure
3.	Provides critical-path data needed to fully address other operable units
Medium Priority Sequencing Criteria:	
1.	Medium potential human health exposure
2.	Medium potential environmental exposure
3.	Potential for recontamination of other operable units located downstream, downgradient, or downwind
4.	Unusually complex problem requiring lengthy evaluation
Low Priority Sequencing Criteria:	
1.	Low potential human health exposure
2.	Low potential environmental exposure
3.	Low present human health or environmental exposure but potential future exposure
4.	Low risk of off-site contamination

The sequencing criteria are ranked according to several factors. Human exposures are generally given a higher ranking than other criteria. There is recognition that some human health concerns pose an immediate health risk that should be dealt with as a removal action. Other health concerns involve chronic risks over a lifetime of exposure that can be responded to with a later, longer-term action. In total the sequencing criteria provide for the orderly resolution of human health and environmental concerns at the Superfund sites.

3.2 RANKING OPERABLE UNITS

Each of the 25 operable units was evaluated against the criteria shown above and placed into a high, medium, or low priority category. This ranking is presented in Table 2. Each of these operable units is shown on the master schedule in Section 5.

3.3 ACCOMPLISHMENTS

A significant amount of work has already occurred on 11 of these operable units. This section briefly summarizes efforts to date.



3.3.1 Milltown Reservoir Site

In 1983 a Remedial Investigation/Feasibility Study (RI/FS) was initiated by MDHES and EPA. As a result of these studies, EPA provided funds for a new water supply system for Milltown in 1985. RI/FS activities are continuing at Milltown under the lead direction of MDHES. These studies will address the need for, and possible solutions to, the contaminated reservoir sediments and ground water at Milltown. In addition, these studies are being expanded to determine if releases of hazardous substances, pollutants, or contaminants have occurred or have the potential for occurring downstream from the reservoir.

Table 2: Proposed List of Priorities of Clark Fork Operable Units	
High Priority Operable Units	
	Mill Creek
	Walkerville
	Butte Priority Soils
	Old Works Removal
	Flue Dust
	Warm Springs Ponds
	Travona Flooding
	Montana Pole
	Mine Flooding (Berkeley Pit)
	Rocker
Medium Priority Operable Units	
	SBC Area I (Metro Storm Drain—Colorado Tailings Streamside Tailings (Colorado Tailings—Warm Springs Ponds))
	Smelter Hill
	Clark Fork River
	Milltown Reservoir
	Anaconda Community Soils
	Anaconda Site-wide Ground Water
	Old Works (General)
Low Priority Operable Units	
	Butte Non-Priority Soils
	Tailings (ground water/alluvium)
	Arbiter
	Smelter Wastes (Beryllium, Slag)
	Anaconda Surface Water and Sediment
	Agricultural Lands
	Active Mine Area
<small>Work on operable units shown in boldface has begun. This includes all high priority and most medium priority operable units.</small>	

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Reference 2

**Excerpts From Progress -
Clark Fork Basin Superfund Sites;
EPA and MDHES; May 1990**

May 1990



PROGRESS

Clark Fork Basin Superfund Sites

By the Montana Department of Health and Environmental Sciences
and the U.S. Environmental Protection Agency

Introduction

Superfund remediation activities are progressing at a rapid pace this spring in the Clark Fork Basin Superfund sites. Major events include accelerated cleanup of the Mill-Willow Bypass, emergency soils removal in Butte, and a study of the Colorado Tailings, which is scheduled for cleanup in 1991. More than 100 years of mining have left a hazardous legacy along Silver Bow Creek and the Clark Fork. Millions of tons of tailings, rich in heavy metals, have contaminated soils, groundwater and surface water. Planned remediation activities will lessen the contribution

of metals to soils and waters.

The U.S. Environmental Protection Agency (EPA) and the Montana Department of Health and Environmental Sciences (MDHES) investigate and clean up Superfund sites in Montana. Periodically, the agencies produce public information on site activities. This progress report summarizes current Clark Fork Basin Superfund activities where the public can obtain more information and how they can get more involved in the Superfund process.

Clark Fork sites have colorful history

Four Superfund sites lie in the Clark Fork Basin from Butte to Missoula, 138 river miles. The Clark Fork sites include the Silver Bow Creek/Butte Area, Montana Pole, Anaconda Smelter and Milltown. Except for the Montana Pole site, contamination at the sites is primarily mining wastes and heavy metals-laden soils and water. The Montana Pole site which lies adjacent to the Silver Bow Creek/Butte Area site in southwestern Butte is contaminated with wood treating wastes

EPA and MDHES have designed a coordinated plan emphasizing efficient investigation and cleanup of the sites. In 1988, EPA published a Clark Fork Master Plan. This summer, EPA will publish an updated and expanded Master Plan. Both the coordinated plan and the Master Plan prioritize the activities of 25 "operable units" and 77 smaller problem areas of the Clark Fork Superfund sites. The Master Plan also includes

work underway by other agencies conducting studies in the basin.

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Silver Bow Creek/Butte Area



Site background

The Silver Bow Creek/Butte Area site generally includes Walkerville, Butte, the Berkeley Pit, Silver Bow Creek, Rocker, the Warm Springs Ponds and the Clark Fork River to the Milltown Reservoir, about five miles southeast of Missoula.

The Silver Bow Creek site officially became a Superfund site in 1983 when it was added to the National Priorities List of Superfund sites. Mining, milling and smelting wastes, primarily heavy metals, have contaminated thousands of acres of flood plain and streambanks as well as residential areas in Butte. The wastes are toxic to plant and aquatic life and may pose a threat to human health.

Since February 1990, EPA has assumed the lead role on all Silver Bow Creek investigations except for studies of streamside tailings which remain under MDHES lead. The main potentially responsible party, ARCO, will be given the opportunity to conduct the actual remedial investigations and feasibility studies for all Silver Bow Creek operable units. EPA may offer the responsible parties the opportunity to conduct site investigations and cleanup. ARCO will conduct its investigations in compliance with work plans developed or approved by, and under close supervision of, EPA and MDHES.

Current activities

Warm Springs Ponds: The ponds were originally built by Anaconda Mining Company beginning in 1911 with the construction of Pond 1. The ponds were designed to trap and hold mining wastes flowing down Silver Bow Creek and other streams before being released into the Clark Fork. MDHES prepared a feasibility study and cleanup plan for the ponds, and held public meetings and hearings last December to present a cleanup plan to the public. MDHES is now preparing detailed responses to the numerous comments received.

In addition, ARCO developed a somewhat different alternative for cleanup of the ponds and presented it to MDHES and the public. MDHES and EPA are reviewing the merits of ARCO's plan in detail. As a result of the public comments and ARCO's proposed plan, the final cleanup of the ponds is likely to be a combination of plans. The final cleanup approach will be uncertain until EPA completes the Record of Decision which will

spell out the selected cleanup plan. Improvements to the pond berms to protect them from earthquake and flood hazards will begin this summer, with other improvements to the pond systems to begin in 1991. The proposed cleanup is expected to defer decisions about the need for an upstream flood management impoundment and the adequacy of utilizing Pond 3 for treatment of flood flows until 1995, when operating experience and other Superfund activities upstream can better define the viability of ARCO's proposed treatment approach.

Mill-Willow Bypass: Because EPA and MDHES suspect the Mill-Willow Bypass is the major area responsible for fish kills in the upper Clark Fork, ARCO has begun to identify and isolate tailings and contaminated soils that wash into the bypass and upper Clark Fork during summer storms. A work plan for removal of these wastes is being developed now and cleanup is projected to begin in the bypass late this summer.

Streamside Tailings: Large amounts of tailings have been deposited on the banks of Silver Bow Creek between the Colorado Tailings in Butte and the Warm Springs Ponds. Because vegetation will not grow in these contaminated areas, they are typically bare and are susceptible to wind and water erosion. MDHES is currently investigating one alternative to revegetate these tailings to prevent erosion and movement of contaminants. In addition, a remedial investigation and feasibility study, which will begin this year and last about two years, will consider several alternatives for handling tailings deposits in the streambed including removal, rechanneling the creek, revegetation and combinations of these alternatives. The Streambank Tailings and Revegetation Study (STARS) test plots are part of this investigation.

Clark Fork River: Tailings have been deposited at numerous locations along the Clark Fork River between the Warm Springs Ponds and Milltown Reservoir. MDHES conducted a preliminary survey of contamination along the Clark Fork. The results of this survey will be available this summer. EPA is planning to begin the remedial investigation/feasibility study on this site in early 1991. The upper portion of the river

is the site of an ARCO-funded demonstration project that will test various methods for stabilizing the tailings in place.

Rocker Timber Framing and Treating Plant: The Rocker plant treated timbers for the mines in Butte. Timber treatment consisted of an arsenic-based preservative which was resistant to fire. Last fall, MDHES directed ARCO to conduct an emergency removal of highly contaminated soils at the site. ARCO completed the removal, contoured the site and tore down some old, potentially dangerous buildings. ARCO transported the soils to a disposal site in Oregon. A remedial investigation will identify remaining contamination sources at the site. This investigation will begin in early 1991 under EPA oversight.

EPA will develop work plans for these studies this summer. Formal negotiations with responsible parties will begin this fall, with field investigations expected in the spring of 1991, and corrective action to begin in two years.

Butte mine flooding: The mine flooding area includes the Berkeley Pit and underground mines. Left unchecked, mine flood water may discharge to groundwater and surface water. The mine water is acidic and is contaminated with heavy metals, sulfates and arsenic. EPA and several potentially responsible parties, including ARCO, Montana Resources Incorporated, ASARCO and Washington Corporation have reached agreement on the Remedial Investigation/Feasibility Study Work Plan. EPA has not reached agreement with several other responsible parties. All consenting parties have agreed to try to complete this study by late 1993. This remedial investigation/feasibility study will evaluate alternatives for addressing the mine flooding problem and determine a critical water level at which the Berkeley Pit has to be maintained to prevent contamination from being spread by flooding.

The Mine Flooding Remedial Investigation will include the following:

1) Inflow control investigation - to evaluate the possibility of controlling flows into the Berkeley Pit.

2) Surface water investigation - to monitor the quality of water at the treated mine water discharge point into Silver Bow Creek to determine whether it meets water quality standards.

3) Syndicate Pit evaluation - to evaluate the effect and possible control of Syndicate Pit water which flows into the Berkeley Pit.

4) Butte disturbed soils investigation - to determine the effect that contamination from mine waste piles in Butte has on mine flooding.

5) Tailing dam safety assessment - to review the safety of the Yankee Doodle Tailings Ponds Dam which lies above the Berkeley Pit.

6) Bedrock groundwater monitoring - monitor water quality in the mines and measure bedrock water levels. The results of this study will give the agencies information they need to determine whether water levels are rising more quickly than previously believed.

7) Leach pad area alluvial investigation - monitor the leach pad area above the Berkeley Pit to determine if they are a source of groundwater and surface water contamination.

8) Private well inventory - to identify and possibly monitor all private and municipal shallow wells to collect information on groundwater levels and quality.

9) Neutralization investigation - to determine if Berkeley Pit water could be neutralized by adding mine tailings to it.

Travona/West Camp: In 1989, EPA began pumping the rising water of the Travona Mine to prevent the water from flooding basements and running into Silver Bow Creek. The waste water pumped from the Travona is discharged to the Butte Metro Treatment Plant and must meet water quality standards, including the "I" classification discharges for toxic metals and drinking water standards for arsenic. The involved responsible parties constructed a pumping and piping system to the Metro sewer line on Iron Street. Approximately 200 gallons per minute of the Travona water has been pumped to the Metro Plant since January 1990, a total of 40,000,000 gallons from January to May. Pumping stopped in May because the water level was brought below the desired control elevation. Pumping will be initiated when necessary to keep the water below the control level.

Butte priority soils: The Butte priority soils include 36 areas of Butte which pose a potential threat to human health and the environment because of lead, zinc, copper, cadmium and/or arsenic. These areas vary in size, location and composition. Some areas are waste rock dumps, smelter wastes or tailings. Cleanup of these sites will proceed in four phases:

1) Time-critical removal - During the 1990 and 1991 construction seasons, one of the responsible parties, ARCO, will remove or reclaim 10 source areas with six of these scheduled for this summer. These 10 source areas cover 12 of the 36 areas so far identified. 2) Non time-critical

Cont. on page 4

PROGRES:



Montana Pole



Site background

Preliminary investigations at the Montana Pole site showed the presence of hazardous contaminants, including pentachlorophenol (PCP) and dioxin, in site soils and groundwater. The Montana Pole site is located at 202 West Greenwood Ave. in Butte. The facility operated from 1947 until 1984 preserving poles, posts and bridge timbers.

Current activities

In June, MDHES begins oversight of a remedial investigation/feasibility study of the Montana Pole site. The remedial investigation/feasibility study will determine the extent of contamination, the effects upon human health

and the environment, and appropriate cleanup alternatives. The downstream extent of contaminant studies associated with the Montana Pole site will be to the lower end of the Colorado Tailings. The Silver Bow Creek Streamside Tailings Remedial Investigation will determine if Montana Pole contaminants have extended further downstream and if they need to be remediated. ARCO will perform the site investigations under MDHES supervision.

A public review period on the Remedial Investigation/Feasibility Study Administrative Order on Consent will end June 1, 1990. MDHES and EPA encourage the public to become involved in the Superfund process at the Montana Pole site.

Silver Bow Creek/Butte Area

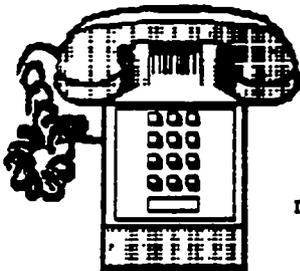
(Cont. from page 3)

removal - EPA is developing a plan for cleanup of the residential areas, in Butte and Walkerville that are not addressed in the time-critical removal action.

3) Lower Area I (Colorado Tailings and Butte Reduction Works) - EPA and ARCO are developing a plan to address this area with the goal of cleanup in 1991. An interim remedy will be selected, consistent with the final remedy, after public input. ARCO will conduct this cleanup

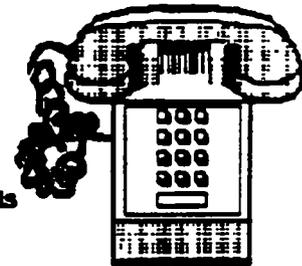
action under an order by EPA.

4) Remedial investigation/feasibility study - EPA and MDHES will address those areas not included in the time-critical and non time-critical removals in a remedial investigation/feasibility study. The investigation and study will focus on how storm run-off from Butte may affect human health and the environment in the Silver Bow Creek study area. EPA has prepared a scoping document and this summer will write a work plan for remedial investigation/feasibility study activities.



Superfund Hotline

If you have questions, concerns or comments about the Superfund program, in general, or about specific sites, call the Montana toll-free Superfund hotline. The hotline is answered by Montana Department of Health and Environmental Sciences Superfund staff in Helena, and is in service 8 a.m. to 5 p.m. weekdays, except holidays. (In-state use only)



1-800-648-8465

Reference 3

**Excerpts From Superfund Program Fact Sheet,
Silver Bow Creek/Butte Area Site;
EPA Region VIII; September 1988**

Superfund Program Fact Sheet

Silver Bow Creek/Butte Area Site Butte, Montana

September 1988

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) in cooperation with the Montana Department of Health and Environmental Sciences, recently completed a study to determine whether mine flooding in the West Camp area of Butte (see page 2 for discussion of West Camp) presents a threat to public health or the environment, and to identify and assess possible solutions to the flooding.

The study indicates that 1) the potential exists for contaminated mine water to discharge into Silver Bow Creek or the adjacent alluvial aquifer; 2) the situation should be monitored so that action can be taken at the proper time to avert such discharge; and 3) there are several response actions that could mitigate the potential problems associated with such discharge.

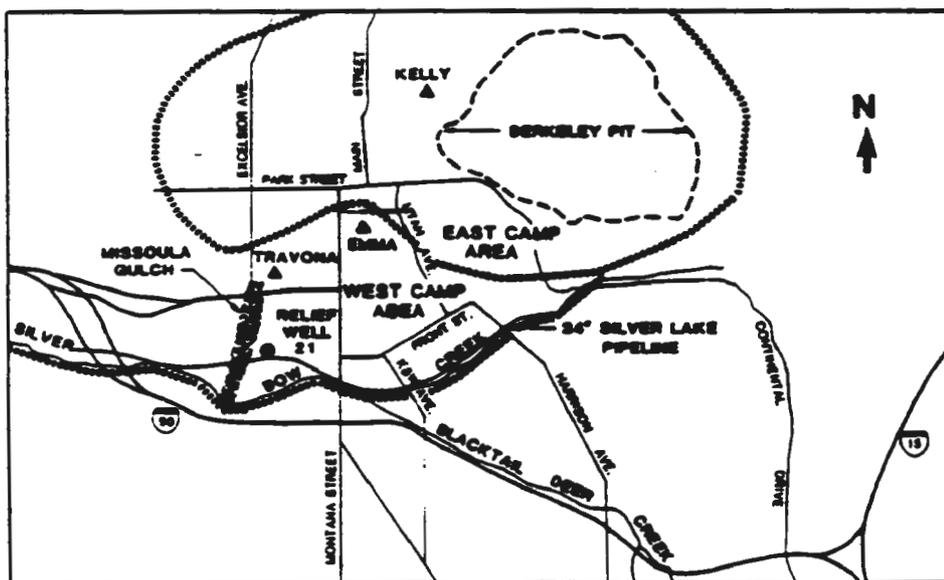
EPA expects to respond in two stages. EPA's current preferred alternative for the first stage is to monitor ground water levels and chemistry so that action can be taken at the proper time to avert discharge of contaminated water into surface or ground water. Results from this first stage and public input will help determine the timing and design for the second-stage response. The monitoring will be used to trigger the implementation of a stage two response that will draw upon one of the other feasible response actions described on pages 2 and 3 of this fact sheet.

EPA is concerned about flooding of the West Camp mines because discharge from underground workings could further contaminate Silver Bow Creek. Ground water samples from the Travona Shaft, located in the West Camp, show elevated levels of arsenic and

heavy metals. EPA believes that Silver Bow Creek could be affected by direct discharge of contaminated ground water to Missoula Gulch, which joins Silver Bow Creek west of Montana Street. Water quality in Silver Bow Creek also could be adversely affected if contaminated ground water from the West Camp mine workings were to flow into the shallow ground water along Silver Bow Creek.

EPA has prepared this fact sheet to describe the options it has studied for solving potential West Camp flooding problems, and to describe its current preferred plan for the first stage response. The public is encouraged to ask questions, comment, and offer suggestions regarding all the possible options.

Comments from the public are sought both at a public meeting on September



Map of Butte Mining District

Public Meeting To Be Held September 14

You are invited to attend a meeting on September 14, 1988 about the West Camp mine flooding. The U.S. Environmental Protection Agency will discuss its proposed solutions to the flooding problem, respond to questions, and receive comments.

Time:

7:00 p.m., September 14, 1988

Place:

Montana College of Mineral Science and Technology, Room 208 of the Engineering Laboratory Classroom (ELC) Building, West Park Street, Butte, Montana.

2702

Reference 4

**Excerpts From Progress Report No. 2:
Clark Fork Superfund Sites;
EPA and MDHES; August 1988**



Progress Report

Clark Fork Superfund Sites

Southwestern Montana

U.S. Environmental Protection Agency &
Montana Department of Health and Environmental Sciences

ISSUES OF INTEREST

Master Plan Develops Priorities

In the cooperative effort to improve the environment in the Clark Fork River Basin, the U.S. Environmental Protection Agency (EPA) and the State of Montana have developed a plan for establishing priorities for study and action in the Basin.

EPA and the State have identified 77 potential contamination problems within the four Superfund sites in the Basin. Each problem represents part of a larger problem or **response action**¹ at a Superfund site. The four sites are the Milltown Reservoir site, the Anaconda Smelter site, the Montana Pole site, and the Silver Bow Creek site. For purposes of study and cleanup, the Butte Addition of the Silver Bow Creek site is being managed separately from the downstream portion of the site.

In order to manage the large number of complex, inter-related problems identified within the Clark Fork Superfund sites, EPA and the Montana Department of Health and Environmental Sciences (MDHES) have consolidated the 77 problem areas into 25 "**operable units**." These 25 operable units are subject to change as more information becomes available. An operable unit is a clearly defined, smaller portion of the overall work to be done at a Superfund site. Each operable unit is studied and addressed separately to provide the most effective cleanup.

EPA and MDHES have been setting priorities on Superfund work to be done throughout the Clark Fork River Basin. They have developed guidelines for establishing the order of work, and based on these guidelines, they have identified high, intermediate, and low priority operable units within the basin (see Table 1, page 3). The guidelines for setting priorities should ensure that the most serious or complex problems are dealt with first.

¹ Words defined in the glossary at the end of this Progress Report appear in bold face type on first mention.

The proposed general guidelines for ranking operable units are presented below.

High Priority Operable Units:

- May have imminent health exposure (e.g., Walkerville).
- Have threat of imminent environmental damage (e.g., Warm Springs Ponds).
- Provide information needed for other operable units (e.g., mine flooding at Berkeley Pit).

Intermediate Priority Operable Units:

- Have long-term lower level health exposure (e.g., Anaconda Community Soils).
- Have potential threat of environmental damage (e.g., Silver Bow Creek Area 1).
- Have potential to contaminate other operable units located downstream, down gradient, or down wind (e.g., Streamside Tailings).
- Have unusually complex problems requiring in-depth investigation (e.g., Smelter Hill).

Low Priority Operable Units:

- Have potential for low-level human health exposure (e.g., agricultural lands).
- Have potential for low-level environmental damage (e.g., active mine area).
- Have low present impact but potential for increased health or environmental damage (e.g., Opportunity Ponds).
- Have low potential for off-site contamination (e.g., Arbiter).

NOTE: The Clark Fork Progress Report provides a periodic overview of Superfund activities and important documents in the study and cleanup of the Clark Fork River Basin. These Reports include information on issues of interest, plans and progress at Clark Fork sites, upcoming meetings, ways to obtain further information, and a glossary of Superfund terms.

Specific questions about these activities should be directed to Bob Fox at the Montana EPA office, 301 South Park, Helena, Montana 59626; phone: (406) 449-5414;

or contact Janie Stiles, Public Information Officer, Department of Health and Environmental Sciences, Cogswell Building, Helena, Montana 59620; phone: 444-2821 or 1-800-648-8465 (toll-free in-state).

Public involvement is an important part of the Superfund process and is encouraged by Superfund personnel. EPA and MDHES encourage residents to offer suggestions for information to include and issues to cover in the Progress Reports.

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14, 1988 (see box below) and during the public comment period from August 29 through September 28. EPA also encourages interested persons to review the full study, called an Engineering Evaluation/Cost Analysis at the information repositories listed at the end of this fact sheet.

After the public comment period closes, EPA will decide how to proceed at the West Camp. The action chosen will be compatible with long-term Superfund plans for the Silver Bow Creek/Butte Area Site.

SITE BACKGROUND

During the period of active mining in the West Camp, ground water was pumped out of the mines from the Emma Shaft to the East Camp, where it was used in Anaconda Minerals Company's water management system. (See map, page 1) The West Camp mines were sealed off from the East Camp mines by watertight bulkheads during the late 1950s.

Pumping of water from the West Camp mines was discontinued in 1965. During the fall of 1965, ground water began to flood basements in the area south of the Emma and Travona Shafts. To control this problem, Anaconda

Minerals Company drilled a well down gradient of the Travona Shaft to intercept water at an elevation below the area where basement flooding was occurring. From 1965 to 1969, water flowed from this well, known as Relief Well 21, into Missoula Gulch and then into Silver Bow Creek. Water levels in the Travona Shaft dropped about 40 feet while water flowed out of Relief Well 21.

The Montana Bureau of Mines and Geology in Butte has monitored water levels in the Travona Shaft and Relief Well 21 since 1982. The 1982 water level in the Travona Shaft was almost 300 feet below the level recorded when the flow from Relief Well 21 stopped in 1969. At that time, the water level in the Travona Shaft was approximately 400 feet below the surface of the ground.

However, in 1984 water levels in the Travona Shaft began rising, and by March 1988 the depth to water was 193 feet. This rise was apparently due in part to the rising water levels in the Berkeley Pit system. Water levels in Relief Well 21 began to rise in 1987 and reached an elevation 50 feet below the surface of the ground in March 1988 (see Figure 1). Recent monitoring results have indicated that the rate at which water levels are rising has slowed. Based on this recent trend, however, EPA has concluded that

it is difficult to predict when contaminated mine water might discharge from Relief Well 21.

EPA became concerned about flooding in the West Camp mines because contaminated mine water may discharge from the mines to Silver Bow Creek. The State of Montana recently upgraded and reclassified Silver Bow Creek from an "E" stream to an "I" stream to establish legal basis to improve the quality of Silver Bow Creek. The change in classification means that the creek must meet higher water quality standards in the future. If flooding were to occur, water from the West Camp could introduce arsenic, zinc, copper, cadmium, lead, and iron in concentrations that would violate requirements for the "I" classification.

WHAT RESPONSES ARE BEING CONSIDERED?

During the study of this problem, EPA identified and screened potential responses to the flooding based on three criteria: effectiveness, implementability, and cost. After the screening, six potential remedies remained:

1. **Monitoring.** EPA would monitor water levels and sample ground water for dissolved metals at the Travona and Emma Shafts, within or near Relief Well 21, and within a new shallow well to be drilled near Missoula Gulch. Flow rates on Silver Bow Creek would also be monitored. EPA would use the monitoring data to refine its estimates of when additional response actions should be taken, and to refine the final design of its second stage alternatives.

Estimated cost*: \$378,507

2. **Pumping and Treatment of Ground Water.** Ground water would be withdrawn from a new well to be drilled near Relief Well 21 and treated with lime. There may also be a need to remove arsenic. The treated water would be discharged to Silver Bow Creek.

Estimated cost: \$1,714,000.

*Estimated cost is a single figure calculated from various future costs to make it possible to compare different alternatives.

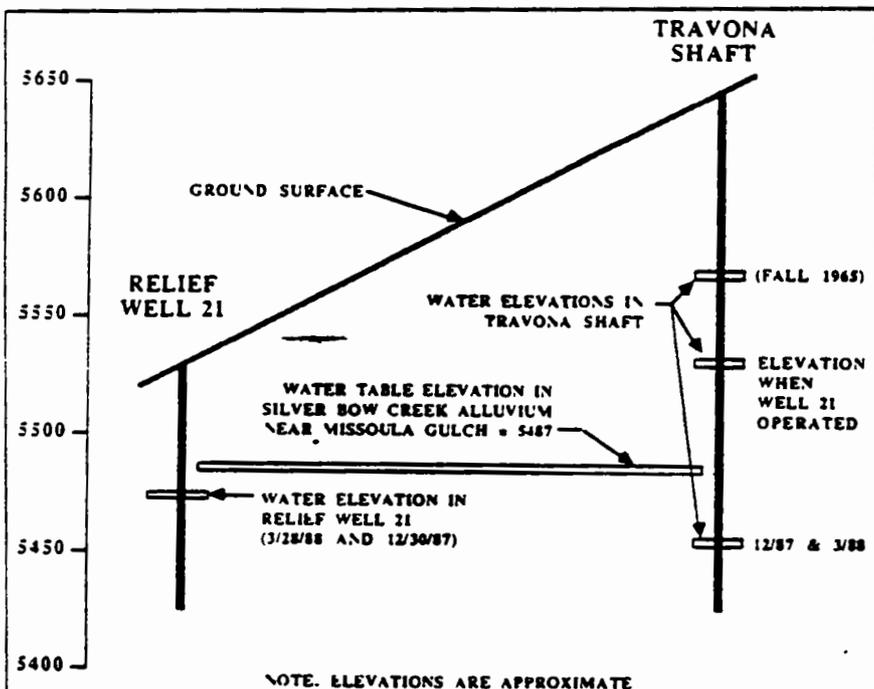


Figure 1 Water Levels in Travona Shaft and Relief Well 21.



EPA DESCRIBES BUTTE ADDITION PROGRESS

The focus at the Butte Addition includes mine flooding issues related to the Berkeley Pit and the Travona Shaft, planning for the Remedial Investigation/Feasibility Study on contaminated soils, and removal actions in Walkerville and at the Timber Butte Mill.

Efforts to Avert Mine Flooding Underway

EPA and MDHES are concerned about the rising water in the Berkeley Pit because contaminated mine water may eventually seep into the shallow ground water or be discharged via surface drainage to Silver Bow Creek. By late 1988 or early 1989, EPA plans to initiate a study regarding the pit and related mine flooding. This study will develop alternatives for preventing possible flooding and the spread of contaminated mine water. The public will have an opportunity to review and comment on the plans prior to initiation of the study. EPA will provide information about a public meeting to local newspapers and radio and TV stations.

EPA is investigating another potential flooding problem in an area of Butte known as the "West Camp" near the Travona Shaft (see map). As the mine water level rises in this area, the potential for spread of metals into Silver Bow Creek and the adjacent alluvial ground water increases. However, data from the Travona and Emma shafts and an observation well in the area show that during the past three months, the rate of water level rise has slowed significantly.

EPA completed an **Engineering Evaluation and Cost Analysis** on the Travona shaft during July 1988. The analysis indicated that it would be appropriate for EPA to continue to monitor the rising mine water in the area and be prepared to conduct an **Expedited Response Action** if necessary to prevent contamination of the shallow ground water and Silver Bow Creek. This action would be compatible with whatever final long-term remedy is implemented after the more comprehensive study that will follow. The Engineering Evaluation/Cost Analysis will be placed in the Butte information repositories listed on page 8, and EPA encourages residents to read and comment on the report. EPA will hold a public meeting in August on the proposed Travona action. The time and location of the meeting will be announced by area newspapers, radio, and TV stations.

Soils Screening Study helps to set priorities

In May 1988, EPA and MDHES completed the Butte area soils screening study that was initiated during the summer of 1987. The full report is available for review at Butte area information repositories. In general, the study showed metals levels to be highest at old mill sites and mine waste dumps. Residences located near mine wastes tended to have higher levels of metals than those located on the flats, or even than those on Butte Hill that are somewhat removed from old mining operations. EPA has prepared a project summary of the soils screening study. Interested residents may obtain a copy by contacting Sara Weinstock, EPA Remedial Project Manager, or Janie Stiles, MDHES Superfund Public Information Officer, at the addresses shown on page 8 of this Progress Report.

Walkerville Removal Completed; Timber Butte Evaluation Underway

The two-part Walkerville Removal has been completed. For one part of the removal, the EPA Emergency Response Branch (removal team) has completed the **Removal Action** begun in Walkerville during April 1988. While mercury vapor did not appear to be a significant problem during tests conducted in 1987, more recent tests revealed that some residences with unexcavated basements in the Walkerville area did contain mercury vapor. Therefore, the removal team excavated basements and built new walls in seven homes where elevated levels of lead and mercury vapor were found.

The removal team also removed soils containing elevated levels of metals located at or adjacent to 22 residences. These materials were removed and stabilized so they cannot be spread by wind or water erosion back into residential areas.

For the other part of the removal, the responsible parties, including Atlantic Richfield Company (ARCO), New Butte Mining, and the City of Walkerville, have completed the majority of their work in removing and regrading several old dumps. The areas will be reseeded and fenced to protect and maintain new vegetation and soil cover over the dumps.

The removal team has also begun to follow up on results of the Soils Screening Study that show very high levels of lead at the Timber Butte Mill. EPA collected air and soil samples at or near the mill property and is now evaluating analytical results of the sampling. After all test results have been evaluated, the removal team may begin work on a removal action at the mill some time during August.

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Reference 5

**Excerpts From Superfund Program Fact Sheet,
Silver Bow Creek/Butte Area Site;
EPA Region VIII; May 1990**

Fact Sheet

Superfund Program



Silver Bow Creek Site Butte Area, Butte, Montana

May 1990

CONTENTS

- The purpose of this fact sheet is to
- Provide background on the Silver Bow Creek/Butte Area Superfund site;
 - Describe the Mine Flooding Work Plan and proposed RI and FS tasks;
 - Describe the Administrative Order on Consent and the Unilateral Order;
 - Describe EPA's and the State's Responsibilities;
 - Answer commonly asked questions; and
 - Describe how the public can become informed about the site and involved in the decision-making process for selecting a cleanup plan

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has completed a Work Plan to assess problems and develop and evaluate solutions to environmental and public health issues related to mine flooding and pit filling at the Silver Bow Creek/Butte Area Superfund site.

The Work Plan was developed in cooperation with the Montana Department of Health and Environmental Sciences (MDHES). It describes activities that will be undertaken during the **REMEDIAL INVESTIGATION/FEASIBILITY STUDY (RI/FS)** on mine flooding. EPA has issued a **UNILATERAL ORDER** and an **ADMINISTRATIVE ORDER ON CONSENT** that require the **POTENTIALLY RESPONSIBLE PARTIES (PRPs)** to conduct the RI/FS.

Public Meeting To Be Held May 30, 1990

A formal public meeting will be held on May 30, 1990. EPA will receive comments on the Work Plan, the Administrative Order on Consent and the Unilateral Order. Your attendance, questions, and comments are encouraged. The meeting will be held at:

TIME: 7:00 p.m.

PLACE: Montana College of Mineral Sciences and Technology, Auditorium, Library Building, West Park Street, Butte, Montana.

SITE DESCRIPTION AND BACKGROUND

The Butte area has been mined almost continuously since 1880. Over this 110-year period, silver, gold, copper, ~~ZINC~~, lead and molybdenum have been mined in about 400 underground mines and several open pit mines. This mining activity has resulted in soil and water contamination and changes in the way ground and surface water flow in and near Butte. In 1985, the Silver Bow Creek site, which had been on the Superfund **NATIONAL PRIORITIES LIST** since December 1982, was expanded to include the Butte Area.

The mining companies installed an

extensive pumping system to dewater the underground mines and the Berkeley Pit during active mining. In the late 1950s bulkheads, or barriers, were installed underground to inhibit the flow of water between the mines and pits and thereby improve the efficiency of pumping operations. The resulting underground systems came to be called the East Camp and the West Camp. The East Camp is the area that includes the mine workings connected to the Berkeley Pit. The West Camp mines are located south and west of the East Camp.

Water was pumped from the West Camp area until 1965. With the end of active mining in 1982, the pumps were turned off and the underground mines began to flood. Once water levels reached the bottom of the pit, it began to fill. The water levels in the West Camp are currently higher than those in the East Camp, with water in the Berkeley Pit lower than the water levels elsewhere in the area. This causes water to flow into the pit. (See Figure 2, page 4)

The study area for the mine flooding portion of the Butte Area site consists of 14 square miles and includes the Berkeley Pit, Yankee Doodle Tailings Ponds, the Montana Resources Leach Pads, all surface areas draining to the mine workings, the Weed Concentrator and the East Camp and West Camp mine workings (see Figure 1 page 2)

EPA is concerned about mine flooding in the area because the water is highly acidic and contains high concentrations of iron, manganese, arsenic, lead, cadmium, copper, zinc and sulfates. If the water continues to rise in the pit, contaminated water may eventually flow into the shallow ground water and to Silver Bow Creek creating the potential for significant environmental impacts and human health problems.

The purpose of Superfund work at this site is to develop solutions to the contamination to prevent these problems from occurring. EPA and the PRPs will develop detailed plans to resolve these problems in the Mine Flooding RI/FS.

'Words shown in **SMALL CAPITAL** letters on the first mention are defined in the glossary on page 4

RI/FS WORK PLAN DESCRIPTION

The Butte Mine Flooding RI/FS Work Plan describes how the involved parties will collect the necessary information to assess the human health and environmental problem associated with mine flooding and develop solutions to the problems identified. This information must be gathered in order to understand what is happening now and to develop the most appropriate solutions. Such information will also help document and support the remedial action taken in the event that litigation becomes necessary. The RI/FS is scheduled so REMEDIAL DESIGN/REMEDIAL ACTION (RD/RA) can start by the Fall of 1993. This allows time to actually design and construct a treatment plant by late 1996 if it is necessary.

The general objectives of the RI/FS are to identify the nature and extent of contamination associated with mine flooding and evaluate remedial alternatives. The specific goals of the remedial response for this work are to mitigate the impact of mine water discharge on Silver Bow Creek and the adjacent ALLUVIAL aquifer and to maintain flow toward the pit and thereby contain the contaminated bedrock ground water in the Berkeley Pit for ultimate treatment. Specific remedial response objectives to meet the goals are to control the rate of mine flooding and to design and implement an appropriate remedy to ensure that discharges of mine water to Silver Bow Creek or the adjacent alluvial aquifer meet applicable state and federal water quality standards.



- **Leach Pad Area Alluvial Investigation:** install monitoring wells to evaluate whether the leach pads are a current source of contamination to the alluvial ground water system and Silver Bow Creek.
- **Private Well Inventory:** identify and possibly monitor all existing private and municipal shallow wells to provide additional information on alluvial water level and water quality.
- **Neutralization Investigation:** sample water and conduct studies to determine the feasibility of neutralizing the pit water by disposing of mine tailings in the pit.

If the need for treatment is postponed as indicated in some of the tasks above, innovative treatment technologies might be developed that will treat the water more completely and efficiently.

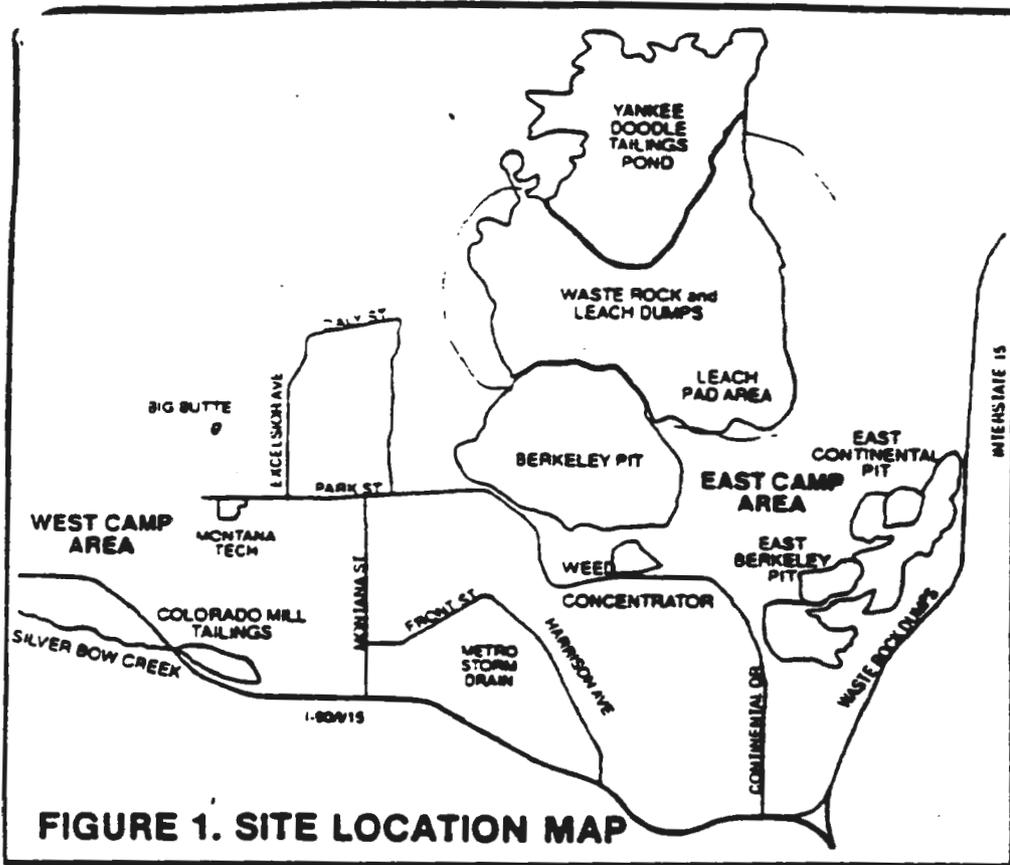


FIGURE 1. SITE LOCATION MAP

TASKS OF THE REMEDIAL INVESTIGATION SUMMARIZED

EPA has directed the PRPs to undertake the following tasks during the Remedial Investigation portion of the RI/FS.

- **Inflow Control Investigation:** monitor significant amounts of water entering the pit ("inflows") so that alternatives to control inflow can be evaluated. If inflows can be controlled, treatment of the pit water potentially could be deferred.
- **Surface Water Investigation:** monitor the flow and quality of water in the Silver Bow Creek/Butte Area at the approximate location where treated mine water discharge would enter the creek. This will provide the data necessary to determine if discharges to Silver Bow Creek meet state water quality limits.
- **Syndicate Pit Evaluation:** evaluate existing data to determine the amount of inflow to the Syndicate Pit system from storm water runoff from upper Missoula Gulch. Storm water entering the Syndicate Pit eventually reaches the Berkeley Pit through the mine workings. If this flow is significant and can be controlled, treatment of the Berkeley Pit water potentially could be deferred.
- **Butte Disturbed Soils Investigation:** review currently available data and relevant literature to determine whether water percolating through disturbed soils and solid waste piles contributes significantly to mine flooding. This study will evaluate whether clay barriers that prevent water seepage ("caps") are appropriate for controlling this inflow. Caps could extend the time available to develop treatment alternatives for the water in the pit.
- **Assessment of Tailings Dam Safety:** review a previous safety evaluation of the Yankee Doodle Tailings Pond Dam to determine safety given the current condition of the dam. If the dam failed, a large amount of water would immediately enter the pit, thereby potentially reducing the amount of time available for action.
- **Bedrock Ground Water Monitoring:** use existing shafts and install wells to monitor water quality and water levels in the bedrock. Resulting data would be used to develop a critical water action level and to monitor whether water levels rise more quickly than anticipated.

ADMINISTRATIVE ORDER ON CONSENT AND UNILATERAL ORDER

EPA has issued an Administrative Order on Consent and a Unilateral Order. These documents outline the work to be conducted during the RI/FS, the schedule for the work, and the parties responsible for each portion of the work. These legal documents direct the PRPs to conduct the work according to the work plan with EPA and MOHES oversight.

The Unilateral Order governs actions by the following companies: New Butte Mining Inc., Central Butte Mining, Inc.; North Butte Mining, Inc.; Tzarina-Travona Mining Corporation; Mountain Con Mining Company; West Butte Metals, Inc.; Blue Bird Mining Company; Eureka Mining Company; Yankee Mining Company; East Ridge Mining Company, and Black Rock Mining Company. These companies are to complete the following tasks, which are described on page 2 of this Fact Sheet.

- Private Well Inventory
- Butte Disturbed Soils
- Bedrock Ground Water Monitoring
- Syndicate Pit Evaluation

The Administrative Order on Consent governs actions by the following companies and individuals: Atlantic Richfield Company (ARCO), Mr. Dennis Washington, Montana Resources, Inc., AR Montana Corporation, ASARCO, Inc., and Montana Resources. All tasks and work outlined in the RI/FS except those specific tasks listed immediately above are to be completed by these companies. In addition, the Administrative Order requires the PRPs to maintain the water elevation in the Berkeley Pit below 5,410 feet (USGS datum).

WHAT ARE EPA'S AND THE STATE'S RESPONSIBILITIES?

EPA, MOHES, and the PRPs each have particular responsibilities related to this RI/FS. The PRPs' responsibilities are spelled out in the section on the Administrative Order on Consent and the Unilateral Order. EPA has the agency lead on all Butte Superfund activities, working with the State.

EPA and the State will:

1. Oversee the RI/FS;
2. Identify appropriate requirements (discharge standards, sludge disposal standards, etc.);
3. Conduct a RISK ASSESSMENT; and
4. Select the final remedy.

INFORMATION CENTERS

EPA and MOHES have established reading rooms where residents can review documents related to the Butte Area Superfund work. The Work Plan for the RI/FS, the Administrative Order on Consent, and the Unilateral Order for Mine Flooding and related documents can be found in these reading rooms. The locations are listed below.

Butte EPA Office
Silver Bow County Courthouse
155 West Granite Street
Butte, MT 59701
(406) 782-4452
Monday-Friday 8:00 a.m. - 5:00 p.m.

U.S. Environmental Protection Agency
Federal Building, 301 South Park
Helena, MT 59626
(406) 449-5414
8:00 a.m. - 5:00 p.m.

Butte Silver Bow Library
106 West Broadway
Butte, MT 59701
(406) 723-8262
Tuesday 12:00 p.m. - 9:00 p.m.
Wednesday 9:00 a.m. - 9:00 p.m.
Thursday-Saturday 9 a.m. - 6:00 p.m.
Closed Sunday & Monday

Montana College of Mineral
Science & Technology Library
West Park Street
Butte, MT 59701
Monday - Thursday
8:00 a.m. - 10:00 p.m.
Friday 8:00 a.m. - 5:00 p.m.
Saturday 9:00 a.m. - 5:00 p.m.
Sunday 1:00 p.m. - 10:00 p.m.

Conceptual Model of Water Levels Below the Surface

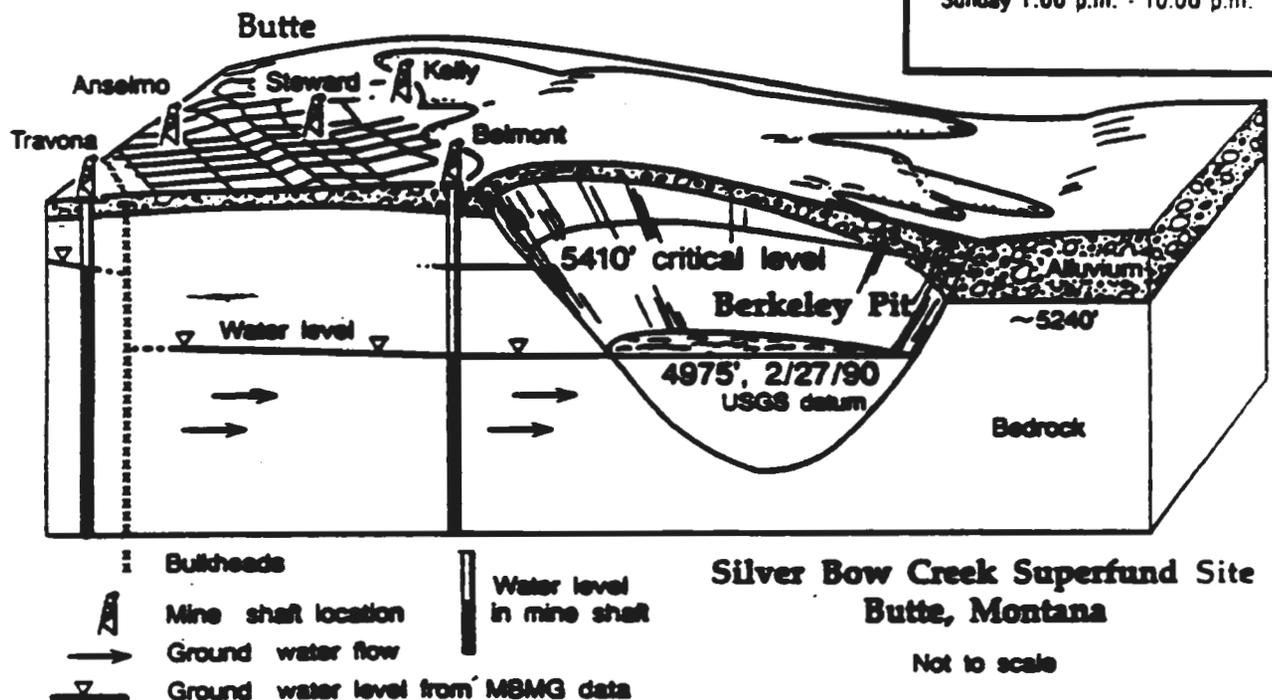


Figure 2 illustrates the relationship of ground water beneath the Butte Area to the Berkeley Pit and the 5,410-foot critical level (USGS datum). Relative water levels are shown to indicate the separation of the East Camp and the West Camp. The data used for water levels in this figure are from the Montana Bureau of Mines and Geology (MBMG).

ANSWERS TO COMMONLY ASKED QUESTIONS

As Superfund work proceeds in the Butte area, residents ask EPA a number of questions. The following are some of the most commonly asked questions, and EPA's responses.

Q. Why is EPA so concerned about the water in the Berkeley Pit?

A. If the water in the pit and associated mines is released, it could further contaminate the ground water and surface water. The water in the pit and mines contains high levels of arsenic, cadmium, lead, copper, zinc, iron, manganese and sulfates. These substances have proven adverse effects on the environment, human health and aquatic life.

Q. Why is the pit water level such an issue?

A. As long as the water level in the pit remains below a critical level, all excess water in the mine workings will continue to flow into the pit. The critical level is based on extensive monitoring of water levels in both the alluvial and bedrock ground water systems by the Montana Bureau of Mines and Geology (MBMG) and the Montana Department of Health and Environmental Sciences (MDHES). This level is the lowest alluvial ground water elevation in the area.

Once the water in the pit exceeds this elevation, the potential exists for water to flow away from the pit into the shallow ground water. Without action to control the water level in the pit, the pit water would contaminate the ground water. Eventually this contaminated ground water would reach Silver Bow Creek and contaminate the stream. MBMG monitoring has revealed that the water in the pit rose 30 feet in 1989. MBMG records also show that the rate of rise has decreased each year. This provides ample time to complete the RI/FS and implement a permanent solution.

The PRPs who signed the Administrative Order on Consent have agreed not to allow the water in the East-Camp system to exceed the 5,410 feet (USGS data) level. If the water does exceed this level, they are subject to \$25,000-per-day stipulated penalties.

Q. Who pays the costs of all the studies and cleanup?

A. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, also known as Superfund, the costs are paid by the PRPs. EPA has issued an Administrative Order on Consent and a Unilateral Order that outline each company's responsibility for the mine flooding work, i.e., who will complete and pay for each part of the work.

Q. Can the metals in the water be recovered and sold to help offset the costs of the cleanup?

A. The Mine Flooding FS will evaluate this alternative. Currently, the technologies that exist to recover the metals may be too expensive to make metal recovery cost effective. Some of the costs to be considered are construction, operation, and maintenance of a facility. Other factors that must be evaluated in relation to these costs are: reduction in sludge volumes, reduction of sludge toxicity, ability to meet water discharge standards and value of recovered metals.

Q. When will a treatment facility be built?

A. The RI/FS is expected to be completed by the fall of 1993. This schedule allows time to design and construct a treatment plant by late 1996 if necessary. However, current information indicates that a much later construction date is appropriate. A final date for construction will be dictated by the Record of Decision (ROD) after completion of the RI/FS. Primary factors involved in this decision will be final critical water levels, the long-term rate of pit filling and the inflow containment measures taken to slow mine flooding.

Q. Why do the studies take so long?

A. The 110-year history of mining in this area has left high levels of contamination in the soil and the water throughout the Clark Fork River Basin. The magnitude of the problems and the volumes of the wastes require extensive evaluation in order to achieve solutions that are effective, implementable, and compatible with other remedies in the Basin. Superfund is an enforcement program, in which those who contaminate the environment are required by law to pay for the cleanup. In order to enforce this the study data must hold up to court scrutiny. The data must also meet quality assurance and quality control requirements and EPA regulations and guidance.



GLOSSARY

A number of technical terms are used in Superfund work; those used in this sheet are defined below.

Administrative Order on Consent: negotiated legal document issued by EPA and signed by PRPs directing an individual business, or other entity to take corrective action or refrain from an activity. It describes the actions to be taken, violations and penalties for failure to comply, which can be enforced in court.

Alluvium: materials deposited by a stream, generally composed of sand, clay, or gravel.

Alluvial: refers to such formations.

Aquifer: A porous underground rock formation composed of materials such as alluvium, sandstone, or limestone that can store and transmit ground water to wells, springs, and creeks.

Bedrock: generally unbroken solid rock overlaid in most places by soil or rock fragments.

Ground Water: The supply of fresh water found beneath the earth's surface.

Institutional Controls: laws which are passed by local governments that govern actions that can be taken at hazardous waste sites. These would include zoning regulation, waste disposal regulations, etc.

National Priorities List (NPL): EPA's list of most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial action under Superfund. A site must be on the NPL to receive money from the Superfund Trust Fund.

Potentially Responsible Parties (PRPs): individuals or companies such as owners, operators, transporters, or waste generators potentially responsible for or contributing to contamination problems at a Superfund site. Whenever possible, EPA requires PRPs through administrative and legal actions, to clean up hazardous waste sites.

Remedial Action: The actual construction and implementation phase of a Superfund site cleanup that follows remedial design.

Remedial Design: A phase of remedial action that follows the RI/FS and includes development of engineering drawings and specifications for a site cleanup.

Remedial Investigation/Feasibility Study (RI/FS): a two-part study to determine the nature and extent of contamination and ways to solve the problems created by this contamination. During the RI, scientists identify the types, locations, and amounts of contamination and the risks they may present to human health and the environment. During the FS, scientists and engineers develop, screen, and evaluate ways to clean up contamination.

Reference 6

**Excerpts From Superfund Program Fact Sheet,
Silver Bow Creek Site, Butte Area;
EPA Region VIII (Montana Office); May 1990**

Fact Sheet

Superfund Program



Silver Bow Creek Site Butte Area, Butte, Montana

May 1990

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) in cooperation with the Montana Department of Health and Environmental Sciences (MDHES) has completed a work plan to eliminate or isolate a number of source areas that may pose potential risks to human health at the Silver Bow Creek/Butte Area site, Butte, Montana. Work will begin in June 1990 and will concentrate on mine wastes dumps located near residential areas, or drainages leading into public areas.

This work is part of a larger overall effort to clean up Butte area neighborhoods that have been contaminated by mining wastes. The cleanup of source areas is necessary before action is initiated on residential properties because source areas potentially could recontaminate properties previously addressed.

DESCRIPTION OF AREA

The area identified for action contains waste material from former mining, milling, and smelter operations in populated areas of Butte and Walkerville, Montana. The area extends from the North Walkerville/Missoula Gulch area to the Berkeley Pit and south to Silver Bow Creek.

The cities of Butte and Walkerville have been divided into six general work areas.

WALKERVILLE: (Priority Soil Area 4)

Rising Star	Magna Carta
Moose Dump Drainage Ditch	Sister
Atlantic	Josephine
Corra II	Rock Island

WESTSIDE BUTTE/WALKERVILLE: (Priority Soil Areas 6, 27)

Eveline Dump
Railroad bed source area west of Montana Tech

SOUTHCENTRAL BUTTE: (Priority Soil Area 29)

Tenson	Heaney
Green Cooper	Child Harold #2

CENTRAL BUTTE: (Priority Soils Area 31)

BA&P Railroad tracks between Maryland and Montana Street.

SOUTHWEST BUTTE: (Priority Soils Area 28, 32)

Travona	South Travona
Star West	Washoe Sampling Works

UPTOWN BUTTE: (Priority Soils Area 5, 9, 18, 20)

Jasper	Steward Mine Yard
West Steward Parking Lot	Mandan Park
Waste Dump Northwest of the Mountain Con II	Old Glory
	Rialto

The bulk of the work will be completed by the Fall of 1990 with the remaining work to be finished by the Fall of 1991.

GOALS

The work is designed to remove or stabilize mining waste materials in order to

Through an agreement with EPA and MDHES, the Potentially Responsible Parties (PRPs) will be responsible for the work and for future maintenance. EPA will provide continuous oversight to assure that work is completed properly and on schedule.

Each source area is unique, and therefore the action taken at each area will be specific to that area. At some locations the work will combine several actions. In general, however, the work will fall into the following categories:

- Total removal—the waste will be removed and taken to one of the disposal areas.
- Partial removal—part of the wastes will be removed and taken to a disposal area. The remaining material will be recontoured to minimize erosion, capped, revegetated and fenced where necessary.

INFORMATION FAIR TO BE HELD MAY 21, 1990

You are invited to attend the Information Fair to learn more about Superfund work on contaminated soils in Butte and Walkerville. The EPA will sponsor the Fair to explain the proposed work and receive public comment. Your attendance, questions, and comments are encouraged.

TIME: 7:00 p.m.

PLACE: Copper King Inn, Convention Center,
Harrison Avenue, Butte, Montana

The Information Fair will feature displays and additional information on remedial plans, and how the proposed work affects nearby drainage, vacant lots, and residential settings within the cities of Butte and Walkerville. EPA personnel will be available to address your comments and concerns regarding this work.

ANSWERS TO COMMONLY ASKED QUESTIONS

As Superfund work proceeds in the Butte area residents ask the EPA a number of questions. Following are some of the most commonly asked questions, and EPA's responses.

Q. What kinds of contamination are present in the soil?

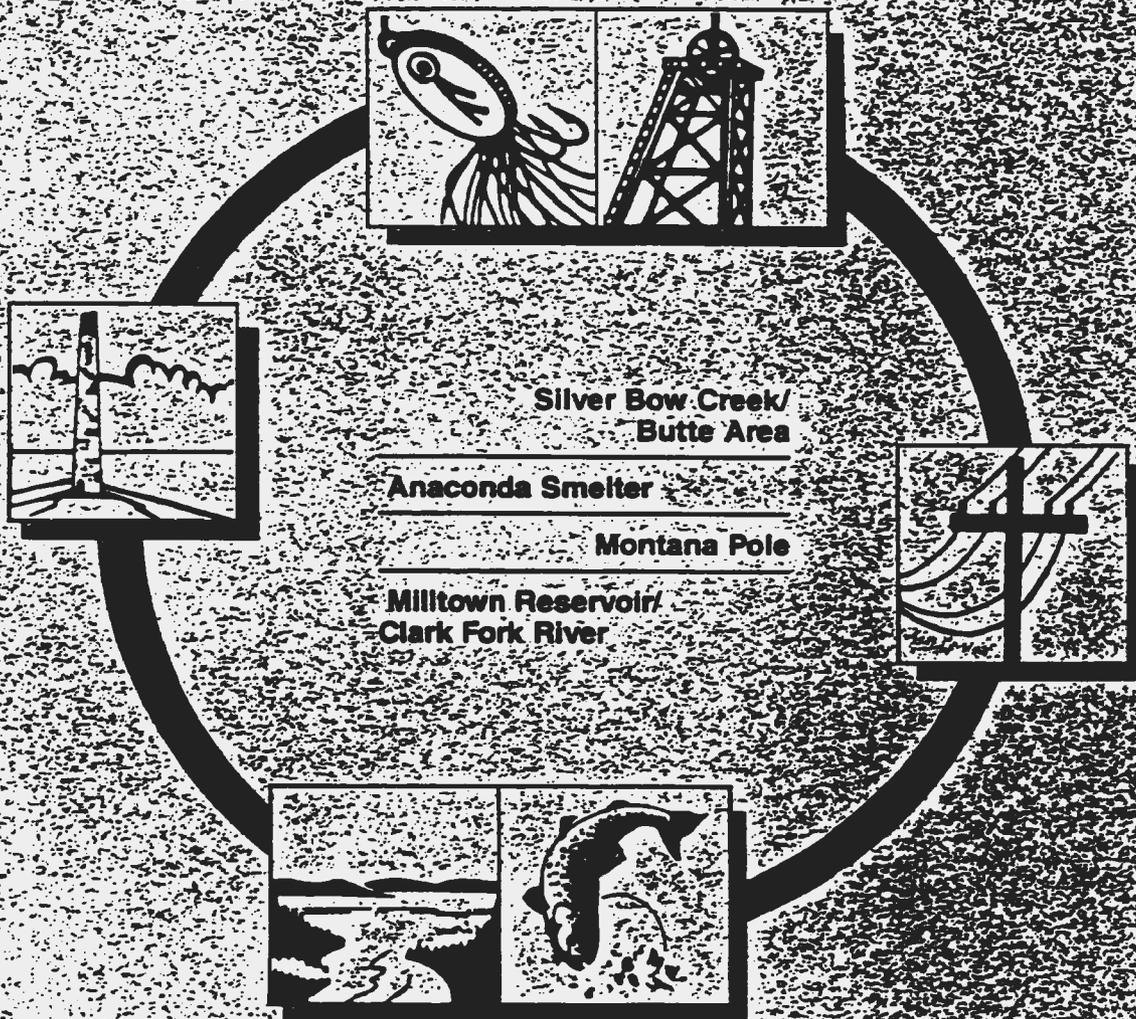
A. Results from soil sampling indicate there may be elevated levels of one or more of the following metals: lead, arsenic, copper, cadmium, and mercury.

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Reference 7

**Excerpts From Clark Fork Superfund Sites: Master Plan;
EPA and MDHES; November 1990**

CLARK FORK SUPERFUND SITES MASTER PLAN



U.S. Environmental Protection Agency November 1990
Montana Department of Health & Environmental Sciences

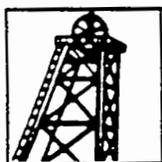
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area Further, EPA is overseeing an engineering evaluation and cost analysis for Lower Area One, which includes the Colorado Tailings, the Butte Reduction Works, and the manganese stock piles.

Initial work has begun on the Priority Soils expedited response action, which will focus on lower level contamination in residential yards.

The operable units and related contamination issues are listed below Operable units are identified in bold face at the left margin, removals are underlined



Butte Area

Priority Soils

- Human health risks associated with exposure to soils contaminated with lead, cadmium, arsenic, and mercury from mining waste

Walkerville—Removal completed in 1988

- Human health risks associated with exposure to soils contaminated with lead and mercury from mining waste.
 - *Remedy:* approximately 300,000 cubic yards of contaminated soils were removed

Timber Butte—Removal completed in 1989

- Human health risks associated with exposure to soils contaminated primarily with lead and arsenic.
 - *Remedy:* approximately 40,000 cubic yards of contaminated soils were removed.

Other Priority Waste Sources—Removal underway in 1990, anticipated to be completed in 1991

- Human health risks associated with exposure to soils contaminated with lead and arsenic from mining waste.
 - *Remedy:* contaminated soils will be removed in 1990 and 1991.

Residential Soils—all identified residences not previously addressed under the other actions.

Mine Flooding (Berkeley Pit)

- Underground mine workings and Berkeley Pit flooding and generating of acid mine waters.
- Potential for discharge of acid mine water to Silver Bow Creek.
- Contamination of ground water.
- Potential impacts to wildlife.

Travona—Removal implemented in 1989

- Flooded underground mine workings
- Potential for discharge of mine water to Silver Bow Creek.
- Contamination of ground water and potential drinking and irrigation water sources.
- Potential impacts to wildlife.
 - *Remedy:* More than 60,000,000 gallons of mine water treated and discharged so far

Butte Non-Priority Soils

- Potential exposure of future human populations to contaminated soils in non-residential areas

Butte Active Mine Area

- Source areas of *fugitive dust* contaminated with heavy metals.
- Source areas of acid mine drainage discharge to the Berkeley Pit.
- Impacts to wildlife resources resulting from exposure to mining waste
- Potential exposure of future human populations to contaminated soils



Silver Bow Creek (Original Portion)

Lower Area One (including Colorado Tailings, Butte Reduction Works, and manganese stock piles)

- Surface soils and sediments, surface water, and ground water contaminated by mine and mill tailings and acid mine water discharges. High levels of heavy metal contamination.
- Contamination of potential drinking water supplies.
- Potential exposure of future human populations to contaminated soils and/or tailings.

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Streamside Tailings

- Extensive deposits of mine tailings and sediments contaminated with heavy metals.
- Potential contamination of irrigation and drinking water supplies.
- Potential exposure of future human populations to contaminated soils and/or tailings

Rocker

- Soils contaminated with arsenic and potential organic contamination as a result of past timber treating activities
- Potential for contamination of ground water and surface water.
- Potential human health risks associated with exposure to contaminated soil and ground water.
 - *Remedy* 1,021 cubic yards of arsenic-contaminated soils and wood chips were removed in 1989

Warm Springs Ponds

- Contaminated surface water, soils, pond bottom sediments, and ground water associated with treatment ponds that capture mining waste from upstream sources.
- Potential for release of contaminated water and sediments due to instability of pond dikes during a flood or earthquake.
- Impacts to wildlife.
- Potential contamination of irrigation and drinking water supplies.
- Potential exposure of future human populations to contaminated soils and/or tailings.

Mill-Willow Bypass—Removal begun July 1990

- *Remedy*: 210,000 cubic yards of tailings and contaminated soils will be removed from the Mill-Willow Bypass and placed in the dry area of Pond 3 by November 1990. The north-south pond berms will be raised and strengthened to withstand a maximum credible earthquake and 0.5 probable maximum flood. The removal will be completed by December 1990.



MONTANA POLE SITE

The Montana Pole site is located in Butte at 202 West Greenwood Avenue. It is 40 acres in size and lies at the southwest edge of the city on the banks of Silver Bow Creek. From 1947 to 1984, the Montana Pole Treating Company used the site as the location of its wood treating operation. Montana Pole commonly used organic compounds including *pentachlorophenol (PCP)* and creosote in its operations. In 1983, EPA determined that wastes were seeping from the site to Silver Bow Creek at the rate of two to five gallons per day. In addition, EPA found that on-site soils and ground water had been contaminated by these wastes. These problems were addressed in a removal action initiated in 1985 while the site was still part of the Silver Bow Creek site. The Montana Pole site became a separate Superfund site in November 1986. Specific problem areas at the Montana Pole site are summarized below

- Pole treatment activities have resulted in high levels of organic contamination in soils and ground water;
- Human health risks associated with exposure to contaminated soil, ground water, and surface water;
- Source of PCP and other organic contamination in ground water and in Silver Bow Creek; and
- Impacts on water and land wildlife.

Montana Pole—Removal completed in 1987

- *Remedy*: 10,000 gallons of contaminated ground water were treated; 12,000 cubic yards of contaminated soils were removed.

In June 1990, MDHES began oversight of a remedial investigation and feasibility study of the Montana Pole site. This will determine the extent of contamination, the effects upon human health and the environment, and the appropriate cleanup alternatives. Contaminant studies associated with the Montana Pole site will be conducted downstream to the lower end of the Colorado Tailings. The streamside tailings remedial investigation will determine if Montana Pole contaminants have extended further downstream and if they need to be remediated. ARCO will perform the site investigations under MDHES's supervision.

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Reference 8

**Excerpts From Site History of Smelter Hill -
Anaconda Smelter NPL Site; Prepared by GCM Services Inc.
For ARCO Coal Company; June 1989**

increasing daily production of 99.97 percent pure copper to 120 tons, putting Daly and the Anaconda Mining Company on equal footing with Michigan copper producers. Additional improvements were made to the Upper Works in 1894. Daly arranged to have the reverberatory furnaces enlarged, increasing daily production and efficiency. By increasing the length of the reverberatories Daly's engineers doubled daily output while maintaining the same fuel consumption. The Lower Works used three masonry flues and smokestacks the size of those at the Upper Works. Yearly production at the Upper and Lower Works (130 million lbs) far outdistanced all the competition in Butte and Great Falls (Boston & Montana, 54 million lbs) by 1901 but Daly's acquisition of other highly productive Butte mines prompted the need for further expansion at Anaconda. Daly's chief problem in his location north of Warm Springs Creek was space for expansion which he solved in 1902 by moving operations south across the valley. Demolition of the Old Works (Upper and Lower) began in 1903, shortly after the startup of the Washoe Reduction Works, with the removal of all equipment, wood and steel, leaving only stone and brick ruins after 1906. (Quivik 1984).

Creation of a Mining and Metallurgical Empire: The Anaconda Copper Mining Co.

By the late 1890s Marcus Daly's consolidation of mining interests in Butte led to a shortage of smelter capacity in Anaconda. In addition, Daly's vision for the future had outstripped his personal financial means. Daly's dilemma attracted the attention of William Rockefeller and Henry H. Rogers of Standard Oil and in 1899 they formed the Amalgamated Copper Company, which absorbed Daly's Anaconda Copper Mining Company. Daly traded his controlling shares in the Anaconda Copper Mining Company for shares in the new copper trust, and as president of Amalgamated, Daly had the assets needed to build the reduction works of his dreams as well as to create America's first fully integrated copper company, with control of all aspects of production from mine to smelter to refinery to fabrication. Daly hired Frank Klepetko, designer of the state-of-the-art Boston & Montana smelter and refinery in Great Falls, to build one of the most efficient and adaptable mineral processing plants in the world. The Washoe Reduction Works began operating in 1902, two years after Daly's death, at a capacity of 4800 tons daily. Klepetko designed the Washoe smelter so that each department could grow and expand with demand: by 1908 production capacity grew to 12,000 tons of ore daily, producing 600,000 lbs of copper and 9000 tons of slag and tailings and by 1933 the Washoe smelter produced 1,000,000 lbs daily. The legacy of Daly's vision did not end with construction of the world's largest non-ferrous mineral processing plant. Daly's successor, John D. Ryan, continued to add to the ACM Co. portfolio by acquiring additional smelting capacity in Great Falls, Montana; Tooele, Utah; mining operations in Arizona and Chile; expanded refining capacity in Great Falls and New Jersey and the purchase of a fabricator in the American Brass Company. Facilities at the Washoe Works expanded into more complete use of the Butte ore with the addition of zinc and manganese plants. ACM Co. interests also included coal, timber and an ore-hauling railroad, the Butte, Anaconda & Pacific. By the end of World War I the ACM Co. represented the most powerful economic and political force in Montana and one of the world's largest producers of base metals (ACM Co. Collection, Tri-County Historical Society, Boxes 8; 59; 60).

HISTORICAL DEVELOPMENT OF THE WASHOE REDUCTION WORKS

When completed in 1902 the Washoe Reduction Works constituted an industrial processing plant of extraordinary magnitude, covering over 230 acres with a monthly copper production of 12 million lbs. Expanding to meet the demand created by increasing Butte mines production, the Washoe eventually expanded to 25 million lbs monthly with a workforce of 2800. To meet the 17,000 ton per day production capacity the Washoe consumed 750 tons of Diamondville, Wyoming bituminous coal (12-15 percent ash), 2500 tons of lime (for flux), 778,000 kilowatt hours of electricity and 60 million gallons of water (75 percent reclaimed in process) transported through eight miles of wooden flume. The following is a detailed description of the on-site

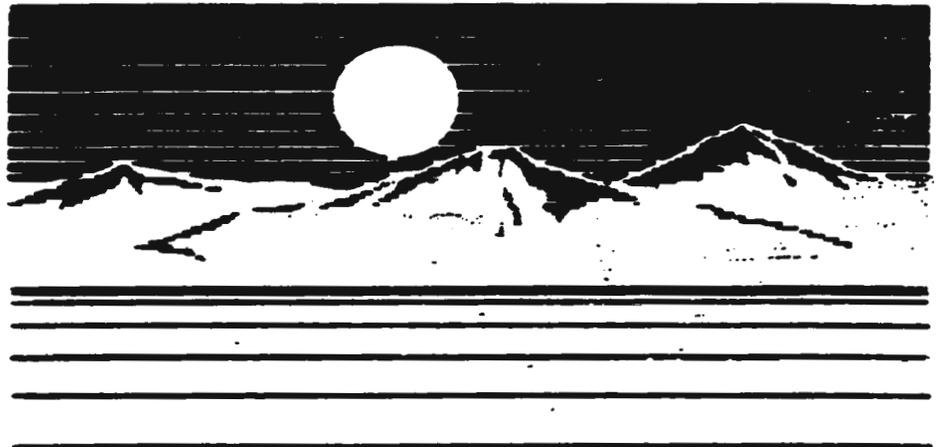
Reference 9

**Excerpts From Feasibility Study For
the Warm Springs Ponds Operable Unit, Volume I, Draft;
MDHES and CH2M Hill; October 1989**

**SILVER BOW CREEK
INVESTIGATION**

**Feasibility Study
for the
Warm Springs Ponds
Operable Unit**

**Montana Department
of
Health and Environmental Sciences
(MDHES)**



**Prepared by
MDHES
CH2M HILL**

DRAFT
Volume I - Report
October 1989

EXECUTIVE SUMMARY

INTRODUCTION

The Warm Springs Ponds are a part of the Silver Bow Creek Superfund Site. The ponds are located at the downstream end of Silver Bow Creek, just above the confluence of the Mill-Willow Bypass and Warm Springs Creek. That confluence is the defined beginning point of the Clark Fork River. Figure ES-1 shows the major features of the Warm Springs Ponds Operable Unit and establishes the boundaries of the study area.

The Clark Fork Basin, which includes the Silver Bow Creek Site, is the largest geographic area in the nation being addressed under Superfund. The Site has been impacted by over 100 years of mining and processing operations in the Butte and Anaconda areas. Mining began with the discovery of gold in 1864 on Silver Bow Creek. By 1884, the Butte area contained over 300 combined copper and silver mines, 9 silver mines, and 8 smelters. Mining and smelting continued until 1982, when the Anaconda Minerals Company, by that time owned by the Atlantic-Richfield Company, closed the Berkeley Pit in Butte. Mining and milling has since resumed, with the takeover of operations by Montana Resources, Inc., and others in 1986.

Over the years, the mining and related activities have resulted in extensive soil, water, and air contamination within the study area. Contamination of Silver Bow Creek occurred from the outset of mining activities. Mining, milling, and smelting wastes were dumped directly into

Silver Bow Creek and transported downstream to the Clark Fork River.

In 1911, the Anaconda Copper Mining Company built its first treatment pond near Warm Springs, Montana, to settle out wastes from Silver Bow Creek before the water reached the Clark Fork River. This is now noted as Warm Springs Pond 1 (see Figure ES-1). Warm Springs Ponds 2 and 3 were constructed in approximately 1916 and 1959, respectively, as additional settling capacity was needed. The ponds now cover an area of approximately 4 square miles. Over the past 80 years, an estimated 19 million cubic yards of tailings and heavy metal contaminated sediments (sludges) have collected in the ponds. The 19 million cubic yards of wastes could cover the playing area of 100 football fields 90 feet deep, which is as high as a nine-story building.

Mining wastes are no longer released directly into Silver Bow Creek, but tailings deposits along the creek banks continue to erode and travel down the creek during periods of above-average flows and floods. It is estimated that approximately 3 million cubic yards of contaminated tailings are still present along the banks of Silver Bow Creek. Through dissolution, the tailings and sediments cause the water flowing in Silver Bow Creek to be contaminated with dissolved metals, particularly copper and zinc. Other metals detected in Silver Bow Creek are arsenic, cadmium, lead, iron, aluminum, and manganese.

The Warm Springs Ponds are still used to contain entrained sediments and treat the contaminated water flowing down Silver Bow Creek before it reaches the Clark Fork River. The ponds operate by settling out tailings particles and other solids and by reducing the concentrations of the

Reference 10

**Excerpts From Proposed Plan: Warm Springs Ponds;
EPA and MDHES; October 1989**

October 1989



Warm Springs Ponds Proposed Plan

Silver Bow Creek Superfund Site Report

By Montana Department of Health and Environmental Sciences
and the U.S. Environmental Protection Agency

Introduction

The Montana Department of Health and Environmental Sciences (MDHES) and the U.S. Environmental Protection Agency (EPA) are seeking comments from the public on the Warm Springs Ponds Feasibility Study and this Proposed Plan to ensure that the remedies selected will meet the needs of the interested public. The Warm Springs Ponds are one of five operable units identified for the Silver Bow Creek Superfund Site. The public comment period extends from October 26 to December 29, 1989.

Sections 113(k)(2)(B) and 117(a) of the Comprehensive Environmental Response, Compensation, and Liability Act (hereafter "CERCLA"), as amended by the Superfund Amendments and Reauthorization Act (SARA), requires the lead agency to issue a proposed plan of remediation (cleanup) for any site addressed under CERCLA and to make the plan available to the public for review and comment. This Proposed Plan fulfills that requirement. The plan discusses alternatives for controlling contamination associated with groundwater, surface water, pond bottom sediments, tailings and contaminated soils within the boundaries of the Warm Springs Ponds operable unit. The plan presents the cleanup alternative preferred by MDHES (the lead agency) and EPA (the support agency); and the rationale for identifying the alternative. It also provides background information on the site, summarizes site risks and the results of the Remedial Investigation, describes cleanup alternatives evaluated for the site, and outlines the public's role in the final selection of a remedy. The preferred cleanup alternative identified is a preliminary selection and will be made final in the Record of Decision (ROD) after MDHES and EPA have considered the public's comments and any new, significant information received during the comment period. The Preferred Alternative is based on the Administrative Record that has been developed, the remedial investigation reports which characterize the site and discuss the nature and extent of contamination, and the feasibility study, which describes how the various remedial alternatives were developed and evaluated.

MDHES emphasizes that comments are being solicited

on all of the alternatives presented in the feasibility study and in this Proposed Plan, not the Preferred Alternative alone. The remedy ultimately selected for the operable unit may be the Preferred Alternative, a modification of it, a combination of elements from some or all of the alternatives, another response action based on new and significant information, or public comments.

Detailed information concerning any of the material included in the Proposed Plan may be found in the remedial investigation and feasibility study reports. These reports have been placed, as have earlier reports, at information repositories. The locations of these repositories are listed on page 16 of this plan.

Additional documentation regarding remedy selection is available in the Administrative Record for the site. The administrative record has been placed at three locations, also listed on page 16 of this plan.*

**Included in the Administrative Record is an outline of a remedial action plan for the Ponds being proposed by the Atlantic Richfield Company (ARCO). ARCO is the identified responsible party for the Warm Springs Ponds.*

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Ponds have a long history

SITE LOCATION

The Warm Springs Ponds operable unit is one of five operable units identified for the Silver Bow Creek Superfund Site. The Silver Bow Creek Site is one of four distinct but contiguous Superfund sites in the Upper Clark Fork Basin area of Montana. The Silver Bow Creek Site begins in Butte and extends approximately 145 river miles to the Milltown Reservoir just east of Missoula.

The Warm Springs Ponds are located within Deer Lodge County, about 27 river miles northwest of Butte, at the end of Silver Bow Creek, just above the confluence of the Mill-Willow Bypass and Warm Springs Creek. The confluence of the Mill-Willow Bypass and Warm Springs Creek is the beginning of the Clark Fork River. The unincorporated town of Opportunity lies at the southern-most edge of the site, west of U.S. Interstate 90 (I-90). The unincorporated town of Warm Springs is at the northern boundary, adjacent to Pond 1 on the west side of I-90. The only incorporated town within the county is Anaconda, approximately six miles west of the site along Highway 48.

The boundaries of the Warm Springs Ponds operable unit are depicted in the figure. The site extends from the intersection of Silver Bow Creek and I-90 upstream of Pond 3 at the south, to the confluence of the Mill-Willow Bypass with Warm Springs Creek at the north. The western boundary is slightly west of the Mill-Willow Bypass (although east of I-90) and the eastern boundary is the interface between marsh vegetation and the foot hills on the eastern edge of the ponds. The site covers approximately 2,500 acres. Its major features include three settling ponds, a series of wildlife ponds, and the Mill-Willow Bypass.

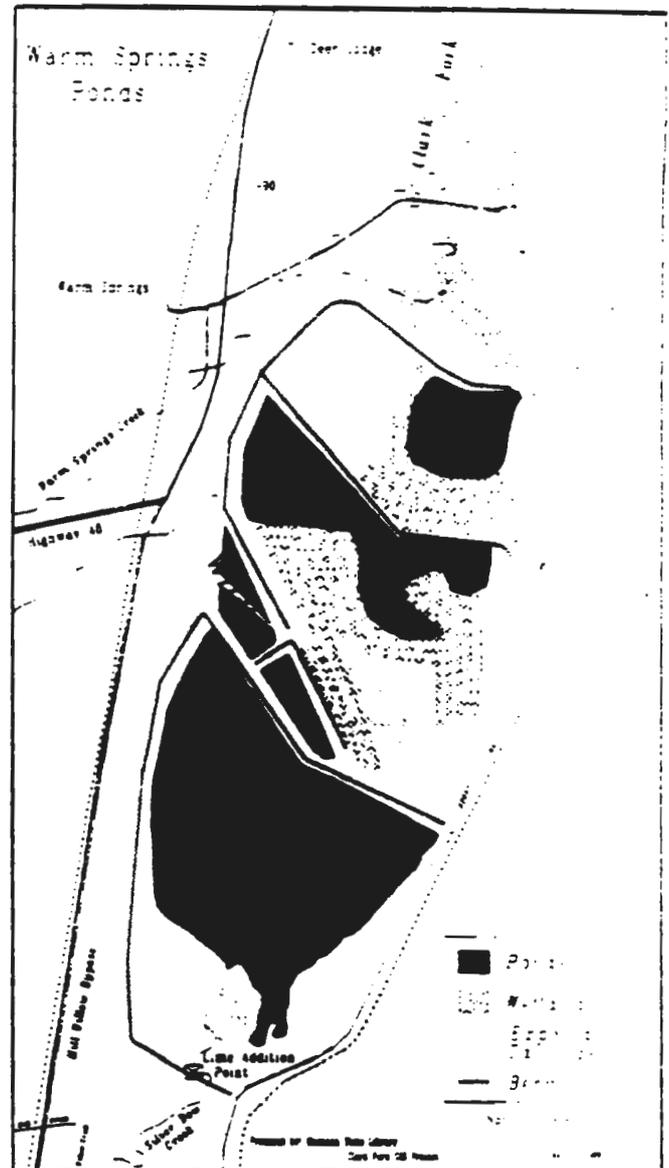
SITE HISTORY

From the beginning of ore concentrating/smelting activities in 1880 until 1911, mining, milling, and smelting wastes from the Butte and Anaconda areas were dumped directly into Silver Bow Creek and were transported downstream to the Clark Fork River, at least as far as Milltown Reservoir, some 145 river miles. Although mining wastes are no longer released directly into Silver Bow Creek, portions of an estimated three million cubic yards of tailings remain deposited along the creek banks where they are subject to erosion and movement down the creek during high flows and floods. Over the past 80 years, an estimated 19 million cubic yards of sediments, tailings and heavy metal sludges have collected in the ponds.

The Anaconda Copper Mining Company (ACM) made the first attempt to control the amount of sediment carried into the Clark Fork River from Silver Bow Creek in 1911 by building a 20-foot high tailings dam on Silver Bow Creek near the town of Warm Springs. This created Warm Springs Pond 1. In 1916 another 18-foot high dam was built at Warm Springs by ACM upstream from the first dam, creating Warm Springs Pond 2. This dam subsequently was raised five feet to a total height of 23 feet during 1967-1969. Warm Springs Ponds 1 and 2 continued to trap and settle out sediment from Silver Bow Creek.

A third and much larger 28-foot high dam was built upstream of Pond 2 by ACM between 1954 and 1959, primarily for sediment control. This structure created Warm Springs Pond 3. The height of this dam was increased by five feet during 1967-1969 to a maximum height of 33 feet.

In 1967, Warm Springs Pond 3 was converted into a treatment facility to treat mill losses, precipitation plant spent



solution from Butte Operations, and overflow from the nearby Opportunity Ponds. Treatment consisted of introducing a lime/water suspension from the Anaconda Smelter into Silver Bow Creek above Warm Springs Pond 3. The addition of the lime suspension raised the pH of the creek water to help precipitate heavy metals in the Warm Springs Ponds. Currently, the ponds are used to physically, chemically, and biologically treat Silver Bow Creek surface water through sedimentation and chemical and biological precipitation of heavy metals.

The current configuration of the Mill-Willow Bypass was constructed about 1969-1970 while making improvements to the Pond 3 berm. The Bypass was constructed to divert what was thought to be relatively clean water from Mill and Willow Creeks around the pond system. Recent information obtained from the remedial investigation indicates that concentrations of metals in these surface waters are higher than originally thought. In 1987 the berm between the Warm Springs Ponds and the Mill-Willow Bypass adjacent to Pond 3 was raised by the Anaconda Minerals Company (AMC) in an attempt to better

protect the integrity of the pond system during flood flows.

The Wildlife Ponds were constructed about 1967 by the Montana Department of Fish and Game in association with AMC. The purpose of the ponds was to enhance waterfowl habitat in the upper Deer Lodge valley. Two large cells and several smaller sub-cells and islands were constructed for this purpose. Water within the Wildlife Ponds is treated water from Pond 3, and its quality is generally much improved over the quality of water entering Pond 3.

The Warm Springs Ponds system is operated by Atlantic Richfield Company (ARCO), successor to AMC, and the Montana Department of Fish, Wildlife, and Parks (MDFWP). Pond 1 is currently not used in the treatment process at the site because the pond is largely filled with sediment. However, Ponds 2 and 3 are still used to treat the contaminated water flowing down Silver Bow Creek before it reaches the Clark Fork River. Under current operating conditions, the available storage capacity remaining in the ponds would allow them to be used for this purpose for approximately 70 years.

Ponds are part of a larger picture

Subsequent to passage of the Superfund law in 1980, and following preliminary investigations and assessments, in September 1983 the Silver Bow Creek Site was placed on the Superfund National Priority List. Since then, MDHES has administered and directed the efforts to conduct remedial investigation/feasibility study (RI/FS) activities at the site.

As mentioned earlier, three other sites in the Upper Clark Fork River Basin have also been listed as Superfund sites. These are the Montana Pole, Anaconda Smelter, and Milltown Reservoir Superfund sites. MDHES and EPA identified 25 different operable units at these four Superfund sites. To ensure that the most serious problems would be addressed first, MDHES and EPA prioritized the 25 units into high, medium, and low priority categories. Those operable units with the greatest potential for human health and environmental exposure have received the highest priority for remedial action. MDHES and EPA identified the Warm Springs Ponds as a high priority operable unit.

The Warm Springs Ponds were identified as a high priority operable unit because they are susceptible to flood and earthquake damage, which potentially could release millions of cubic yards of tailings, sediments containing tailings, and metal precipitates into the Clark Fork River causing considerable environmental damage downstream of the ponds. The Warm Springs Ponds are not strong enough to withstand even a moderate earthquake. A 100-year flood could cause extensive damage to the berms supporting the ponds, while a 1,000 year flood or probable maximum flood could result in a general failure of the pond system.

In addition to the potential for catastrophic flood or earthquake damage, the Warm Springs Ponds present significant environmental and human health threats associated with contaminated surface water, soils, and tailings. These contami-

nated media, and their interaction, have contributed to recurrent fish kills in the Mill-Willow Bypass and the Clark Fork River, the most serious of which occurred in July 1989. An estimated 5,000 fish were killed during that single episode.

The location of the Warm Springs Ponds operable unit, in relation to other operable units at the Silver Bow Creek Site as well as other sites in the Clark Fork River Basin, played a significant part in determining the remediation alternatives available to achieve a permanent remedy at the Ponds. All threats to human health and the environment at Warm Springs Ponds can be attributed to contamination which has migrated to the Ponds from upstream sources, has passed through the Ponds, or has been deposited within the boundaries of the operable unit. The primary vehicle for the migration of contamination to the Ponds has been, and continues to be, surface water flowing from Silver Bow, Mill, and Willow creeks. Surface water functions to transport other media, such as tailings and sediments to the Warm Springs Ponds. While surface water contamination upstream from the ponds likely will be reduced by future cleanup actions, until then and for the foreseeable future, that surface water will require treatment to reduce its toxicity as it flows downstream into the Clark Fork River.

Some of the contamination at the Warm Springs Ponds is located within the operable unit and either is migrating or has the potential to migrate from the operable unit downstream. Other contamination continues to migrate from upstream sources to the operable unit. Therefore, source control measures in some instances and migration management measures in other instances will need to be used to achieve the Superfund statutory mandate of assuring permanent protection of human health and the environment.

1997
Dennis R. Risk

Site risks summarized

A Public Health and Environmental Assessment (PHEA) was conducted to determine the potential threat to human health and the environment posed by contaminants present at the Warm Springs Ponds. The no-action alternative assessed in the PHEA assumes continuation of current site operations and conditions. The human health risk characterization of the site includes potential health effects that are both carcinogenic (cancer causing) and non-carcinogenic.

Health Risks

The contaminants of concern are inorganic metals such as arsenic, cadmium, copper, lead and zinc and their compounds. Potential human health risks from these and other contaminants were calculated using current and future residential, occupational, and recreational exposure scenarios involving contaminated media (soils, sediments, water) and contamination within the food chain (waterfowl and fish). The PHEA exposure scenarios defined the amounts of contaminated media that could be absorbed by quantifying each potential receptor/media/exposure pathway combination for the site. The scenarios assessed consider current site conditions and take into account potential future site developments (additional recreational use, new residential areas, etc.).

The maximum potential excess lifetime carcinogenic risks for all site media under the current recreational scenario is estimated to be 8×10^{-5} (eight chances in 100,000). The maximum potential excess lifetime carcinogenic risks for all site media under the current occupational scenario is an estimated 2×10^{-4} (two chances in 10,000). In other words, if assumptions concerning current occupational use are accurate, a worker at the site is subjected to increased cancer risks because of frequent and long-term exposure to the contaminated media. The increased risk is estimated to be two chances in 10,000 which is a high cancer risk by EPA standards. EPA considers acceptable a range of 1×10^{-4} to 1×10^{-7} (one chance in 10,000 to one chance in 10,000,000). The maximum excess lifetime potential carcinogenic risk for all site media under the future residential scenario is estimated at 2×10^{-2} (two chances in 100). No potential human health threat was identified from exposure to noncarcinogenic contaminants for the current recreational, the current occupational, or the future residential scenarios.

Under the current residential scenario, potential carcinogenic risks were identified only for the inhalation and ingestion of contaminated dust. At the town of Warm Springs, the excess lifetime cancer risk for dust inhalation or ingestion ranged from an estimated 1×10^{-4} (one chance in 1,000,000) to 1×10^{-3} (one chance in 100,000). At residences east of the operable unit, excess lifetime cancer risks due to dust inhalation or ingestion ranged from zero to 9×10^{-4} (nine chances in 1,000,000). No potential human health threat was identified from exposure to noncarcinogenic contaminants for the current residential scenario.

Environmental Risks

Under current conditions, the average concentrations of several site inorganic contaminants in surface water exceed Montana standards for the protection of aquatic life. The chronic toxic effects of site contaminants may be expressed in local fish and wildlife populations through reduced growth rates, reduced fertility, and increased mortality. A principal environmental impact associated with the operable unit is the periodic fish kills in the Clark Fork River. MDHES believes the kills result from the solubilization of metal salts from tailings in the Mill-Willow Bypass during summer rainfall events. Current effects on other local wildlife populations are unknown.

Future adverse environmental effects without remediation are expected to be similar to current conditions. Periodic fish kills can be expected to recur and chronic contaminant effects (reduced growth, fertility, etc.) may be expressed in fish and/or wildlife populations. The potential also exists for a catastrophic event (flood, earthquake) where the pond system berms could be breached, releasing site contaminants that could adversely affect aquatic resources (fish and wildlife populations, aquatic habitat) for miles downstream.

PUBLIC MEETINGS

Anaconda - Thursday, Nov. 9 at 7 p.m. in the Metcalf Center.

Missoula - Monday, Nov. 13 at 7 p.m. in the St. Patrick Hospital Broadway Building Auditorium.

Butte - Wednesday, Nov. 15 at 7 p.m. in the Mining/Geology Building, Room 206, at Montana Tech.

The Montana Department of Health and Environmental Sciences will hold three public meetings to discuss the options for cleanup of the Warm Springs Ponds operable unit of the Silver Bow Creek Superfund site as discussed in this Proposed Plan.

For more information, call Janie Stiles, MDHES, 1-800-648-8465, in Helena

Ponds underwent careful study

In October 1984, MDHES contracted with MuluTech of Butte to perform a remedial investigation (RI) of the Silver Bow Creek site. The RI consisted of coordinated individual studies to develop data on the extent and severity of contamination within the entire site. This Phase I RI included a study of the Warm Springs Ponds.

In May 1987, MuluTech reported the findings of the Phase I RI conducted for the ponds. Upon completion of the Phase I RI, several data gaps were identified for which additional information was necessary before a feasibility study (FS) could be completed.

In February 1986, MDHES contracted with CH2M-Hill of Helena to complete Phase II RI/FS activities at the Silver Bow Creek site. Among the first investigations undertaken was the Phase II RI for the Warm Springs Ponds. Phase II RI activities began in October 1987 and CH2M-Hill reported the findings of the Phase II RI in May 1989.

As a result of all previous investigations undertaken, the following problems have been identified at the site:

1) Pond instability creates the potential for release of contaminated pond bottom sediments to the Clark Fork River during high flows, floods and earthquakes due to failure of the pond berms;

2) The tailings in and along the Mill-Willow Bypass are

a source of high concentrations of dissolved metals and are the likely cause of fish kills in the Bypass and Clark Fork River during rainfall runoff events;

3) Tailings within the Mill-Willow Bypass continually erode and transport dissolved metals and sediment to the Clark Fork River;

4) Under normal flow conditions, the concentration of dissolved metals in Mill, Willow, and Silver Bow creeks and the Clark Fork River exceed those concentrations acceptable under State water quality standards;

5) The Warm Springs Ponds are ineffective in capturing tailings transported by Silver Bow Creek during high flows and floods. During these conditions a portion of the streamflow is routed around the ponds and transported to the Clark Fork River, untreated;

6) A groundwater contamination plume exists within and below Pond 1; and

7) There is the potential for unacceptable human exposure to exposed tailings and contaminated soils within the boundaries of the Warm Springs Pond operable unit.

Objectives of Ponds cleanup

The existence of environmental and human health problems within the operable unit directly correlates with non-compliance with applicable or relevant and appropriate requirements (ARARs) or unacceptable health risks. It is the ARARs and human health protectiveness standards which form the basis of remedial action objectives. Remedial action objectives are essentially site cleanup goals designed to address the problems identified at the site.

Based on the identified problems, the results of the Public Health and Environmental Assessment, and the analysis of ARARs, a list of remedial action objectives has been identified for all of the media at the site:

1) For pond bottom sediments, the remedial objective is to prevent releases of the pond bottom sediments due to floods or earthquakes. The Montana Department of Natural Resources and Conservation (DNRC) dam safety requirements have been identified as the applicable standard. The standard requires protecting the ponds to fractions of a probable maximum flood (PMF) and to the maximum credible earthquake (MCE).

2) For surface water, the remedial objectives are to:

- Meet ambient water quality standards established pursuant to the Montana Water Quality Act for arsenic, cadmium, lead, mercury, copper, iron and zinc at a "compliance point" just above the defined starting point of the Clark Fork River

- Prevent ingestion of water within the operable unit above the Montana Public Water Supply Act's maximum contaminant levels for arsenic, cadmium, lead, mercury and silver, and above established reference doses for copper, iron, lead, zinc, and cadmium. Also, prevent ingestion of water containing arsenic in concentrations that would cause excess cancer risk greater than 10^{-4} to 10^{-7} (one chance in 10,000 to one chance in 10,000,000).

- Inhibit the migration of tailings from the Mill-Willow Bypass to the Clark Fork River in order to reduce the potential for future exceedances of ambient water quality standards in the Clark Fork River.

- Inhibit the migration of tailings from the upper reaches of Silver Bow, Mill, and Willow creeks to the Clark Fork River in order to reduce the potential for recontamination of the Mill-Willow Bypass and future exceedances of ambient water quality standards in the Clark Fork River.

3) For tailings deposits and contaminated soils the

remedial objective is to reduce the potential for direct human contact, inhalation, and ingestion of exposed tailings and contaminated soils posing excess cancer risks above 10^{-4} to 10^{-7}

4) For groundwater, the remedial objective is to reduce

the levels of arsenic, cadmium, and other contaminant concentrations in the groundwater in the Pond 1 area to achieve compliance with Montana groundwater maximum contaminant levels.

Cleanup alternatives summarized

The remedial action alternatives that were developed in the FS to address the site problems just identified are described below. The numbering system used here is consistent with the numbering system used in Chapter 8 of the FS. The descriptions include the estimated present-worth costs and the timeframe that may be required to implement or complete the activity for each of the alternatives. In general, the alternatives are presented in order of their overall protectiveness in addressing the problems at the site; Alternative 1 being more protective and Alternative 7 being the no-action alternative.

In addition to the cleanup alternatives, the Superfund program requires that a "no-action" alternative be evaluated at every site. The no-action alternative serves primarily as a point of comparison for the other alternatives, but would only be selected if human health and environmental risks were found to be negligible. Based upon the risks present at the site, MDHES and EPA believe that all the media (surface water, groundwater, pond bottom sediments, and soils) require remediation.

Alternative 1 (\$1,193,300,000)

The components of Alternative 1 include solidifying all on-site contaminated soils, tailings, sediments, and sludges to protect against a probable maximum flood (PMF) and a maximum credible earthquake (MCE); constructing a new treatment pond for surface water treatment and an upstream flood impoundment to capture flood flows for additional treatment; and installing a groundwater interception trench to capture and then treat contaminated groundwater as it migrates from the ponds.

The current inability of the three existing ponds to withstand floods and earthquakes would be addressed by using an in-situ (in-place) solidification process to stabilize the pond bottom sludges and sediments. This would minimize the risk of pond failure due to an earthquake or flood event. In addition, contaminated soils and exposed tailings which exceed an action level of 250 parts per million (ppm) for arsenic and 750 ppm for lead would be excavated and disposed of in the existing ponds prior to solidification. This alternative would effectively limit the toxicity and mobility of tailings to acceptable concentration levels and greatly reduce the potential for future human or animal contact with harmful contaminants.

Alternative 1 would also improve surface water quality with the construction of a new pond treatment system. A new treatment pond would be constructed to replace the existing, now solidified, pond system. The new pond would be capable of capturing and treating flows up to 600 cubic feet per second (cfs). This is the flow the current pond system is capable of treating.

In addition, an upstream flood impoundment (8,000 acre-feet) would be constructed to provide settling and treatment of flows on Silver Bow Creek up to the peak flow of a 100 year flood (4,000 cfs). Currently flood flows on Silver Bow Creek which exceed 600 cfs (the design limit of the Pond 3 inlet structure) are routed around the ponds, untreated. A flow of 600 cfs on Silver Bow Creek represents, approximately, a two- to three- year return flood.

The goal of the upstream impoundment is to prevent large quantities of sediments and dissolved metals from bypassing the pond system and flowing into the Clark Fork River. The impoundment would serve two functions. First, it would serve as a conventional sedimentation basin; as the velocity of the water entering the impoundment slows, the sediment being transported by the flow would settle out. Second, the impoundment would have the storage capacity to contain up to the 100-year flood. The water would then be metered to the ponds for treatment of dissolved metals, if necessary. Floods exceeding 4,000 cfs would be routed around the impoundment to protect it from damage due to overflowing.

Contaminated groundwater moving from the operable unit would be collected in an open trench constructed within and below Pond 1. The collected groundwater would then be pumped to the inlet of the new pond for treatment. This would reduce the discharge of contaminated groundwater into the Clark Fork River, and enable the aquifer to be used for drinking water and other beneficial uses.

Alternative 1 is one of two alternatives expected to exceed at least one ARAR. Whereas the DNRC safety standards require protection of the existing pond and 3 to 0.2, 0.3, and 0.5 PMF, respectively, the in-situ solidification process would provide protection of all three against the full PMF. Alternative 1 is expected to meet all other ARARS with one exception; surface water standards for arsenic and mercury for protection of public health from ingestion of contaminated water and fish are technically

Reference 11

Excerpts from Telecon between Maria Leet (SAIC) and Russ Forba (EPA) on October 22, 1990.



An Employee-Owned Company

Contract No. _____

Contact Report

Originator T. [unclear] Date 1/22/01 Time _____

Made Call Received Call Meeting at SAIC Meeting At _____

Person(s) Contacted (Organization) [unclear]

SAIC Personnel _____

Purpose of Contact [unclear]

Significant Topics Discussed:

1. [unclear] → [unclear]

2. [unclear] → [unclear]

3. [unclear] → [unclear]

4. [unclear] → [unclear]

5. [unclear] → [unclear]

Action Items:

Person Responsible	Required Action	Date Required
<u>[unclear]</u>	<u>[unclear]</u>	<u>[unclear]</u>
<u>[unclear]</u>	<u>[unclear]</u>	<u>[unclear]</u>
<u>[unclear]</u>	<u>[unclear]</u>	<u>[unclear]</u>

Distribution: _____

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Reference 11

**Excerpts From Record of Decision, Silver Bow Creek/
Butte Area NPL Site, Warm Springs Operable Unit,
Upper Clark Fork River Basin, Montana;
EPA; September 1990**

**RECORD OF DECISION
PART I: THE DECLARATION**

Silver Bow Creek/Butte Area NPL Site
Warm Springs Ponds Operable Unit
Upper Clark Fork River Basin, Montana

STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected interim remedial action for the Warm Springs Ponds, an operable unit of the Silver Bow Creek/Butte Area NPL Site (original portion), in the Upper Clark Fork River Basin of southwestern Montana. The selected remedial action was developed in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), 42 USC Sec. 9601, et seq. and, to the extent practicable, the National Contingency Plan (NCP), 40 CFR Part 300. This decision is based on the administrative record for the site.¹

All determinations reached in the Record of Decision were made in consultation with the Montana Department of Health and Environmental Sciences (MDHES), which conducted the Remedial Investigations and Feasibility Study for this operable unit and participated fully in the development of this Record of Decision.

¹ The administrative record index and copies of key site documents are available for public review at the Missoula Public Library, the Montana Tech Library on West Park Street in Butte and other information repositories in the Clark Fork Basin. The complete administrative record may be reviewed at the offices of the U.S. EPA, 301 South Park, Federal Building, Helena, MT.

ASSESSMENT OF THE SITE

Actual and threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this Record of Decision, may present an imminent and substantial endangerment to public health, welfare, or the environment.

DESCRIPTION OF THE REMEDY

The Warm Springs Ponds Operable Unit is one of eleven operable units identified as part of the Silver Bow Creek/Butte Area NPL Site in the Upper Clark Fork Basin area of Montana. The Warm Springs Ponds Operable Unit is located within Deer Lodge County, approximately 27 river miles northwest of Butte and just above the confluence of the Mill-Willow Bypass and Warm Springs Creek. Silver Bow, Mill, Willow and Warm Springs creeks are principal headwaters streams of the Clark Fork River, which begins at the northernmost boundary of the Warm Springs Ponds Operable Unit.

The operable unit covers approximately 2,500 acres that include three settling ponds, the area below the Pond 1 berm to the Clark Fork River's beginning point, a series of wildlife ponds, and the Mill-Willow Bypass (see Figure 1). The remedy includes means for controlling contamination associated with pond bottom sediments, surface water, tailings and contaminated soils, and ground water within the boundaries of the operable unit. The selected remedy for the Warm Springs Ponds Operable Unit may be summarized as follows:

- ♦ Allow the ponds to remain in place; Ponds 2 and 3 will continue to function as treatment ponds until upstream sources of contamination are cleaned up;
- ♦ Raise and strengthen all pond berms according to specified criteria, which will protect against dam failure in the event of major earthquakes or

floods, and increase the storage capacity of Pond 3 to receive and treat flows up to the 100-year flood:

- ♦ Construct new inlet and hydraulic structures to prevent debris from plugging the Pond 3 inlet and to safely route flows in excess of the 100-year flood around the ponds;
- ♦ Comprehensively upgrade the treatment capability of Ponds 2 and 3 to fully treat all flows up to 3,300 cfs (100-year peak discharge) and construct spillways for routing excess flood water into the bypass channel;
- ♦ Remove all remaining tailings and contaminated soils from the Mill-Willow Bypass, consolidate them over existing dry tailings and contaminated soils within the Pond 1 and Pond 3 berms and provide adequate cover material which will be revegetated;
- ♦ Reconstruct the Mill-Willow Bypass channel and armor the north-south berms of all ponds to safely route flows up to 70,000 cubic feet per second (one-half of the estimated probable maximum flood);
- ♦ Flood (wet-close) all dry portions of Pond 2;
- ♦ Construct interception trenches to collect contaminated ground water in and below Pond 1 and pump the water to Pond 3 for treatment;
- ♦ Dewater wet portions of Pond 1 and cover and revegetate (dry-close) all areas within the Pond 1 berms;

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- ♦ Establish surface and ground water quality monitoring systems and perform all other activities necessary to assure compliance with all applicable or relevant and appropriate requirements.
- ♦ Implement institutional controls to prevent future residential development, to prevent swimming, and to prevent consumption of fish by humans; and
- ♦ Defer, for not more than one year after the effective date of this document, decisions concerning the remediation of contaminated soils, tailings, and ground water in the area below Pond 1, pending evaluation of various wet- and dry-closure alternatives and a public review.

Although the majority of known tailings and contaminated sediments and soils deposits within this operable unit will be remediated by actions specified in this Record of Decision, a final soil cleanup level is not selected. A decision regarding a final soil cleanup level, which affects primarily the area below Pond 1, but also the Mill-Willow Bypass and all dry portions of the ponds, will be made within one year of the effective date of this document. In addition, the final decision concerning the ultimate disposition of Ponds 2 and 3 must be deferred until upstream sources are cleaned up and the two ponds cease to be needed as treatment ponds. Each of these decisions will be subjected to separate public reviews, during which a range of alternatives will be examined and public input solicited.

The selected remedy presented in this Record of Decision attempts to permanently remediate the principal threats posed by contamination at the site. The remedy will reduce or eliminate most of the human health and environmental threats present at this operable unit, but the remedy is an interim measure for the reasons stated below. Future records of decision, or other decision documents, will direct cleanup actions at the other operable units and NPL sites that affect Silver Bow Creek and the Warm Springs ponds.

Until those source areas are cleaned up, the effectiveness and permanence of this remedy cannot be fully or finally determined.

One component of the selected remedy presented in this Record of Decision departs significantly from the preferred remedy, as originally identified and evaluated in the feasibility study and described in the proposed plan. Whereas the feasibility study and proposed plan recommended construction of an upstream sediment settling basin, and as a consequence, discontinuance of Pond 2 as a treatment pond, the selected remedy presented herein calls for storage and treatment of flood flows (up to the 100-year event) in Pond 3 and retention of Pond 2 as a treatment pond.

The rationale for this significant change is as follows:

1. There was considerable public opposition to the proposed upstream settling basin. Residents of the Deer Lodge Valley were concerned about economic and environmental impacts that might have been caused by the impoundment.
2. Upon examination of an alternative proposal presented by the potentially responsible party, the Atlantic Richfield Company (ARCO), specifically to store and treat flows up to the 100-year flood within Pond 3, the EPA and State concluded that that is an acceptable alternative to the concept of an upstream settling basin. In fact, treatment of dissolved metals in flood waters would not have been a feature of the upstream settling basin; however, such treatment will be possible once the selected remedy is in place. This revised component of the selected remedy offers the additional advantage of keeping contaminants within the existing boundaries of the operable unit.

While this departure represents a significant change to the preferred remedy identified in the proposed plan, it was developed through constructive dialogue with the public and ARCO. The overall remedial objectives, as evaluated in the feasibility study and described in the proposed plan, remain unchanged.

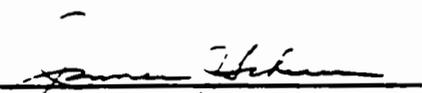
As a result of the dialogue with the public and ARCO, which followed a series of public meetings concerning the proposed plan, the Mill-Willow Bypass Removal Action was initiated. On July 3, 1990, the EPA and ARCO entered into agreement through an Administrative Order on Consent to undertake expedited action on the tailings and contaminated soils along the Mill-Willow Bypass. In the process of developing a work plan for this removal action, many state and federal agencies, ARCO, and the public have cooperated to assure that the extensive excavation, consolidation and disposal of tailings and contaminated soils, and raising, widening, and armoring of the north-south pond berms are completed in a manner consistent with the overall remedy. At the time of signing of this document, the removal action is proceeding well and invaluable experience has been gained concerning site conditions, which will facilitate followup work prescribed in this Record of Decision.

DECLARATION

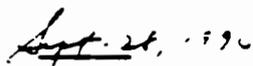
The selected remedy is protective of human health and the environment; attains and complies with federal and state requirements that are applicable or relevant and appropriate for this remedial action except where waivers, as noted, have been applied; and is cost-effective. The remedy utilizes permanent solutions and treatment alternatives that reduce the toxicity, mobility, or volume as a principal element to the maximum extent practicable for this operable unit. The use of treatment alternatives to address the human health and environmental threats posed by the pond bottom sediments, exposed tailings, and contaminated soils was determined not to be practicable because of the extensive volume of material present on the site and the absence of available technologies to effectively treat the contaminants.

Because this remedy will result in hazardous substances remaining onsite, a review will be conducted within five years after commencement of remedial action to ensure that the remedy continues to provide adequate protection of human health and the environment. Additionally, the remedy selected by this Record of Decision will be subject to a separate public review once work at the other NPL sites that affect this operable unit is completed.

Signature:



James J. Scherer
Regional Administrator (Region VIII)
U.S. Environmental Protection Agency



Date

and swamps. The presence of the pond system affects shallow ground water elevations and ground water movement within the site.

Shallow aquifers occur along present-day stream channels but do not extend laterally throughout the site. Deeper aquifers are associated with Tertiary-age valley fill and thick deposits of glaciofluvial material. These aquifers generally exhibit moderate to low permeabilities and are probably connected on a regional scale, although fine-grained interbeds tend to confine the deeper aquifers locally.

The uppermost aquifer at the site is a 10- to 15-foot-thick sand and gravel unit, which is typically present approximately 10 feet below ground surface. This sand and gravel aquifer appears to be present throughout most of the site. Ground water movement through the site is generally south to north, although a significant component of ground water enters from the Opportunity Ponds area to the southwest. (See Figure 2).

No domestic well is located within the Warm Springs Ponds Operable Unit. Several are located east of the pond system within a mile of the operable unit, but these wells are completed in bedrock aquifers that do not appear to be affected by the pond system. The town of Warm Springs derives its water from supply wells constructed in unconsolidated Tertiary deposits, from depths of approximately 200 feet. These wells appear to be supplied with water derived from ground water resources west of and hydraulically isolated from the Warm Springs Ponds.

4.3 NATURE AND EXTENT OF CONTAMINATION

Sediments, surface water, soils, and ground water are all affected by contaminants in the Warm Springs Ponds Operable Unit. A schematic that shows the contaminated areas and the migration pathways is presented as Figure 3. Four contaminated media have been identified for the operable unit: pond bottom sediments, surface water, tailings deposits and contaminated soils, and ground water. The media are discussed in the following

TABLE 1
SUMMARY OF AREAS AND VOLUMES OF CONTAMINATED MEDIA

	Area (acres)	Volume	
		(acre-feet)	(cubic yards)
<u>Pond Bottom Sediments</u>			
Pond 1			
Exposed Sediments	59	455	734,000
Vegetated/Submerged Sediments	<u>225</u>	<u>1,340</u>	<u>2,156,000</u>
	284	1,795	2,890,000
Pond 2			
Exposed Sediments	155	900	1,300,000
Vegetated/Submerged Sediments	<u>347</u>	<u>2,230</u>	<u>3,590,000</u>
	502	3,030	4,890,000
Pond 3			
Submerged Sediments	665	6,903	11,180,000
Total Pond Bottom Sediments	1,451	11,755	18,960,000
<u>Surface Water</u>			
Silver Bow Creek ^a			
Mill and Willow Creeks ^b			
<u>Tailings Deposits and Contaminated Soil</u>			
Mill-Willow Bypass ^c			
Exposed Tailings	21	47	75,800
Vegetated Tailings & Contaminated Soil	<u>33</u>	<u>80</u>	<u>130,000</u>
	54	127	205,800
Area Above Pond 3			
Exposed Tailings	22	56	90,300
Vegetated Tailings & Contaminated Soil	<u>268</u>	<u>700</u>	<u>1,130,000</u>
	290	756	1,220,300
Area Below Pond 1			
Exposed Tailings	17	48	77,400
Vegetated Tailings & Contaminated Soil	<u>59</u>	<u>246</u>	<u>397,000</u>
	76	294	474,400
<u>Ground water^d</u>			
Area of contaminated aquifer beneath & downgradient of Pond 1	180		

^aFlow ranges from 28-112 cfs (73 cfs average). Data collection from March 1985 to August 1985

^bFlow ranges from 3-87 cfs (27 cfs average). Data collected from December 1984 to August 1985.

^cInsert Mill-Willow Bypass tailings and contaminated soils are being removed by an expedited action schedule for completion in November 1990.

^dExceedences of primary maximum contaminant levels for arsenic and cadmium.

sections. Table 1 presents a breakdown of the areas and volumes for each of the four media.

4.3.1 Sediments, Tailings, and Contaminated Soils

Two of the media--the pond bottom sediments, and the tailings deposits and contaminated soils--contain the majority of the contaminants in the Warm Springs Ponds Operable Unit. These materials are typically fine to coarse sand and generally contain metals associated with the sulfide ore body present near Butte. Pond bottom sediments are also comprised of precipitated hydroxides and oxyhydroxides resulting principally from the addition of lime to treat the water entering the pond system and from biologically mediated precipitation.

The exposed (unsubmerged) sediments, tailings deposits and contaminated soils cover an area of approximately 634 acres within the Warm Springs Ponds Operable Unit. Thicknesses of these deposits range from less than 1 inch to several feet. The submerged sediments in Ponds 1, 2, 3, and the wildlife ponds cover an area of approximately 1 227 acres and range in thickness from less than 1 foot to over 20 feet. (See Table 1)

4.3.2 Surface Water

The data obtained during the remedial investigation characterize the surface water for near-average flow rates. Few data are available to characterize the surface water quality during higher flows because of drier-than-normal conditions in the area experienced during the remedial investigation. No opportunity was available during the sampling period to collect flow and contamination data during one of the high runoff events that cause inflows to be diverted around the pond system.

Surface water samples were collected at 25 sampling points in and adjacent to the Warm Springs Ponds Operable Unit during Phase I and Phase II remedial investigations. The Phase I remedial investigation showed that metals are being removed from the Silver Bow

Creek flow by the current pond treatment system. Inflow loads of total copper and total zinc were reduced by over 90 percent by the time the water left the pond system during the summer months and by 50 to 70 percent during winter months. Although metals concentrations are reduced in the pond system, Montana's chronic ambient water quality standards for copper, lead, and zinc were occasionally exceeded in the water leaving the pond system, particularly in winter months. Ambient standards for cadmium and iron were also frequently exceeded during the sampling events.

Four 24-hour, or diurnal, sampling episodes were completed within the Warm Springs Ponds system during the Phase II remedial investigation to gain a better understanding of changes in water quality over 1-day periods and on a seasonal basis. These sampling episodes were completed in September 1987 and in January, April, and July 1988.

Hourly data from the diurnal sampling studies have been compiled.⁴

The data for the 24-hour sampling episodes indicate the following:

- ♦ pH varied by up to 2.2 units throughout the day at all stations sampled.
- ♦ Total metals concentrations decreased 50 to 90 percent between pond system inflow and outflows.
- ♦ Dissolved metals concentrations for copper and zinc were generally 20 to 50 percent higher in the winter at all sampling stations in the pond system. Higher dissolved metals concentrations in the winter correlate directly with lower pH values measured during winter sampling events.

⁴ CH2M HILL, 1989 Phase II Remedial Investigation Data Summary.

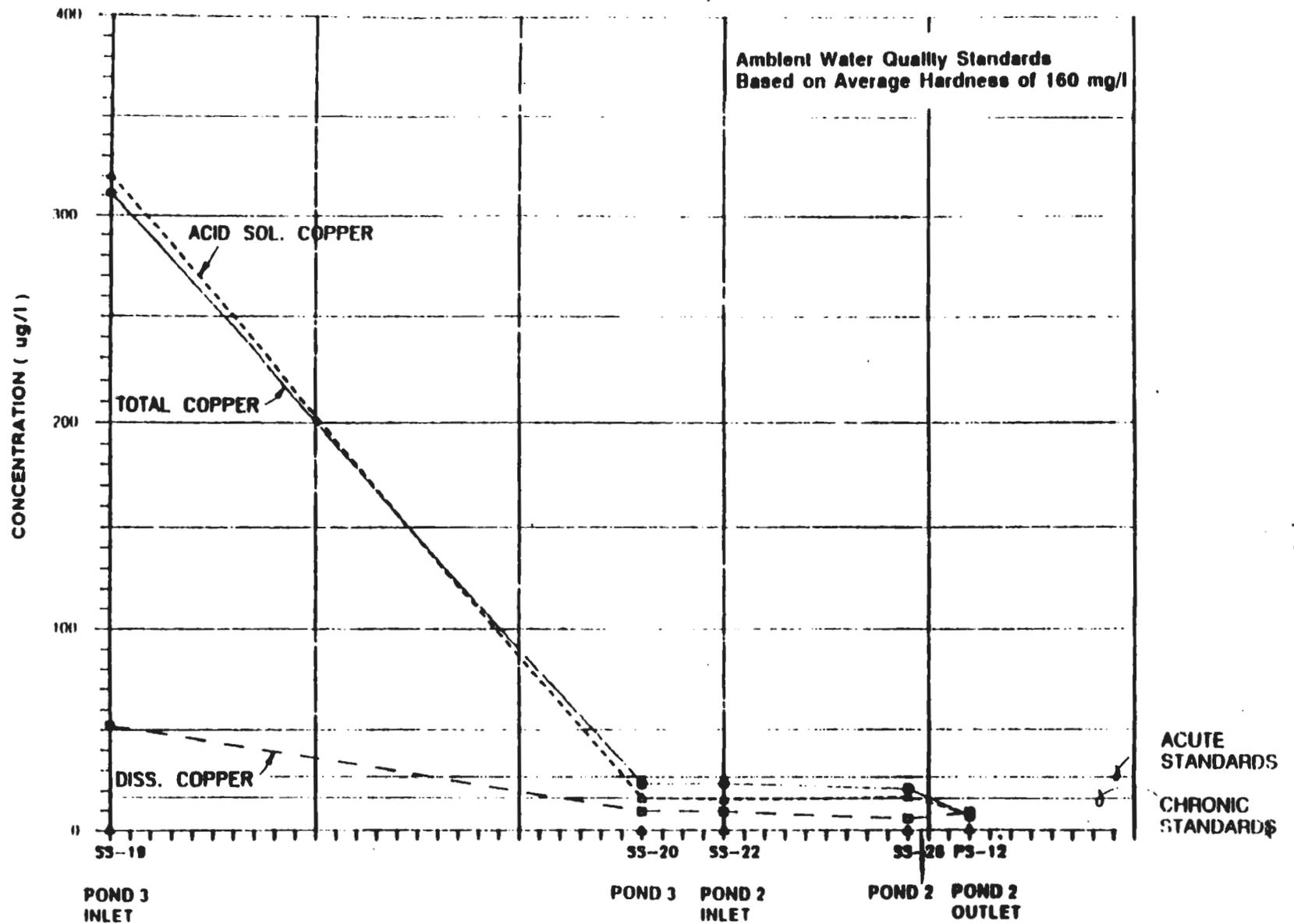
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The pond system reduced metals concentrations at the outflows from the system during the four diurnal sampling events, frequently to levels below both chronic and acute aquatic standards. Figure 4 shows an example of this phenomenon recorded during one of the diurnal sampling events.

Removal of metals in the ponds is accomplished by physical, biological, and chemical processes. Physical reduction of metal-bearing solids occurs through simple sedimentation. Increases in pH, which are partly due to the addition of lime and partly due to photosynthesis, can precipitate metals as a result of changing metals solubilities. Yet another important metals removal mechanism may be the precipitation of calcite and coprecipitation of metals and phosphorus, which follow the photosynthetic removal of carbon dioxide and a compensating shift in the bicarbonate buffering system.⁵ Direct uptake or absorption of metals by algae and aquatic macrophytes is also probable. Addition of lime to the Silver Bow Creek inflow during the winter months also contributes to precipitating metal contaminants when the amount of sunlight to support photosynthesis is reduced.

Several fishkills have occurred in the Mill-Willow Bypass and in the upper Clark Fork River, with the most recent known episode being in July 1989. Analysis of fish tissue by Montana Department of Fish, Wildlife, and Parks from one event in the summer of 1986 revealed acute copper poisoning as the cause of the fish mortality. Although MDFWP did not determine the source of metals responsible for the killings, that source most likely consists of tailings material along the Mill-Willow Bypass.

⁵ Wetzel, R.G., 1973. Limnology Philadelphia W B Saunders Company.



NOTE:
 BASED ON PHASE II RI,
 24 HOUR SAMPLING -- SEPTEMBER 1987
 SOURCE: PHASE II RI REPORT, CH2M HILL 1989

FIGURE 4
DECREASE IN
COPPER CONCENTRATIONS
THROUGH THE POND SYSTEM
WARM SPRINGS PONDS

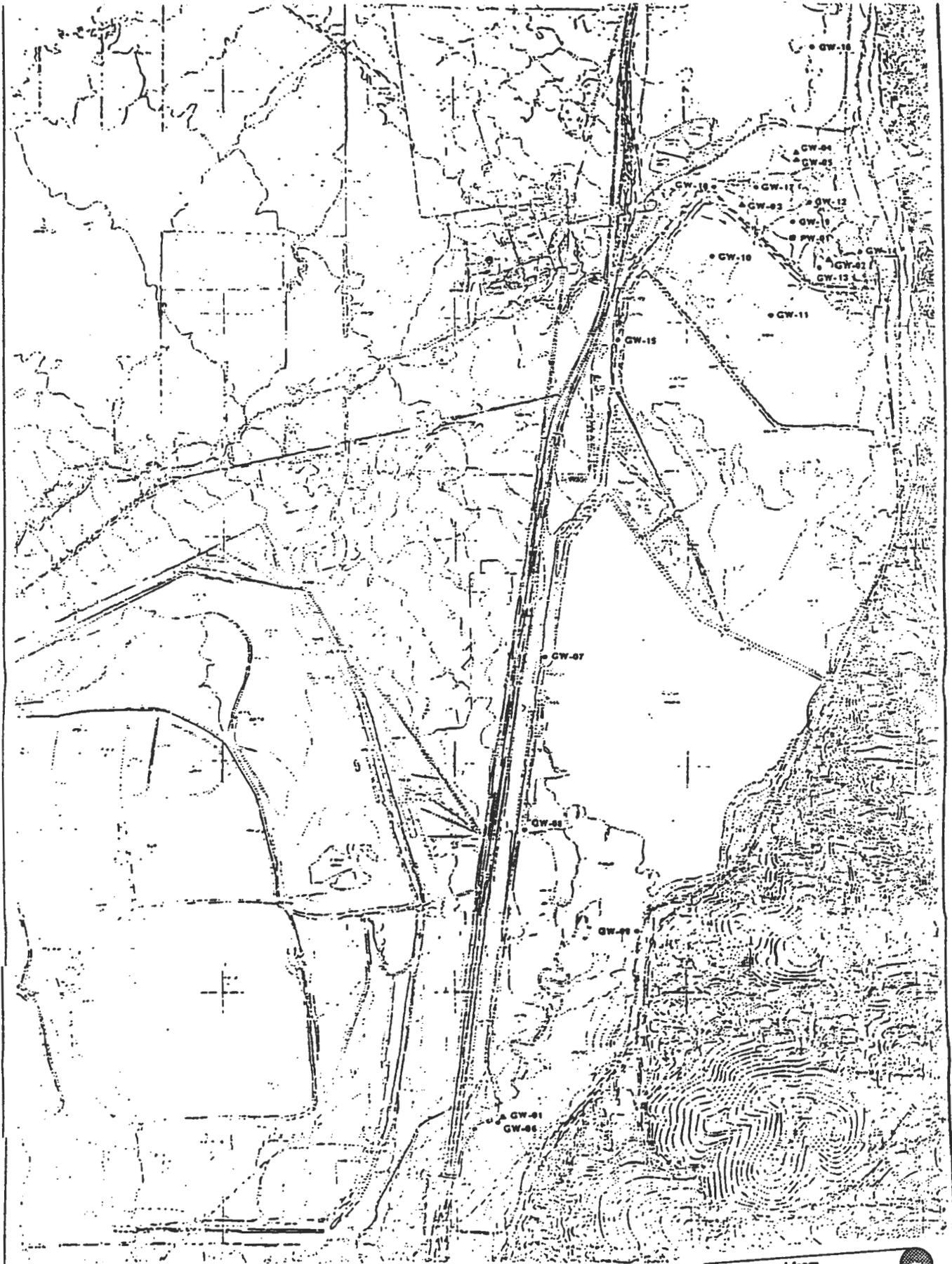
4.3.3 Ground Water

Ground water quality data were generated through sampling of 19 monitoring wells on two occasions (January and May, 1988) Figure 5 shows the locations of the monitoring wells at the site. Table 2 summarizes ground water quality data for these monitoring wells.

Ground water beneath Ponds 2 and 3 may be contaminated also. Wells were not installed to determine the quality of the ground water beneath those two ponds. Given the hydrogeology of the site, contaminated ground water under the ponds would flow north and be detected at the northern end of the pond system.

With one exception, all detected exceedences of the primary maximum contaminant levels for metals (arsenic and cadmium) were north of the Pond 1 berm. Ground water quality downgradient of Pond 1 is generally of poorest quality immediately north of the berm. Most metal contaminants decrease to the north, or downgradient of the pond system. Concentrations of most metals also decrease with depth.

Highest concentrations of metals are generally associated with the shallow sand and gravel aquifer in the area immediately below the Pond 1 berm. Calculations of ground water discharge from the area below Pond 1 into the Clark Fork River indicate that the ground water system contributes very little flow to the river because of the relatively low permeability and low gradient of the shallow aquifer. Under average conditions, the flow in the Clark Fork River is approximately 137 cfs, while the ground water discharge to the river is approximately 1.0 cfs. Nevertheless, the exceedences of the maximum contaminant levels for arsenic and cadmium in the ground water constitute a violation of the drinking water standards.



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0 2000
SCALE IN FEET

- LEGEND**
- ▲ PHASE I RI MONITORING WELL
 - PHASE II RI MONITORING WELL
 - PHASE II PUMPING WELL

FIGURE 2-13
LOCATION OF
GROUNDWATER MONITORING WELLS
WARM SPRINGS PONDS
FEASIBILITY STUDY

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TABLE 1
GROUND WATER QUALITY DATA SUMMARY
WARM SPRINGS PONDS OPERABLE UNIT

Parameter	Maximum Concentration (a)	Minimum Concentration (a)	Average Concentration (a)	Number of Samples	Maximum Contaminant Level(s) (Maximum Ground Water Regulations)
Upgradient Monitoring Wells					
Arsenic	0.3	2.0	4.2	3	50 ^b
Cadmium	7.0	<5.0	3.4	3	10 ^b
Copper	1.7	2.1	1.3	3	1,000 ^c
Lead	1.2	<1.0	0.34	3	50 ^b
Manganese	22.0	<3.0	7.3	3	50 ^c
Zinc	21.2	4.7	10.3	3	5,000 ^c
Iron	28.0	<15.0	19	3	300 ^c
Sulfate (mg/l)	68.0	23	49	3	250 ^c
Mill-Willow Bypass (Shallow Wells)					
Arsenic	41.0	<2.0	9.2	10	50 ^b
Cadmium	11.7	<5.0	3.7	10	10 ^b
Copper	15.0	<6.0	4.6	10	1,000 ^c
Lead	18.0	<1.0	2.5	10	50 ^b
Manganese	14,500	45	4,755	10	50 ^c
Zinc	1,250	12.7	265	10	5,000 ^c
Iron	4,000	25.0	805	10	300 ^c
Sulfate (mg/l)	1,130	20.0	563	10	250 ^c
Mill-Willow Bypass (Deep Wells)					
Arsenic	<2.0	<2.0	1.1	3	50 ^b
Cadmium	5.2	<5.0	2.9	3	10 ^b
Copper	7.1	<6.0	4.0	3	1,000 ^c
Lead	2.0	<1.0	1.1	3	50 ^b
Manganese	9,550	7.0	2,221	3	50 ^c
Zinc	38.0	6.2	22.2	3	5,000 ^c
Iron	70	<15	33	3	300 ^c
Sulfate (mg/l)	1,060	92.0	494	3	250 ^c
Downgradient of Pond 1 (Shallow Wells)					
Arsenic	197.0	<2.0	28.0	14	50 ^b
Cadmium	12.7	<5.0	3.6	14	10 ^b
Copper	15.9	<6.0	5.8	14	1,000 ^c
Lead	<2.0	<1.0	2.0	14	50 ^b
Manganese	31,600	309	10,297	14	50 ^c
Zinc	253	16.3	89.0	14	5,000 ^c
Iron	80,900	45	16,220	14	300 ^c
Sulfate (mg/l)	1,020	250	950	14	250 ^c
Downgradient of Pond 1 (Deep Wells)					
Arsenic	<3.0	<2.0	1.0	13	50 ^b
Cadmium	8.4	<5.0	4.3	13	10 ^b
Copper	<8.0	<6.0	3.5	13	1,000 ^c
Lead	<2.0	<1.0	0.8	13	50 ^b
Manganese	4,460	3.0	5.7	13	50 ^c
Zinc	43	6.2	19.8	13	5,000 ^c
Iron	409	<15	52	13	300 ^c
Sulfate (mg/l)	1,150	55	531	13	250 ^c

a All values in ug/l unless otherwise noted.
b Primary standard (based on health criteria)
c Secondary standard (based on suitability criteria).

Notes

1. Upgradient wells include WSP-GW-01, 06, and 09 (Figure 2-8).
2. Shallow wells are generally less than 15 feet deep, deep wells are generally 25 to 40 feet deep.
3. Mill-Willow shallow wells include WSP-GW-07S, 08S, 15S, 16S, and 17 (Figure 2-8).
4. Mill-Willow deep wells include WSP-GS-07D, 08D, 15D, and 16D (Figure 2-8).
5. Shallow wells downgradient of Pond 1 include WSP-GW-02S, 03S, 05, 12S, 13S, 14S, and 19S (Figure 2-8).
6. Deep wells downgradient of Pond 1 include WSP-GW-02D, 03D, 04, 12D, 13D, 14D, and 19D (Figure 2-8).
7. Average values calculated using one-half detection limit, when applicable. January and May 1988 data.
8. Additional maximum contaminant levels are: mercury and compounds: 2; nitrate: 10,000; selenium and compounds: 10; and silver: 50

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5.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Applicable or relevant and appropriate requirements (ARARs) are a basic standard by which all aspects of contaminant cleanup are measured. Compliance with ARARs or invocation of an appropriate ARAR waiver, is required by Section 121 (d) of CERCLA. The feasibility study evaluated potential compliance of the developed remedial alternatives with federal and Montana ARARs. Compliance with ARARs is a threshold determination for selection of a remedy. 40 CFR § 300.430(f)(i)(A).

The discussion of ARARs in this section is a general discussion, which highlights the major ARARs for the remedial action. A full list of all ARARs and compliance points, as well as information to be considered ("TBCs"), and other relevant legal requirements, is contained in the attachment to Part II: The Decision Summary. The basis for EPA's selection of the ARARs is given in the feasibility study and Part III, Responsiveness Summary.

ARARs are divided into three categories: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs include laws and regulations that set human health- or environmentally-based numerical values governing materials having certain chemical or physical characteristics. These values set the acceptable concentrations of chemicals that may be found in, or released to, the environment. Location-specific ARARs restrict contaminant concentrations or cleanup activities due to the site's geographic or physical location. Action-specific ARARs are based on actions taken during contaminant cleanup.

Section 121(d)(4) of CERCLA, 42 U.S.C. § 9621(d)(4), provides for the waiver of ARARs if certain criteria are met. This Record of Decision waives two ARARs for surface water--arsenic and mercury--and establishes replacement numeric limitations for those standards waived. The waivers are based on technical impracticability from an engineering perspective, as permitted under section 121(d)(4)(c) of CERCLA, 42 U.S.C.

§ 9621(d)(4)(c). The replacement criteria will remain fully protective of human health and the environment. The replacement criteria are

Mercury: 0.0002 mg/l

Arsenic: 0.02 mg/l

There is uncertainty over whether creation of permanent disposal facilities within Ponds 1 and 3 and the Pond 2 and 3 impoundments in place is in compliance with a relevant and appropriate requirement from the State's Solid Waste Disposal Regulations, which prohibits disposal of solid waste within the 100-year floodplain. EPA believes that the waste units will be outside of the floodplain when the Pond berms are raised and strengthened to specified standards. Even if the water within the ponds is considered part of the floodplain, the disposal units are probably outside of the 100-year flood pool of the water within the Ponds. To the extent the areas within the pond berms are considered to be within the 100-year flood plain, EPA waives the Solid Waste Disposal ARAR pursuant to section 121(d)(4)(c), as technologically infeasible from an engineering perspective and pursuant to section 121(d)(4)(A), as an interim action.

Additionally, if it is later determined that the area within the Pond berms is within the 100-year floodplain, then a waiver of the state's solid waste disposal regulations, prohibiting disposal within the 100-year floodplain, is invoked, on the same bases as above.

5.1 CHEMICAL-SPECIFIC ARARs

The most significant state and federal chemical-specific ARARs consist of standards protecting the quality of surface and ground water resources for human health and environmental purposes. Surface water ARARs include ambient water concentration limits to protect both aquatic life and public health, point source discharge standards for discharges from the pond system, and drinking water standards. Ground water ARARs include only drinking water standards. The contaminants of concern at the site are arsenic, cadmium, copper, iron, lead, silver, selenium, mercury, aluminum, and zinc.

5.2 LOCATION-SPECIFIC ARARs

Important location specific ARARs include cleanup activity restrictions to protect and minimize impacts on historically significant features and endangered species.

5.3 ACTION-SPECIFIC ARARs

Action-specific ARARs pertinent to the Warm Springs Ponds Operable Unit include regulations concerning dam safety in event of floods and earthquakes, hazardous waste management and land reclamation for mining areas.

Dam safety regulations address berm design and modification for the existing treatment system. Hazardous waste management ARARs include requirements for contaminant disposal. Reclamation ARARs require proper grading, backfilling, subsidence stabilization, water control, revegetation and other measures needed in surface mining areas to eliminate damage from soil erosion, subsidence, landslides, water pollution, and hazards dangerous to life and property.

SECTION 6.0
SUMMARY OF HUMAN HEALTH AND ENVIRONMENTAL RISKS

A public health and environmental risk assessment was conducted by the Montana Department of Health and Environmental Sciences to identify and characterize the actual and potential threats to human health and the environment posed by contaminants present at the Warm Springs Ponds Operable Unit. Carcinogenic and noncarcinogenic human health effects were characterized, as were significant environmental effects. With respect to both human health and the environment, endangerment was established.

6.1 HUMAN HEALTH RISKS

The EPA has determined that the Warm Springs Ponds Operable Unit poses the following actual or potential endangerment to human health:

- ♦ Workers at the ponds face an increased risk of cancer estimated to be 2×10^{-4} , or two excess cancers in 10,000 individuals exposed for a lifetime, due to incidental ingestion of arsenic in the contaminated soils, sediments and tailings. Recreationists (hunters, fishermen, bird watchers) also face increased cancer risk from exposure to arsenic.
- ♦ Workers and recreationists face additional cancer and noncancer health risks due to ingestion of lead and other hazardous substances in the contaminated soils, sediments, and tailings.
- ♦ Current residents adjacent to the ponds face actual or potential risks from contaminated soils, sediments, and tailings becoming wind-borne. If homes were to be built within the operable unit boundaries, residents would also face risks greater than the levels noted above.

- The contaminated ground water below Pond 1 poses a potential threat to users of the ground water.
- The berms protecting the ponds fail to meet current dam safety standards. Their failure due to a flood or earthquake could result in catastrophic consequences, including loss of life.

The baseline risk assessment establishes current and potential threats to human health. 40 CFR § 300.430(d)(4).

The NCP states that the goal of a Superfund cleanup should be reduction of risk to acceptable ranges, if ARARs do not exist or are not sufficiently protective. The point of departure, or target risk range, is 1×10^{-6} for cancer risk and levels that do not create adverse effect, incorporating a margin of safety, for systemic toxicants. 40 CFR § 300.430(e)(2)(i)(A)(2).

The preamble to the NCP states that the 1×10^{-6} risk range should be the goal of any cleanup, unless revision to a lesser protective level is appropriate for site specific reasons. 55 FR 8715-8717. Risks should not exceed 1×10^{-4} .

6.2 SUMMARY OF TOXICITY ASSESSMENT

Arsenic, a known carcinogen, is present at this operable unit. Samples of exposed tailings and contaminated soils contained a maximum arsenic concentration of 597 mg/kg and an average of 349 mg/kg arsenic. Lead, a hazardous substance that is both a suspected carcinogen and toxic noncarcinogen, is also present at elevated concentrations (maximum of 1000 mg/kg and average of approximately 490 mg/kg). Risks from lead were not quantified in the risk assessment, but the presence of lead risks is noted. In addition to its suspected carcinogenic effects, lead is known to damage the central nervous system and cause other serious health effects. The EPA believes there is no safe threshold for lead

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intake. Other hazardous substances, such as cadmium, are also present at elevated concentrations.

6.3 SUMMARY OF EXPOSURE ASSESSMENT

In addition to serving as an active water treatment system for contaminants transported by Silver Bow Creek, the Warm Springs Ponds and surrounding area also function as a wildlife management area. Since two employees of the Montana Department of Fish, Wildlife and Parks work within the operable unit, managing the wildlife area, their occupational exposure was evaluated. A recreational exposure scenario was also evaluated because hunters and fishermen are often present at the ponds. The risk to current residents was evaluated because several homes are located near the operable unit boundary.

As required by EPA policy, the risk assessment also examined risks under a future residential scenario. Because the operable unit is comprised almost entirely of the ponds and associated wetlands, EPA considers it unlikely that homes will be built within its boundaries. To ensure that future residential development does not occur, the Record of Decision requires implementation of institutional controls. The remedy then focuses on active measures to address the occupational, recreational, and environmental threats.

The current human exposure routes are summarized on Figure 6 for each exposure scenario. The principal component of human health risk comes from incidental ingestion of arsenic during occupational activity.

6.4 RISK CHARACTERIZATION

The risk assessment evaluated risks from carcinogenic elements such as arsenic, lead, and cadmium, and risks from numerous noncarcinogenic elements such as copper, iron, lead, and zinc. The human health risks from noncarcinogens are evaluated based on their

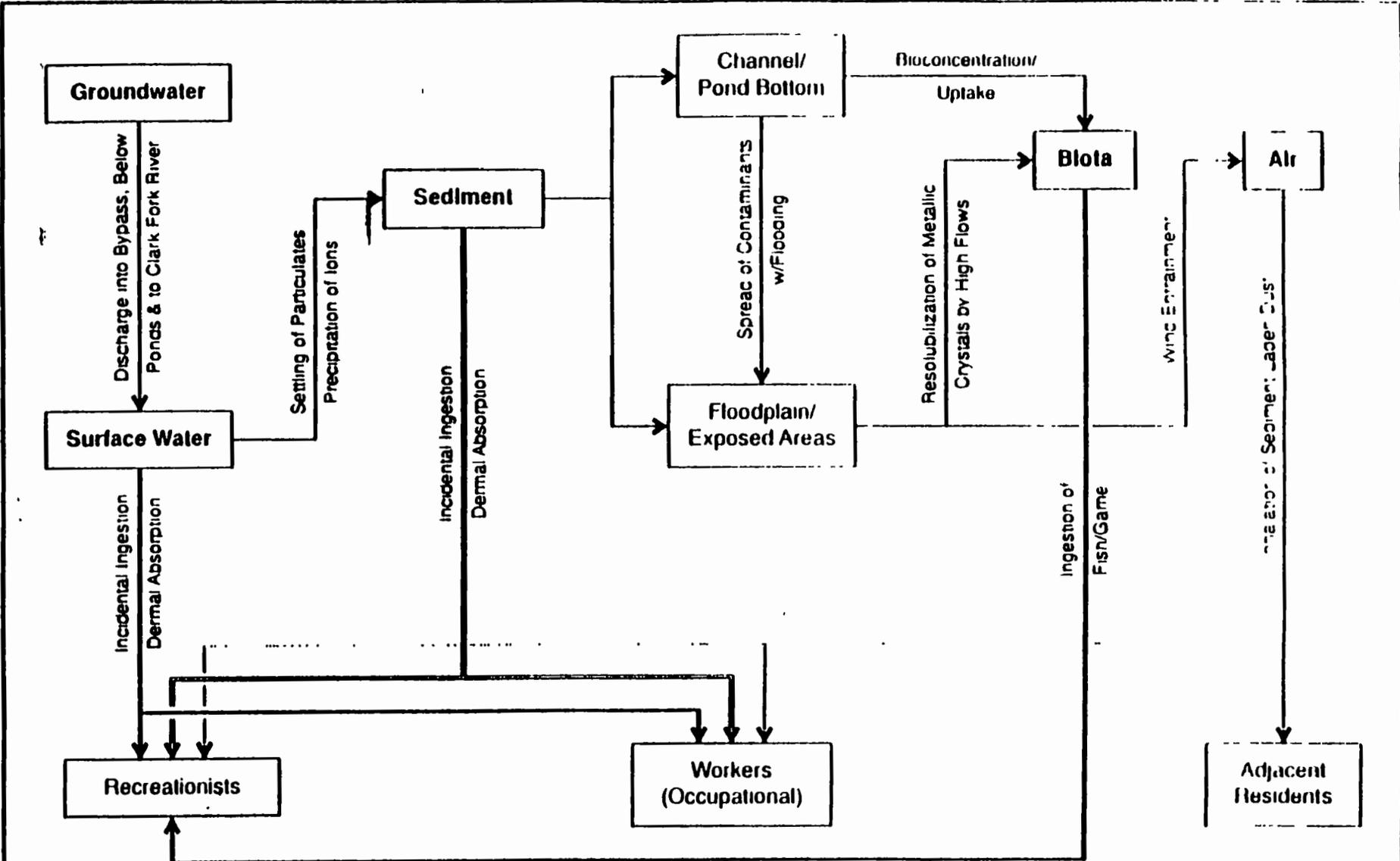


FIGURE 6
POTENTIAL CURRENT HUMAN
PATHWAYS OF EXPOSURE
WARM SPRINGS PONDS

hazard index. If the combined chemical hazard index is greater than one (based on a detailed calculation presented in the risk assessment), then an unacceptable risk is present. Although some risks due to noncarcinogens were found, the hazard index was in all cases less than one. As indicated previously, lead was not quantitatively evaluated in the risk assessment. However, the EPA believes there is no safe threshold for lead intake. Although copper and zinc do not present a risk to human health, they do pose significant risks to the environment, especially to aquatic organisms.

The maximum excess lifetime cancer risk due to arsenic exposure (arsenic is the contaminant of primary concern) for workers at the ponds is estimated to be 2×10^{-4} , or two excess cancers in every 10,000 exposed individuals. This estimated risk is based on exposure to maximum measured concentrations of arsenic in exposed tailings and contaminated soils present at the Warm Springs Ponds, but excluding the Mill-Willow Bypass.

Because of difficulties in developing risk-based cleanup levels for the occupational and recreational scenarios, EPA has elected to delay selection of a specific health-based soil cleanup action level. The EPA will continue to examine appropriate methods for calculating specific soil cleanup levels for this operable unit. Nevertheless, EPA is confident that the risk assessment has demonstrated actual and potential risks posed by conditions at this operable unit to justify the Record of Decision requirements. The next section, concerning environmental risks, explains how the human health risks will be reduced by mitigation of the environmental risks.

6.5 ENVIRONMENTAL RISKS

The EPA has determined that the Warm Springs Ponds pose the following actual or potential endangerment to the environment.

- ♦ Periodic fishkills have occurred due to salts of copper and zinc washing from tailings deposits into the Clark Fork River during thunderstorms. Contaminated soils, sediments, and tailings also pose an unquantifiable chronic risk to aquatic life and wildlife, both within the boundaries of the operable unit and in the river downstream.
- ♦ Water quality criteria for the protection of aquatic life have been exceeded by water discharged from the ponds, and by water routed around the ponds without treatment.
- ♦ The berms protecting the contaminated pond water and sediments fail to meet current dam safety standards. Their failure due to floods or earthquakes could result in catastrophic environmental consequences in the Clark Fork River

Although this Record of Decision does not require a specific soil cleanup action level, EPA is confident that the risk assessment has sufficiently demonstrated the actual and potential environmental risks posed by conditions at the Warm Springs Ponds to justify the cleanup requirements.

The actions required by this Record of Decision are necessary and appropriate to address the risks described above, even though an exact quantification of acceptable risk levels was not determined. The actions required will reduce or eliminate the principal risks. This statement is based on the knowledge that several components of the selected remedy require excavation or covering of exposed tailings, sediments, and contaminated soils. For example, drying and covering Pond 1 will retard or stop the ground water contamination which currently exists, and increasing the operational level of Pond 2 will flood areas of contaminated soils, sediments, and tailings, thereby reducing exposure by direct contact to those areas.

Up to 80 percent of the suspended solids would continue to be settled out within the basin, but only flows up to 600 cfs (the inlet capacity of Pond 3) would then be treated in the ponds for dissolved metals. The remainder of the flows discharged over the spillway of the settling basin would be routed around Pond 3 and flow down the bypass without treatment of dissolved metals.

The actions proposed in Alternative 3 are expected to result in compliance with all State and federal ARARs. These include Montana's dam safety standards, aquatic water quality standards (with the exception of arsenic and mercury, as previously described), maximum contaminant levels, and selected RCRA closure requirements.

The actions proposed for Alternative 3 are technically feasible and are expected to reliably reduce the environmental and human health risks at the site. The actions proposed may result in adverse effects to wetlands, endangered species, or historical resources. The estimated present worth cost is \$71,100,000. It is estimated that the remediation measure identified will take 5 years to complete.

8.4 ALTERNATIVE 3+3A \$(57,416,000)

Alternative 3+3A, identified by the EPA and MDHES as the selected remedy, is a synthesis of Alternative 3 and ARCO's Alternative 3A. Alternative 3+3A was developed following consultation with the public and ARCO to address concerns about some of the aspects of Alternative 3 as presented in the feasibility study. Alternative 3+3A includes many of the features of Alternative 3, including protecting the pond berms against the maximum credible earthquake and fractions of the probable maximum flood, upgrading the treatment system, removing Mill-Willow tailings, covering and revegetating Pond 1, and installing ground water interception trenches. It is different from Alternative 3 in that storage of flood flows would be within Pond 3 rather than in an upstream impoundment; the bypass channel would be realigned in places; Pond 2 would be improved and retained

Pond stability in this alternative is achieved by protecting Pond 1 against a 0.2 PMF, Pond 2 against a 0.3 PMF, and Pond 3 against a 0.5 PMF. These are the standards that are required by Montana's dam safety regulations for high hazard dams such as those at the Warm Spring Ponds.

In Alternative 3, all exposed tailings and contaminated soils in the Mill-Willow Bypass, within Pond 3, and below Pond 1 that exceed an action level of 250 ppm arsenic and 750 ppm lead would be excavated and disposed of in Pond 1. Pond 1 would be closed with a RCRA-compliant cap as described in Alternative 1.

Consolidating excavated material into Pond 1 under a RCRA-compliant cap would effectively isolate the material from direct contact and effectively limit the mobility of the material. It would also effectively consolidate all material which exceeds the cleanup criteria within a smaller area. As long as the cap is properly maintained, the material would be safe from release because of erosion of the cap.

The final difference between Alternatives 2 and 3 is that Alternative 3 includes the construction of a smaller upstream settling basin (2,000 acre-feet). During flood flows on Silver Bow Creek greater than 600 cfs, surface water would pass through the upstream settling basin. The settling basin would be similar to the upstream impoundment with two exceptions. First, the storage capacity would be much lower (2,000 acre-feet versus 8,000 acre-feet). Second, the amount of water that would receive full treatment for both suspended solids and dissolved metals would be less.

During flood flows between 600 and 4,000 cfs, all surface water from Silver Bow Creek would pass through the upstream settling basin. Full treatment would be provided for floods that do not completely fill and then overflow the 2,000 acre-foot settling basin. Suspended solids would settle within the basin and the captured water would then be released slowly from the basin for treatment of dissolved metals in Pond 3. Floods that exceed the storing capacity of the settling basin, however, would be only partially treated.

Up to 80 percent of the suspended solids would continue to be settled out within the basin, but only flows up to 600 cfs (the inlet capacity of Pond 3) would then be treated in the ponds for dissolved metals. The remainder of the flows discharged over the spillway of the settling basin would be routed around Pond 3 and flow down the bypass without treatment of dissolved metals.

The actions proposed in Alternative 3 are expected to result in compliance with all State and federal ARARs. These include Montana's dam safety standards, aquatic water quality standards (with the exception of arsenic and mercury, as previously described), maximum contaminant levels, and selected RCRA closure requirements.

The actions proposed for Alternative 3 are technically feasible and are expected to reliably reduce the environmental and human health risks at the site. The actions proposed may result in adverse effects to wetlands, endangered species, or historical resources. The estimated present worth cost is \$71,100,000. It is estimated that the remediation measure identified will take 5 years to complete.

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TABLE 6
COST ESTIMATES FOR THE ACTION ALTERNATIVES

Cost Components	Alternative 1	Alternative 2	Alternative 3	Alternative 3:3A	Alternative 4	Alternative 5	Alternative 6
Estimated Construction Cost	\$1,685,000,000 00	\$250,000,000 00	\$60,100,000 00	45,700,000 00	\$65,500,000 00	\$56,000,000 00	\$46,100,000 00
Engineering Design	4,000,000 00	4,000,000 00	4,200,000 00	3,500,000 00	4,600,000 00	3,900,000 00	3,200,000 00
Services During Construction	7,000,000 00	4,000,000 00	4,200,000 00	3,500,000 00	4,600,000 00	3,900,000 00	3,200,000 00
Administrative & Legal	3,000,000 00	3,000,000 00	3,000,000 00	2,800,000 00	3,300,000 00	2,800,000 00	2,300,000 00
Total Project Cost	1,679,000,000 00	261,000,000 00	71,500,000 00	55,500,000 00	78,000,000 00	66,600,000 00	54,800,000 00
Operation and Maintenance (Yearly Costs)	<u>283,000 00</u>	<u>301,000 00</u>	<u>300,000 00</u>	<u>379,000 00</u>	<u>293,000 00</u>	<u>284,000 00</u>	<u>270,000 00</u>
Total Present Worth Cost	\$1,191,500,000 00	\$241,500,000 00	\$71,100,000 00	\$57,416,000	\$77,000,000 00	\$66,300,000 00	\$55,100,000 00

Reference 12

**Excerpts From Silver Bow/Butte Site Profile,
Document #983-TS1-RT-ETTR; Author Not Provided; Undated**

TABLE 11

SUMMARY OF DOMESTIC WELLS(a) EXHIBITING FEDERAL DRINKING WATER
STANDARD EXCEEDENCES

<u>Sulfate</u>	<u>Cadmium</u>	<u>Iron</u>	<u>Arsenic</u>	<u>Zinc</u>
DW-131	DW-206	DW-131	DW-230(b)	DW-132
DW-132		DW-336		
DW-202		DW-337		
DW-207				
DW-311				
DW-314				
DW-318				
DW-504				

Notes:

- (a) Well locations shown on Map 7.
- (b) Exceedence measured was for total fraction; corresponding dissolved fraction was less than standard of 0.05 mg/L.

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Impacts to Silver Bow Creek measured during the RI are described below, presented as percent contributions to the creek and gross material loadings. Table 7 summarizes ground-water loading to Silver Bow Creek.

Most, if not all, of the contaminant loads in the Metro Storm Drain (MSD - that portion of Silver Bow Creek which flows through Butte) were derived from ground water, although some of the loads may be from sediment re-entrainment. Ground water from the MSD was a significant source of zinc, cadmium, sulfate, copper, iron, arsenic, and lead to Silver Bow Creek at the confluence with Blacktail Creek, and it degraded water quality at that point. Table 8 shows a ranking of contaminant sources to Silver Bow Creek with loads in lbs/day.

A significant inflow of contaminated ground water was present between Montana Street and the Colorado Tailings. Large increases in copper, zinc, sulfate, arsenic, and cadmium loads are apparent in this reach. Ground-water inflow here must be of extremely poor quality to cause these drastic increases in metal loads.

Another significant ground-water inflow is present along the Colorado Tailings, although its flow contribution is half that of the previous one. This inflow contributes significant loads of copper, zinc, iron, arsenic, and cadmium to Silver Bow Creek and also must be ground water with high concentrations of contaminants.

Table 9 briefly describes the major surface water contaminant sources and Table 10 describes ground-water contaminant sources.

Federal drinking water standards were exceeded for most parameters at several wells sampled in the RI study area (Table 11). Concentrations exceedences were measured for arsenic, cadmium, copper, iron, lead, zinc, and sulfate.

A total of 4,250,000 cubic yards of mixed tailings, mine waste rock, natural sediments, and precipitates were estimated to occur along Silver Bow Creek from Butte to Warm Springs and along the upper Clark Fork River from Warm Springs to Deer Lodge, Montana. Over 1,100 acres of visible waste deposits were mapped during the preliminary Silver Bow Creek Remedial Investigation (SBC RI) studies.

Acid Mine Waters

Mine waste water was discharged into Silver Bow Creek beginning in the early 1880's. From the 1880's until the early 1900's water pumping systems were operated at virtually every mine in Butte to remove mineral-laden water from mines. In 1912, it was estimated that 4,000-5,000 gpm was pumped from the Butte mines.

In 1889 the Anaconda Company began precipitating copper out of the mine waste water and continued this operation into the 1970's. Throughout this period, mineral-laden water was discharged from precipitation plants into Silver Bow Creek. Water quality data characteristics of the chemical composition of mine waste water during this period is not readily available. Chemical characteristics of mine water and precipitation plant spent leach solution discharged into Silver Bow Creek in 1972 is shown in Table 6.

Timber Treatment Sites

The Anaconda ~~Post~~ Treatment Facility (pickling plant) near Rocker (see Map 3) treated mine timbers with a preservative containing arsenic. Waste material from the pressure treatment was dumped along the banks of Silver Bow Creek. This facility operated at Rocker from the early 1900's until 1956. Also, creosote was used at this plant to treat poles and to lubricate the skids for mine timber loading and unloading. Surface soils at this facility had very high levels of arsenic. This site is currently

**SILVER BOW/BUTTE
SITE PROFILE
Document # 983-TS1-RT-ETTR**

A. SITE OPERATIONS

A.1 PRODUCTS - Gold, Silver, Copper, Lead, Manganese

A.2 SITE OPERATION

A.3 PROCESSES

<u>Products</u>	<u>Process</u>	<u>Time Period</u>
Gold/Silver, Lead/Silver Copper/zinc/manganese	Mining	1864 - Present
Copper/Silver	Milling	1866 - 1910
	Separation/concentration	
	Jigging	
	Flotation	
	Heap Roasting	
	Stall Roasting	
	Hearth Roasting	
Gold/Silver/Copper Copper/Zinc	Smelting	1866 - 1910
	Blast Furnace	
	Reverberatory	
	Pyritic	

Waste Management Practices:

- Direct dumping of mining, milling, and smelting wastes into Silver Bow Creek (1870's - 1972)

Streamside Tailings Impacts

Erosion of streamside tailings deposits were not evaluated per se during the RI. Instead, sediment entrainment was quantified, which represents both bank erosion and channel sediment re-entrainment. Distinguishing between the two processes is not possible with existing data.

Surface water data indicate contributions of channel or bank material during higher flows to be significant along Silver Bow Creek from the Colorado Tailings to Silver Bow and from Ramsay Flats to Fairmont Hot Springs. In both these reaches, increases in solid-phase metals (copper, zinc, iron, arsenic, and lead) during high flows are consistent. This probably represents previously deposited metals (including those precipitated from discharge of mineral-laden mine waste water) that are remobilized during higher flows and the lack of extremely high flows during the RI probably prevented significant bank erosion from occurring in the study area.

Table 12 summarizes metal loads contributed in both stretches, some of which are probably from stream bank tailings. The Surface Water and Point Source Investigation (Appendix A of RI, MultiTech, 1987) found both ground water and channel sediments to be major sources of water quality degradation in Silver Bow Creek. Impacts of ground-water inflow were especially severe; impacts of bank entrainment could not be specifically evaluated.

Other Impacts

For the protection of aquatic life, the concentrations of total recoverable arsenic, cadmium, copper, lead, and zinc in natural waters should not exceed specific criteria. Table 13 shows the number of times the USEPA one-hour or Montana Department of Health and Environmental Sciences criteria were exceeded at each surface water station sampled during the SBC

RI. For comparison, the number of measurements of a contaminant are also indicated.

Tables 14 and 15 show the number of water samples exceeding the primary and secondary standards for drinking water at each of the surface and ground-water sampling sites. Also shown in these tables are the number of measurements at each site for total arsenic, cadmium, copper, iron, lead, and zinc.

Algae

Water quality and algal sampling conducted during the Silver Bow Creek Remedial Investigation (Multitech, 1987) provided limited evidence that the algal communities in the Warm Springs Ponds have shown some metal uptake (Table 16). Algal communities situated between the confluence of Silver Bow and Blacktail Creeks and the Warm Springs Ponds have been slowly recovering over the past ten years.

Riparian Vegetation

The riparian communities associated with the Silver Bow Creek and the upper Clark Fork River have been significant receptors of waste and contaminants transported by the Silver Bow Creek and the upper Clark Fork river. Approximately 11,000 acres of riparian community areas have been inundated by waste materials which do not support vegetative growth. Additional areas have been affected by contaminant migration.

Agricultural Soils and Crops

The Agriculture Investigation provided circumstantial evidence that approximately 5,400 acres of land have been contaminated by heavy metals to varying degrees of severity, by using Silver Bow Creek or Upper Clark Fork river water for irrigation. During the Phase One (reconnaissance level) investigation, 38 soil horizon and 18 plant samples were acquired at 16

Creek as far downstream as Miles Crossing; pollution stress apparently resulted also in depauperate communities as far downstream as east of Opportunity. Since then, more tolerant forms have begun recolonizing this stream reach. However, the degree of annual fluctuation in both organism density and biomass levels, as well as generally low diversity, indicate early stages of biological recovery.

High density and biomass levels, but low diversity communities, or organic matter-tolerant caddis flies plus Dipterans exist immediately downstream from the Warm Springs Ponds discharge into the Clark Fork River.

Fisheries

The RI provided evidence that fish, particularly rainbow trout, are receptors of heavy metal contaminants present within and downstream of the study area (Table 17). Arsenic concentrations in all tissues tested were below USDA food standards.

Measurable concentrations of PCP and PCB were found in the tissues tested (Tables 18 and 19).

Waterfowl

The Waterfowl Investigation provides evidence that, at least cadmium is accumulating in waterfowl residing in the wildlife management area of the Warm Springs Ponds. Analytical results indicate that only cadmium was significantly elevated above background levels in liver tissue, but not in muscle tissue. None of the other trace elements were found to exceed background levels in either tissue type (Table 20).

PCP was detected in muscle and particularly in liver tissues. The concentrations measured do not appear to represent a significant public health concern. Three of the four muscle tissues from wildlife ponds'

have developed on alluvial fans and pediments (U.S. Soil Conservation Service 1973). In the valleys, gently sloping, deep soils have developed along terraces. Adjacent to Silver Bow Creek and the Clark Fork River, shallow, gravel-textured to deep, fine-grained alluvial soils have developed. Nutrient rich, organic soils of various depths are present in some low and wetland areas.

Much of the natural soil in the study area has been affected by mining wastes. Many soils along Silver Bow Creek and the Clark Fork River floodplain are covered with waste materials which may contain a seasonally fluctuating water table.

These mining-related wastes are generally sandy textured, reflecting their granitic origin, and typically have high concentrations of metals and sulfide minerals. The oxidation of sulfide minerals produces acidic conditions that increase the solubility of many metals. Accumulation of bio-available heavy metals severely limits vegetation establishment, which in turn limits soil development.

Pathways

Groundwater containing various dissolved and suspended pollutants were produced from the characterized and potential waste sources by surface water infiltrating downward through the sources, and/or by non-contaminated ground-water contacting the sources. Once entrained in the aquifer, the pollutants were distributed to other components of the site ecosystem by discharge to surface water and by beneficial water use (primarily irrigation) withdrawal from the aquifer.

Groundwater efficiency as a pathway was determined by site-specific factors. The physiochemical properties and concentrations of the contaminants were affected by the nature of the source, reactions occurring within the ground water, and aquifer ground-water interactions as they migrated away from the source. Contaminant plume distribution was affected

Mining Waste NPL Site Summary Report

**Silver Mountain Mine
Loomis, Washington**

**U.S. Environmental Protection Agency
Office of Solid Waste**

June 21, 1991

FINAL DRAFT

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SILVER MOUNTAIN MINE

LOOMIS, WASHINGTON

INTRODUCTION

The Site Summary Report for the Silver Mountain Mine is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of the summary by the EPA Region X Remedial Project Manager for the site, Neil Thompson.

SITE OVERVIEW

The Silver Mountain Mine is an inactive precious metal heap leaching site, which covers approximately 5 acres in a remote area of northern central Washington State. In 1980 and 1981, previously mined materials (approximately 5,300 tons of ore) were piled on top of a plastic liner and treated with sodium cyanide and caustic soda in an attempt to leach and recover gold and silver. Leachate flowed from the leach heap through a lined ditch to a plastic lined basin. Activated carbon at the site was possibly intended for use to remove the metal cyanides from the leachate. Approximately 4,400 pounds of sodium cyanide was used to treat the tailings pile (leach heap). The site was abandoned in 1981 without removal of any chemicals or treatment of cyanide leaching solution.

Arsenic, antimony, and cyanide are the primary contaminants of concern. Population near the site is relatively sparse, with less than 20 people within a 3-mile radius served by drinking water wells. The land closest to the site is used for cattle grazing. The closest domestic water well is located approximately 3 miles south of the site.

The Washington Department of Ecology conducted three remedial actions at the site, the last occurring in 1985. In addition, in 1988 the Bureau of Mines closed and sealed a shallow well at the site. A Record of Decision (ROD) describing the remedy at the site, selected in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), has been signed by the Region X Administrator and verbally concurred on by the State of Washington. This ROD estimates the present value of costs of future remedial actions, assuming a 30-year period for

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Silver Mountain Mine

site activities, to be \$635,600. Currently, EPA is nearing completion of the technical design phase of the remedial action. The timing of construction will depend on fund financing.

OPERATING HISTORY

Underground mining for silver, gold, and copper began at the site in 1902. EPA's Remedial Investigation Report states that the mine was active in 1936, 1943, 1945, and 1956, and that by 1956 the mine had approximately 2,000 feet of underground mine workings and a few thousand tons of mine dump. A mill was built in 1952 but may have never been used. No other records of production were found. From late 1980 to late in the summer of 1981, Precious Metals Extraction (PME), Ltd., constructed and operated the leaching operation described above (Reference 1, Executive Summary, page 1, and Chapter 1, page 5). This operation was abandoned in 1981 with no site closure or clean-up of contaminated material (Reference 1, Chapter 1, page 7).

Detailed records on the process used by PME and the construction of the leach heap and leachate collection pond were not available to EPA during its Remedial Investigation. However, field observations and data collected by the Bureau of Mines during its investigation in 1989 provided basic information on the leaching process and unit construction (Reference 1, Chapter 1, pages 5 through 7).

"PME cleared an area of approximately 180 feet by 140 feet, adjacent to existing mine dumps. A leach pad base of sandy soil up to 3 feet thick and graded with a 2.5 percent slope to the southwest was prepared. At the southern end of the leach pad a rectangular trench 7 feet by 75 feet and averaging 4 feet in depth was dug as a leachate collection pond. The soil base and pond were then covered with a green 20-mil thick plastic liner. Another layer of sandy soil, from 0 to 6 inches thick was then placed over the plastic liner. Last, approximately 5,300 tons of material from the mine dump were loaded onto the pad. The prepared heap was approximately 100 feet long, 105 feet wide, and 14 feet high" (Reference 1, Chapter 1, page 6). As stated above, several tons of caustic soda and lime, and approximately 8,000 pounds of sodium cyanide were combined with water and applied to the leach heap (Reference 2, page 1; Reference 3, page 1).

Processing of the leachate to remove the precious metals may have been accomplished through direct electroplating or by using activated carbon. Information on the type processing is not conclusive, however containers of activated carbon were found onsite. The operation was abandoned in the late summer of 1981 without neutralizing the solution in the leachate pond or materials in the leach heap. Empty cyanide drums and large containers of activated carbon also remained onsite (Reference 1, Chapter 1, page 6; Reference 3, page 1).

SITE CHARACTERIZATION

EPA conducted a Remedial Investigation, completed in January 1990, to determine the environmental characteristics and the type and extent of contamination. EPA found four potential sources of contaminants (the leach heap, mine dump, mine drainage, and bedrock) and four potential exposure pathways (onsite soils, onsite surface water, onsite ground water in a shallow aquifer, and offsite ground water in the Horse Springs Coulee-Aeneas Lake aquifer.) The contaminants of concern have been identified as arsenic, cyanide, and antimony (Reference 1, Executive Summary, page 2; Reference 4, page 9).

Soils

Samples taken during EPA's Remedial Investigation show levels of arsenic at moderate to high concentrations in both the mine dump and the leach heap, the three highest values being 652 milligrams per kilogram (mg/kg) at the toe of the heap, 626 mg/kg at the top of the heap, and 1,075 mg/kg in the mine dump. Cyanide levels in the heap reach 173 mg/kg and appear to concentrate at the toe of the heap with values of 10 times those occurring elsewhere in the heap (Reference 1, Chapter 4, pages 2 through 5).

Arsenic, antimony, lead, other metals, and cyanide are contaminants at lower levels in the shallow soils under the leachate pond and in soils adjacent to the leach heap (Reference 1, Executive Summary, page 2 and Chapter 4, pages 2 through 5).

Ground Water

Ground-water monitoring was conducted during May, June, and July 1989. Onsite concentrations of ground-water contaminants were compared to concentrations in downgradient water supply wells in the Horse Springs Coulee Aquifer. Cyanide, as well as sodium, potassium, nitrate, nitrite, and fluoride are contaminants that originate at the leach heap. Contaminants that originate in the mine dump include arsenic, antimony, barium, chromium, copper, chloride, iron, lead, manganese, nickel, silver, and zinc. In addition, arsenic and antimony occur in mine drainage and originate in the bedrock of the mine workings (Reference 1, Executive Summary, page 2 and Chapter 4, pages 13 through 33).

Ground-water contaminants from the leach heap extend in a plume at least as far downgradient as the furthest monitoring well (Well 3), 50 feet southeast of the heap. However, the Remedial Investigation Report concluded that as of 1989 ground-water contaminants do not influence the nearest

offsite water supply wells 2 to 4 miles downgradient to the southeast of the site (Reference 1, Executive Summary, page 3 and Chapter 4, pages 13 through 33).

Fate and Transport of Cyanide

According to EPA's Remedial Investigation, the future impact of cyanide on ground and surface water is primarily controlled by the amount and form of cyanide remaining in the leach heap, and by seepage and degradation rates. These factors indicate that the cyanide concentrations occurring in ground water during 1989 probably originated in spillage or leachate pond overflow at the time of leach heap operations in 1980 and 1981. The Remedial Investigation estimates that, as a result of remedial actions, little or no leachate has been produced since the heap was covered in 1985. However, according to the Remedial Investigation, with time and deterioration of the plastic liners, leaching of cyanide from the heap would be expected to resume with transport of cyanide to ground water. Infiltration of cyanide is projected to occur at progressively reduced concentrations and rates as a result of degradation, including speciation to hydrogen cyanide and subsequent volatilization. Projected maximum concentrations of cyanide in leachate are on the order of a few milligrams per liter (mg/l). Infiltration of leachate at these concentrations is projected to decrease to significantly lower levels during passage through the unsaturated zone (Reference 1, Executive Summary, pages 2 and 3).

Fate and Transport of Arsenic

The future impact of arsenic on ground and surface water is primarily controlled by the amount and form of arsenic in mined materials, the amount and form of arsenic in bedrock, and the sorption capacity of iron- and aluminum-rich soils, according to the Remedial Investigation. These factors indicate that, as the materials in the heap and dump oxidize, leachate from the leach heap and mine dump could produce high concentrations of arsenic, on the order of a few tens of mg/l. The Remedial Investigation concluded that with time and the anticipated decrease in sorption capacity of the soils, arsenic concentrations impacting ground water could reach the same level as those in the infiltrating leachate. In 1989, levels of arsenic in ground water indicated that oxidation of the mine dump and buried bedrock has not yet progressed to the point of producing highly concentrated leachate. Elevated levels of arsenic in mine drainage in 1989, however, indicated that oxidation may now be taking place in the mine workings. Consequently, according to the Remedial Investigation, a potential exists for arsenic concentrations to increase in leachate from the mine or any of the mined material continually exposed to the oxidizing influences of weathering or water infiltration (Reference 1, Executive Summary, page 3).

ENVIRONMENTAL DAMAGES AND RISKS

Initial interest in the site was created in 1981, when the owner of the land's surface rights informed the Okanogan County Health Department of the heap leaching operation (Reference 1, Chapter 1, page 7; Reference 5). Originally, the Washington Department of Ecology responded to the threat caused by the cyanide in the leachate collection basin. Upon further investigation, EPA found additional potential sources of contaminants (the leach heap, mine dump, mine drainage, and bedrock), and additional contaminants of concern (arsenic and antimony, as well as cyanide) (Reference 1, Executive Summary, pages 1 and 2; Reference 4, page 9).

The Remedial Investigation, completed in January 1990, presented a human health risk assessment for the site. The risk assessment identified arsenic, antimony, and cyanide as the contaminants of concern at the site. Population near the site is sparse, with less than 20 people within a 3-mile radius served by drinking water wells. The land closest to the site is used for cattle grazing. The closest domestic water well is located approximately 3 miles south of the site. Currently, the closest livestock watering well is located 2 miles from the site. Other concerns include use of the site by local teenagers who may potentially become exposed to the contaminants (Reference 1, Chapter 6, pages 12 and 13; Reference 3, page 1; Reference 4, page 10).

Arsenic, antimony, and cyanide are the most important contaminants in water. Based on future exposure scenarios, exposure to arsenic in water could result in an increase in cancer risk of 2×10^{-4} . There is also risk of noncarcinogenic effects from arsenic, cyanide, and other chemicals (Reference 1, Executive Summary, page 4).

The most important contaminant in soil is arsenic. Based on future exposure scenarios, exposure to soil could result in an increased cancer risk of 2×10^{-3} , as well as noncarcinogenic effects (Reference 1, Executive Summary, page 4).

REMEDIAL ACTIONS AND COSTS

The Washington Department of Ecology conducted three remedial actions at the site, the last occurring in 1985. In addition, in 1988 the Bureau of Mines closed and sealed a shallow well at the site.

The site was included on the NPL in October 1984. A ROD describing the final EPA remedy at the site has been signed by the Region X Administrator and verbally concurred on by the State of Washington. Each of these actions, as well as available cost data, are described below.

Silver Mountain Mine

On November 19, 1981, the Washington Department of Ecology treated the leachate in the trench with approximately 600 pounds of chlorine (calcium hypochlorite), which converted the cyanide to carbon and nitrogen. The neutralized solution was then pumped into a County water truck and sprinkled over a wide area (Reference 1, Chapter 1, pages 8 and 9; Reference 6). A second attempt to neutralize leachate collected in the basin was made by Washington Department of Ecology in December 1982. However, concentrations continued to increase after neutralization due to continued leaching from the mine tailings. The cost of the first neutralization, in 1981, was approximately \$930 for chlorine and gasoline (Reference 1, Chapter 1, page 8; Reference 3, page 5; Reference 6).

In June 1985, the Washington Department of Ecology stabilized the site by removing liquids and residue from the leachate pond, and covering the leaching heap and pond with geotextile fabric and a 33-mil hypalon liner (Reference 1, Chapter 1, page 9).

In November 1988, the Bureau of Mines permanently closed the shallow well located 75 feet south of the leach heap. The well was viewed as a potential conduit for contaminants to enter the aquifer. The well was sealed by filling it with bentonite and capping it with a concrete/bentonite mixture (Reference 1, Chapter 1, page 9).

The remedial actions presented in the ROD consist of the following (Reference 4, page 2):

- Consolidating and grading approximately 5,740 cubic yards of contaminated materials.
- Covering the materials with a soil/clay cap.
- Fencing the site and sealing the underground mine entrance.
- Disconnecting the mine drainage pipe from the existing stock tank and installing a new well in Horse Springs Coulee aquifer to provide an alternative water supply for the cattle.
- Placing a deed restriction to protect the cap.
- Monitoring the ground water to assure that it does not become contaminated. If ground-water analyses indicate contamination at a concentration in excess of EPA health-based levels, a contingent ground-water treatment program will be implemented. Notice will be provided to the community of the ground-water sampling and results and any potential contamination.

The estimated capital cost of the above remedial action is \$370,360 and the annual operating and maintenance costs are \$39,650. The present value, assuming a 30-year period for site activities, is

\$635,600 (Reference 4, page 25). More specific cost estimates are provided in the Feasibility Study Report.

According to the Remedial Project Manager for the site, these costs will be revised after final design. Estimates are now closer to \$700,000 just for the construction of the cap. The State will be in charge of periodic monitoring.

CURRENT STATUS

According to the Remedial Project Manager for the site, EPA is nearing completion of the remedial action design. The design addresses all activities identified in the ROD, from consolidating and capping contaminated materials to monitoring the ground water. Because it is a fund-lead site, timing of the construction depends on fund financing. Once financed, the construction can be completed in a single construction season (Reference 7).

Silver Mountain Mine

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Reference 1

**Excerpts From Remedial Investigation Report,
Silver Mountain Mine; EPA Region X;
January 19, 1990**

**REMEDIAL INVESTIGATION REPORT
SILVER MOUNTAIN MINE
OKANOGAN COUNTY, WASHINGTON**

January 19, 1990

**U.S. Environmental Protection Agency
Region 10
Seattle, Washington**

EXECUTIVE SUMMARY

The Silver Mountain Mine site comprises about five acres in Okanogan County, Washington, which have been contaminated with mining wastes containing cyanide, arsenic, and other metals. The mine site is six miles northwest of Tonasket along the west margin of Horse Springs Coulee, a north-south trending valley. Horse Springs Coulee contains as much as 150 feet of unconsolidated glacial drift and alluvium overlying metasedimentary bedrock. Unconsolidated sediments thin toward the valley wall in the area of the mine site. The region is semi-arid with scrub vegetation and is used primarily for cattle grazing.

Underground mining for silver, gold, and copper production began at the site in 1902. Mining occurred in silicified zones of disseminated sulfides in the bedrock. By 1956, sporadic development produced about 2000 feet of underground mine workings and a few thousand tons of mine dump consisting of waste and mineralized rock. A 400-ton per day mill was constructed in 1952, but may never have been used. The mill has since been removed.

From 1980 to 1981, Precious Metals Extraction, Ltd., constructed and operated a cyanide leach heap of previously mined material in an attempt to extract silver and gold. The heap consisted of about 5300 tons of ore in a 100 X 105 X 14 foot pile on top of a 20-mil plastic liner. About 4400 pounds of sodium cyanide was mixed with water and sprayed on the top of the heap. The cyanide-laden effluent was then collected in a leachate pond at the base of the heap. The leach heap operation was abandoned in 1981 without cleanup of contaminated material.

The Washington Department of Ecology investigated the site in 1981 and in 1982 used sodium hypochlorite to neutralize the leachate pond and heap. The U.S. Environmental Protection Agency conducted a Preliminary Assessment and Site Inspection in 1984. The site was added to the National Priority List of Superfund sites in 1984. In 1985, the Department of Ecology conducted a site stabilization effort which included removal of liquids from the leachate pond and installation of a 33-mil plastic cover over the heap and pond to reduce infiltration. Empty cyanide drums were also removed, a fence was installed, and the site was posted. A Remedial Investigation and Feasibility Study under an Interagency Agreement with the U.S. Bureau of Mines was commenced by EPA in 1988.

The physical and chemical characteristics of the site and the nature and extent of contamination were evaluated by field

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geologic mapping, hydrogeological investigation, and chemical and petrographic analysis of site materials. The hydrogeological investigation incorporated four monitoring wells and three offsite water supply wells, and two surface water sites. Thirty-four samples of leach heap and mine dump material, twenty samples of nearby soils, and three rounds of water samples from the seven wells and two surface water sites were collected and analyzed. The investigation identified and evaluated four potential sources of contaminants: the leach heap, mine dump, mine drainage, and bedrock. Potential exposure pathways for contaminants were identified as onsite soils, onsite surface water, onsite ground water in a shallow aquifer, and offsite ground water in the Horse Springs Coulee-Aeneas Lake aquifer.

Elevated levels of contaminants in solid material are largely confined to mined bedrock that has been crushed through the process of mining. The mined material has been either abandoned in unleached piles (mine dump), or abandoned after leaching with cyanide solutions (leach heap). Relative to background soils, levels of arsenic, antimony, lead, and other metals and metalloids are elevated in the mine dump, and these same constituents plus cyanide are elevated in the leach heap. The same contaminants occur at lower, but still elevated, concentrations in shallow soils beneath the heap leachate collection pond and in a localized area of shallow soil within 25 feet adjacent to the heap.

Onsite concentrations of ground water contaminants were compared to concentrations in downgradient water supply wells in the Horse Springs Coulee aquifer. Contaminants which originated at the leach heap and which were elevated in onsite ground water included cyanide, and slightly elevated levels of sodium, potassium, nitrate, nitrite and fluoride. Elevated contaminants which originated either at bedrock or at the mine dump included arsenic, antimony, barium, chromium, copper, chloride, iron, lead, manganese, nickel, silver, and zinc. In addition, elevated arsenic and antimony occur in mine drainage and originate in the mine workings in bedrock.

Ground water contaminants from the leach heap extend in a plume at least as far downgradient as the furthest monitoring well, Well 3, 50 feet southeast of the heap. Ground water contaminants from either the mine dump or bedrock are substantially reduced at Well 3, which is 100-200 feet downgradient of these potential sources. No ground water contaminants influence the nearest offsite water supply wells 2-4 miles downgradient to the southeast of the mine site.

The future impact of cyanide on ground and surface water is primarily controlled by the amount and form of cyanide remaining in the heap, and by seepage and degradation rates. Measurements

of total and weak acid dissociable cyanide indicate that the cyanide in heap material is mostly in the form of poorly soluble iron cyanide compounds. The estimated degradation and seepage rates for cyanide indicate that the levels now occurring in ground water probably originated in spillage or leachate pond overflow at the time of leach heap operations during 1980 and 1981. Probably little, if any, leachate has been produced since the heap was covered in 1985. However, with time and deterioration of the plastic top and bottom liners, leaching of cyanide from the heap would be expected to resume with transport of cyanide to ground water. Infiltration of cyanide is projected to occur at progressively reduced concentrations and rates as a result of degradation, including speciation to hydrogen cyanide (HCN) and subsequent volatilization. Projected maximum concentrations of cyanide in leachate are on the order of a few milligrams per liter. Infiltration of leachate at these concentrations is projected to degrade to significantly lower levels during passage through the unsaturated zone.

The future impact of arsenic on ground and surface water is primarily controlled by the amount and form of arsenic in all mined materials, including the heap and mine dump, by the amount and form of arsenic in bedrock, and by the sorption capacity of iron- and aluminum-rich soils. The estimated solubility of arsenic and sorption capacity of soils indicate that, as the surficial piles oxidize, leachate from the heap and the mine dump could produce high concentrations of arsenic on the order of a few tens of milligrams per liter. Retardation of initially high concentrations of arsenic in leachate could occur during infiltration. However, with time and saturation of sorption sites, arsenic levels impacting ground water could reach the same levels of arsenic as infiltrating leachate. Current levels of arsenic in ground water indicate that oxidation of the mine dump and buried bedrock has not yet progressed to the point of producing highly concentrated leachate. Current elevated levels of arsenic in mine drainage, however, indicate that oxidation may now be taking place in the mine workings. Consequently, a potential exists for arsenic concentrations to increase in leachate from any of the mined material continually exposed to the oxidizing influences of weathering or water infiltration.

At present, water supply wells in the main part of Horse Springs Coulee aquifer are not affected by contaminated ground water from the mine site. The projected impact from estimated future levels of contaminants is significantly less in the Horse Springs Coulee aquifer than in the shallow aquifer at the mine site because of dilution resulting from a large contrast in ground water flow between the two areas.

The human health risk from cyanide, arsenic, and other contaminants is based on the likely future use of the site.

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time, vegetation, wildlife, and other biota could potentially be exposed to toxic concentrations of metals in ponded heap leachate or in heap soils. Soils in the heap and dump are most likely to be toxic if they erode, spread out, leach, or are otherwise made more available to onsite biota.

Air transport of particulates from the tailings pile is negligible under present conditions. Ground water is not toxic to plants or aquatic biota at present. Surface water transport is absent for most of the year and the intermittent streams do not feed the closest surface water bodies of concern. Transport to these nearby sensitive communities in Horse Springs Coulee does not occur by either surface water or ground water discharge from the site.

Although small in area, the soils nearby the heap and dump are contaminated with arsenic, manganese, selenium, and zinc, at concentrations that can affect vegetation and animals. In particular, ruminants, rabbits, rodents, and birds are at risk when consuming vegetation, soil biota, and associated soil from these contaminated soils. Manganese and selenium concentrations are of concern throughout the site, including background areas.

Based on information about the cyanide heap leaching operation at the site, an abandoned leach heap and adjacent mine dump are considered to be sources of contamination. The Remedial Investigation addresses potential contamination in the leach heap, the mine dump, onsite soils and surface water, and underlying ground water. Potential releases of hazardous materials to the air are considered in the risk assessment portion of the RI report.

1.2 SITE BACKGROUND

This section includes a brief description of the site, information about historical development and land use practices, a summary of events leading to the site's inclusion on the NPL, and a discussion of the results of previous investigations.

1.2.1 Site Description.

The Silver Mountain Mine site consists of five acres in Okanogan County, north-central Washington (southwest quarter of Section 34, T38N, R26E). The site (Figure 1.1) is six air miles northwest of the town of Tonasket (population 1055) and lies in a north-south trending basin between a scarp on the west and a low ridge on the east. The valley is part of a larger north-south running valley known as Horse Springs Coulee.

The area surrounding the site is semi-arid with scrub vegetation and is used primarily for cattle grazing. From county road 9410, an unpaved access road leads 1.5 miles to the site, which is surrounded by a barbed-wire fence.

Of key interest at the site is a heap of mined material and a trench remaining from an abandoned cyanide heap leaching operation (Figure 1.2). These will be referred to as the leach heap and leachate pond in this report. Both the heap and the pond are presently covered with a scrim-reinforced Hypalon liner, to be referred to as the cover. Directly west of the leach heap is a larger pile of unprocessed mined material, which will be referred to as the mine dump.

The foundations of a former mill building are about 250 feet southwest of the heap. A mine entrance, or adit portal, is located approximately 200 feet west of the heap in the scarp, and water from saturated mine workings is piped from within the portal to a cattle watering trough, or stock tank, outside the fenced area. Approximately 75 feet south of the heap was a shallow well, now sealed and abandoned. A small freshwater seep northwest of the heap creates a small shallow pool of standing water. A single tree provides shade and seasonal greenery at the site.

metals are then recovered from the solution. The used solution is typically adjusted for pH and cyanide content and is re-applied to the top of the ore heap until sufficient recovery of the precious metals is made. Additional information on cyanide heap leaching techniques is provided in Appendix A.

No historical records or company staff are available to describe the process used during the development by Precious Metals Extraction (PME). The following scenario is based on field observations and data collected by the Bureau in 1989. To begin the heap leaching process, PME cleared an area approximately 180 feet by 140 feet, adjacent to existing mine dumps. A leach pad base of sandy soil, up to 3 feet thick and graded with a 2.5 percent slope to the southwest, was then prepared. At the southern end of the sloped pad base a rectangular trench 7 feet by 75 feet and averaging 4 feet in depth, was dug as a leachate collection pond. The soil base and pond were then covered with a green 20-mil thick plastic liner. Another layer of sandy soil, from 0 to 6 inches thick, was then placed over the plastic liner. Last, approximately 5,300 tons of material from the mine dump were loaded onto the pad. The prepared heap was approximately 100 feet long, 105 feet wide, and 14 feet high.

Ecology and Environment (1985) report that during the months PME operated the heap leach, several tons of caustic soda and lime and approximately 4,400 pounds (20 55-gallon drums) of granular sodium cyanide were combined with water and pumped over the heaped material on the pad. After the alkaline cyanide solution percolated through the heap and drained into the collection pond, the remaining processing sequence is unclear. Ecology and Environment (1985) state that gold and silver were electroplated directly from the metals-laden leachate and that the alkalinity and cyanide content of the leachate were adjusted before reapplication of the solution to the heap. Woodward-Clyde (1987) report that activated carbon was used to remove the silver and gold from the leachate. Direct electrowinning of leach solutions is possible, but the two most commonly used methods for removing gold and silver from alkaline cyanide heap leach solutions are Merrill-Crowe zinc dust precipitation and activated carbon adsorption. Photographs taken by the Department of Ecology in July 1981 and July 1982 (Appendix B) suggest that solution was pumped from the leachate pond into barrels of activated carbon lined up next to the pond. Excess solution was allowed to overflow the barrels onto a plastic liner and run back into the pond. The photos also indicate that the carbon, containing gold and silver, may have been pressure-stripped of the precious metals on site.

Available information does not indicate whether an additional tank or pond was used to adjust the alkalinity and

On November 13, 1981, the Superior Court of the State of Washington issued an order for Okanogan County officials to enter the site and address potential health hazards posed by the leachate in the collection pond and by discarded chemical and processing containers.

The owner of the property surface rights put temporary fencing around the site to prevent cattle from exposure to contaminated pond liquids in 1981.

In November 1981, Department of Ecology sampling indicated total cyanide concentrations of 600 mg/l in the leachate pond and <0.002 mg/l in the onsite well. Ecology neutralized leachate in the collection pond with sodium hypochlorite (HTH) which converts cyanide to carbon and nitrogen. Free chlorine was observed, indicating that neutralization was complete. Using a water tanker-spray truck, Ecology sprayed the neutralized solution around the mine area. Additional HTH was put into the trench to neutralize any leachate that might collect over the winter.

In Spring of 1982, Department of Ecology sampled the winter leachate and found total cyanide values of 220 mg/l. Soil where the neutralized liquids had been disposed of in November 1981 were also sampled and indicated 0.22 mg/kg total cyanide. HTH solids which had settled in the pond were stirred up to activate neutralization.

In December 1982, the pond was again neutralized by the Department of Ecology. Reportedly, the liquid was circulated repeatedly through the heap during neutralization. Over 5 hours, total cyanide levels in the pond dropped from 19 mg/l to <0.007 mg/l. Small amounts of liquid coming from the heap after the process were measured at 30 mg/l total cyanide. A soil sample taken near the pond showed 100 mg/kg total cyanide. In November 1983, samples from the leachate pond indicated that leaching by rain and snowmelt through the heap had brought total cyanide concentrations in the pond up to 9.2 mg/l.

In September of 1984, Ecology and Environment, Inc. (E & E) conducted a preliminary site inspection for EPA and made recommendations for neutralizing cyanide in the leach heap. Leachate collection pond liquids, heap soil, and onsite background soil were analyzed for total cyanide and metals. E & E collected two water and two soil samples for the Department of Ecology.

to 561 mg/kg, copper to 546 mg/kg, lead to 267 mg/kg, barium to 110 mg/kg, nickel to 51 mg/kg, and silver to 39 mg/kg. Mercury ranges from values below the detection limit of 0.02 mg/kg to maximum concentrations of 0.36 mg/kg in the heap and 0.78 mg/kg in the mine dump.

Cyanide results are shown in Table 4.1 both as total cyanide and as weak acid dissociable (WAD) cyanide. Total cyanide ranges up to 173 mg/kg in the heap with a corresponding weak acid dissociable cyanide value of 15.1 mg/kg.

Examination of Table 4.1 and Figure 4.1 indicates that preferential concentration of cyanide occurs at the toe of the heap, with values about ten times those occurring elsewhere in the heap. Additionally, a few other elements including sodium, manganese, copper, zinc, and lead, are concentrated along with cyanide at the toe of the heap, whereas chromium appears to be depleted from the top of the heap.

Arsenic occurs at moderate to high concentrations in both the mine dump and the leach heap, as shown in Figure 4.2. The three highest values of arsenic are 652 mg/kg at the toe of the heap, 626 mg/kg on top of the heap and 1075 mg/kg in the mine dump.

The results of toxicity characteristic testing of eight samples are listed in Table 4.2, four samples as EP-Toxicity (extraction procedure toxicity test) and four as TCLP (toxicity characteristic leaching procedure). The EP toxicity tests show that heap material does not exceed inorganic leachate criteria that would designate the waste as hazardous waste under federal RCRA regulations (40 CFR Section 261) or dangerous waste under Washington State Dangerous Waste regulations (WAC 173-303).

Of the eight parameters analyzed in the toxicity characteristic tests, lead, cadmium, and barium appear to leach from the heap material at concentrations greater than that found in ground water samples. The test procedures are performed under acidic conditions and would indicate that these metals should be relatively high in leachate if the heap were leached under acidic conditions. Both the heap and ground water are slightly alkaline, however, and acidic leaching should not occur under current conditions. Additional discussion of the leaching characteristics of heap material with respect to cyanide and arsenic is included in Chapter 5.

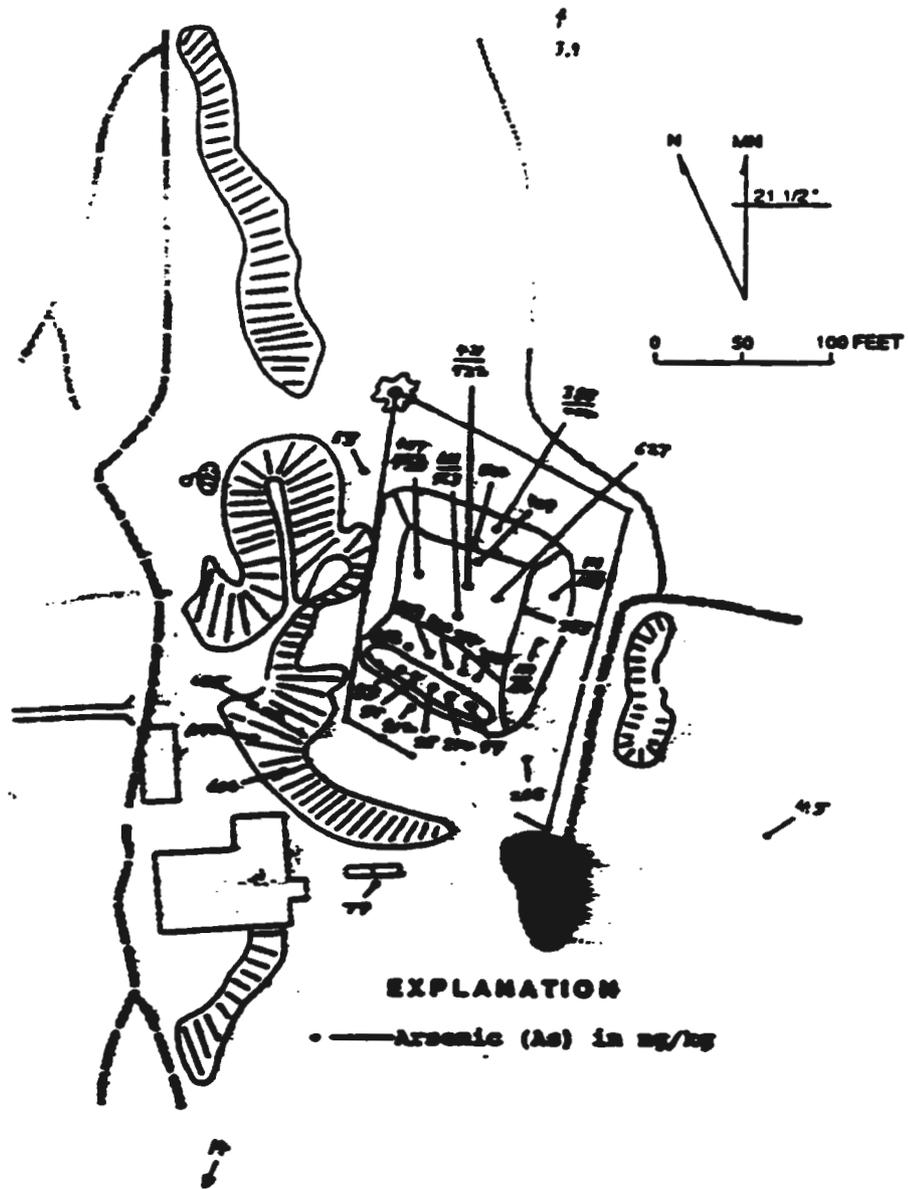


Figure 4.2. The distribution of arsenic in the leach heap, mine dump, and soil. Sample locations are numbered in figure 2.3a. Data are in mg/kg. The two values noted by arrows are background samples no. 53 and 54. Values separated by horizontal line represent upper and lower samples at the same location.

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Table 4.3a. Organic analytical results for gages: Volatile organic compounds.

Compound	Sample Numbers														
	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016
Chloromethane	10 U	11 U	12 U	12 U	10 U										
Bromomethane	10 U	11 U	12 U	12 U	10 U										
Vinyl Chloride	10 U	11 U	12 U	12 U	10 U										
Chloroethane	10 U	11 U	12 U	12 U	10 U										
Methylene Chloride	3 J	5 U	9	9	5 J	5 J	4 J	10	3 J	5 U	4 J	4 J	4 J	4 J	4 J
Acetone	10 U	11 U	12 U	12 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Carbon Disulfide	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1-Dichloroethane (total)	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Chloroform	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-Dichloroethane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-Butanone	10 U	11 U	12 U	12 U	10 U										
1,1,1-Trichloroethane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Carbon Tetrachloride	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Vinyl Acetate	10 U	11 U	12 U	12 U	10 U										
Bromodichloromethane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,2-Dichloropropane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
cis-1,3-Dichloropropane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Trichloroethane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Dibromochloromethane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,2-Trichloroethane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Benzene	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Trans-1,3-Dichloropropane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Bromoform	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	10 U	11 U	12 U	12 U	10 U										
2-Hexanone	10 U	11 U	12 U	12 U	10 U										
Tetrachloroethane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
1,1,2,2-Tetrachloroethane	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Toluene	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Chlorobenzene	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ethylbenzene	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Styrene	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Total Xylenes	5 U	5 U	6 U	6 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U

Notes: Data qualifier of "U" = the material was analyzed for but not detected. The numerical value shown is the sample quantitation limit.
 Data qualifier of "J" = the associated numerical value is an estimated quantity.
 Data qualifier of "UJ" = the material was analyzed for but not detected. The sample quantitation limit is an estimated quantity.

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Table 4.3b. (Continued) Soils Analytical Results Semivolatile Organics and Total Organic Carbon

Fluorene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
4-Nitroaniline	3200 U	3400 U	3700 U	3700 U	3200 U	3300 U	3400 U	3300 U	3200 U	3200 U	3300 U	3300 U	3300 U	3200 U	3300 U
4,6-Dinitro-2-Methylphenol	3200 U	3400 U	3700 U	3700 U	3200 U	3300 U	3300 U	3300 U	3200 U	3200 U	3300 U	3300 U	3300 U	3200 U	3300 U
N-Nitrosodiphenylamine(1)	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
4-Bromophenyl-phenylether	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Hexachlorobenzene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Pentachlorophenol	3200 U	3400 U	3700 U	3700 U	3200 U	3300 U	3300 U	3300 U	3200 U	3200 U	3300 U	3300 U	3300 U	3200 U	3300 U
Phenanthrene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Anthracene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Di-n-Butylphthalate	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Fluoranthene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Pyrene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Butylbenzylphthalate	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
3,3'-Dichlorobenzidine	1300 U	1400 U	1500 U	1500 U	1300 U	1400 U	1300 U	1400 U	1300 U	1300 U	1400 U	1400 U	1300 U	1300 U	1400 U
Benzo(a)Anthracene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Chrysene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
bis(2-Ethylhexyl)Phthalate	1100	690 U	760 U	770 U	310 J	93 J	220 J	690 U	160 J	110 J	680 U	680 U	670 U	110 J	680 U
Di-n-Octyl Phthalate	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Benzo(b)Fluoranthene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Benzo(k)Fluoranthene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Benzo(a)Pyrene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Indeno(1,2,3-cd)Pyrene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Dibenz(a,h)Anthracene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Benzo(g,h,i)Perylene	670 U	690 U	760 U	770 U	660 U	680 U	670 U	690 U	660 U	670 U	680 U	680 U	670 U	670 U	680 U
Total Organic Carbon		0.98		1.2		0.5		2.2		0.7					

Notes: Data qualifier of "U" = the material was analyzed for but not detected. The numerical value shown is the sample quantitation limit.
 Data qualifier of "J" = the associated numerical value is an estimated quantity.
 Data qualifier of "UJ" = the material was analyzed for but not detected. The sample quantitation limit is an estimated quantity.

Tec results are an average of replicate analysis.

Cyanide analyses were made of samples collected after first checking for the presence of interfering constituents, including sulfides or oxidants, using the procedure discussed in Chapter 2. Cyanide samples were then preserved with sodium hydroxide. Anion and cyanide results are listed in Tables 4.5 (Round 1), 4.6 (Round 2), and 4.8 (Round 3).

4.3.2.1 Onsite Ground Water

The field parameters (Table 3.3) and the relative proportions of the major dissolved constituents may be used to characterize the general compositional pattern in ground water. Figure 4.3 displays a trilinear Piper diagram (after Piper, 1944) of the proportions in milliequivalents of the major cations (sodium, potassium, calcium, and magnesium) and anions (chloride, sulfate, bicarbonate, and carbonate) for all of the Round 3 analyses (Tables 4.7 and 4.8). The Piper diagram, laboratory analyses, and field parameters indicate that onsite ground water is a neutral to slightly alkaline magnesium-sodium sulfate solution with about 400-900 mg/L total dissolved solids.

The major cations, in order of decreasing concentration, are sodium, magnesium, calcium, and potassium. Samples from Monitoring Well 3, at the southeast corner of the leach heap, showed the highest concentrations of major cations. Samples from Wells 1 and 4 were relatively high in iron and aluminum. The highest values in Round 3 were obtained from Well 1 with 10.7 mg/L of iron and 9.3 mg/L of aluminum. Other dissolved constituents measured at relatively high concentrations in Round 3 samples include manganese at 270 $\mu\text{g/L}$ and copper at 48 $\mu\text{g/L}$ in Well 1, and antimony at 44 $\mu\text{g/L}$ in Well 2.

The major anions in onsite ground water, in order of decreasing abundance, are sulfate, bicarbonate, nitrate, and chloride. The Piper diagram (Figure 4.3) indicates a somewhat higher proportion of sulfate in onsite ground water relative to offsite water. However, no compositional trend comparable to that for cations is apparent for the anions shown in the diagram.

In Round 3 the highest nitrate concentration occurred in samples from Well 3, at 17 mg/L. Much greater concentrations of nitrate, the highest at 120 mg/L, were found in Round 2 samples from Wells 1, 2, and 3. Round 2 values are qualified as estimates, however, and neither the high concentrations nor the distribution pattern of nitrate from Round 2 were verified in Round 3. Thus the nitrate values from Round 3 are considered to be the most representative.

For all three rounds, total cyanide concentrations are

consistently highest in Well 3, with values ranging from 30 $\mu\text{g/L}$ in Round 2 to 280 $\mu\text{g/L}$ in Round 3. Corresponding weak acid dissociable cyanide concentrations for Well 3 range from 3.1 to 92 $\mu\text{g/L}$.

Two divergent distribution patterns of major constituents and contaminants are apparent from the Round 3 data. An increase in concentration of several parameters occurs in the downgradient direction as ground water passes beneath the heap. A representative example of this pattern is the distribution of cyanide, nitrate, and electrical conductivity shown in Figure 4.4. All are highest to the southeast in well 3 which is the downgradient direction. This pattern is consistent with the compositional trend for major cations showing increasing proportion of sodium and potassium in the downgradient direction from wells 1 and 2 to wells 3 and 4 (Figure 4.3). Other parameters showing the same trend include fluoride and nitrite.

On the other hand, other parameters show higher concentrations in wells 1 and 2, which lie respectively upgradient and marginal to the downgradient direction from the heap. Included in this set of parameters are arsenic, antimony, barium, chloride, chromium, copper, iron, lead, manganese, nickel, silver, and zinc. The concentrations of arsenic are displayed in figure 4.4.

4.3.2.2 Onsite Surface Water

In contrast to the onsite ground water, both the seep and the mine drainage are slightly alkaline magnesium sulfate solutions (Tables 4.7, 4.8). As shown by the Piper diagram (Figure 4.3), sodium and potassium occur in much lower proportions in the surface water than in the ground water. With the exception of arsenic, elevated levels of most constituents do not occur in the surface water. Although cyanide was detected at 1.2 $\mu\text{g/L}$ in a Round 2 sample of the mine drainage, it was below detection limits in the other two rounds.

Arsenic, on the other hand, is higher in the mine drainage than in any other water at this site. Dissolved arsenic concentration in the mine drainage was 91 $\mu\text{g/L}$ in Round 3.

4.3.2.3 Offsite Ground and Surface Water

Samples from the three wells within three miles downgradient of the site indicate that ground water from the main portion of the Horse Springs Coulee-Aeneas Lake aquifer is a calcium-magnesium bicarbonate solution (Figure 4.3) varying from neutral

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to slightly alkaline. The offsite ground water samples were lower in the proportion of sodium, potassium, and sulfate in comparison with onsite water. The offsite water also had lower concentrations of all other major constituents (Table 4.7, 4.8) and did not contain elevated levels of contaminants. Overall, water drawn at the offsite wells appears to be of good quality.

The quality of offsite surface water was not investigated. The closest discharge of water from the area of the mine site to an offsite surface water body is likely no closer than Aeneas Lake, five miles to the southeast (Russell and Eddy, 1971). The flow path would be from onsite, through the Horse Springs Coulee aquifer, to Aeneas Lake. The three water supply wells examined during the Remedial Investigation lie between the mine site and the lake. The water quality in these wells is expected to be more indicative of ground water directly upgradient of any discharge to surface water (such as Aeneas Lake) than onsite ground water. As noted above, these wells have generally good water quality. Therefore, onsite contaminants are unlikely to extend at present to either offsite ground water or surface water.

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Table 4.4. Water Analytical Results. Round 1 Metals.

Location	WFOC #	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb
Monitoring Well 1F	890515041	6000	2.2 J	4.9 R	72.2 J	1.0 WJ	1.0 U	43500	9.5	3.9	27.0 J	6530	16.4 R
Monitoring Well 1U		8670	3.0 R	6.9 R	78.9 J	1.0 WJ	1.0 U	44900	15.3	6.8	41.7 J	10200	20.5 R
Monitoring Well 2F	890515042	188	77.7 J	17.6 R	32.2 J	1.0 WJ	1.0 U	51000	2.8	2.0 U	23.1 J	540	20.2 R
Monitoring Well 2U		281	59.0 J	17.9 R	33.9 J	1.0 WJ	1.0 U	51100	3.6	2.5 U	20.0 J	587	17.1 R
Monitoring Well 3F	890515043	36.3	1.7 J	2.0 R	42.6 J	1.0 WJ	1.0 U	89300	2.3	7.5	14.2 J	102	13.5 R
Monitoring Well 3U		37.5	175 R	5.0 R	30.1 J	1.0 WJ	1.0 U	87200	2.0 U	6.1	11.9 J	92.5	9.3 R
Monitoring Well 4F	890515044	2720	5.4 J	13.1 R	59.9 J	1.0 WJ	1.0 U	22100	6.8	2.5 U	13.4 J	2050	12.7 R
Monitoring Well 4U		1620	6.2 J	17.0 R	58.0 J	1.0 WJ	1.0 U	22300	3.1	2.5 U	16.2 J	1310	18.0 R
Stock TankF	890515045	22.6	10.5 J	83.5 R	13.4 J	1.0 WJ	1.0 U	44800	3.8	2.5 U	14.9 J	52.7	11.5 R
Stock TankU		26.7	32.0 J	87.3 R	8.8 J	1.0 WJ	1.0 U	43000	14.5	2.5 U	12.5 J	110	8.6 R
Mine SeepF	890515046	96.3	1.0 WJ	2.3 R	14.6 J	1.0 WJ	1.0 U	64200	2.4	1.0 U	16.6 J	343	11.9 R
Mine SeepU		277	0.7 WJ	4.5 R	17.0 J	1.0 WJ	1.0 U	66000	3.3	2.5 U	14.4 J	495	11.2 R
Irrigation Well 1F	890515047	10.8	0.1 WJ	2.0 R	22.4 J	1.0 WJ	1.0 U	50500	4.1	2.5 U	13.8 J	45.0	20.6 R
Irrigation Well 1U		15.8	0.8 WJ	2.0 R	24.0 J	1.0 WJ	1.0 U	50200	6.0	2.5 U	14.9 J	169	8.3 R
Irrigation Well 2F	890515048	10.0	0.1 WJ	6.1 R	30.8 J	1.0 WJ	1.0 U	67600	5.8	2.5 U	13.9 J	54.3	10.7 R
Irrigation Well 2U		11.7	100 J	9.2 R	29.0 J	1.0 WJ	1.0 U	65300	2.8	2.5 U	14.7 J	146	12.7 R
RinseatF	890515049	56.3	0.3 WJ	2.0 R	4.8 J	1.0 WJ	1.0 U	397	6.1	2.5 U	24.8 WJ	107	12.2 R
RinseatU		46.7	0.1 WJ	2.0 R	3.4 J	1.0 WJ	1.0 U	354	4.4	2.5 U	23.8 WJ	133	14.2 R
RinseatPB		76.8		2.0	5.1	0.6	0.9	397	5.5	0.1	64.4	176	19.1
RinseatF	890515050	32.4	0.1 WJ	3.5 R	10.8 J	1.0 WJ	1.0 U	628	5.3	2.5 U	23.4 WJ	140	20.6 R
RinseatU		26.8	0.1 WJ	2.4 R	3.4 J	1.0 WJ	1.0 U	351	8.6	2.5 U	31.0 WJ	102	13.0 R
RinseatF	890515051	35.3	0.1 WJ	2.0 R	2.4 J	1.0 WJ	1.0 U	592	16.4	2.5 U	26.4 WJ	157	9.4 R
RinseatU		57.0	0.1 WJ	2.6 R	3.4 J	1.0 WJ	1.0 U	954	32.2	2.5 U	51.9 WJ	812	89.5 R
Deionized WaterF	890515052	26.7	17.5 WJ	2.9 R	2.0 J	1.4 WJ	1.0 U	105	3.6 U	2.5 U	30.1 WJ	72.9 J	21.0 R
Deionized WaterU		21.1	0.1 WJ	2.0 R	6.8 J	1.0 WJ	1.0 U	173	2.0 U	2.5 U	29.9 WJ	60.0 J	27.9 R

- Note: 1. All concentrations are in µg/L (ppb).
 2. Suffix "F" = filtered, "U" = unfiltered, "D" = duplicate
 3. U denotes compound not detected. Numerical value given is the level of quantification.
 4. WJ denotes compound not detected. Numerical value given is the estimated level of quantification.
 5. J denotes that the numerical value given is an estimated quantity.
 6. R denotes data are unusable. Compound may or may not be present.

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Table 4.4. (Continued)

Location	Mg	Mn	Hg	Mo	Ni	K	Se	Si	Ag	Sodium	Tl	Sn	V	
Monitoring Well 1F 41500	129	0.20 UJ	10	13.3	3030 J	2.3 J	100 U	2.0 UJ	75100 J	0.1 UJ	9	U	15.6	
Monitoring Well 1U 43600	200	0.20 UJ	8	18.2	3630 J	4.1 J	100 U	2.0 UJ	84700 J	0.1 UJ	9	U	23.1	
Monitoring Well 2F 90900	86.7	0.20 UJ	10	8.7	3450 J	0.4 UJ	100 U	3.4 UJ	52400 J	0.1 UJ	9	U	2.5 U	
Monitoring Well 2U 93700	113	0.20 UJ	12	8.5	3450 J	0.3 UJ	100 U	2.0 UJ	52600 J	0.1 UJ	9	U	2.5 U	
Monitoring Well 3F 80200	49.3	0.20 UJ	12	7.1	4400 J	6.3 J	100 U	2.0 UJ	103000 J	0.1 UJ	11		2.5 U	
Monitoring Well 3U 79800	47.8	0.20 UJ	15	7.2	5490 J	6.2 J	100 U	2.0 UJ	137000 J	0.1 UJ	9	U	2.5 U	
Monitoring Well 4F 14100	40.1	0.20 UJ	18	7.4	2750 J	1.2 UJ	100 U	2.0 UJ	60700 J	0.1 UJ	9	U	4.6	
Monitoring Well 4U 14400	31.2	0.20 UJ	17	6.1	3090 J	1.1 UJ	100 U	2.0 UJ	67200 J	0.1 UJ	9	U	3.5	
Stock Tank	73100	2.3	0.20 UJ	6	10.7	1160 J	1.2 UJ	100 U	2.0 UJ	19800 J	0.7 R	9	U	2.5 U
Stock Tank	71400	3.8	0.20 UJ	6	14.0	1230 J	1.3 J	100 U	2.0 UJ	21000 J	0.3 R	9	U	2.5 U
Line Sump	74900	5.3	0.20 UJ	5	4.0	1520 J	5.8 J	100 U	2.0 UJ	21800 J	0.1 R	4		2.5 U
Line Sump	75300	7.5	0.20 UJ	5	5.0	1630 J	4.9 J	100 U	2.0 UJ	21000 J	0.3 R	9	U	2.5 U
Irrigation Well 1F 26100	2.0	0.20 UJ	5	2.3	3250 J	1.7 J	100 U	2.0 UJ	20100 J	0.4 R	9	U	2.5 U	
Irrigation Well 1U 26000	2.0	0.20 UJ	5	4.2	3270 J	1.9 J	100 U	2.0 UJ	20700 J	0.2 R	9	U	2.5 U	
Irrigation Well 2F 19700	2.0	0.20 UJ	5	3.5	2500 J	1.7 J	100 U	2.3 UJ	14500 J	0.5 R	9	U	2.5 U	
Irrigation Well 2U 19400	2.0	0.20 UJ	9	3.7	3200 J	1.9 J	100 U	2.0 UJ	18100 J	0.6 R	0		2.5 U	
Lineate	153	2.9	0.36 UJ	5	12.9 J	390 J	0.1 UJ	100 U	2.0 UJ	699	0.2 UJ	0		2.5 U
Lineate	146	2.9	0.20 UJ	5	14.9 J	351 J	0.1 UJ	100 U	2.0 UJ	604	0.2 UJ	9	U	2.5 U
Lineate	156	4.7		1	77.9	433		100 U	0.0	794		1		0.12
Lineate	464	3.2	0.38 UJ	5	98.8 J	139 J	0.1 UJ	100 U	0.2 UJ	660	0.6 UJ	9	U	2.5 U
Lineate	202	3.1	0.20 UJ	5	27.9 J	201 J	0.1 UJ	100 U	2.0 UJ	441	0.4 UJ	2		2.5 U
Lineate	490	3.9	0.20 UJ	5	14.3 J	530 J	0.1 UJ	100 U	2.0 UJ	785	0.3 UJ	0		2.5 U
Lineate	1100	8.7	0.20 UJ	5	42.4 J	527 J	0.1 UJ	100 U	2.9 UJ	886	0.3 UJ	9	U	2.5 U
Ionized Water	100 U	2.2	0.20 UJ	5	30.3 J	100 U	0.1 UJ	100 U	2.0 UJ	100 U	0.6 UJ	2		2.5 U
Ionized Water	100 U	2.3	0.20 UJ	5	25.4 J	100 U	0.1 UJ	100 U	2.0 UJ	110	0.6 UJ	9	U	2.5 U

Notes: 1. All concentrations are in µg/l (ppb).

2. Suffix "F" = filtered, "U" = unfiltered, "D" = duplicate

3. U denotes compound not detected. Numerical value given is the level of quantification.

4. UJ denotes compound not detected. Numerical value given is the estimated level of quantification.

5. J denotes that the numerical value given is an estimated quantity.

6. R denotes data are unusable. Compound may or may not be present.

Table 4.5. Water Analytical Results. Round 1 Anions and Cyanide.

Location	WFOC #	Cl	F	SO ₄ CM(Total)	CM(MAS)
Monitoring Well 1	890515041	7.5	0.47 U	220	1.9 R -----
Monitoring Well 2	890515042	4.4	0.77 U	541	3.2 R -----
Monitoring Well 3	890515043	5.4	0.82 U	770	40.2 R -----
Monitoring Well 4	890515044	3.0	0.31 U	100	7.0 R -----
Monitoring Well 4B		3.0	0.29	126	
Stock Tank	890515045	1.9	0.34 U	252	0.2 R -----
Mine Seep	890515046	1.8	0.45 U	274	0.2 R -----
Irrigation Well 1	890515047	1.4	0.36 U	110	0.4 R -----
Irrigation Well 2	890515048	1.4	0.12 U	128	0.2 R -----
Rinse	890515049	0.26	0.03 U	1.7	0.2 R -----
Rinse	890515050	0.17	0.02 U	4.3	0.2 R -----
Rinse	890515051	0.51	0.02 U	3.6	0.2 R -----
Deionized Water	890515052	0.10	0.11 U	1.3	0.2 R -----

- Notes: 1. F, Cl and SO₄ values are in milligrams/litogram of sample.
 2. Total cyanides reported as micrograms/liter (ppb)-distillation method
 3. ----- Denotes sample not analyzed.
 4. U denotes compound not detected. Numerical value given is the level of quantification.
 5. R denotes data are unusable. Compound may or may not be present.

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Table 4.6. Water Analytical Results. Round 2 Anions and Cyanide.

Location	WFOC #	Cl	F	NO3	SO4	CN(Total)	CN(As)
Monitoring Well 1	890607055	6.4 J	0.26	121 J	156 J	0.80	---
Rinsate	890607056	0.15 J	0.03 U	0.18 J	0.19 J	0.40	---
Monitoring Well 2	890607057	3.0 J	0.36	98.5 J	315 J	2.6	---
Rinsate	890607058	0.14 J	0.03 U	0.16 UJ	0.19 J	0.80	---
Monitoring Well 3	890507059	3.1 J	0.54	42.5 J	482 J	30.6	3.2
Monitoring Well 3D		---	---	---	---	---	3.1
Rinsate	890607060	0.12 J	0.03 U	0.16 UJ	0.18 J	0.80	---
Monitoring Well 4	890607061	1.1 J	0.31	8.2 J	87.4 J	0.01 U	---
Stock Tank	890607062	1.5 J	0.16	0.25 J	160 J	1.2	---
Stock Tank B		1.5 J	0.15	0.25 J	160 J	---	---
Mine Soap	890607063	1.1 J	0.22	0.23 J	173 J	0.01 U	---
Monitoring Well 3	890607064	2.4 J	0.65	34.1 J	358 J	31.6	3.0
Monitoring Well 3D		---	---	---	---	32.8	---
Irrigation Well 2	890907065	0.88 J	0.07	1.1 J	35.9 J	0.80	---
Residence	890607067	0.88 J	0.12	15.5 J	40.8 J	0.40	---
Transport Blank		0.07 UJ	0.03 U	0.16 UJ	0.13 UJ	0.01 U	---

- Notes:
1. F, Cl, NO3 and SO4 concentrations are in mg/L (ppm)
 2. Suffix "F" = filtered, "U" = unfiltered, "D" = duplicate
 3. Cyanide concentrations are in µg/L (ppb)-distillation method
 4. "----" denotes sample not analyzed.
 5. Nitrate reported as NO3-
 6. U denotes compound not detected. Numerical value given is the level of quantification.
 7. UJ denotes compound not detected. Numerical value given is the estimated level of quantification.
 8. J denotes that the numerical value given is an estimated quantity.

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Table 4.7. Water Analytical Results. Round 3 Metals.

Location	WFOC #	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb
Monitoring Well 1F	890727069	9250 J	0.1 UJ	9.1 J	91 J	1.0 UJ	1	43500 J	17.1	7.5 UJ	47.6	10700	12.2
Monitoring Well 1U		12000 J	1.4 J	10.9 J	136 J	1.5 J	2	62600 J	31.6	9.4 UJ	56.7	16900	23.2
RinseatF	890727070	77 J	0.5 UJ	0.1 UJ	2 UJ	1.0 UJ	1 U	170 J	2.2 U	2.5 UJ	5.0 U	80	5.0 U
RinseatU		18 J	0.1 UJ	0.1 UJ	2 J	1.0 J	1 U	235 J	2.0 U	2.5 UJ	5.0 U	58	5.0 UJ
Monitoring Well 2F	890727071	213 J	44.0 J	15.3 J	49 J	1.0 UJ	2	31900 J	13.1	3.0 UJ	5.0 U	511	7.7
Monitoring Well 2U		168 J	40.4 J	14.3 J	32 J	1.0 UJ	1	40600 J	2.5	2.5 UJ	11.1	377	6.5
RinseatF	890727072	20 J	0.1 UJ	0.2 UJ	2 J	1.0 UJ	1 U	137 J	2.0 U	2.5 UJ	5.0 U	35	5.0 U
RinseatU		44 J	0.1 UJ	0.2 UJ	2 J	1.0 UJ	1	450 J	2.0 U	2.5 UJ	5.0 U	38	5.0 U
Monitoring Well 3F	890727073	101 J	15.7 J	3.7 J	22 J	1.0 UJ	1 J	67600 J	3.3 U	9.3 UJ	5.4	160	5.0 U
Monitoring Well 3U		106 J	2.3 J	3.5 J	22 J	1.0 UJ	1 J	57800 J	2.0 U	2.5 UJ	10.3	164	5.0 U
Monitoring Well 3DF	890727074	59 J	15.5 J	3.3 J	22 J	1.0 UJ	1 UJ	43900 J	2.0 U	3.9 UJ	5.4	160	5.0 U
Monitoring Well 3DU		93 J	21.2 J	3.9 J	17 J	1.0 UJ	2 J	43100 J	2.0 U	3.3 UJ	6.9	245	5.0 U
RinseatF	890727075	14 J	3.7 J	0.1 UJ	2 UJ	1.0 UJ	1 UJ	137 UJ	2.0 U	2.5 UJ	5.0 U	35	5.0 UJ
RinseatU		15 J	20.7 J	0.1 UJ	2 J	1.0 UJ	1 UJ	100 UJ	3.5	2.5 UJ	5.0 U	32	5.0 UJ
Monitoring Well 4F	890727076	1160 J	2.7 R	13.9 J	51 J	1.0 UJ	1 UJ	22400 J	2.5	2.5 UJ	5.0 U	1390	5.0 U
Monitoring Well 4U		164 J	6.1 R	14.2 J	52 J	1.1 J	3 J	17400 J	9.5	2.9 UJ	5.0 U	206	5.0 U
Stock TankF	890727077	26 J	4.9 R	91.0 J	9 J	1.0 UJ	1 U	45300	2.0 U	2.5 U	5.0 U	52 U	5.0 U
Stock TankU		55 J	4.5 R	95.0 J	10 J	1.0 UJ	1 U	25100	2.0 U	2.0 U	5.0 U	62 U	5.0 U
Mine SeepF	890727078	573 J	0.7 R	4.8 J	16 J	1.0 UJ	1 U	56500	4.3 J	2.5 U	7.6	1040	5.0 U
Mine SeepU		3000 J	1.0 R	8.6 J	38 J	0.9 UJ	1	60400	3.4 J	2.5 U	19.0	4880	7.1
Irrigation Well 1F	890727079	12 J	0.1 UJ	1.6 J	25 J	1.0 UJ	1 U	42000	4.7 U	2.5 U	9.5	43 U	5.0 U
Irrigation Well 1U		10 J	0.1 UJ	2.0 J	27 J	1.0 UJ	1 U	48000	2.0 U	2.5 U	5.0 U	77 U	5.0 UJ
Irrigation Well 2F	890727080	10 U	0.1 UJ	1.2 UJ	24 J	1.0 UJ	1 U	61600	2.0 U	2.5 U	5.0 U	29 U	5.0 U
Irrigation Well 2U		10 U	0.1 UJ	1.3 J	28 J	1.0 UJ	1 U	57900	2.0 U	2.5 U	5.0 U	32 U	5.0 UJ
ResidenceF	890727081	20 U	0.1 UJ	1.0 UJ	19 J	1.0 UJ	1 U	71400	2.5 U	2.5 U	5.0 U	57 U	5.0 U
ResidenceU		17 U	0.1 UJ	1.0 UJ	18 J	1.0 UJ	1 U	47200	2.0 U	2.5 U	5.0 U	26 U	5.0 UJ
Deionized WaterF	890727082	13 U	0.1 UJ	0.3 UJ	4 J	1.0 UJ	1 U	178 U	2.2 U	2.5 U	5.0 U	40 U	5.0 UJ
Deionized WaterU		10 U	0.1 UJ	0.1 UJ	1 J	1.0 UJ	1 U	108 U	2.0 U	2.5 U	5.0 U	25 U	5.0 UJ
Transport BlankU	ALRC1	21 U	0.1 UJ	0.3 UJ	1 UJ	1.1 J	1 U	258 U	2.0 U	2.5 U	5.0 U	36 U	5.0 U
Transport BlankU	ALRC2	10 U	0.1 UJ	0.1 UJ	1 UJ	1.0 UJ	1 U	125 U	2.0 U	2.5 U	5.0 U	38 U	5.0 UJ

- Note: 1. All concentrations are in µg/L.
 2. Sample location suffix "F" = filtered, "U" = unfiltered, "D" = duplicate
 3. "----" denotes sample not analyzed.
 4. U denotes compound not detected. Numerical value given is the level of quantification.
 5. UJ denotes compound not detected. Numerical value given is the estimated level of quantification.
 6. J denotes that the numerical value given is an estimated quantity.
 7. R denotes data are unusable. Compound may or may not be present.

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Table 4.7. (Continued)

Location	Mg	Mn	Hg	Mo	Ni	K	Se	Ag	Si	Na	Tl	Sn	V	Zn
Monitoring Well 1F	63200 J	271	0.2 U	20.0	22.4	3620	J 3.7 J	7.5	4840	69400 J	1.1 UJ	31.5	28.9	117
Monitoring Well 1U	60900 J	421	0.2 U	10.0 U	38.4	4050	J 3.9 J	5.0 U	---	53800 J	0.1 UJ	20.0 U	40.7	129
Resatef	100 U	2	0.2 U	10.0 U	2.0	100	U 0.2 UJ	5.0 U	292	114 U	1.6 UJ	20.0 U	6.8	13
ResateU	100 U	2	0.2 U	10.0 U	2.1	100	U 0.2 UJ	5.0 U	---	192 U	0.4 UJ	20.0 U	5.2	4
Monitoring Well 2F	97500 J	93	0.2 U	19.0	10.1	2840	J 0.5 UJ	5.0 U	5100	39900 J	1.1 UJ	26.0	2.5 U	33
Monitoring Well 2U	94700 J	77	0.2 U	18.5	9.3	2670	J 0.7 UJ	5.0 U	---	38100 J	0.1 UJ	31.5	2.5 U	30
Resatef	100 U	2	0.2 U	10.0 U	2.0	100	U 0.1 UJ	5.0 U	47	173 U	0.5 UJ	20.0 U	2.5 U	7
ResateU	412	2	0.2 U	10.0 U	2.5	100	U 0.1 UJ	5.0 U	---	277 U	1.0 UJ	20.0 U	2.5 U	6
Monitoring Well 3F	67600 J	123	0.2 U	25.5	6.1	4540	J 2.3 J	5.0 U	5430	117000 J	1.2 R	67.0	5.5 U	10
Monitoring Well 3U	69000 J	122	0.2 U	20.5	5.5	4650	J 2.3 J	5.0 U	---	119000 J	1.5 R	20.0 U	2.5 U	3
Monitoring Well 3DF	67700 J	123	0.2 U	24.0	5.6	4430	J 1.8 J	5.0 U	5410	119000 J	2.5 R	37.5	2.5 U	8
Monitoring Well 3DU	74500 J	134	0.2 U	25.0	5.6	4800	J 2.5 J	5.0 U	---	121000 J	0.7 R	20.0 U	2.5 U	5
Resatef	100 U	2 U	0.2 U	10.0 U	2.6	100	U 0.1 UJ	5.0 U	42	149 U	0.5 R	20.0 U	2.5 U	6
ResateU	100 U	2 U	0.2 U	10.0 U	3.3	100	U 0.1 UJ	5.0 U	---	112 U	1.0 R	20.0 U	2.9	7
Monitoring Well 4F	18200 J	69	0.2 U	19.5	4.7	2500	J 0.2 UJ	5.0 U	24	45400 J	0.1 R	23.5	3.5	7
Monitoring Well 4U	16100 J	46	0.2 U	12.0	9.1	1620	J 0.6 UJ	5.0 U	---	31700 J	0.7 R	20.0 U	2.8	5
Stock TankF	82200	2	0.2 U	12.0	10.7 U	984	J 1.6 R	5.0 U	5910	15900 J	1.3 UJ	20.0 U	2.5 U	9
Stock TankU	76200	2	0.2 U	10.0 U	13.4	914	J 1.7 R	5.0 U	---	15400 J	0.1 UJ	20.0 U	2.5 U	5
Mine SeepF	80100	19	0.2 U	10.0 U	7.9 U	1630	J 4.1 R	5.0 U	4170	17400 J	0.1 UJ	20.0 U	2.5 U	24
Mine SeepU	78100	41	0.2 U	10.0 U	16.2	2390	J 10.1 R	5.0 U	---	16400 J	0.1 UJ	20.0 U	2.6	56
Irrigation Well 1F	30700	2 U	0.2 U	12.0	3.2 U	2530	J 1.5 R	5.0 U	16	16000 J	0.6 UJ	20.0 U	2.5 U	4
Irrigation Well 1U	32300	2 U	0.2 U	10.0 U	2.0 U	2090	J 1.2 R	5.0 U	---	18500 J	0.1 UJ	20.0 U	2.0 U	2
Irrigation Well 2F	21100	2 U	0.2 U	10.0 U	2.3 U	2440	J 2.5 J	5.0 U	9090	12900 J	0.1 UJ	20.0 U	2.5 U	23
Irrigation Well 2U	20300	2 U	0.2 U	10.0 U	2.1 U	2430	J 2.3 J	5.0 U	---	12500 J	0.8 UJ	20.0 U	2.5 U	13
ResidenceF	27300	2 U	0.2 U	10.0 U	5.3 U	2500	J 2.6 J	5.0 U	87	18000 J	0.1 UJ	54.0	2.5 U	4
ResidenceU	22600	2 U	0.2 U	10.0 U	2.0 U	2590	J 2.4 J	5.0 U	---	18000 J	0.1 UJ	22.5	2.5 U	2
Deionized WaterF	100 U	2 U	0.2 U	10.0 U	4.3 U	100	UJ 0.1 UJ	5.0 U	3	141 UJ	0.1 UJ	20.0 U	2.5 U	3
Deionized WaterU	100 U	2 U	0.2 U	10.0 U	3.4 U	100	UJ 0.1 UJ	5.0 U	---	100 UJ	0.7 UJ	20.0 U	2.5 U	2
Transport BlankF	100 U	2 U	0.2	10.0 U	3.6 U	100	UJ 0.2 UJ	5.0 U	26	108 UJ	0.2 UJ	20.0 U	2.5 U	8
Transport BlankU	100 U	2 U	0.2	10.0 U	3.6 U	100	J 0.1 UJ	5.0 U	0	108 UJ	0.1 UJ	20.0 U	2.5 U	2

- Notes:
1. All concentrations are in µg/L.
 2. Sample location suffix "F" = filtered, "U" = unfiltered, "D" = duplicate
 3. "----" denotes sample not analyzed.
 4. U denotes compound not detected. Numerical value given is the level of quantification.
 5. UJ denotes compound not detected. Numerical value given is the estimated level of quantification.
 6. J denotes that the numerical value given is an estimated quantity.
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Table 4.8. Water Analytical Results. Round 3 Anions and Cyanide.

Location	WFOC #	Alkalinity	Ammonium	Chloride	Fluoride	Nitrite	Nitrate	Sulfate	CN (Tot.)	CN (MA)
Monitoring Well 1	890727069	364	0.02 U	6.9	0.41	0.01 U	5.5	209	0.6	---
Rinse	890727070	0.11	0.02 U	0.06	0.01 U	0.01 U	0.01	0.49	0.1 U	---
Monitoring Well 2	890727071	230	0.02 U	3.6	0.50	0.01 U	3.0	434	1.6	---
Rinse	890727072	0.07	0.02 U	0.06	0.01	0.01 U	0.01 U	1.9	0.1 U	---
Monitoring Well 3	890727073	228	0.02 U	3.7	0.69	1.3	15.9	536	281	43
Monitoring Well 3D	890727074	226	0.02 U	3.8	0.73	1.4	17.1	563	283	91
Rinse	890727075	0.05	0.02 U	0.07	0.01 U	0.01 U	0.06	1.8	0.5	---
Monitoring Well 4	890727076	232	0.02 U	3.6	0.11	0.01 U	2.0	183	9.6	---
Stock Tank	890727077	241	0.02 U	2.4	0.25	0.01 U	0.12 U	407	0.1 U	---
Mine Seep	890727078	347	0.02 U	2.6	0.34	0.01 U	0.01 U	251	0.1 U	---
Irrigation Well 1	890727079	199	0.02 U	2.2	0.20	0.01 U	2.8	122	0.1 U	---
Irrigation Well 2	890727080	215	0.02 U	1.8	0.16	0.01 U	2.8	82.4	0.1 U	---
Residence	890727081	218	0.02 U	1.9	0.13	0.01 U	3.3	117	0.1 U	---
Deionized Water	890727082	0.08	0.02 U	0.06 U	0.01 U	0.01 U	0.01 U	0.40	0.1 U	---
Transport Blank	890727083	0.08	0.02 U	0.06 U	0.01 U	0.01 U	0.01 U	0.03 U	0.12	---
Transport Blank	890727084	0.05	0.02 U	0.06 U	0.01 U	0.01 U	0.11	0.03 U	0.12	---

- Notes: 1. All anion concentrations are in mg/L or ppm, except cyanides which are in µg/L.
 2. Alkalinity is in units of mg/L calcium carbonate.
 3. "----" denotes sample not analyzed.
 4. Nitrate and nitrite are reported as NO₃ and NO₂, respectively.
 5. U denotes compound not detected. Numerical value given is the level of quantification.
 6. R denotes data are unusable. Compound may or may not be present.

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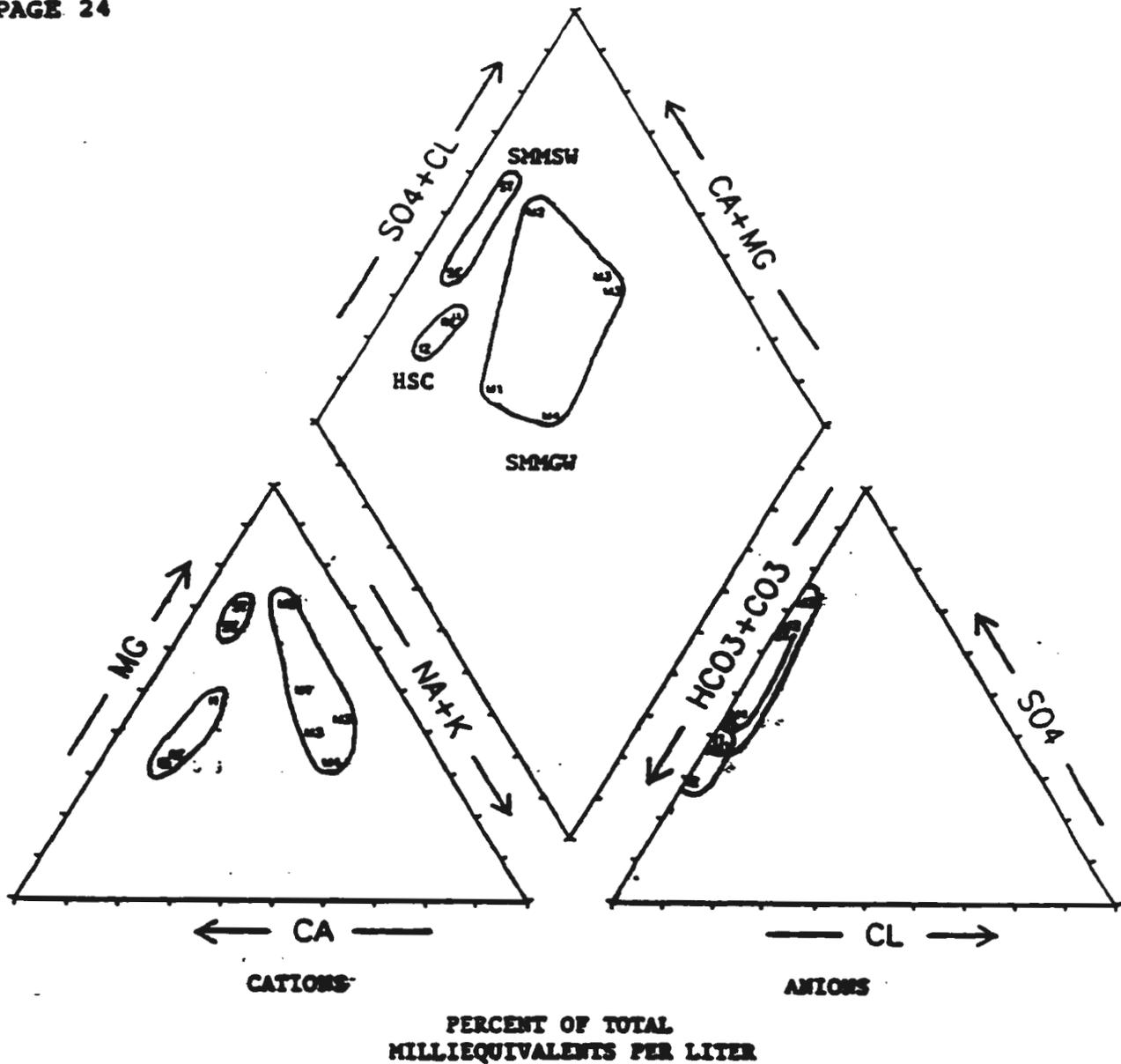


Figure 4.3. Piper diagram of percentage milliequivalents of major cations (left triangle), anions (right triangle), and combined ions (diamond). Values are grouped according to type of sample locality: SMM GW—ground water in shallow aquifer at Silver Mountain Mine where M1, M2, M3, and M4 represent monitoring wells; SMM SW—onsite surface water where ST is stock pond and SE is seep; and HSC—offsite ground water in Horse Springs Coulee where I1 and I2 are irrigation wells and RE is a residential water supply well.

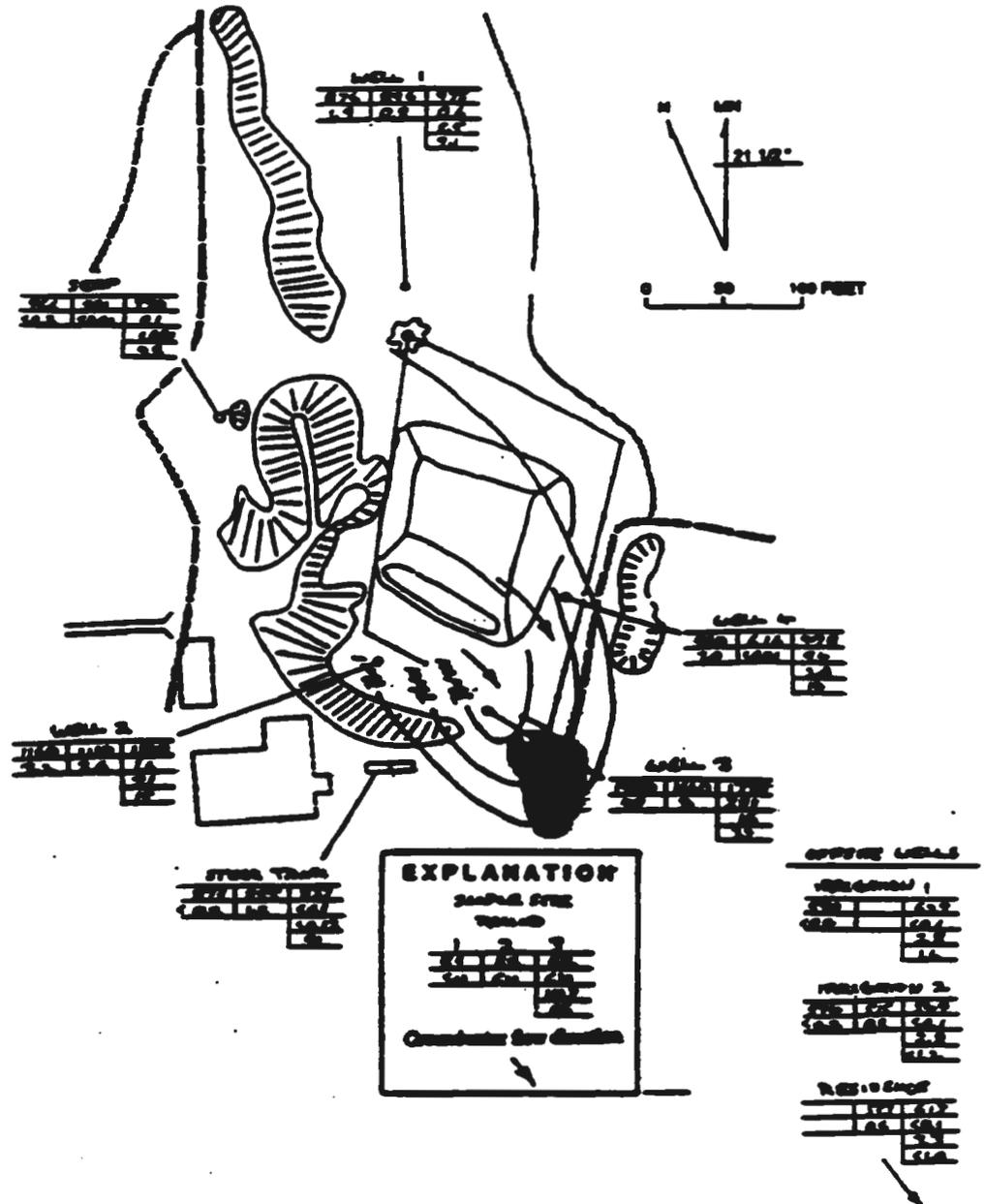


Figure 4.4. The distribution of electrical conductivity (EC in μS), cyanide and arsenic (CN and AS in $\mu g/L$), and nitrate (NO_3 in mg/L) in ground water and surface water. Electrical conductivity, cyanide, and nitrate values indicate the presence of a dilute plume (shown by inferred contours) extending from the leach heap in the downgradient direction to the southeast. As discussed in the text, other parameters which show a similar distribution include sodium, potassium, and fluoride. The distribution of arsenic, on the other hand, indicates highest values associated with sources to the west of the heap including mine drainage, the mine dump, or bedrock. As discussed in the text, elevated antimony and several other metals also originate west of the heap.

4.4 NATURE OF CONTAMINATION

The analytical results of rock, soil, and water samples and the risk evaluation in Chapters 6 and 7 indicate that two potential contaminants of concern, cyanide and arsenic, merit further discussion, particularly with respect to their amount and chemical form.

4.4.1 Cyanide

4.4.1.1 Cyanide in Rock and Soil

The quantity of cyanide in the leach heap may be estimated by combining measured concentrations with assumptions concerning the central part of the heap where samples were not collected. The distribution of measured concentrations suggests preferential concentrations of cyanide at the toe of the heap, where leachate discharged into the pond. Relatively high concentrations would also be expected next to the liner under the heap materials, since leaching solutions would have flowed through the heap and saturated materials on the liner before travelling toward the pond.

Therefore, for the purpose of estimating quantities, the center was divided into two equal parts. The upper half was assumed to have concentrations of cyanide comparable to that found in the top samples, whereas the lower half was assumed to be comparable to the toe samples. These assumptions should be environmentally conservative, because they probably overestimate the amount of cyanide in the lower half of the heap's center. Table 4.9 lists the data used to derive estimated values for the quantity of contaminants in the heap. The volumes of different parts of the heap are taken from Appendix C, and the concentrations are from Table 4.1.

These data and assumptions yield an average mass of 200 kg (440 lbs) of cyanide, as CN, in the heap. About 2000 kg (4400 lbs) of sodium cyanide (NaCN) is believed to have been applied to the heap during leaching operations (see Section 1.2.2). This amount of NaCN would correspond to 1060 kg of CN. Therefore, on the basis of averaged values, approximately 19% of the cyanide originally applied to the heap remains in place. The remainder of the cyanide either discharged to the leachate pond, where it was removed in metals-laden ore solution or was degraded by treatment or natural processes, or infiltrated into the ground through the liner or through spills.

Table 4.9. List of cyanide and arsenic concentrations and mass in the heap and pond bottom.

HEAP	VOLUME ft ³	MASS OF HEAP		CONCENTRATION		MASS OF CONTAMINANT		
		10 ⁺⁶ lbs	10 ⁺⁶ kg	mg/kg RANGE	mg/kg AVERAGE	kg RANGE	kg AVERAGE	lbs AVERAGE
TOTAL CYANIDE								
Top	27720	2.63	1.19	1.7 - 14	5.8	2.0 - 17	6.9	15
Side	43418	4.12	1.87	0.2 - 3.3	1.4	0.4 - 6.2	2.6	5.7
Toe	12144	1.15	0.52	86 - 173	106	45 - 90	55	121
Center	27720	2.63	1.19	86 - 173	106	102 - 206	126	278
Pond	6379	0.61	0.27	5.4 - 101	33	1.5 - 27	8.9	20
Total	117377	11.15	5.06	0.2 - 173	27	150 - 350	200	440
ARSENIC								
Total	111002	10.55	4.78	64 - 650	398	310 - 3100	1900	4200

Mass determined from volumes of different parts of heap (Appendix ?) and density of 95 lbs/ft³.

Toe volume corresponds to south slope in Appendix ?; side volume with north, west, and east slopes; top volume with top half of center block; center volume with bottom half of center block; and pond with 3-foot deep block beneath the pond.

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The chemical form of the cyanide may be estimated from data on total and weak acid dissociable cyanide and from correlation with concentrations of other elements found in the heap. Figure 4.5 shows the relation between total and weak acid dissociable cyanide for data from Table 4.1. A linear regression calculation illustrated in Figure 4.5 indicates that about 11 percent of the cyanide is in weak acid dissociable form. As noted in section 4.1.2, some other elements, including sodium, copper, zinc, and lead, tend to be preferentially concentrated at the toe of the heap along with cyanide. Of these elements, sodium would be the most likely to combine with cyanide in a weak acid dissociable form.

The less soluble forms that make up the remaining 89% of the total cyanide may consist of a variety of compounds. The high iron content of the heap material suggests that iron cyanide compounds may predominate in the poorly soluble fraction. Preferential concentration of zinc, copper, and lead at the toe of the heap suggests these elements may also be incorporated into iron cyanide compounds. Chapter 5 discusses contaminant mobility in relation to the probable forms of cyanide.

4.4.1.2 Cyanide in Water

The results of the field and analytical work indicate that a dilute cyanide plume extends from the heap toward Well 3, 25 feet south of the heap in a downgradient direction. The concentration of cyanide in ground water at the site is about 1,000 to 10,000 times lower than the estimated concentration of the original leaching solution. The plume does not extend as far as the nearest water supply well, located 2 miles downgradient in the Horse Springs Coulee aquifer.

Between June and July 1989, cyanide concentrations increased by a factor of about 10 in Well 3. The increase occurred during a period of decreasing water level at Well 3 and rising levels at the other wells. The increase in cyanide was not accompanied by a corresponding increase of the same magnitude in other constituents. The significance of the increase is not known. Perhaps cyanide is held in moderately soluble solid phases in the aquifer material near the heap and is remobilized at low levels by transient infiltration events. The data for weak acid dissociable cyanide indicate that about 10-30 percent of the aqueous cyanide is in the weak acid dissociable form.

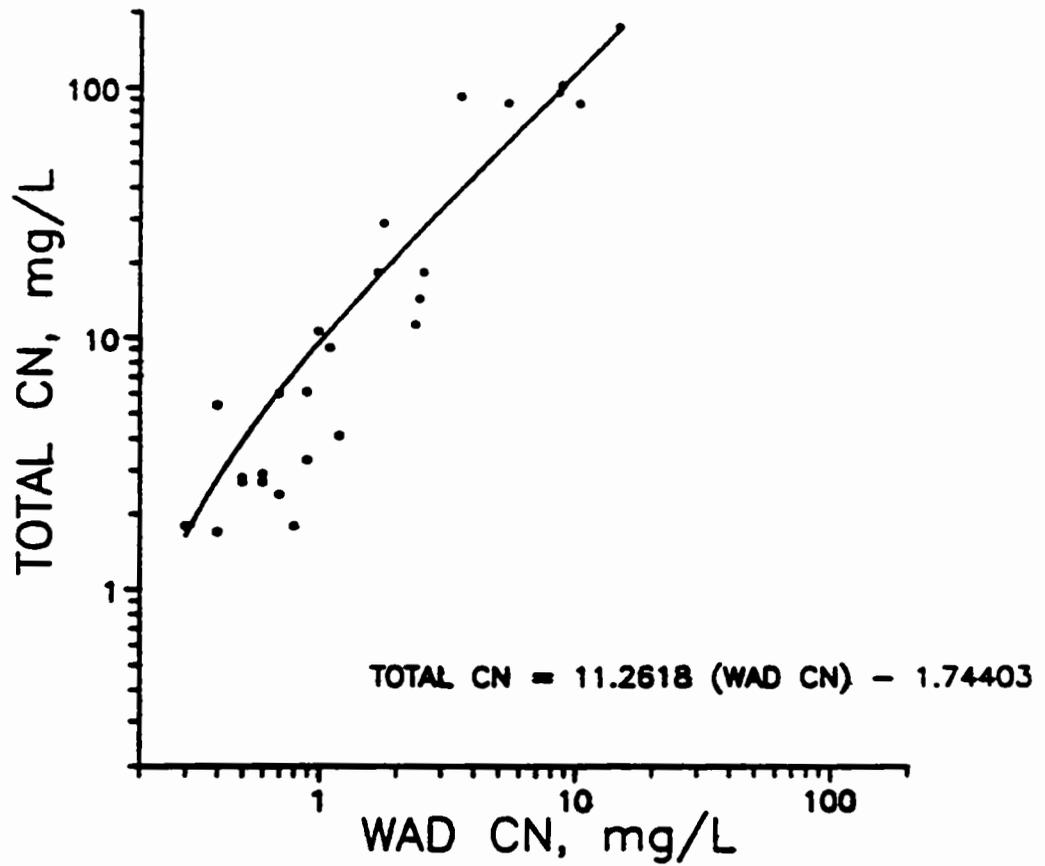


Figure 4.5. Graph showing correlation between total cyanide and weak-acid dissociable (WAD) cyanide in samples of leach heap material. A linear regression curve that accounts for 90% of the residuals is shown as a solid line through the data points.

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The relatively high concentration of cyanide in soil beneath the pond liner suggests that at least one likely pathway to ground water is leakage through or over the liner. Concentrations in the soil under the pond liner are comparable to those found at the toe of the heap and probably could only have resulted from direct contact of the soil with leaching solutions. Drainage of leaching solution or runoff into the subsequently plugged well southeast of the heap was considered as another possible pathway. However, samples of this well taken in 1981 and 1983 (Table 1.1) showed cyanide below detection limits (0.002 mg/l) and argue against the well as a contaminant pathway to ground water.

4.4.2 Arsenic

4.4.2.1 Arsenic in Rock and Soil

The quantity of arsenic in the heap may be estimated in a manner similar to that for cyanide, using heap dimensions and measured concentrations (Table 4.9). Unlike cyanide, the arsenic was not preferentially concentrated at the toe or in any other part of the heap. Arsenic quantity can thus be estimated based on the range and average of values for all heap samples. Using the data in Table 4.1, a range of 64 to 650 mg/kg for arsenic in 23 samples, or an average of 398 mg/kg, yields a mass range of 310 to 3100 kg or an average of 1900 kg (4200 lbs) of arsenic in the heap.

The average concentration of arsenic in the leach heap samples was about half of the average concentration in the samples of unleached mine dump material (Figure 4.2). Assuming that the heap material originally contained a similar amount of arsenic to that in the mine dump, perhaps as much as half of the arsenic originally in the heap may have been removed by leaching.

The present capacity of the heap to be a source for arsenic in ground water should be similar to that of the abandoned mine. In 1984, arsenic was detected at an elevated level of 110 $\mu\text{g/l}$ in the leachate pond. This concentration indicates some leaching of arsenic from the heap at that time. A comparable level, up to 91 $\mu\text{g/l}$, occurs in mine drainage at present (Figure 4.4). Currently, the mine drainage contains the highest arsenic values detected in any water at the site.

The mine drainage concentrations and 1984 leachate value may provide an estimate of the general leaching potential of arsenic from bedrock and from mined materials. The potential for arsenic leaching in the future depends on the form in which arsenic

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exists in the rock. The form of arsenic was investigated in a petrographic analysis of heap samples (Appendix D). On the basis of electron microprobe results, arsenic probably occurs as sub-microscopic sulfide minerals, including arsenopyrite and arsenic-bearing pyrite. The mobility of arsenic in the sulfide form is discussed in Chapter 5.

4.4.2.2 Arsenic in Water

Arsenic occurs in ground water at concentrations as high as 15 $\mu\text{g/L}$. No clear influence of the heap is apparent in the distribution of the arsenic (Figure 4.4). A comparison of arsenic values for onsite wells with those of wells off site suggests a somewhat higher level of arsenic in ground water at the site than in the main part of the Horse Springs Coulee aquifer. Arsenic in on-site ground water samples ranged from 3.3 to 15 $\mu\text{g/L}$, with an average of 10 $\mu\text{g/L}$ for 4 samples. Offsite samples had values of <1 and 1.6 $\mu\text{g/L}$.

4.4.3 Sources of Contaminants in Ground Water

The distribution of cyanide in ground water, relative to flow direction and to the leach heap, clearly shows that the area of the heap and leachate pond is the source of this contaminant. As discussed under the extent of contaminants in Section 4.3.2.2, several additional parameters, including sodium, potassium, fluoride, nitrate, and nitrite show the same distribution pattern as cyanide for Round 3 samples. The elevated levels of these parameters downgradient of the heap can be inferred to originate from leakage, spillage, or overflow of leaching solutions used on the heap.

As noted above, several additional parameters including arsenic, antimony, barium, chromium, copper, lead, iron, manganese, nickel, silver, and zinc show a divergent distribution pattern with preferentially greater concentrations in Wells 1 or 2. Although present in heap materials, the distribution of these parameters in ground water clearly indicates an origin other than the heap. Wells 1 and 2 are downgradient of three potential sources: the mine dump, mine drainage (well 2 only), and bedrock. The relative influence of these three potential sources is somewhat speculative at present. The proximity of the well intakes to both bedrock and to the probable infiltration path through the mine dump (Figure 3.1b), suggests that either or both could be the primary source for these parameters.

Two of the probable bedrock contaminants, arsenic and antimony, have higher concentrations in well 2 compared to well

1. The elevated levels of arsenic and antimony in well 2 suggest that whatever bedrock or mine dump influence exists for these contaminants is further enhanced by the mine drainage. The high levels of arsenic (Round 3) and antimony (Round 1) in the stock tank also suggest that mine drainage is a potentially major source of these contaminants to ground water.

4.5 SUMMARY

The nature and extent of contamination at Silver Mountain Mine has been evaluated by field geologic mapping, hydrogeologic investigation incorporating four monitoring wells and three offsite water supply wells, and analysis of the chemical composition of 34 samples of leach heap and mine dump material, 20 samples of nearby soils, and three rounds of water samples from seven wells and two surface water sites. Elevated levels of contaminants in solid material are largely confined to mined bedrock that has been crushed through the process of mining and abandoned in piles (mine dump), or that has additionally been abandoned after leaching with cyanide solutions (leach heap). Contaminants are considered elevated in relation to background soils that may be influenced by natural erosion of bedrock and glaciofluvial deposition, but are not influenced by mining activities. Contaminants that appear to be elevated relative to background soils consist primarily of arsenic and other metals and metalloids in the mine dump, and these same constituents plus cyanide in the leach heap. The same contaminants occur at lower, but still elevated, concentrations in shallow soils beneath the heap leach collection pond and in a localized area of shallow soil within 25 feet adjacent to the heap.

Elevated levels of contaminants also occur in ground water at the mine site and in surface water in a stock pond fed by mine drainage. In this respect, elevated aqueous contaminants from the heap are considered elevated relative to concentrations upgradient of the heap. Elevated contaminants from other sources, the mine dump, mine drainage, and bedrock, are considered elevated when more concentrated than the furthest downgradient monitoring well at the site, Well 3. Elevated constituents in ground water consist of cyanide and slightly elevated levels of sodium, potassium, nitrate, nitrite, and fluoride originating from the leach heap, and arsenic, antimony, barium, chromium, copper, chloride, iron, lead, manganese, nickel, silver, and zinc originating either from bedrock or the mine dump. Additionally elevated arsenic and antimony occur in mine drainage.

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Ground water contaminants from the leach heap extend in a plume at least as far downgradient as the furthest monitoring well, well 3, 50 feet southeast of the heap. Ground water contaminants from either the mine dump or bedrock are substantially reduced at well 3, which is 100-200 feet downgradient of these potential sources. No ground water contaminants influence offsite water supply wells 2-4 miles downgradient to the southeast of the mine site.

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- Russell, Robert H., and Eddy, Paul A., 1972, Geohydrologic evaluation of Aeneas Lake-Horse Springs Coulee, Okanogan County, Washington: Washington Department of Ecology Investigations, January 1972, 16 p., 1 app.

300 and 350 ug/day respectively (USEPA, 1989e; 1989g). Estimated intake of these compounds from the Silver Mountain Mine site is low compared to the average daily intake from food, which is not associated with adverse effects. Thus, the lack of toxicity information for these elements is expected to have a minor impact on the findings of the risk assessment.

The second major area of uncertainty is evaluation of risks from dermal contact. Dermal Rfd's have not been developed, therefore oral Rfd's were used by converting the orally administered dose to an absorbed dose. Since there is little data in the studies used to develop Rfd's regarding the amount of chemical absorbed, it was assumed that only 5% of the orally administered dose was absorbed in the GI tract. This assumption is believed to be conservative and could have a significant impact on the results of the risk assessment.

6.3 EXPOSURE ASSESSMENT

6.3.1 Potentially Exposed Populations

Current. The 1987 community relations plan (Woodward-Clyde Consultants, 1987) and documentation for the NPL listing of the site provide information about the current population and demography in the site vicinity. No significant changes in the population distribution of the area are believed to have occurred since the information was assembled.

Within a three-mile radius of the site, fewer than 20 people are served by water supply wells. The land immediately surrounding the site is owned by a Loomis resident who uses the land for cattle grazing. The nearest residence is a single family dwelling on a farm three miles south of the site. At this location a domestic well (sampled during the Remedial Investigation) serves the residence, and a larger well supplies water for irrigation. The nearest well, used for cattle watering and for irrigation, is approximately two miles from the site. The site is located midway between Loomis (population 200) and Tonasket (population 1055). The largest town in Okanogan County is Omak (population 4,000), 26 miles south of the site.

Use of the site by local teenagers has been reported by the land owner. Early reports indicate that warning signs posted around the site were removed more than once. Ecology records also document that after the placement of the pond and heap cover, much of the rope used to hold this down was removed. Based on the above information, only infrequent visitors to the site are thought to be currently exposed.

Future. It is expected that the site will continue to be accessible to visitors in the future assuming there is no cleanup or remedial action. Others who could be exposed in the future include workers at the site or residents if people choose to live there. If it becomes profitable to continue the original mining activity, exposure to workers, ie. miners, would be a distinct possibility. Workers and residents are expected to spend far more time at the site than infrequent visitors, and as a result will be at greater risk. Since current exposures are low in comparison to potential future exposures, only future exposure scenarios will be quantified in the risk assessment.

6.3.2 Reasonable Maximum Exposure (RME)

Draft revisions of the preamble to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (USEPA, 1989L) indicate that remedial actions at Superfund sites should be based upon the "reasonable maximum exposure". This is the highest exposure reasonably expected to occur at the site, and is intended to protect currently exposed individuals as well as those who may be exposed in the future. The method of establishing the "reasonable maximum exposure" for Silver Mountain Mine follows.

Of the current and future potentially exposed populations described in 6.3.1, workers or residents exposed in the future are expected to be at higher risk than those who currently visit the site only occasionally. Therefore, estimating exposure and risk based on future exposure scenarios is expected to be protective of both currently and potentially exposed populations and will be used to develop the reasonable worst case.

As far as could be determined, the Silver Mountain Mine site has not been occupied in recent times. At present the nearest residence is three miles away, roughly in the center of the Hors Springs Coulee. The nearest population center, Tonasket, is six miles distant. Residential growth into the immediate vicinity of the Silver Mountain Mine site, though possible, does not appear likely in the near future. In addition, ground water availability in the immediate vicinity of the mine is very low in comparison to the center of the coulee (Chapter 3), making the site less desirable for residential occupation than areas of greater groundwater availability, assuming groundwater is used as a drinking water supply.

The site has a history of industrial use (mining) beginning in 1902 with the Silver Star Mine, and most recently the cyanide leach operation in 1981. It is possible that mining activities could occur again if it became profitable. Given the previous history of the mine, limited ground water availability, lack of

Reference 2

**Letter Concerning Cyanide Contamination
at the Silver Star Mine; From Patrick D. Ewing, Chemist,
Precious Metals Extraction, Ltd., to Dennis Bowhay,
Washington Department of Ecology; August 20, 1982**

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PATRICK D. EWING
BOX 115
BURTON, WASHINGTON 99813

AUGUST 20, 1982

MR. DENNIS BOWHAY
DEPARTMENT OF ECOLOGY
3621 WEST WASHINGTON AVENUE
TAKIMA, WASHINGTON 99903

RE: CYANIDE CONTAMINATION AT THE "SILVER STAR MINE"

DEAR MR. BOWHAY:

THIS LETTER IS TO INFORM YOU OF CERTAIN FACTS WHICH I HAVE REGARDING THE "SILVER STAR MINE" NEAR TONASKET, WASHINGTON. AS I TOLD YOU DURING OUR PHONE CONVERSATION OF JULY 15, 1982, I WORKED AT THIS MINE FROM NOVEMBER 1980 TO JANUARY 1981. I WAS EMPLOYED AS A CHEMIST TO HELP OPERATE THIS FACILITY. THE COMPANY WHICH WAS ATTEMPTING TO OPERATE THIS MINE WAS CALLED PRECIOUS METALS EXTRACTION, INC. (PME INC.) - A WASHINGTON CORPORATION. THE PRESIDENT OF PME INC. WAS J. WAYNE TATMAN - THE MAN WHO HIRED ME. HIS SILENT PARTNER WAS G. PATRICK MORRIS. THERE WERE SEVERAL OTHER INVESTORS INVOLVED WHO I KNOW OF. THEY WERE DOUGLAS OSTROM, C. JAMES ENGLAND, AND MEL FRUIT. ALL OF THESE PEOPLE ARE FROM THE SEATTLE AREA.

THIS MINING TECHNIQUE IS CALLED HEAP LEACH CYANIDATION AND INVOLVES A PROCESS OF LEACHING METALS FROM ORE USING A CYANIDE SOLUTION. THE CYANIDE SOLUTION IS PUMPED TO THE TOP OF A PILE OF ORE AND ALLOWED TO LEACH TO THE BOTTOM OF THE PILE WHICH IS LINED WITH PLASTIC. THE PLASTIC DRAINS TO A LINED DITCH ALONGSIDE THE PILE AND THE METALLIC CYANIDE IS REMOVED FROM THE SOLUTION USING ONE OF A VARIETY OF CHEMICAL METHODS.

MY CONCERN PRESENTLY IS THAT THE CYANIDE WAS NOT BEEN DESTROYED. THERE WERE ABOUT TWENTY DRUMS OF SODIUM CYANIDE (420 POUNDS EACH) WHICH WERE ADDED TO THE PROCESS IN ADDITION TO SEVERAL TONS OF CAUSTIC AND LIME. THE WATER SAMPLES WHICH I CHECKED HAD CYANIDE LEVELS GREATER THAN ONE THOUSAND PPM USING APHA STANDARD METHOD 412-C, 1980 AND A PH GREATER THAN 11. IN ADDITION TO THE FREE CYANIDE, THERE MAY BE SUBSTANTIAL AMOUNTS OF HEAVY METAL CYANIDES OR OTHER COMPOUNDS WHICH MAY PRESENT A THREAT TO THE ENVIRONMENT INCLUDING THE GROUND WATER. THESE COMPOUNDS MAY BE FOUND IN THE DITCH WATER AND SLUDGE AS WELL AS THE ORE PILE.

THERE IS A DRAINAGE WELL BY THE FENCE LINE ABOUT THIRTY FEET FROM THE POND WHICH WAS PUT THERE TO DRAIN THE ENTIRE LOWER AREA WHICH FLOODED FROM TIME TO TIME. IF IT HAS NOT ALREADY HAPPENED, THERE MAY BE A SUBSTANTIAL RAIN OR SNOW FALL ONTO THE PILE WHICH EXCEEDS THE CAPACITY OF THE DITCH, FLOWS INTO THIS WELL AND THUS CONTAMINATES THE GROUND WATER DIRECTLY. THERE IS ALSO SOME QUESTION IN MY MIND ABOUT THE INTEGRITY OF THE LINER ITSELF GIVEN THE EXISTING CIRCUMSTANCES. IT HAS ALREADY COLLAPSED NEAR THE FRONT EDGE OF THE DITCH AND MAY BE PUNCTURED BY FREEZING ICE, BY LARGE ANIMALS WALKING IN IT, BY VANDALISM, OR BY A COMBINATION OF THESE.

AN ADDITIONAL CONCERN IS THAT THE LEACHATE MIGHT ESCAPE THE PLASTIC LINER BY TRAVELLING SIDEWAYS WITHIN THE PILE AND FIND A PATH OVER THE EDGE OF THE PLASTIC WHERE THE ORE HAS COLLAPSED. I SAW THIS HAPPEN DURING THE TIME I WAS THERE AND THE CONDITIONS WHICH CAUSED THIS TO HAPPEN HAVE NOT BEEN CORRECTED.

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THE FOLLOWING LIST INCLUDES ALL OF THE PEOPLE WHO I KNOW TO HAVE BEEN DIRECTLY INVOLVED IN THE "SILVER STAR MINE"

J. WAYNE TATMAN
1913 CAMAS COURT S.E.
RENTON, WASHINGTON 98055 ✓
PHONE 206-255-0280
PRESIDENT AND GENERAL MANAGER OF PME INC. ORIGINAL MANAGER AT "SILVER STAR MINE"

DOUGLAS OSTREM
14622 NE 32ND
BELLEVUE, WASHINGTON
PHONE 206-891-7879
INVESTOR IN PME INC. LATER WAS APPOINTED GENERAL MANAGER OF "SILVER STAR MINE"
OWNS A SILVER MINE NEAR CONCONULLY, WASHINGTON

C. JAMES ENGLAND
4444 BONNY GRAE DRIVE
BELLEVUE, WASHINGTON
PHONE 206-454-0999 OR 206-325-1228 OR 206-821-2861
INVESTOR AND PILOT FOR PME INC.
SUPPOSEDLY WAS BOUGHT OUT BY PAT MORRIS IN LATE JANUARY 1981

MEL FRUITT
702 WEST CASINO ROAD
APT. V103
EVERETT, WASHINGTON 98224
CONSTRUCTED PILE OF ORE WITH WAYNE TATMAN - BOUGHT OUT BY TATMAN BEFORE I WAS HIRED.

G. PATRICK MORRIS
13021 9TH NW
SEATTLE, WASHINGTON ↙
PHONE 206-365-4331 (HOME), 206-363-3603 (WORK)
INVESTOR IN PME INC. BOUGHT OUT JIM ENGLAND
HAS A BUSINESS INTEREST IN HERFYS AND KEENER FOODS - MULTIMILLIONAIRE

DR. (WILLIAM?) GROVES
PHONE 604-604-9934 (WORK), 604-621-4983 (HOME)
WAS A CONSULTANT TO WAYNE TATMAN AND PME INC.

WESTERN TESTING LABS
NUMBER 3 - 1000 LINDA WAY
SPARKS, NEVADA 89431
BILL CLEM ASSAYER
PERFORMED TESTING OF ORE FOR PME INC.

BILL PETERSON
ORIENT, WASHINGTON
PHONE 509-634-2915
LEASED EQUIPMENT TO PME INC.

Reference 3

**Excerpts From Potential Hazardous Wastes Site:
Preliminary Assessment, Silver Mountain Mine, Washington;
Washington Department of Ecology; Undated**

<p>POTENTIAL HAZARDOUS WASTE SITE PRELIMINARY ASSESSMENT</p> <p>Summary Memorandum</p>	<p>Site ID WA D980722739</p> <p>County Okanogan</p> <p>Priority Assessment MEDIUM</p> <p>Backlog Red Cat 85</p> <p>Date/Revision</p>
Name and Location:	
<p>Silver Mountain Mine Loomis, WA T38N, R26E, Sec 34 WM</p>	<p>Contact J. McDaniel Telephone (509) 223-3175 Site Status () Active (X) Inactive () Unknown</p>
Site Description/TSD Activities:	
<p>Site is an abandoned silver/gold mine located in N central WA. In an effort to extract precious minerals from mine tailings a process called heap leach cyanidation was used in which a plastic liner was laid and the mine tailings piled on top. Approx. 20 drums of sodium cyanide and sev. tons of caustic soda were poured on & leachate collected in basin.</p>	
Waste Types/Quantities/Characteristics:	
<p>Tailings pile - Approx. 400 cubic yd of material have been contaminated by cyanide. Leachate collection basin - Approx. 30,000 gal of liquid in the collection basin is contaminated by cyanide and numerous heavy metals.</p>	
Physical/Social Environment:	
<p>Site is in a remote area with the nearest residence 3 mi to the NW. Area is primarily used for cattle grazing. Site is in an arid region with evapotranspiration equaling rainfall. Nearest surface water is an intermittent stream 2300' to the east with a less than 3% slope of intervening terrain.</p>	
Pollutant Mobilization/Pathways/Risk:	
<p>There is an uncapped well on site providing direct access to groundwater at a depth of about 20'. Soil is a highly permeable sandy gravel. Significant potential exists for GW contamination. The only uses of GW within 3 mi are irrig., stock watering and a single upgradient well 3 mi away which serves 1 family. Little potential for surface water contamination.</p>	
Priority Assessment/Backlog Reduction Category:	
<p>MEDIUM: Contamination probably not a threat to off-site pop. but may represent a serious health threat to any people, livestock or wildlife on site. Cyanide contamination over 200 times above EPA limits have been measured in collection basin. WDOE has already twice neutralized cyanide in basin but concentrations have always increased again with leaching.</p>	
Followup Recommendations:	
<p>Site should be immediately fenced and posted. Due to the relatively small quantity of hazardous material and the confined nature of the waste, remedial action is feasible. The possibility of removing the contaminated material or continuing neutralization action should be evaluated.</p>	

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POTENTIAL HAZARDOUS WASTE SITE
PRELIMINARY ASSESSMENT
Part 2 - Waste Information

I. IDENTIFICATION

01 State WA 02 Site Number D980722789

II. WASTE STATES, QUANTITIES, AND CHARACTERISTICS

01 Physical States (check all that apply) <input checked="" type="checkbox"/> A Solid <input type="checkbox"/> B Slurry <input type="checkbox"/> C Powder Fines <input checked="" type="checkbox"/> F Liquid <input type="checkbox"/> D Sludge <input type="checkbox"/> G Gas <input type="checkbox"/> E Other	02 Waste Quantity at Site (measures of waste quantities must be independent) Tons: _____ Cubic Yards: 4150 No. of Drums: _____	03 Waste Characteristics (check all that apply) <input checked="" type="checkbox"/> A Toxic <input type="checkbox"/> E Soluble <input type="checkbox"/> I Highly Volatile <input type="checkbox"/> B Corrosive <input type="checkbox"/> F Infectious <input type="checkbox"/> J Explosive <input type="checkbox"/> C Radioactive <input type="checkbox"/> G Flammable <input type="checkbox"/> K Reactive <input type="checkbox"/> D Persistent <input type="checkbox"/> H Ignitable <input type="checkbox"/> L Incompatible <input type="checkbox"/> M Not Applicable
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III. WASTE TYPE

Category	Substance Name	01 Gross Amount	02 Unit of Measure	03 Comments
SLU	Sludge			
OLW	Oily Waste			
SOL	Solvents			
PSD	Pesticides			
OCC	Other Organic Chemicals			
IOC	Inorganic Chemicals	4150	cu yd	Sum of solid and liquid wastes
ACD	Acids			
BAS	Bases	Unknown	N/A	Caustic soda
MES	Heavy Metals	Unknown	N/A	Leached from mine tailings.

IV. HAZARDOUS SUBSTANCES (see Appendix for most frequently cited CAS numbers)

01 Cat.	02 Substance Name	03 CAS Number	04 Storage/Disposal Method	05 Concentration	06 Measure of Concentration
IOC	Sodium cyanide	143339	20 drums poured on tailings pile	Unknown	N/A
IOC	Caustic soda	1310732	Several tons on pile	Unknown	N/A
	ENVIRONMENTAL DATA				
IOC	Total cyanide	57135	Mine tailings	360-390	mg/kg
IOC	Total cyanide	57135	Groundwater on site	<0.002	mg/l
IOC	Total cyanide	57135	Leachate col. basin	0-1100	mg/l
MES	Copper compounds	unknown	Leachate col. basin	0.05-100	mg/l
MES	Zinc compounds	unknown	Leachate col. basin	0.42-190	mg/l
MES	Cadmium compounds	unknown	Leachate col. basin	.02-1.08	mg/l
MES	Iron compounds	unknown	Leachate col. basin	9.3-340	mg/l
MES	Lead compounds	unknown	Leachate col. basin	.16-0.22	mg/l
MES	Nickel compounds	unknown	Leachate col. basin	.05-3.0	mg/l
MES	Chromium compounds	unknown	Leachate col. basin	.02-0.17	mg/l
MES	Silver compounds	unknown	Leachate col. basin	.12-0.91	mg/l
MES	Mercury compounds	unknown	Leachate col. basin	42	ug/l

V. FEEDSTOCKS (see Appendix for CAS numbers)

Category	01 Feedstock Name	02 CAS Number	Category	01 Feedstock Name	02 CAS Number
FDS	Sodium cyanide	143339	FDS		
FDS	Caustic soda	1310732	FDS		
FDS			FDS		
FDS			FDS		

VI. SOURCES OF INFORMATION (cite specific references, e.g., state files, etc.)

WDOE Files

POTENTIAL HAZARDOUS WASTE SITE PRELIMINARY ASSESSMENT		I. IDENTIFICATION	
Part 3 - Description of Hazardous Conditions & Incidents		01 State	02 Site Number
		WA	D980722799
II. HAZARDOUS CONDITIONS AND INCIDENTS (continued)			
01 () J. Damage to Flora	02 () Observed (Date	) ( ) Potential	() Alleged
03 Narrative Description None observed.			
01 (X) K. Damage to Fauna	02 () Observed (Date	) ( ) Potential	(X) Alleged
03 Narrative Description (include name(s) of species) The owner reported a dead cow and dead birds on site but a definite cause/effect relationship has not been established.			
01 () L. Contamination of Food Chain	02 () Observed (Date	) ( ) Potential	() Alleged
03 Narrative Description None observed.			
01 (X) M. Unstable Containment of Wastes (soils/runoff/standing liquids/leaking drums)	02 (X) Observed (Date	08/13/82	() Potential () Alleged
03 Population Potentially Affected: <10 04 Narrative Description Wastes are in an uncovered plastic lined collection basin. The Okanagon Co. Health Dept. is concerned that the plastic liner may soon deteriorate. The collection basin overflows during heavy rains.			
01 () N. Damage to Offsite Property	02 () Observed (Date:	) ( ) Potential	() Alleged
03 Narrative Description None observed.			
01 () O. Contamination of Sewers, Storm Drains, WWTs	02 () Observed (Date:	) ( ) Potential	() Alleged
03 Narrative Description No sewers, storm drains, WWTs in the area.			
01 () P. Illegal/Unauthorized Dumping	02 () Observed (Date	) ( ) Potential	() Alleged
03 Narrative Description None reported.			
05 Description of Any Other Known, Potential, or Alleged Hazards None.			
III. TOTAL POPULATION POTENTIALLY AFFECTED: <10			
IV. COMMENTS			
WDOE has made 2 attempts to neutralize the cyanide with HTH with the 1st attempt in the winter of 81/82 and the 2nd in the winter of 82/83. The cyanide in the collection basin has been neutralized after each attempt but concentrations have increased again with continued leaching from the mine tailings.			
V. SOURCES OF INFORMATION (cite specific references: state files, reports, etc.)			
WDOE Files; EPA Files; USGS Topo maps (Aeneas Lake and Enterprise, 7 1/2"); WDOE report, 1972, Geohydrologic Eval. of Aeneas Lake - Horse Springs Coulee, Okan. Co., WA; B. Nelson, Okanagon Co. Health Dept.			

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Reference 4

**Excerpts From Record of Decision for the
Silver Mountain Mine Superfund Site;
Thomas P. Dunne, Acting Regional Administrator, EPA Region X;
March 27, 1990**

DECLARATION

**for the Silver Mountain Mine
Superfund Site**

RECORD OF DECISION

SITE NAME AND LOCATION

**Silver Mountain Mine
Okanogan County, Washington**

STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected remedial action for the Silver Mountain Mine site, developed in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986, and, to the extent practicable, the National Contingency Plan. This decision is based on the Administrative Record for this site. The attached index identifies the items that comprise the Administrative Record upon which the selection of remedial action is based.

The State of Washington has verbally concurred on the selected remedy.

ASSESSMENT OF THE SITE

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, may present an imminent and substantial endangerment to public health, welfare, or the environment.

SELECTED REMEDY DESCRIPTION

This is the first and final Record of Decision, because the entire site is being handled as a single operable unit. The Silver Mountain site is an abandoned mine dump where a heap leaching operation left cyanide and arsenic contamination. The Washington Department of Ecology stabilized the site in 1985, treating the immediate threat of cyanide in the leach heap. The selected remedy will provide long-term environmental protection by:

Because this remedy will result in hazardous substances remaining onsite above health-based levels, a review will be conducted within five years after commencement of remedial action to ensure that the remedy continues to provide adequate protection of human health and the environment.

3/27/90

A handwritten signature in cursive script that reads "Thomas P. Dunne". The signature is written in dark ink and is positioned above a solid horizontal line.

Date

Thomas P. Dunne
Acting Regional Administrator
U.S. Environmental Protection Agency
Region 10

Migration Pathways

Contamination is believed to originate from four main sources: the leach heap, mine dump, mine drainage, and bedrock. Leaching, weathering, erosion, infiltration and other processes and mechanisms have intermixed contamination from man-made and natural sources, and transported it to other media. The potential exposure pathways are through groundwater, air, surface water and soil contact.

The potential for airborne migration of arsenic or cyanide is minimal. The heap is presently covered with a 33-mil hypalon liner. Should the liner fail, the top layer of the heap is so coarse that very little contaminated soil would blow from the heap, as estimated by worst case modelling.

Likewise, the potential for transport of contaminants from the site via surface water is minimal. The topography at the site is relatively flat and there is no connection with surface water bodies in the area. The closest surface water is approximately two miles from the site.

The main potential pathway of off-site contaminant migration identified for this site is the regional groundwater system (the Horse Springs Coulee aquifer). As stated above, cyanide and arsenic were detected in the shallow aquifer under the site during the remedial investigation. The quantity of water flowing through the shallow aquifer is very low (with an estimated specific discharge of 0.1 ft/yr), and it currently is not used as a source of drinking water, rather it connects with the regional aquifer downgradient of the site. Groundwater sampling will continue to confirm whether elevated concentrations of contaminants from the site are affecting the Horse Springs Coulee aquifer.

Potential exposure pathways for contaminants in soil include inadvertent ingestion (e.g., while eating or smoking), direct dermal contact, and inhalation of suspended particulates. The last of these is not considered significant, since it is unlikely that contaminated soil particles will be inhaled unless the heap is disturbed.

VI. SUMMARY OF SITE RISKS

Introduction

A baseline risk assessment was conducted as part of the Remedial Investigation to estimate the risks to human health and the environment that are posed by the existing conditions at the Silver Mountain Mine site. The baseline risk assessment estimated that there are unacceptable potential

The treatment alternative requires about a year's work. Safety clothing and equipment are required to assure worker safety, and precautions are taken when materials are hauled offsite, as in the above alternative. This alternative has the lowest short-term effectiveness because the likelihood of contaminated materials becoming airborne during sizing operations is very high.

Implementability

Offsite landfilling is easy to implement. Loading, hauling, and long-term disposal services are readily available, and landfill capacity does not pose a problem. No future site remediation or monitoring is required. Some potential for groundwater contamination remains at the site due to naturally occurring arsenic in the bedrock.

Capping is also easily implemented. The technology to construct the alternative is well developed and the means to perform maintenance functions on the cap and monitor the effectiveness of the remedial action are available.

Treatment is less implementable. The technologies to wash and size the contaminated materials and to treat the rinsate are generally proven, and the availability of equipment and technical personnel should be good. However, treatability tests are required to determine how effective this alternative will be in reducing arsenic concentrations. It is doubtful that treatment/removal of fines could reduce the arsenic present in the sulfide mineral form to the cleanup standard of 200 mg/kg (see Table 6 below). In addition, the ARARs for this alternative might necessitate disposal of wastewater off-site, making implementation more difficult than originally planned. Under this alternative, the site requires no future monitoring, but if treatability studies indicated the need, capping and groundwater monitoring will be added to this alternative.

Cost

The capping alternative has an estimated capital cost of \$370,360 and annual O&M costs of \$39,650. The present value, based on a 30-year period for site activities, is \$635,600.

Capital costs for the treatment alternative are estimated at \$855,290, and present worth at \$1.2 million. No monitoring or maintenance costs are included.

Offsite disposal would cost an estimated \$1.4 million.

Toxicity Assessment

Cancer potency factors (CPFs) have been developed by EPA's Carcinogenic Assessment Group for estimating excess lifetime cancer risks associated with exposure to potentially carcinogenic chemicals. CPFs, which are expressed in units of $(\text{mg/kg/day})^{-1}$, are multiplied by the estimated intake of a potential carcinogen, in mg/kg/day, to provide an upper-bound estimate of the excess lifetime cancer risk associated with exposure at that intake level. The term "upper bound" reflects a conservative estimate of the risks calculated from the CPF. Use of this approach makes underestimation of the actual cancer risk highly unlikely. Cancer potency factors are derived from the results of human epidemiological studies or chronic animal bioassays to which animal-to-human extrapolation and mathematical extrapolation models have been applied.

Reference doses (RfDs) have been developed by EPA for evaluating the potential for adverse noncarcinogenic health effects resulting from chemical exposure. RfDs, which are expressed in units of mg/kg/day, are estimates of daily exposure levels for humans, including sensitive individuals, below which noncarcinogenic effects are not expected to occur. Estimated intakes of chemicals from environmental media (e.g., the amount of a chemical ingested from contaminated drinking water) can be compared to the RfD. RfDs are derived from human epidemiological studies or animal studies to which uncertainty and modifying factors have been applied (e.g., to account for the use of animal data to predict effects on humans). These uncertainty factors help ensure that the RfD will not underestimate the potential for adverse noncarcinogenic effects to occur.

Table 2 lists cancer potency factors and reference doses for contaminants of concern identified in the baseline risk assessment.

Table 2. Cancer Potency Factors & Reference Doses

<u>Contaminant</u>	<u>Oral CPF</u> (mg/kg/day)	<u>Chronic Oral Reference Dose</u> (mg/kg/day)	<u>Level of Confidence</u>
Arsenic	50	1 E-03*	not established
Cyanide	none	2 E-02	medium
Antimony	none	4 E-04	low
Lead	none	none devel'd	not applicable
Nitrate	none	1 E+00	high
Nitrite	none	1 E-01	high

* 1 E-03 = 1×10^{-3}

Risk Characterization

Excess lifetime cancer risks are determined by multiplying the average daily dose with the cancer potency factor. These risks are probabilities that are generally expressed in scientific notation (e.g., 1×10^{-6} or 1 E-06). An excess lifetime cancer risk of 1 E-06 indicates that, as an upper bound, an individual has a one in one million chance of developing cancer as a result of site-related exposure to a carcinogen over a lifetime under the specific exposure conditions at the site. Because these are upper bound estimates, it is likely that the actual risk is less than the estimated excess cancer risk.

Potential concern for noncarcinogenic effects of a single contaminant in a single medium is expressed as the hazard quotient (HQ) (or the ratio of the estimated intake derived from the contaminant concentration in a given medium to the contaminant's reference dose). By adding the HQs for all contaminants within a medium or across all media to which a given population may reasonably be exposed, the Hazard Index (HI) can be generated. The HI provides a useful reference point for gauging the potential significance of multiple contaminant exposures within a single medium or across media.

a. Excess Lifetime Cancer Risks

Future lifetime cancer estimates are based entirely on exposure to arsenic assuming industrial site usage and reasonable maximum exposure arsenic concentrations. In addition to arsenic, other contaminants at the Silver Mountain Mine site that are known or probable human carcinogens are beryllium, cadmium, chromium, nickel, and lead. However, beryllium, cadmium, chromium, and nickel have only been found to be carcinogenic via inhalation. As stated above, inhalation of particulates and volatiles is not a significant pathway for this site. The carcinogenicity of lead could not be evaluated because a cancer potency factor has not been established at this time. The carcinogenic risk from exposure to arsenic is shown in Table 3 for each exposure pathway.

b. Noncarcinogenic Effects

Risks of developing noncarcinogenic effects are presented in terms of a hazard quotient and hazard index. If the exposure is equal to or less than the RfD--a hazard quotient of 1.0 or less--then adverse effects are not expected. If the hazard quotient is greater than 1.0, there is an increasing chance that adverse effects will occur. The hazard indices, summed across each exposure pathway, are shown in Table 3. Table 4 shows the noncarcinogenic and carcinogenic risks broken down by contaminant and medium.

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Table 3. Carcinogenic & Noncarcinogenic Risks

<u>Pathway/Medium</u>	<u>Arsenic Carcinogenic Risk</u>	<u>Hazard Quotient</u>
Soil ingestion	2.3 E-04	2.7 E-01
Water ingestion	2.4 E-04	3.1 E+00
Dermal contact	1.9 E-03	2.2 E+00
Particulate inhalation	0.0 E+00	0.0 E+00
<u>Vapor inhalation</u>	<u>0.0 E+00</u>	<u>0.0 E+00</u>
Total Risk	2.3 E-03	5.5

Table 4. Reasonable Maximum Exposure Risks by Medium

A. NONCARCINOGENIC

	Rfd Ratio	
	Water	Soil
Antimony	1.7E+00	6.3E-02
Arsenic	2.5E-01	2.2E+00
Barium	4.7E-02	6.3E-03
Beryllium	5.1E-03	4.2E-04
Cadmium	9.8E-02	2.5E-02
Chromium	1.1E-01	1.2E-02
Copper	2.6E-02	1.1E-04
Cyanide	4.2E-01	3.7E-02
Fluoride	2.0E-01	0.0E+00
Manganese	3.6E-02	1.6E-02
Mercury	5.7E-03	5.0E-03
Nickel	3.3E-02	8.7E-03
Nitrate	0.0E+00	0.0E+00
Nitrite	0.0E+00	0.0E+00
Selenium	2.2E-02	1.7E-03
Silver	1.4E-02	2.1E-02
Thallium	1.1E-02	1.7E-02
Tin	9.0E-04	0.0E+00
Vanadium	7.8E-02	1.3E-02
Zinc	1.1E-02	7.1E-03
Hazard Index:	3.1	2.4

Combined Hazard Index: 5.5

B. CARCINOGENIC (Arsenic only)

	Water	Soil
	2.4E-04	2.1E-03
Total risk:	2.3E-03	

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Table 5. Stock Tank Drinking Water Risks

Noncarcinogenic Risks		Carcinogenic Risk	
Compound	Hazard quotient	Compound	Risk
Antimony	0.0E+00		
Arsenic	1.6E-00	Arsenic	1.6E-03
Barium	3.4E-03		
Beryllium	1.7E-03		
Cadmium	1.7E-02		
Chromium	3.4E-03		
Cyanide	4.1E-03		
Fluoride	7.1E-05		
Manganese	2.0E-04		
Mercury	5.7E-03		
Nickel	1.1E-02		
Selenium	0.0E+00		
Silver	1.4E-02		
Thallium	1.1E-02		
Tin	2.9E-04		
Vanadium	2.4E-03		
Zinc	5.1E-04		

Hazard Index =	1.7E+00		

The total noncarcinogenic hazard quotient for the water in the stock tank is 1.7. Arsenic, with a hazard quotient of 1.6, accounts for nearly all of this risk. The risks presented by the stock tank are shown in Table 5 above.

Conclusions - Human Health Risks

At the Silver Mountain Mine site, the most important exposures routes are ingestion of and dermal contact with soil, and ingestion of groundwater or surface water.

Using reasonable maximum exposure assumptions, arsenic, antimony, and cyanide are the most important contaminants in water. Nitrate/nitrite and lead were each present in a single groundwater sample at concentrations above established criteria, though these samples may not be representative of overall site conditions. Exposure to arsenic in water could result in an increased cancer risk of 2 in ten thousand. There is also a risk of noncarcinogenic effects, mainly neurologic, liver, and skin related, from arsenic, cyanide and

other chemicals. The hazard quotient for these effects is 2.5.

The most important contaminant in soil is arsenic. Exposure to soil could result in an increased cancer risk of two in one thousand. The hazard index of 2.4 indicates that soil exposure could also result in a risk of noncarcinogenic effects, principally skin and neurologic disorders.

Uncertainty is inherent in all risk assessments. The major sources of uncertainty in the Silver Mountain Mine risk assessment are toxicity reference values, assumed future land use, the actual toxicity/risk of the dermal pathway, and the water data (as mentioned above). Due to the uncertainty in these and other areas, conservative assumptions were made in order to be protective of human health.

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this Record of Decision, may present an imminent and substantial endangerment to public health, welfare, or the environment.

Environmental Risks

The greatest risk to wildlife and plants appears to be from the arsenic concentrations in the soils surrounding the leach heap. These soils are contaminated with levels of arsenic toxic to vegetation and ruminants, and are likely to be utilized by sagebrush biota, although the area involved is small. In the future, once the heap cover deteriorates, there may be some acute toxicity at times from temporary ponding of leachate. Soils from the heap and dump may exert their potential toxicity if they erode, spread out, leach, etc.

There is no current risk to wildlife or plants from groundwater, and no future risk is anticipated. Surface waters, however, attract wildlife, enhancing exposure to toxic levels of pollutants within those waters. The mine drainage to the trough will probably continue to be a source of elevated arsenic concentrations. To a lesser extent, the seep area may continue to be a source of elevated aluminum, copper, and lead.

VII. DESCRIPTION OF ALTERNATIVES

The Feasibility Study developed eight alternatives, utilizing a variety of treatment, containment, and disposal options, to reduce the risks remaining at the site after early initial treatment actions. The three alternatives which best met the evaluation criteria (protectiveness, cost effectiveness, compliance with regulations) were selected for detailed analysis and are described below, along with the no action alternative, which must be considered to comply with the NCP. As discussed further in Section X of this document, the primary applicable or relevant and appropriate regulations are action-specific. There are no location-specific ARARs for this site, and the Safe Drinking Water Act standards are the only potentially applicable chemical-specific ARAR. The alternatives are referred to by the numbers assigned in the Feasibility Study and Proposed Plan.

Alternative 1: No Action

This alternative leaves the site as-is, with no treatment or containment of contaminated materials and no restrictions on site access. The leach heap is subjected to all normal weathering forces and seasonal water runoff. No ARARs are invoked, and thus none are violated.

Alternative 2: Grading, Clay/Soil Cap, Institutional Controls, and Groundwater Monitoring

This alternative consists of a series of actions leading to capping the leach heap. First, all contaminated materials on site are consolidated onto the leach heap, with sampling conducted to verify that contaminated materials are adequately consolidated. These contaminated materials consist of surface soils surrounding the heap that contain cyanide and elevated arsenic concentrations and approximately 1600 yd³ of mineralized mine dump. The leach heap is then graded and contoured to a shape that will minimize water erosion of the surface layer and seasonal runoff contact with the reshaped heap. A soil/clay mixture is placed and compacted over the graded heap to reduce infiltration of both air and water into the contaminated materials.

Because the wastes at Silver Mountain Mine are specifically exempt from the Resource Conservation & Recovery Act, the remedy does not involve the disposal of RCRA-regulated waste, and RCRA land disposal restrictions and Subtitle C closure standards are not applicable. The Washington State Dangerous Waste Act does regulate certain wastes containing concentrations of arsenic greater than 100 mg/kg if the waste was generated after 1981. Because the

waste at the site was generated prior to this date, the State Dangerous Waste rules are not applicable; however, they have been determined to be relevant and appropriate to the type of waste being managed.

The cap will be designed and constructed to promote drainage, minimize erosion of the cover, and provide long-term minimization of migration of liquids through the underlying contaminated materials. Because mean annual precipitation is only 11.4 inches per year, the cap is expected to readily meet or exceed these performance criteria. Long-term operation and maintenance will be conducted to monitor the groundwater around the site and to ensure the integrity of the cap.

Groundwater sampling is conducted for five years or more to verify whether contaminants are migrating. As an added precaution, a restriction or notice not to disturb the cap shall be placed on the deed for the site, and a fence with appropriate warning signs is constructed around the site to limit access. The community will be provided notice of groundwater sampling activities, sampling results, and the potential for contamination of the low-yield aquifer under the site.

This alternative does not completely eliminate the problem of the remaining cyanide and toxic metals migrating from the leach heap, but it does minimize these problems by shielding the contaminated materials from the conditions that promote migration of arsenic and cyanide. The cap significantly reduces natural oxidation of the metal sulfides and the remaining cyanide compounds and eliminates casual contact with the contaminated materials by humans and animals. Future disturbance of the cap is minimized by the fencing and deed restrictions placed on the site.

ARARs for this alternative include Occupational Health and Safety Administration (OSHA) regulations on worker safety, Clean Air Act (CAA) emission standards during implementation, Washington State Dangerous Waste regulations on capping, Maximum Contaminant Levels (MCLs) for groundwater protection, and the state's Minimum Standards for Construction and Maintenance of Wells.

Construction of the cap should take 2-3 months. Operation and maintenance (O&M) requirements include semi-annual groundwater sampling and yearly inspections of the site to monitor the condition of the cap. The present value cost, including construction and O&M, is estimated at \$635,600.

Alternative 6: Removal and Continuous Rinse to Treat for Cyanide,
Fine Solids to Resource Conservation and Recovery Act (RCRA)
Disposal to Remove Arsenic

The major feature of this alternative is the additional treatment of approximately 5740 yd³ of heap, mine dump, and soil to destroy the remaining cyanide and remove the more mobile arsenic. The material is moved to a trommel where it is rinsed with water (to remove the cyanide and water-soluble metals) and sized to remove the finer solids. Oversized solids are allowed to drain and then are left on the site if they meet treatment standards of 200 mg/kg arsenic and 95 mg/kg cyanide (see Table 6 below). The fine solids are further dewatered and then transported to a landfill that meets RCRA requirements.

Treatability tests are needed to determine the proper operating conditions for meeting the arsenic and cyanide treatment standards. It is doubtful that this alternative can meet the arsenic standard of 200 mg/kg, because it will not remove the arsenic that is present in the tightly bound sulfide mineral form. The arsenic in this form is not mobile now, but it will slowly oxidize and become available to the environment over time.

The rinsate is processed to destroy the cyanide and remove the soluble metal contaminants by precipitation. Treated rinsate would be released to the ground if it meets State land application discharge limits. The discharge of treated rinsate is regulated under the State Water Pollution Control Act (RCW 90-48), although no discharge limits specific to this project have been set by the State. The volume of rinse water generated is estimated to be 400 gal/hr. The metal-containing sludge generated by the rinsate treatment is disposed of at a hazardous waste facility, in accordance with Resource Conservation and Recovery Act (RCRA) regulations.

ARARs include the OSHA and CAA requirements as under Alternative 2, and several State of Washington water quality regulations, including the State Water Pollution Control Act and the State Waste Discharge Permit Program (although no permits are required for on-site activities).

No groundwater monitoring or institutional controls are included in this alternative. The estimated time required for implementation is one year. Neither O&M nor monitoring is anticipated in the cost calculation. However, both groundwater monitoring and capping may be needed if treatability study results show that health-based risk levels cannot be met through treatment. Estimated present worth costs are \$1.2 million.

Alternative 7: Offsite RCRA Disposal

The major features of this alternative are the excavation, transport, and disposal of approximately 5740 yd³ of contaminated materials (leach heap, mineralized mine dump, and surrounding soil). The contaminated materials are hauled in appropriately controlled trucks to an existing RCRA landfill. After disposal, the site no longer has any contaminated materials stored on it, and there is no need to restrict site entry and future use. Because the low-yield aquifer is affected by naturally occurring arsenic in the bedrock, the community will be provided notice of the possibility of groundwater contamination.

ARARs include the State Dangerous Waste Regulations for transportation and disposal of hazardous wastes; the CAA and OSHA regulations again apply during implementation. Implementation time for this alternative is 2-3 months. No O&M, monitoring, or institutional controls are required. Disposal costs are estimated at \$1.4 million.

VIII. SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

Each of the four alternatives described in the preceding section was evaluated according to the following nine criteria:

Threshold Criteria

1. Overall protection of human health and the environment: whether or not the remedy provides adequate protection or describes the mechanisms for controlling risk for the different exposure pathways.
2. Compliance with ARARs: whether or not the remedy ensures compliance with Applicable or Relevant and Appropriate Requirements of other federal and state environmental standards or statutes.

Primary Balancing Criteria

3. Long-term effectiveness and permanence: the ability of the remedy to provide protection and reduce risks to health and the environment after cleanup goals have been met.
4. Reduction of toxicity, mobility, or volume through treatment: the anticipated effectiveness of treatment technologies used.

5. Short-term effectiveness: the speed with which the remedy achieves protection, as well as any adverse effects which it may create during construction and implementation.
6. Implementability: the technical and administrative feasibility of the remedy.
7. Cost: includes capital and O&M costs.

Modifying Criteria

8. State acceptance: whether the state concurs with or opposes the remedy.
9. Community acceptance: whether or not the remedy is acceptable to the community, and how it addresses their continuing concerns about the site.

The following section describes how each alternative meets the various criteria.

Overall Protection of Human Health and the Environment

The offsite disposal option affords the strongest measure of protection at the site, in that the contaminated materials are completely removed from the site. Once the materials are removed, there will be no restrictions on activities at the site. However, disposal at another facility merely moves the risk from one site to another. Some potential for groundwater contamination remains at the site due to naturally occurring arsenic in the bedrock.

The capping alternative prevents direct contact with the contaminated materials, by means of both the cap itself and the fence erected around the heap. There still remains a small potential for arsenic and the remaining cyanide to mobilize and enter the ground under the capped heap; however, the cap should minimize that potential by minimizing contact of air and water with the contaminated materials. Groundwater monitoring and contingent groundwater treatment included in this alternative will assure that it remains protective.

The treatment alternative provides a good measure of protection, because all of the contaminated material will be washed and the more mobile arsenic in the fine materials will be removed and disposed offsite. However, the washed coarse material, which will remain onsite, will still contain arsenic-bearing sulfide minerals. The arsenic in this form has a low mobility, but over time the sulfide minerals will oxidize and the arsenic will become available to the environment. Depending on treatment results (whether health-

based levels can be achieved), capping and groundwater monitoring may have to be added to this alternative.

The no action alternative does not protect human health or the environment. Humans and animals can come in contact with the contaminated materials, and potentially harmful leachate could accumulate in the catchment pond downslope from the leach heap during wet periods of the year, as the existing cover deteriorates from natural weathering.

Since the no action alternative fails to meet this threshold criterion, it will not be considered further in this analysis.

Compliance with ARARs

The capping and offsite disposal alternatives meet all ARARs. The treatment alternative can be designed to meet ARARs, but some difficulty may arise due to Washington State regulations governing wastewater. If rinsate treatment operations cannot be designed to meet State standards, the wastewater might have to be transported a minimum of 30 miles to a POTW for treatment.

Long-Term Effectiveness and Permanence

Offsite disposal of the contaminated materials eliminates the long-term risks associated with the site. No institutional barriers or restrictions are placed on the site and there is no need for any inspection, repair, or maintenance activities. Some potential for groundwater contamination remains at the site due to naturally occurring arsenic in the bedrock.

The capping alternative is highly reliable and effective. Due to the dry climate in the area, the need for major repairs of the cap during its 30-year design life is considered very low. A notice or restriction in the deed to the property should restrict future owners from disturbing the cap.

The treatment alternative has, in theory, a high level of long-term effectiveness. The washed materials left onsite are free from cyanide and soluble-metal contaminants. While this technology is not new, its effectiveness in meeting the arsenic treatment standard is not known. The arsenic remaining in the cleaned materials is in the form of low mobility sulfide minerals that undergo slow oxidation. Over time the arsenic would become more mobile due to natural weathering conditions. No institutional controls or barriers are included, but if treatability studies indicated the need,

capping and groundwater monitoring will be added to this alternative.

Reduction of Contaminant Mobility, Toxicity, or Volume

Early treatment actions significantly reduced the concentration of cyanide in the leach heap. Further treatment of the leach heap would reduce the toxicity and somewhat reduce the volume of the washed materials to be left onsite. Cyanide and soluble-metal contaminants are washed from the contaminated material, and the rinsate is subsequently treated to destroy and precipitate the contaminants. The principal threat, arsenic, is partially removed (rather than treated) through sizing operations that separate out the fine materials. Precipitated sludge and fine solids are disposed at a hazardous waste site. Arsenic in the form of sulfide minerals remains in the washed materials, but it has very low mobility.

Capping the heap greatly reduces the potential for the contaminants to move into the environment, because it eliminates wind and water erosion. Capping minimizes water and air infiltration into the heap, thus limiting the natural oxidation rate of the metal sulfides and the cyanide and metal complexes; this in turn significantly reduces the potential for contaminant mobility. Capping slows the natural degradation of cyanide. This alternative does not reduce the volume of contaminated materials.

Disposal of the materials at a hazardous waste landfill does not reduce either the toxicity or the volume of the contaminants. Placement of the contaminated materials in a properly constructed RCRA landfill should reduce the mobility of the contaminants into the environment.

Short-Term Effectiveness

The capping alternative has the highest short-term effectiveness, as it takes only 2-3 months to implement and involves the least movement of contaminated materials. Worker safety is assured through wetting the contaminated materials to control blowing dust, and taking other routine safety measures to prevent exposure to contaminated material.

Offsite disposal also takes 2-3 months and requires safety precautions during the removal of the leach heap materials. Materials are hauled to the landfill in appropriately sealed and labeled trucks to minimize the risk of human contact with the contaminants.

The treatment alternative requires about a year's work. Safety clothing and equipment are required to assure worker safety, and precautions are taken when materials are hauled offsite, as in the above alternative. This alternative has the lowest short-term effectiveness because the likelihood of contaminated materials becoming airborne during sizing operations is very high.

Implementability

Offsite landfilling is easy to implement. Loading, hauling, and long-term disposal services are readily available, and landfill capacity does not pose a problem. No future site remediation or monitoring is required. Some potential for groundwater contamination remains at the site due to naturally occurring arsenic in the bedrock.

Capping is also easily implemented. The technology to construct the alternative is well developed and the means to perform maintenance functions on the cap and monitor the effectiveness of the remedial action are available.

Treatment is less implementable. The technologies to wash and size the contaminated materials and to treat the rinsate are generally proven, and the availability of equipment and technical personnel should be good. However, treatability tests are required to determine how effective this alternative will be in reducing arsenic concentrations. It is doubtful that treatment/removal of fines could reduce the arsenic present in the sulfide mineral form to the cleanup standard of 200 mg/kg (see Table 6 below). In addition, the ARARs for this alternative might necessitate disposal of wastewater off-site, making implementation more difficult than originally planned. Under this alternative, the site requires no future monitoring, but if treatability studies indicated the need, capping and groundwater monitoring will be added to this alternative.

Cost

The capping alternative has an estimated capital cost of \$370,360 and annual O&M costs of \$39,650. The present value, based on a 30-year period for site activities, is \$635,600.

Capital costs for the treatment alternative are estimated at \$855,290, and present worth at \$1.2 million. No monitoring or maintenance costs are included.

Offsite disposal would cost an estimated \$1.4 million.

State Acceptance

The Washington State Department of Ecology has given verbal approval of Alternate 2, capping.

Community Acceptance

Two commentors suggested using an alternative other than the selected capping alternative. Community interest in the site is generally low. A total of three private citizens and one local official commented on the proposed plan: two favored a capping option, the official favored taking no action, and the other citizen gave no opinion. All public comments are shown in Section XI of this document, the "Responsiveness Summary."

IX. THE SELECTED REMEDY

The selected remedy is Alternative 2 (grading and capping the leach heap; institutional controls; and groundwater monitoring). EPA and the state of Washington agree that this alternative best meets the selection criteria. A more detailed description of the components of the remedy follows.

Consolidation and Grading

All contaminated soils and mine dump material will be consolidated with the leach heap, graded, and contoured to a shape that will minimize water infiltration. Locations which might include such materials include the mine dump areas and surface soils around the leach heap. This work will be accomplished using conventional earth-moving equipment. Samples will be collected after contaminated materials have been consolidated to verify that all material contaminated with concentrations of arsenic greater than 200 mg/kg or cyanide greater than 95 mg/kg is made part of the heap. The rationale for these cleanup standards are shown in Table 6 below.

Table 6. Cleanup Standards for Leach Heap, Mine Dump, and Soil

<u>Constituent</u>	<u>Concentration at Site</u>	<u>Standard</u>	<u>Rationale</u>
arsenic	274 mg/kg max	200 mg/kg	Hazard Index = 1.0 Cancer Risk = 10^{-4}
cyanide	101 mg/kg max	95 mg/kg	Hazard Index = 0.1

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Capping

Capping is the most important component of this remedy in terms of preventing contaminant migration. Five types of caps were evaluated in the Feasibility Study; the soil/clay type was selected because it was as protective as any other evaluated, and it was the most cost effective. The Remedial Design work will include designing a specific cap to meet the following criteria: promote drainage, minimize erosion of the cover, and provide long-term minimization of migration of liquids through the underlying contaminated materials.

Mine Adit and Stock Tank

The entrance to the mine will be plugged using conventional techniques in order to protect public safety, particularly the curious visitor who may enter the mine. The pipe that now carries mine drainage water to the stock tank will be removed. A new well will be installed on the land owner's property in the Horse Springs Coulee aquifer to replace the stock tank as an animal water supply.

Institutional Controls

The site will be fenced to prevent people and animals from disturbing the cap and existing monitoring wells. A restriction or notice will be placed on the deed to the property which restricts future disturbance of the cap. The community will be provided notice of sampling of the low-yield aquifer under the site, the sampling results, and the potential for contamination, including that from naturally occurring arsenic in the bedrock.

Groundwater Monitoring

A groundwater monitoring program will be implemented to verify concentrations of potential contaminants, both spatially and temporally. During the Remedial Investigation, groundwater concentrations of contaminants exceeded human health-based standards on a sporadic basis. A groundwater monitoring program to meet the objective of detecting and verifying the extent of contamination would be conducted in two stages:

Stage 1. Existing wells will be sampled on a quarterly basis for two years for selected parameters to verify any changes in contaminants of concern at the site, and whether they occur at concentrations above cleanup standards. All existing wells will be used in the verification analysis for cyanide, nitrate, and nitrite, which are the groundwater contaminants that originate only in the heap. The other contaminants of concern, arsenic, antimony, and lead, have a probable major

source in bedrock and would therefore be verified primarily in well 3, which should have the least bedrock influence among existing wells. If elevated levels of contaminants are not detected, sampling frequency will be decreased to semi-annually.

If elevated levels of contaminants are detected and verified, a more extensive monitoring system will be established in Stage 2 to monitor contamination at the point of compliance and to clarify the natural bedrock component of contamination in relation to contamination coming from on-site sources. If elevated levels of contaminants are not verified, Stage 2 will not be needed either for verification of contamination or for compliance monitoring. The selected parameters and the standard (acceptable concentration) for each are shown in Table 7 below.

Stage 2. The more extensive monitoring system will include the four existing monitoring wells, three additional downgradient wells, one additional upgradient well, and a contingency for a fourth additional downgradient well if required to adequately span the flow path of groundwater at the point of compliance. Two of the downgradient wells will be installed at the point of compliance established in the western margin of the Horse Springs Coulee aquifer. A third downgradient well and an upgradient well will be installed to provide an adequate two-dimensional array of monitoring points to verify the direction of flow.

Table 7. Groundwater Parameters & Standards

Constituent	Concentration		Rationale
	at Site	Standard	
antimony	40 ug/l	120 ug/l	Health based level
arsenic	14 ug/l	6 ug/l	10(-4) cancer risk
cyanide	122 ug/l	154 ug/l	Health advisory
lead	23 ug/l	20 ug/l	Proposed MCL
nitrate (N)	17 mg/l	10 mg/l (as N) (45 mg/l as NO ₃)	MCL
nitrite (N)	0.4 mg/l	1 mg/l (as N) (3.3 mg/l as NO ₂)	Proposed MCL
combined nitrate and nitrite	17.4 mg/l	10 mg/l (as N)	Proposed MCL

The parameters to be used for ground water monitoring will include the field parameters (water level, temperature, pH, electrical conductivity, and Eh) and the parameters of concern identified in the Remedial Investigation (total cyanide, weak acid dissociable cyanide, arsenic, antimony, lead, nitrate, and nitrite). The need for continued groundwater monitoring will be evaluated during the five-year review of the site.

A statistical procedure will be used to evaluate monitoring data for determining the spatial and temporal trends in contaminant levels. Groundwater treatment design would begin if the Stage 2 (point of compliance) wells show contamination coming from the site exceeds the standards in Table 7 and is not the result of naturally occurring contamination, based on statistical evaluation of all the data.

Contingent Groundwater Treatment Program

If groundwater treatment is chosen as a remedial alternative based on analyses of monitoring results, groundwater extraction and treatment at the surface will be employed. Potential treatment for cyanide could be chosen from methods listed in Section 2.5.4 of the Feasibility Study Report (EPA, Jan. 17, 1990) for treatment of rinsewater from leachate. Potential treatment for arsenic will employ arsenic

removal by use of iron sulfate or other precipitant. In this method of treatment, ferric sulfate is added as a floc to the water to be treated. A high oxidation state is maintained by aeration during treatment in order to keep iron in the ferric form and arsenic in the arsenate form. A slightly acidic operating pH of pH 6-7 is maintained to promote chemical removal of arsenic from water by any of three following processes:

1. Precipitation of ferric arsenate.
2. Coprecipitation of arsenic with ferric hydroxide.
3. Adsorption of arsenic with ferric hydroxide.

Arsenic removal is then completed by separation of sludge from water.

As noted above, groundwater treatment would not be implemented until the level of groundwater contamination is verified. A design phase would also precede any groundwater treatment to verify that groundwater extraction is practical in the shallow aquifer. On the basis of the Remedial Investigation, groundwater treatment is at present considered to be an inappropriate alternative because of the low levels of contaminants and the low hydraulic conductivity of the shallow aquifer.

Points of Compliance

A point of compliance for groundwater standards will be established in the western margin of Horse Springs Coulee aquifer 100-200 feet downgradient from the edge of the leach heap. This point is chosen on the basis of two findings of the Remedial Investigation:

1. The shallow aquifer beneath the heap has a very low hydraulic conductivity on the order of 7×10^{-6} cm/s. Such low hydraulic conductivity makes the shallow aquifer unusable as a water supply. Horse Springs Coulee aquifer, on the other hand, is an important water supply for irrigation and residential use. The part of Horse Springs Coulee aquifer adjacent to the mine site is the most appropriate point to monitor for effects of contaminants.
2. Some of the contaminants of concern (arsenic, antimony, and lead) in the shallow aquifer have a potential natural source in bedrock adjacent to the leach heap and mine dump. A point of compliance in Horse Springs Coulee aquifer, rather than the shallow aquifer, is more removed from the potential bedrock source and will better allow differentiation of contaminants from the mining activities versus naturally occurring contaminants.

X. STATUTORY DETERMINATIONS

The selected remedy meets statutory requirements of Section 121 of CERCLA, as amended by SARA, and to the extent practicable, the National Contingency Plan. The evaluation criteria are discussed below.

1. Protection of Human Health and the Environment

The selected remedy will protect human health and the environment by consolidating the contaminated materials onto the leach heap; capping and covering the heap and implementing institutional controls to minimize exposure; and monitoring the groundwater to assure it is not affected by sources at the site. These are all long-term measures. In the short term, standard health and safety precautions will be taken to protect workers; no other populations are currently at risk from this site.

2. Attainment of ARARs

The selected remedial actions meets all identified ARARs. These are listed below, by media. Except for the Safe Drinking Water Act (SDWA) standards, these are all action-specific ARARs (SDWA standards are chemical-specific). There are no location-specific ARARs for this site.

Hazardous Waste:

RCRA. Not applicable due to mining waste exclusion (40 CFR 261.4). Not relevant and appropriate because the waste at the Silver Mountain Mine site does not exhibit a characteristic of hazardous waste and is not similar to a RCRA waste.

Washington State Dangerous Waste Regulations (WAC 173-303). Some wastes containing greater than 100 ppm arsenic are regulated as dangerous wastes. Although the remedial actions planned do not constitute treatment, storage, or disposal, the actions are sufficiently similar to make these regulations relevant and appropriate. Specific sections of the regulations that are relevant and appropriate include:

Section 610 Closure and Postclosure

Subsection 2a: Closure performance standard. Must close in a manner that: minimizes the need for further maintenance; and controls, minimizes or eliminates to the extent necessary to protect human health and the environment, postclosure escape of dangerous waste, dangerous constituents, leachate, contaminated runoff, or dangerous waste decomposition products to the ground, surface water, groundwater, or the atmosphere; and returns the land to the appearance and use of surrounding

land areas to the degree possible given the nature of the previous dangerous waste activity.

Subsection 7d: Postclosure care and use of property. Postclosure use of property on which dangerous wastes remain after closure must never be allowed to disturb the integrity of the final cover or any other components of any containment system, or the function of the facility's monitoring systems, unless the Department finds that the disturbance is necessary to the proposed use of the property, and will not increase the potential hazard to human health or the environment.

Subsection 10b(i) (A) (B): Notice in deed to property. Within sixty days of closure the owner or operator must: record, in accordance with state law, a notation on the deed to the property, or on some other instrument which is normally examined during title search, that will in perpetuity notify any potential purchaser of the property that the land has been used to manage dangerous wastes; and that its use is restricted as specified in subsection 7d.

Section 645, subsection 8: Groundwater monitoring requirements.

Section 665, subsection 6: Closure and postclosure care for landfills. This subsection contains general requirements for a final cover, maintenance, and monitoring.

Water:

Safe Drinking Water Act, Maximum Contaminant Levels (MCLs). An applicable requirement at the point of compliance, these are the federal standards for drinking water supplies. MCLs exist for several elements found at the site, including arsenic, cadmium, lead, silver, and several others.

Minimum Standards for Construction and Maintenance of Wells (WAC 173.160). An applicable requirement, this state of Washington regulation addresses how wells must be installed and abandoned by licenses well contractors. The well to be drilled to replace the stock tank must comply with both the administrative and substantive requirements of WAC 173.160 and WAC 173.162, because the well will be located in the Horse Springs Coulee aquifer, outside of the site boundaries.

State Water Pollution Control Act (RCW 90.48). This could be applicable if groundwater treatment were conducted. This act requires the use of all known available and reasonable methods to prevent and control pollution of the waters of the state. Specific substantive requirements are set forth in:

90.48.010 Policy enunciated

90.48.020 Definitions (pollution & waters of the state)
 90.48.080 Discharge of polluting matter in waters prohibited.

Regulation of Public Ground Waters (RCW 90.44). This could be applicable if groundwater treatment were conducted. This chapter establishes that the "first in time, first in right" doctrine of water appropriation applies to groundwater as well as surface water. If the groundwater extraction system adversely impacts either the quantity or quality of a senior water right holder, the impacts must be mitigated.

Water Resources Act of 1971 (RCW 90.54). This could be applicable if groundwater treatment were conducted. This act sets forth fundamentals of water resource policy for the state to insure that waters of the state are protected and fully utilized for the greatest benefit to the people of the state and, in relation thereto, to provide direction to the Department of Ecology and other state agencies and officials, in carrying out water and related resources programs. Specific substantive requirements are set forth in:

90.54.020 General declaration of fundamentals for utilization and management of waters of the state. Establishes: beneficial uses; the basis for allocation which includes the loss of opportunity in the equation for maximum net benefits; base flow in perennial streams and rivers shall be retained, and all known available and reasonable methods of treatment shall be applied to discharge of wastes into waters of the state.

Protection of Withdrawal Facilities Associated with Ground Water Rights (WAC 173-150). This could be applicable if groundwater treatment were conducted. The purpose of this chapter is to establish and set forth the policies and procedures of the Department of Ecology in regard to the protection of the availability of groundwater as it pertains to the water withdrawal facilities of holders of groundwater rights. Particularly:

173-150-060 Defines impairment of water rights.
 173-150-090 Voluntary agreements. Allows junior and senior water right holders to reach a mutually satisfying agreement regarding impairment of water supply by one of the parties.
 173-150-100 Ensures protection of water quality as well as quantity.

Water Quality Standards for Surface Waters of the State of Washington (WAC 173-210). This would be applicable if groundwater treatment were conducted and resulted in discharges to surface water. The purpose of this regulation is to establish water quality standards for surface water of

Reference 5

**Notes Concerning Damage Report and Mineral Rights;
Dennis Bowhay, Washington Department of Ecology;
July 21, 1983**

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Dennis:

7-21-83

223-375

Jim McDaniel stopped by the Okanogan County Health Dept. to report to Karen that one of his calves got into the fenced area of Silver Mt. Mine and died. Jim also stated that he has seen a number of dead birds in the area recently. Suggested further testing.

Also: T. Roben, Green Acres Rd. - Blue Mail Box - phone 826-6815, now claims to own the mineral rights to Silver Mt. Mine.

given

gilbert brown

Robinson Canyon Rd
Omak

5 or 67 years

Two years ago somebody used cyanide

P.O. Box 925
Omak 98941

Reference 6

**Memorandum Concerning Neutralization
of Silver Mountain Cyanide; From Harold Porath,
Washington Department of Ecology, to John Hodgson,
Washington Department of Ecology; November 19, 1981**



STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

MEMORANDUM

TO: Jonn Hodgson
FROM: Harold Porath
SUBJECT: Neutralization of Silver Mountain Cyanide
DATE: November 19, 1981

Harry Tracy, Ed Denika, Karen Albrecht, Barry Nelson, and Harold Porath met at 1400 hours, November 18, 1981, to look over pictures of Silver Mountain Mine and to discuss operating procedures for the neutralization of the cyanide solution at Silver Mountain Mine planned for the following day. Arrangements had already been made to pickup a diaphragm pump from the City of Omak, and for a water truck (Okanojua County Public Works) to be at the mine site the following day. Tracy, Denika and Porath then traveled to Silver Mountain Mine to enable Tracy and Denika to get a first hand look at the site and to further refine operational plans for the following day.

After picking up the pump, Tracy, Denika, Albrecht and Porath arrived at Silver Mountain Mine at 8:25 hours, and immediately cleared debris from a section of the site to allow vehicles access to the cyanide trench. The pump was positioned along side the trench in such a manner that the solution could be circulated within the trench. Barrels and other debris were also removed from the trench. The county water truck, driven by Dwayne More than arrived.

A sample for cyanide analysis was collected before the neutralization process was begun. The pH was measured at this time and found to be pH = 10. The pump was started and chlorine was added starting at 9:15 hours. Dry calcium hypochlorite was slowly shoveled into one end of the cyanide solution trench directly in front of the suction intake to the pump. In this way, the chlorine was sucked into the pump and mixed with the cyanide solution using the action of the pump to mix and dissolve the chlorine. Observations of the pump discharge at the far end of the cyanide solution trench indicated that the calcium hypochlorite was almost completely dissolved in the cyanide solution.

Reference 7

**Telephone Communication Concerning the Current Status
of the Silver Mountain Site;
From Ingrid Rosencrantz, SAIC,
to Neil Thompson, EPA Region X Remedial Project Manager;
August 9, 1990**

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**TELECOMMUNICATIONS
SUMMARY REPORT**

SAIC Contact: **Ingrid Rosencrantz**

Date: **8/9/90**

Time: _____

Made Call **X** Received Call

Person(s) Contacted (Organization): **Neil Thompson, EPA Region X RPM, Silver Mountain Mine,
(206) 442-1987.**

Subject: **Silver Mountain Mine Site**

Summary: EPA is nearing completion of the Remedial Action design phase. The RPM anticipates having biddable documents by the end of the quarter. Construction will depend on fund financing - it is a fund-lead project and requires the State to match funds. Construction can be completed in one construction season. The design addresses the entire ROD - capping through ground-water monitoring.

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Mining Waste NPL Site Summary Report

**Smuggler Mountain
Pitkin County, Colorado**

**U.S. Environmental Protection Agency
Office of Solid Waste**

June 21, 1991

FINAL DRAFT

Prepared by:

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DISCLAIMER AND ACKNOWLEDGEMENTS

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract Number 68-W0-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Paula Schmittial of EPA Region VIII [(303) 293-1527], the Remedial Project Manager for the site, whose comments have been incorporated into the report.

**SMUGGLER MOUNTAIN
PITKIN COUNTY, COLORADO**

INTRODUCTION

The Site Summary Report for the Smuggler Mountain site is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of the summary by the EPA Region VIII Remedial Project Manager for this site, Paula Schmittial.

SITE OVERVIEW

The Smuggler Mountain site is located immediately northeast of the City of Aspen in Pitkin County, Colorado. One hundred ten acres of waste rock, tailings, and slag (containing high levels of lead and cadmium) comprise the site. The mining wastes that characterize the site are the result of years of extensive mining, milling, and smelting operations. Silver, lead, and zinc mining operations were conducted in the late 1800's and early 1900's. In the 1960's, a reprocessing facility was run at the site. Soil is the primary contaminated medium; however, contaminants have been found in ground and surface water. The key contaminants of concern are lead, cadmium, zinc, and other heavy metals (Reference 1, Summary of Remedial Alternative Selection, Section A).

EPA determined that the site was to be defined as those areas with surface contamination of greater than 1,000 parts per million (ppm) lead (Reference 2, page 1-3). There are two Operable Units designated within the site. Operable Unit 1, indicated by the bold black lines in Figure 1, encompasses residential areas including the site repository at the Mollie Gibson Park (designated for soil remediation). The boundaries of Operable Unit 2, the Smuggler Mine, have not yet been established (see Figure 2) (Reference 8).

The site is within the City of Aspen, Colorado, which has a year-round population of 4,500 (Reference 1, Abstract; Reference 4, page 1). In many cases, development in the Aspen area has taken place directly over waste piles, or waste piles have been moved to the side of developed areas and remain as berms or mounds of contaminated soil. The site is approximately 90 percent developed (97 percent within Operable Unit 1) as residential housing (Reference 3, page 2; Reference 4,

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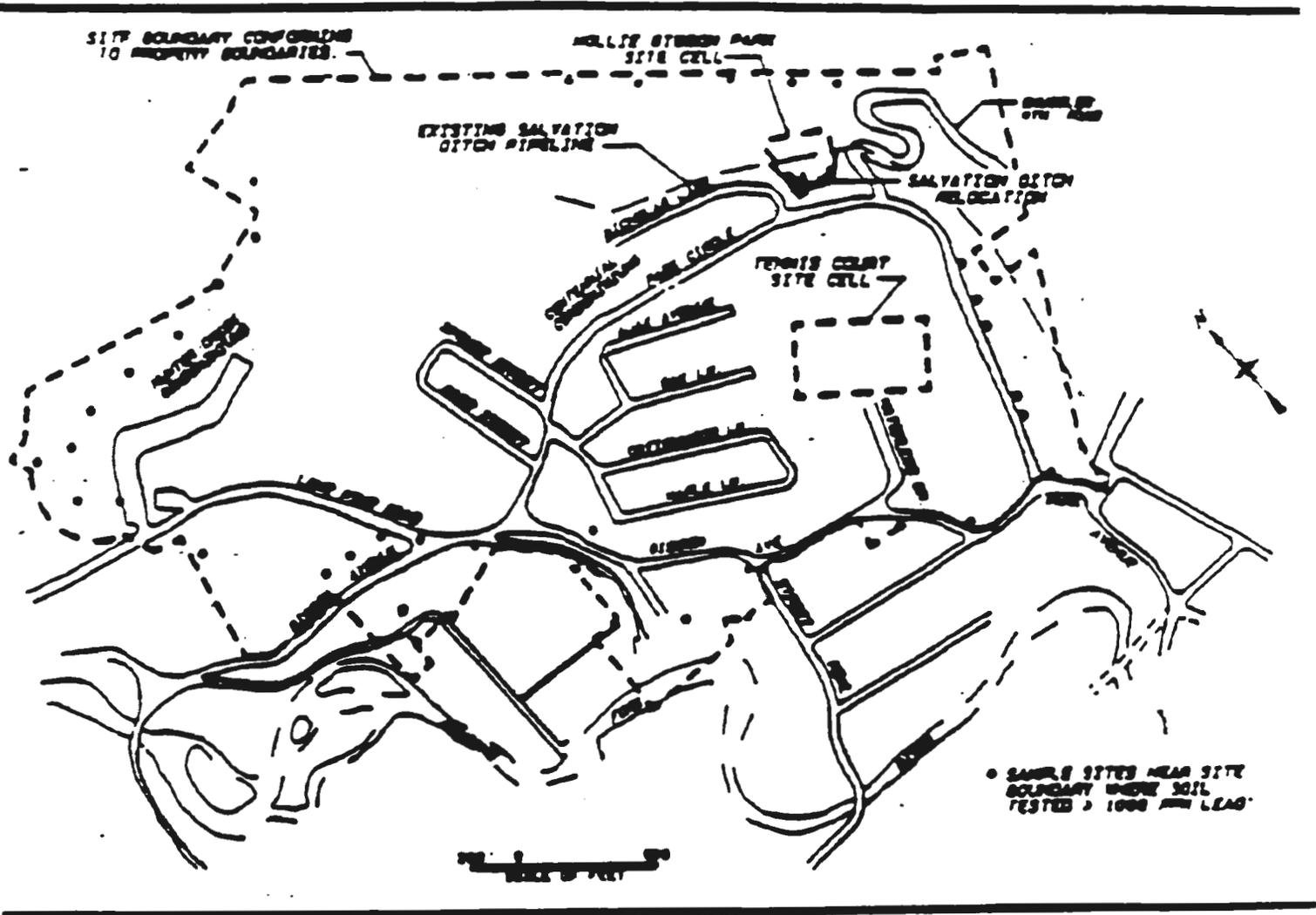


FIGURE 1. SMUGGLER MOUNTAIN SITE VICINITY MAP

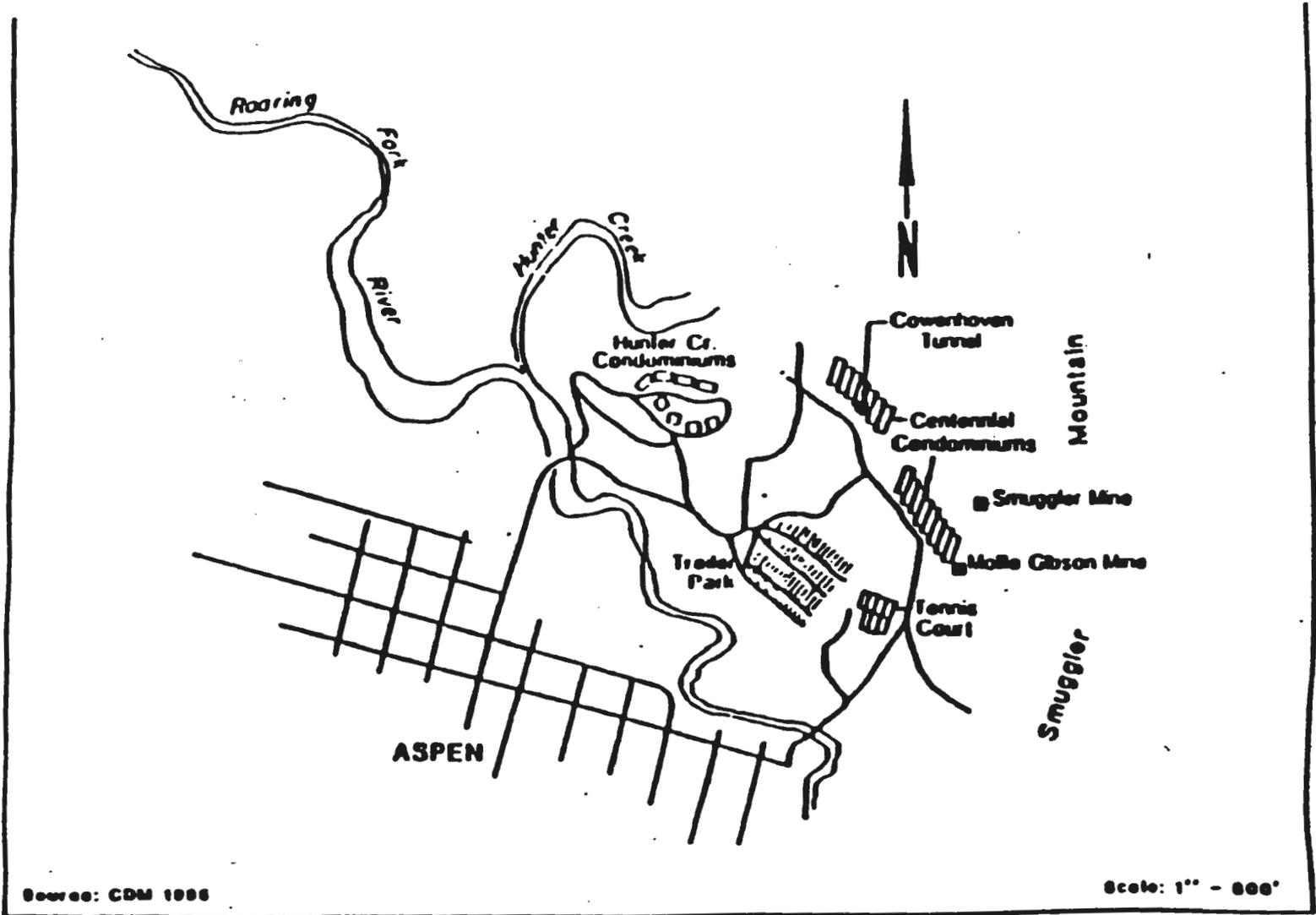


FIGURE 2. PRESENT SITE FEATURES

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Smuggler Mountain

page 1). The residential properties consist of two large condominium complexes, two mobile home parks, several small condominium developments (4 to 12 units), approximately 25 to 30 homes, and a tennis club (see Figure 1) (Reference 4, page 1; Reference 1, Summary of Remedial Alternative Selection, Section A).

EPA added the site to NPL in May 1986. The Operable Unit 1 Remedial Investigation/Feasibility Study was completed by the Potentially Responsible Party (PRP) in early 1986 and amended by EPA in the same year. Using the Remedial Investigation data, EPA prepared an Endangerment Assessment. The Superfund Enforcement Decision Document, signed on September 29, 1986, describes the remedial actions to be taken at the site (Reference 1, Abstract and Cover Memorandum). Subsequent sampling (in 1988) prompted EPA to change the selected remedy for Operable Unit 1 and postpone re-evaluating the remedy for Operable Unit 2 until a Remedial Investigation/Feasibility Study was completed (Reference 3, page 5).

OPERATING HISTORY

In the late 1800's and early 1900's, mining companies ran extensive silver, lead, and zinc mining, milling, and smelting operations onsite. Although several small operations started and stopped after 1930, records indicate that the bulk of the mining wastes at the site were placed on the steep slope of the western side of Smuggler Mountain near the Smuggler shaft from 1880 to 1915. In the mid-1960's, a reprocessing facility was run on the site, causing the dispersion of the wastes from the relatively distinct piles at the mine shaft to other locations throughout the site. Also, a number of settling ponds were created around the site during reprocessing. The wastes were dispersed further by subsequent residential development (Reference 1, Site History, Section B; Reference 2, page 2-1).

Mine wastes, such as waste rock, tailings, and slag, comprise much of the site. It is estimated that approximately 2.4 million cubic yards of these waste materials were generated at the site; however, volume estimates are uncertain and have been difficult to determine (Reference 5, page 2-3). The wastes have been spread over a wide area and at depths varying from 1 or 2 to 40 feet. They occur covered, uncovered, or mixed with native soil, and they contain high concentrations of lead and cadmium, among other constituents (Reference 1, Site History, Section B; Reference 5, pages 2-1, 2-3, and 2-6).

SITE CHARACTERIZATION

Soils, surface water and sediments, ground water, and air at the site were sampled by the PRPs and EPA to define the extent of contamination. The site is characterized by high concentrations of lead, cadmium, and zinc, as well as elevated concentrations of arsenic, barium, copper, manganese, silver,

and mercury (found in tailings and other mining wastes). Tables 2 through 9 in the attached Reference 1 present the concentration levels of these and other constituents in each medium (Reference 1, Current Site Status, Section C). The following sections characterize each medium (soils, surface water, sediments, ground water, and air). According to EPA Region VIII, the available air, ground-water, and surface-water data has not provided a complete characterization of contamination for those media.

Soils

The site, for purposes of action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), was defined as those areas having surface contamination of lead at concentrations over 1,000 ppm. Figure 1 outlines the most recent site boundary determined by extensive surface and subsurface soil sampling and testing. Soil-sample analyses indicated that all tailings materials, or materials which contained mine tailings, had levels greater than EPA's action level of 1,000 ppm (Reference 2, page 1-3; Reference 3, page 4).

Several soil sampling projects have been completed. Sampling was conducted downslope from the tailings piles in 1983 by Ecology and Environment. Results found elevated levels of arsenic, barium, cadmium, copper, lead, manganese, and zinc (levels not provided) (Reference 2, page 2-6).

Four soil types were sampled during the 1986 Remedial Investigation/Feasibility Study:

- Mine Tailings - By-products of Smuggler silver/lead mine operations
- Man-made Fill - Material used as fill that contains some mine tailings usually identified by its gray to black color
- Fill - Soil used as fill, which may include dirt, stone, brick, slag, glass, etc., but does not contain mine tailings
- Native Soil - Undisturbed, natural soil varying from alluvial terrace deposits to glacial drift and colluvium.

Both mine tailings and man-made fill were considered to be contaminated with lead at concentrations greater than 1,000 ppm. Each sample of fill and native soil had lead levels below 1,000 ppm (Reference 1, Current Site Status, Section C; Reference 2, pages 1-3, 3-5, and 3-6). The average

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lead values for surface samples and subsurface samples collected for the 1986 Remedial Investigation/Feasibility Study are presented in Table 1 below (Reference 2, page 4-13).

TABLE 1. AVERAGE LEAD CONCENTRATIONS IN SOILS

	Surface (in ppm)	Subsurface (in ppm)
Mine Tailings	10,477	7,923
Man-made Fill	—	2,985
Fill	546	520
Native Soil	443	452

Cadmium is also of concern due to its toxicity. Laboratory analyses showed that all samples with a high lead content also contained significant amounts of cadmium; samples that exhibited low lead also exhibited low cadmium (Reference 2, pages 5-1 and 5-2).

According to EPA Region VIII, 1,000 soil samples were collected from various depths (the surface to approximately 4 feet) in the residential and commercial areas built on tailings in 1988. The samples were analyzed using X-ray Fluorescence (XRF). However, the most extensive soils sampling program took place in 1990. At that time, over 3,300 samples were collected from over 1,100 sample locations. Three samples were extracted from each location at defined depths: 0 to 2 inches, 2 to 6 inches, and 6 to 12 inches. XRF was used to analyze the samples for lead. Soil lead concentrations were found to range from 0 to 107,000 ppm. The geometric mean of all lead samples collected during the 1990 sampling was 6,577 ppm. Table 2 provides a percentage breakdown by lead concentration of all samples collected in 1990 (Reference 8).

**TABLE 2. LEAD CONCENTRATIONS IN SOILS
PERCENTAGE OF SAMPLES BY CONCENTRATION
RANGE**

Lead Concentration (in ppm)	Percentage of Samples
0 - 500	49
500 - 1,000	16
> 1,000	35

Surface Water and Sediments

The Roaring Fork River is approximately 1,000 feet downgradient to the southwest of the site. There are no major, natural drainage channels crossing the site; however, two small- to moderate-sized basins located to the east and northeast affect site drainage. Hunter Creek (see Figure 2) passes approximately 500 feet to the north of the site. The Salvation Ditch (see Figure 1), an irrigation canal, surfaces on the northern part of the site from a buried pipe. Drainage at the site occurs largely as runoff although channelization of mine-drainage water, such as from the Mollie Gibson Mine shaft and the Cowenhoven Tunnel, which both traverse the site, is apparent (see Figure 2).

Samples taken in 1983 showed that Total Dissolved Solid (TDS) concentrations ranged from 540 milligrams per liter (mg/l) for the Mollie Gibson drainage to 918 mg/l for the Cowenhoven Tunnel (which discharge to the Roaring Fork River and Hunter Creek, respectively) (Reference 2, page 2-4).

Roaring Fork River was sampled in 1983, and barium, iron, manganese, and zinc were detected at levels within the compliance range for Federal and State ambient water quality standards. Stream sediments were also sampled. Based on the available data, it was concluded in the Enforcement Decision Document that onsite contaminants were not mobile enough to cause a substantial increase in the levels of metals in surface water and surface-water sediments (Reference 1, Current Site Status, Section C). Results of the Remedial Investigation indicated that the existing surface-water system, including Cowenhoven and Mollie Gibson drainages, Hunter Creek, and the Roaring Fork River, has not been contaminated by onsite tailings (Reference 6, page 21).

Although the Enforcement Decision Document's abstract mentioned that the City of Aspen obtains drinking water from surface waters in the area, no further mention was made of drinking-water sources, and no indication was given of any associated concern. This is most likely because surface-

Smuggler Mountain

water samples were within Federal and State standards for the metals of concern (Reference 1, Abstract).

Ground Water

Ground water beneath the Smuggler site occurs in both unconsolidated surficial deposits and within the underlying sedimentary bedrock strata. The bedrock has extensive faulting and fracturing, which control the occurrence and flow of ground water in undisturbed strata. It is likely that the ground-water flow within the aquifers is also complicated by underground mine workings. The bedrock ground-water system is not of great concern because of the limited existing and potential future use. Current water resources are from the alluvial aquifer of the Roaring Fork River Valley; the only concern relative to the aquifer underlying the site is whether it recharges the alluvial aquifer. Based on existing knowledge of the site, the alluvial system recharge is provided from the Cowenhoven and Mollie Gibson adits, not the bedrock ground-water system (Reference 6, page 11).

The unconsolidated surficial aquifer is in direct communication with the ground water in the alluvium of the Roaring Fork Valley and is, therefore, of greater concern than the bedrock ground water (Reference 6, pages 11 and 12). Investigations indicate that there is no alluvial ground-water system underneath the tailings at the site (Reference 2, page 2-4).

Prior to 1985, contamination was found in private wells drawing from the alluvial aquifer; however, it could not be determined if it resulted from the natural condition of the nearby bedrock, the heavy metal-laden tailings at the Smuggler site, or (as alleged by some PRPs) the lead solder in the water pipes. A 1985 Focused Feasibility Study (focusing on ground-water contamination) concluded that the risk associated with the ground-water medium was moderate. However, largely insoluble heavy metals may be leached by infiltrating rainfall, and the ground water could contribute to the contamination of surface water through the interface between alluvial ground water and the surface waters in the Roaring Fork River and Hunter Creek (Reference 5, pages 3-2 and 3-4).

Concern over the contamination of ground water onsite and offsite from tailings leachate was expressed in the 1986 Remedial Investigation/Feasibility Study. However, acid/base balance studies determined that the buffering capacity of the natural soils would most likely prevent acid mine drainage problems (Reference 2, page 1-4).

Seven existing private wells and eight newly installed monitoring wells were sampled between 1983 and 1986. The potential ground-water problem was indicated by elevated levels of cadmium, zinc, uranium, and gross alpha. Elevated levels of cadmium were noted in two private wells and two EPA

monitoring wells. Cadmium in one EPA monitoring well was near EPA's Maximum Contaminant Level (MCL) of 0.01 mg/l. Uranium and gross alpha were found to be elevated in two monitoring wells, and zinc concentrations were highest in a private well. PRPs have postulated that despite the abundance of calcium carbonate in the host rock, leaching could occur in localized pockets of mineralized materials if derived from the core of the mineralized zone. Results indicated that lead and arsenic are not ground-water contaminants (Reference 1, Current Site Status, Section C).

During the Remedial Investigation/Feasibility Study, selected ground-water samples were analyzed for radium-226, gross alpha, and uranium because of the potential for elevated concentrations of radioactivity. Results indicate that gross alpha concentrations do not exceed MCLs under the Safe Drinking Water Act [set at 15 pico Curies per liter (pCi/l)]. Uranium values, however, exceed the Colorado guidance level of 10 pCi/l (about 0.015 mg/l) (see Table 3). In addition, samples in two wells were found to have substantially high levels of uranium and gross alpha, which is consistent with the wells showing higher TDS and trace-metal concentrations. Because radioactivity appears to be associated only with the tailings, it is believed that leaching of tailings is occurring (Reference 6, Table 1). It was recommended in the Addendum to the Remedial Investigation/Feasibility Study that monitoring for radionuclides should continue (Reference 6, pages 12 through 15).

Air

Air samples were taken from onsite and background locations in 1985. Levels of arsenic, cadmium, lead, and zinc in the air onsite were elevated as compared to background. Only cadmium and arsenic were found to be present at levels above the proposed National Emissions Standards for Hazardous Air Pollutants (Reference 1, Current Site Status, Section C). No additional information was provided in the references concerning air quality.

ENVIRONMENTAL DAMAGES AND RISKS

The site was first identified in 1981 when research into crop uptake of trace metals indicated a potentially serious problem with the uptake of lead and cadmium by vegetables grown on regraded mine and mill tailings (Reference 7, page 1).

Presently, the potential for human exposure exists through direct contact of soils and inhalation of contaminant-laden dusts by people onsite as well as those in nearby residential areas. The risk of ingesting drinking water contaminated by site soils also exists, although due to site conditions (i.e., soil and pollutant characteristics), the potential for exposure is significantly reduced (Reference 2, page 5-2).

TABLE 3. GROUND-WATER ANALYSES FOR FEBRUARY 1986

Parameter	Units	Well Number					
		GW-1	GW-5	GW-7	GW-8	GW-9	GW-10
Arsenic	mg/l	ND	Dry	ND	ND	ND	ND
Cadmium	mg/l	ND	Dry	0.010	ND	ND	ND
Calcium	mg/l	46.5	Dry	168.0	22.3	120.0	136.0
Iron	mg/l	0.034	Dry	0.121	0.026	0.022	0.086
Lead	mg/l	ND	Dry	ND	ND	ND	ND
Magnesium	mg/l	14.5	Dry	53.9	6.2	41.2	39.5
Manganese	mg/l	0.025	Dry	0.226	0.05	ND	0.174
Potassium	mg/l	0.95	Dry	2.43	ND	1.49	1.64
Sodium	mg/l	19.4	Dry	4.95	0.93	3.97	6.19
Zinc	mg/l	0.020	Dry	1.44	0.065	0.460	0.066
Oil and Grease	mg/l	1.1	Dry	2.2	1.4	ND	ND
TOC	mg/l	15.0	Dry	2.1	4.6	4.9	1.7
Chloride	mg/l	29.0	Dry	ND	ND	ND	30.0
Sulfate	mg/l	111.0	Dry	215.0	30.0	313.0	220.0
Bicarbonate	mg/l	54.0	Dry	180.0	49.0	162.0	199.0
TDS	mg/l	280.0	Dry	905.0	95.0	625.0	625.0
Radium-226	pCi/l	0.04 ± 0.02	Dry	0.45 ± 0.02	0.21 ± 0.01	0.34 ± 0.02*	0.37 ± 0.02
Gross Alpha	Pci/l	3.0	Dry	140.0	4.0	120.0*	17.0
Uranium	mg/l	0.0024	Dry	0.310	0.00021	0.230*	0.036

Validation criteria qualifiers pertain to some data and are included in REM II files.

- Duplicate values:
- Radium-236 0.36 ± 0.02
- Gross alpha 100
- Uranium 0.210

Source: CDM, 1986

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Lead and cadmium are the two metals of most concern at the site due to their elevated concentrations at the site and acute toxicities. Lead exposure is of specific concern to children, who have the greatest risk of exposure through soil ingestion and a greater susceptibility to blood lead poisoning. It should be noted that toxic effects of lead ingestion in children from lead-based paints (i.e., elevated blood levels) have been documented, but exposure to lead in tailings and soil such as those at the Smuggler site has not been documented (Reference 2, page 2-7).

Cadmium can also be acutely toxic, and cadmium compounds are generally more bioavailable than lead compounds. A ground-water sample in one well at the site (on one occasion) had a cadmium concentration of 13 micrograms per liter ($\mu\text{g/l}$), which exceeded the ambient water quality standard of 10 $\mu\text{g/l}$. The well was checked again and found to be less than 10 $\mu\text{g/l}$ (Reference 2, page 2-7). Studies have also shown that cadmium may be carcinogenic to humans, has chronic effects on the kidneys, and may affect human reproduction. Plants, including leafy green vegetables and root crops, are subject to uptake of cadmium from contaminated soils. Ingestion of such vegetables may cause exposure of humans to cadmium (Reference 4, page 2).

The metals found at the site are relatively insoluble due to the relatively neutral pH (6.38 to 7.22) of the tailings, soil, and bedrock materials. The insolubility of the metals decreases their bioavailability and, therefore, their toxicity (Reference 2, pages 2-7 and 2-8).

REMEDIAL ACTIONS AND COSTS

The Smuggler Mountain site was added to the NPL in May 1986. The Enforcement Decision Document describing the final remedial action for Operable Unit 1 was signed on September 29, 1986. There are two Operable Units: (1) residential areas, including the site of a repository at the Mollie Gibson Park; and (2) the Smuggler Mine site. The remedy for the first Operable Unit, as decided in 1986, was separated into 5 components: (1) source isolation of high-lead wastes; (2) source isolation of low-lead wastes; (3) increased ground-water monitoring; (4) alternative water supply; and (5) operation and maintenance of low- and high-lead waste caps. The remedy for Operable Unit 2 is mine reclamation and possible ground-water corrective action (Reference 1, Cover Memorandum).

During the design of the remedy presented in the 1986 Decision Document, additional soil sampling was conducted to determine the necessary capacity for the onsite repository. The results of this sampling, which was conducted in 1988, indicated that the remedy selected in 1986 for Operable Unit 1 needed to be changed because it was unreasonable to separate remediation by level of

Smuggler Mountain

contamination, as the levels were so interspersed. According to EPA Region VIII, in 1990, additional sampling was conducted to determine final design requirements. The final remedial actions to be conducted at the site, decided in 1990, are presented below (Reference 3, pages 2, 3, and 5; Reference 4, pages 1 and 2).

The revised remedy consists of four major elements: (1) onsite repositories; (2) clean-up of individual residential properties; (3) remedial action at Hunter Creek & Centennial Condominiums; and (4) institutional controls. In general, the minimum requirements for the site remedy are that the top 1 foot of soil must not show lead contamination levels greater than 1,000 ppm, and that there is a healthy vegetative cover, a paved driving area, raised garden beds, and limited access under homes, decks, and similar structures (Reference 3, pages 5 through 12).

Onsite Repository

Two onsite repositories will be constructed to serve as the primary locations for disposal of contaminated soil/tailings excavated during the residential clean-up. These repositories will be located at the Racquet Club (with a design capacity of 9,000 cubic yards) and the Mollie Gibson Park site (with a design capacity of 45,000 cubic yards) (Reference 8). The park repository will also serve as the "open" repository for disposal of contaminated soil/tailings displaced due to property development within the site boundary subsequent to clean-up. The Salvation Ditch irrigation pipeline (see Figure 1), which passes through the Mollie Gibson Park site, is currently being relocated to accommodate the repository. Additionally, the clean fill and topsoil used as cap material for the repository will have lead concentrations of 250 ppm or less. The Smuggler Racquet Club property is the proposed location of this repository (Reference 3, pages 5 through 7).

Clean-up on Individual Residential Properties

Properties with soil lead concentrations above 1,000 ppm will be fully remediated using a geo-textile liner covered with foot of clean fill and topsoil and a vegetative cover to minimize erosion. The geo-textile liner is used to prevent mixing of the contaminated materials with the clean fill. Properties with soil-lead concentrations of less than 1,000 ppm may require some remedial action to meet the minimum requirements of the remedy as described above (Reference 3, pages 7 through 9).

Remedial Action at Hunter Creek and Centennial Condominiums

The proposed remedy at the condominiums is similar to the remedy for the individual properties, except that 6 inches of clean topsoil and a vegetative cover will be required to minimize erosion for all areas not paved or covered by permanent structures. A geo-textile liner covered with 1 foot of clean soil will be required for all existing (and any new) play areas because of the threat of lead exposure to children. One foot of clean sand over the geo-textile liner and the 1-foot soil cover may be substituted for a vegetative cover (Reference 3, pages 9 and 10).

Institutional Controls

"Institutional Controls" refers to administrative requirements adopted by governing bodies to require or prohibit certain types of activities. In this case, they will include various measures to maintain the integrity of the soil and vegetative cover. For example, notices to future owners of properties on the site will advise them of the need to maintain the vegetative cover on their property. County ordinances can also serve as institutional controls (Reference 3, pages 10 through 12).

For Operable Unit 2, the 1986 decision listed mine reclamation and ground-water remediation as the remedies. The final decision for Operable Unit 2 requires completion of a Remedial Investigation/Feasibility Study to characterize the wastes and determine the appropriate extent of the remedy at the Smuggler Mine site in accordance with the National Contingency Plan (Reference 1; Reference 4). Note that in the 1985 Focused Feasibility Study, a preferred action for ground-water remediation was presented. This included criteria for technical effectiveness, safety, and public acceptance. In the 1990 remedy, however, ground-water remediation was excluded from the remedy for Operable Unit 1. It is expected that ground-water remediation will be included in the remedial action for Operable Unit 2, subsequent to completion of the Remedial Investigation/Feasibility Study (Reference 5, page 1-3; Reference 3). In the 1990 remedy, the estimated cost of site remediation is \$7.2 million (Reference 4, page 15).

Smuggler Mountain

CURRENT STATUS

Operable Unit 1 is presently in the Remedial Design/Remedial Action phase of clean-up. Extensive soil sampling was conducted to identify the percent of lead in the soil. The design team is working with homeowners on remediation. Of 160 residents, 158 have voluntarily participated in EPA's plans. A demonstration project, including the remediation of soil at approximately nine homes, was to begin in mid-July 1990, to demonstrate how EPA would remediate the soils. The project was modified because Pitkin County would not allow access to the disposal site until a Consent Decree was established; however, EPA was able to conduct the demonstration project on two properties in September and October 1990. The completion of the Salvation Ditch irrigation pipeline relocation project is scheduled for June 1, 1991. Further work on Operable Unit 2 has not yet been scheduled (Reference 8).

REFERENCES

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2. Remedial Investigation/Feasibility Study, Smuggler Mountain Site; Fred C. Hart Associates, Inc.; March 1986.
3. Soil Clean-up of Smuggler Mountain Site, Aspen-Pitkin County, Colorado, Explanation of Significant Differences; EPA Region VIII; March 1989.
4. Soil Clean-up of Smuggler Mountain Site, Aspen-Pitkin County, Colorado, Explanation of Significant Differences; EPA Region VIII; May 16, 1990.
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7. Potential Hazardous Waste Site Identification and Preliminary Assessment, Smuggler Mine Site; EPA Region VIII; March 31, 1984.
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Smuggler Mountain

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Reference 1

Excerpts From Superfund Enforcement Decision Document:
Smuggler Mountain Co., EPA/ROD/RO2-86/037;
EPA; September 1986

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Superfund Enforcement Decision Document:

Smuggler Mountain, CO



TECHNICAL REPORT DATA

(Please read instructions on the reverse before completing)

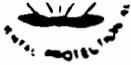
1 REPORT NO. EPA/ROD/RO8-86/005		2.	3 RECIPIENT'S ACCESSION NO.	
4. TITLE AND SUBTITLE ENFORCEMENT DECISION DOCUMENT Smuggler Mountain, CO			8 REPORT DATE September 26, 1986	
			9 PERFORMING ORGANIZATION CODE	
7 AUTHOR(S)			8 PERFORMING ORGANIZATION REPORT NO.	
9 PERFORMING ORGANIZATION NAME AND ADDRESS			10 PROGRAM ELEMENT NO.	
			11 CONTRACT/GRANT NO.	
12 SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency 401 M Street, S.W. Washington, D.C. 20460			13 TYPE OF REPORT AND PERIOD COVERED Final ROD Report	
			14 SPONSORING AGENCY CODE 800/00	
15 SUPPLEMENTARY NOTES				
16 ABSTRACT <p>The Smuggler Mountain site is located immediately northeast of the City of Aspen in Pitkin County, CO. It comprises 110 acres of waste rock, tailings, and slag containing high levels of lead and cadmium. The site is in close proximity of Aspen, CO which has a year-round population of 4,500. In many cases, development in the Aspen area has taken place directly over waste piles, or waste piles have been moved to the sides of developed areas and remain as berms or mounds of contaminated soil. Portions of contaminated soil have also been used for fill in some areas. The City of Aspen obtains drinking water from surface waters in the area. The Roaring Fork River passes the site approximately 1,000 feet downgradient to the southwest, and is the nearest surface water. The mining wastes which characterize the site are the result of years of extensive mining, milling and smelting operations. As a result, wastes are highly dispersed, and little is known about their disposition. Soil is the primary contaminated medium; however, contaminants have been detected in some ground and surface waters.</p> <p>The selected remedial action for the site is broken into two distinct operable units. Operable Unit 1 - excavation and permanent onsite disposal of soils with lead above 5,000 ppm, including a RCRA multi-layer cap; soil capping of all areas with lead between 1,000 and 5,000 ppm lead; five-year ground water monitoring; and provision of a (See Attached Sheet)</p>				
17 KEY WORDS AND DOCUMENT ANALYSIS				
a DESCRIPTORS		b IDENTIFIERS, OPEN ENDED TERMS		c COSATI Field Code
Enforcement Decision Document Smuggler Mountain, CO Contaminated Media: soil, gw Key contaminants: heavy metals, lead, cadmium, zinc				
18 DISTRIBUTION STATEMENT		19 SECURITY CLASS. This Report		21 NO OF PAGES
		None		22
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EPA/ROD/RO8-86/005
Smuggler Mountain, CO

16. ABSTRACT (continued)

permanent alternate water supply for 5-7 residences. Operable Unit 2 - supplemental RI/FS, with possible ground water remediation and mine reclamation activities. Estimated capital cost of the remedy is \$1,816,550 with annual O&M costs of \$30,900.



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
ONE DENVER PLACE - 999 18TH STREET - SUITE 1300
DENVER, COLORADO 80202-2413

ENFORCEMENT DECISION DOCUMENT
REMEDIAL ALTERNATIVE SELECTION

SITE

Smuggler Mountain
Pitkin County, Colorado

DOCUMENTS REVIEWED

I am basing my decision primarily on the following documents describing the analysis of the cost and effectiveness of remedial alternatives for the Smuggler Mountain Site:

- Smuggler Mountain Remedial Investigation/Feasibility Study
Fred C. Hart Associates; March 1986
- Smuggler Mountain Endangerment Assessment
Clement Associates, May 1986
- Smuggler Mountain Focused Feasibility Study
Fred C. Hart Associates, July 1985
- Smuggler Mountain Addendum to Remedial Investigation/Feasibility Study
Camp, Dresser and McKee, May 1986
- Hunter Creek Soils Investigations and Corrective Measure Recommendations
Engineering Science, 1985
- Final Technical Oversight Report, Activities 11/84 - 3/86, for the
Smuggler Mountain Site
Camp, Dresser and McKee, August, 1986
- Issues Abstract for Smuggler Mountain Enforcement Decision Document,
Clemens, September 1986

DESCRIPTION OF SELECTED REMEDY

I have carefully reviewed and considered all the information, the alternatives analysis, and the public comments pertaining to the selection of a remedy for the Smuggler Mountain Site. Based on my review, I have determined that the following actions at the Smuggler Mountain Site will effectively mitigate and minimize damage to and provide acceptable protection of the public health, welfare, and the environment. This determination is made by the Regional Administrator of Region VIII consistent with the delegation of authority for remedy selection dated May 6, 1986.

450

The selected alternative is separated into two operable units. The first operable unit addresses the Smuggler site and does not include the reclamation of the actual Smuggler Mine portion of the site. A second operable unit will address the mine reclamation work and will consider ground- and surface-water response actions if the results of ground water monitoring during the first operable unit indicate that such actions are appropriate.

Operable Unit 1 - Site Remedy:

A. Source Isolation of High-Level Wastes.

Create an on-site repository on County-owned property to permanently dispose of the high-level wastes (over 5,000 ppm lead) excavated from the site. The repository will be under the perpetual care of a permanent entity, Pitkin County, to assure the permanent disposition of the contaminants. Consolidate all high level wastes from the site (excluding the mine site) in the repository. Cap the repository with a multi-layer, stable cap that meets RCRA performance standards for in-place closure (40 CFR Part 264, Subpart N).

B. Source Isolation of Low-Level Wastes.

Isolate all low-level wastes (defined as areas with soil lead concentrations of between 1,000 and 5,000 ppm lead) by capping in place with 6-12 inches of clean topsoil and revegetating.

C. Increase Ground-Water Monitoring.

Monitor ground water quarterly on-site for a period of five (5) years to determine efficacy of the caps in enhancing ground-water quality. Quarterly reports to EPA will describe the results of monitoring and note any trends observed. Monitoring results and reports will be used to determine if further response actions are required.

D. Alternate Water Supply.

Provide a permanent, alternate, water supply by closing ground-water wells for 5-7 residences and connecting the residences to the existing public water supply.

E. Operation and Maintenance of Low- and High-Level-Waste Caps.

Periodically inspect caps to note and repair any deterioration, disturbance, or discontinuity to prevent cap failure. Weekly inspections are anticipated during the first year. Bi-monthly inspections will take place for the second year. After two years, inspections will be conducted monthly. From the beginning of the fourth year, quarterly inspections will be conducted for the next twenty-six years.

Operable Unit 2 - Mine Reclamation and Possible Ground-Water Corrective Action:

A. Addendum to Remedial Investigation and Feasibility Study (RI/FS).

An addendum to the existing RI/FS will be prepared to characterize the nature and extent of contamination and determine the appropriate extent of remedy at the Smuggler-Durant Mine site. This addendum will be

pared in accordance with the National Contingency Plan. The Smuggler Mine RI/FS will be subject to public comment prior to selection of a remedy.

B. Possible Ground-Water Corrective Action.

Current water quality data do not justify action, and ground-water conditions are expected to improve after operable unit one is implemented. However, ground-water monitoring results from the first operable unit will be used to determine if ground-water response actions need to be implemented. This determination will be made in a subsequent decision document.

C. Performance of Remedy.

Perform remedy as approved by EPA in a subsequent decision document. Such remedy will include reclamation of the mine site and, if determined to be necessary, ground-water corrective action.

DECLARATIONS

Consistent with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), 42 U.S.C. section 9601 et seq., and the National Contingency Plan (40 C.F.R. Part 300), I have determined that the selected remedy at Smuggler Mountain is cost-effective and consistent with a permanent remedy that provides adequate protection of public health, welfare, and the environment. I also have determined that the action being taken is a cost-effective alternative when compared to the other remedial options

viewed. The State of Colorado has been consulted on the selected remedy. The action will require future operation and maintenance activities to ensure the continued effectiveness of the remedy. These activities will be considered part of the approved action. EPA has not reached agreement with the responsible parties at the site to implement the selected remedy.

Ground water quality will continue to be monitored on site. Subsequent response action will be considered if the monitoring shows increasing contamination.

The EPA or the potentially responsible parties for the Smuggler-Durant Mine area of the site will conduct an additional RI/FS to further characterize the extent of contamination at that portion of the site, and will undertake further response actions as determined to be necessary by EPA in a subsequent decision document.

John G. Welles
Regional Administrator
Region VIII

TO BE SIGNED ON SEPTEMBER 29, 1986

NOT
SIGNED
Blake's getting a
signed copy

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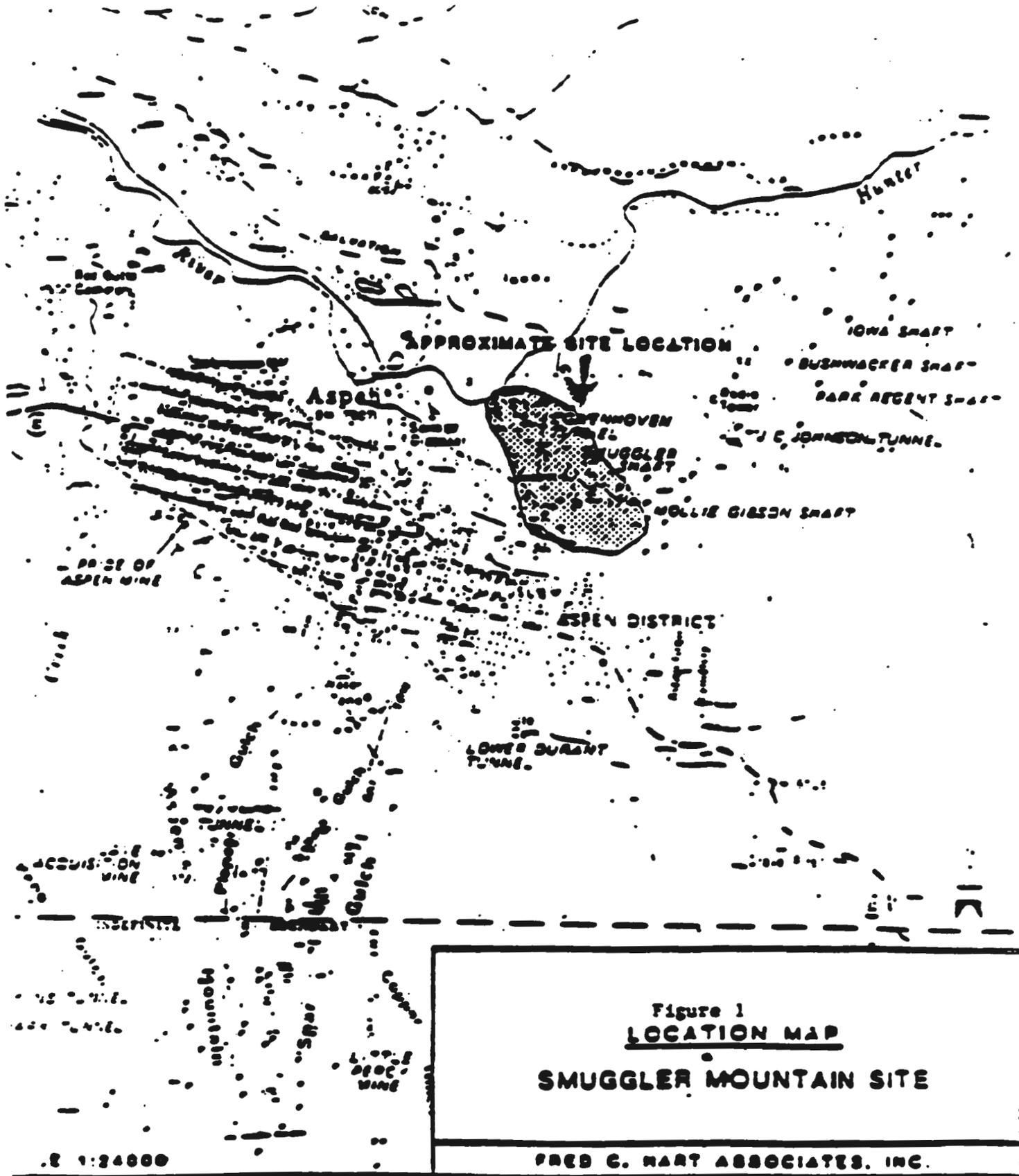
SUMMARY OF REMEDIAL ALTERNATIVE SELECTION

A. SITE LOCATION AND DESCRIPTION

The Smuggler Mountain Site is located immediately northeast of the City of Aspen in Pitkin County, Colorado. The location of the site is shown on Figure 1. Beginning with the old Smuggler-Durant mine workings located high on the steep slope of the western side of Smuggler Mountain, the site grades into the gentler slopes and terraces to the west-southwest towards the City. Present site features are shown on Figure 2. Site elevation ranges from 7,930 to 8,160 feet above mean sea level. The site has been significantly altered over the years by extensive commercial and residential development. Mine wastes, such as waste rock, tailings, and slag, comprise much of the site. The wastes occur either covered, uncovered, or mixed with native soil and contain high levels of minerals containing lead and cadmium, among other constituents. Through the Endangerment Assessment (EA) process, EPA has established a site boundary based upon a 1,000 milligrams per kilogram (mg/kg) or parts per million (ppm) soil-contamination level in soils and mine wastes. This action level has been concurred upon by the Agency for Toxic Substances and Disease Registry (ATSDR) in their letter to EPA Region VIII of September 11, 1986. The State had recommended an action level of 500 ppm lead, but such a level was determined by ATSDR not to be appropriate. Accordingly, the 110-acre site is defined by a 1,000 ppm lead isopleth which is shown on Figure 3.

The site is in close proximity to the resort city of Aspen which has a year-round population of 4,500. Consequently, the site is comprised of both developed and undeveloped properties. In many cases, development has taken place immediately on top of waste piles, or such piles have been moved to the sides of developed areas and remain as berms or mounds of contaminated soil. Portions of the contaminated soil have been excavated, used for fill, or otherwise disturbed by grading, significantly altering the topography of the site over the years.

The Roaring Fork River passes the site approximately 1,000 feet downgradient to the southwest. Site drainage occurs largely as surface runoff with channelization from mine discharge water (the Mollie Gibson Mine Shaft discharges to the Roaring Fork River, and the Cowenhoven Tunnel discharges to Hunter Creek). Drainage is also affected by two moderately sized basins: Hunter Creek to the north; and the Salvation irrigation ditch, which transverses the site at an elevation of approximately 8,000 feet. The ground-water system at the Smuggler site is complex and not clearly defined. Ground water has been found to be present in both the sedimentary bedrock and in the unconsolidated surficial deposits. Flow in the sedimentary bedrock is characterized by secondary permeability, i.e., fractures and fault systems. Current ground-water use in the area is limited to some private wells that tap the alluvial aquifer of the Roaring Fork River Valley. The City of Aspen does not use the alluvial aquifer but uses surface water from other sources. Accordingly, the importance of the hydrology of the underlying sedimentary strata is restricted to its role in recharging the Roaring Fork alluvial system.



APPROXIMATE SITE LOCATION

Aspen

ASPEN DISTRICT

Figure 1
LOCATION MAP

SMUGGLER MOUNTAIN SITE

FRED C. HART ASSOCIATES, INC.

1:24000

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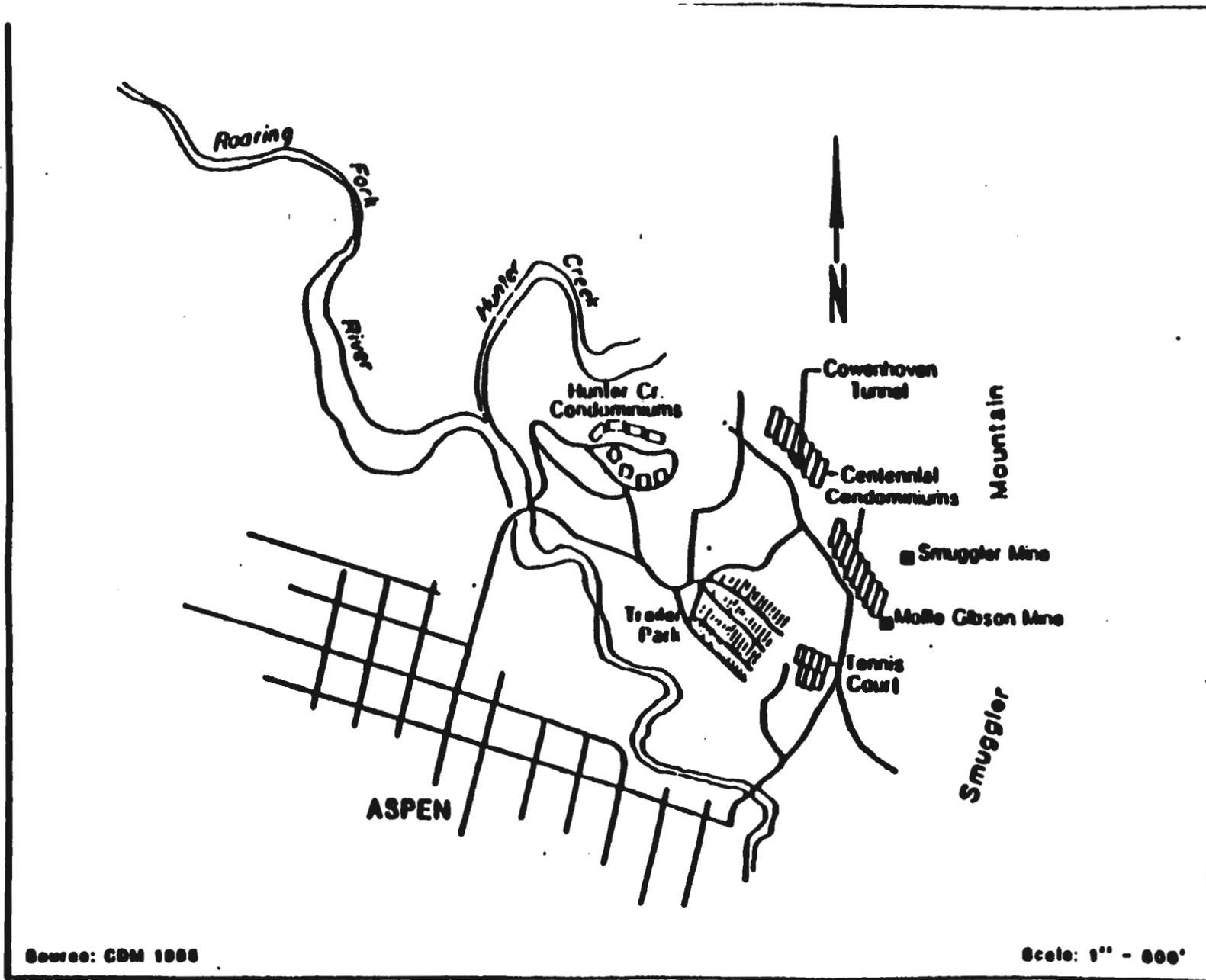
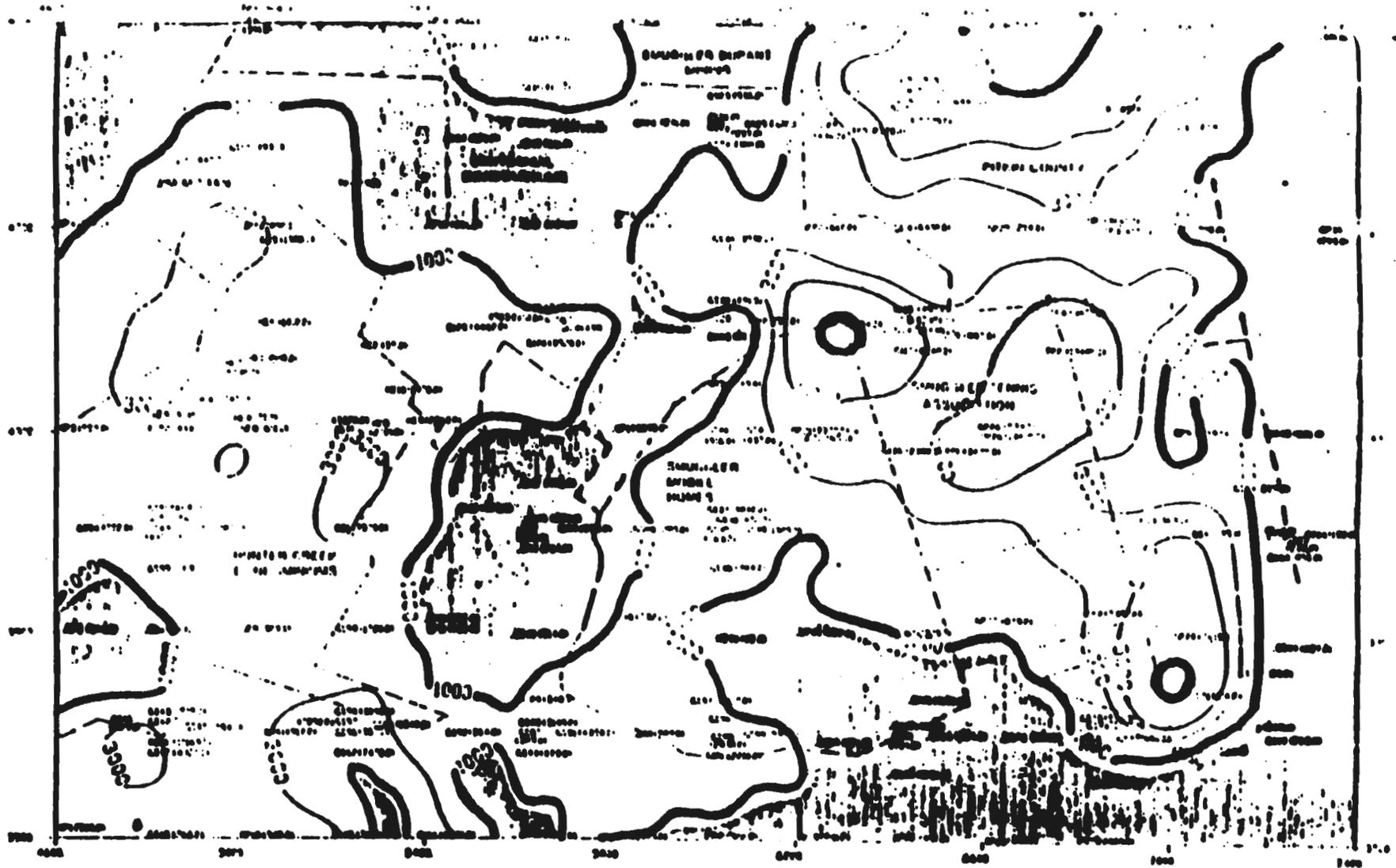


Figure 2 - Present Site Features

855

956



LEGEND

-  Less than 1000 ppm Pb
-  1000 ppm Pb Contour
-  3000 ppm Pb Contour
-  5000 ppm Pb Contour
-  10,000 ppm Pb Contour



Figure 3

**LEAD CONTAMINATION
IN PAVED SURFACES**

CONCENTRATIONS IN PPM
BASED ON SURFACE AREA
OF SURFACES



Scale 1:500
Graphic Courtesy of EPA

Software by Coastal Systems, Inc.

5. SITE HISTORY

The mining wastes which characterize the site are the results of years of mining, milling, and smelting operations. Mining companies ran extensive silver, lead, and zinc mining operations on-site in the late 1800's and early 1900's. Although several small operations started and ceased on the site after 1930, records indicate that the bulk of the mining wastes at the site were placed from 1880 to 1915 on the steep slope of the western side of Smuggler Mountain near the Smuggler Mine shaft. In the mid-1960's, a reprocessing facility was run at the site, causing the dispersion of the wastes from the relatively distinct piles at the mine site to other locations in the vicinity. The reprocessing also spawned a number of settling ponds around the site. The wastes were dispersed further by subsequent residential development.

From the time of the generation of the mining wastes to the present, the materials have been strewn and dispersed over a wide area and at varying depths from 1 or 2 feet to 40 feet. The relative toxicity of the remnants of the waste piles varies with the degree to which they are mixed with or covered by other materials (native soil, topsoil, etc.). Since the waste piles have been randomly dispersed, much of their disposition is unknown. The site is underlain by relatively permeable strata. Ground water and, ultimately, surface water may be affected by the percolation of precipitation through the mineralized waste materials.

A number of investigations have taken place at the site. Air quality, stream sediment, surface- and ground-water quality and soil/tailings data were collected in the vicinity of the Smuggler site by EPA and the Potentially Responsible Parties (PRPs) from June 1982 through June 1986. Analyses of soil and plant samples taken from the area in 1982 indicated elevated levels of trace metals (lead, cadmium) and called the site to the attention of local, State, and Federal authorities. At the request of Pitkin County environmental officials, the EPA Field Investigation Team (FIT) performed a sampling investigation at the site in 1983. The Smuggler site was proposed for the National Priorities List (NPL) in October 1984 and became final on the NPL in May 1986. On several occasions during 1981-1983, news releases, meetings, and other publicity issued by the Aspen Public Health Department advised local residents against a) the use of garden soils suspected to be derived from tailings and b) children playing in tailings (Dunlop 1986). Following negotiations with the identified PRPs in early 1985, EPA approved the PRPs' proposal to conduct the Remedial Investigation/Feasibility Study (RI/FS) with EPA retaining an oversight role.

EPA issued three orders pertaining to the site during 1985. In June, EPA issued a unilateral Administrative Order which names the property owners, describes the site and potential hazards, and requires that EPA be notified of and give approval for any movement of the soils or mining wastes in excess of one cubic yard. An Administrative Order on Consent was negotiated and signed by EPA and the PRPs in July 1985. This Order accepts the PRPs' RI/FS work

plans and sets forth other legally binding agreements to govern various site activities. EPA and the property owners also entered into a Consent Order in August to undertake a limited emergency action on the site in which the heavily contaminated area south of the mine and north of the tennis courts was isolated by installing a fence to prevent access, and signs were erected to warn the residents.

The final RI/FS was submitted to EPA in early 1986. EPA prepared an endangerment assessment based on the RI in May 1986, and an addendum to the RI/FS was prepared in June 1986. The data from these and other related studies are summarized on Table 1 and Figure 4.

C. CURRENT SITE STATUS

The total quantity of contaminated materials at the site has been estimated at approximately 410,000 cubic yards. The site is characterized by high concentrations of lead, cadmium, and zinc, as well as elevated concentrations of arsenic, barium, copper, manganese, silver, and mercury as found in tailings and other mining wastes. Three different media were sampled by the PRPs and EPA at the site to further define the extent of contamination. The results of the sampling are:

Soil Sampling. Field activities have concentrated on determining the extent of lead contamination. The initial site definition shown on Figure 5 was adopted as a FIT starting point for investigation when the site was proposed for the MFL in October 1984. The site definition was based on data from preliminary soil lead content values compiled by the FIT investigation. The emphasis of subsequent surface sampling programs conducted by the PRPs and EPA was to define the horizontal and vertical distribution of lead in the soil. A perpendicular grid system with 400-foot sampling intervals was adopted to provide field reference for sample locations, and soil sampling went as deep as 35 feet. The sampling grid is illustrated in Figure 6. A summary of the soil sampling activities is shown on Table 2. The initial FIT site definition was refined by the PRP efforts which distinguished the site by using four soil conditions, i.e., mine tailings, fill, man-made fill, and native soil. Both mine tailings and man-made fill were considered to be contaminated with lead at concentrations of over 1,000 ppm. Figure 7 illustrates the PRP site definition. The EPA contractor (Camp, Dresser & McKee) collected additional soil samples, conducted soil analyses, and defined the site in terms of the 1,000 ppm soil lead contour with the use of geostatistics. The resulting contour map (Figure 8), which also shows contours of higher levels of contamination, has been adopted as the site definition map by EPA and the PRPs.

Surface Water and Sediment Sampling. FIT conducted two surface water sampling efforts in the vicinity of the Smuggler Mine site. The sampling locations and the rationale for choosing them are shown on Table 3. A summary of the results of the surface water sampling efforts are shown on Table 4. Only barium, iron, manganese and zinc were detected in the river. In addition, the levels of these constituents found in the river

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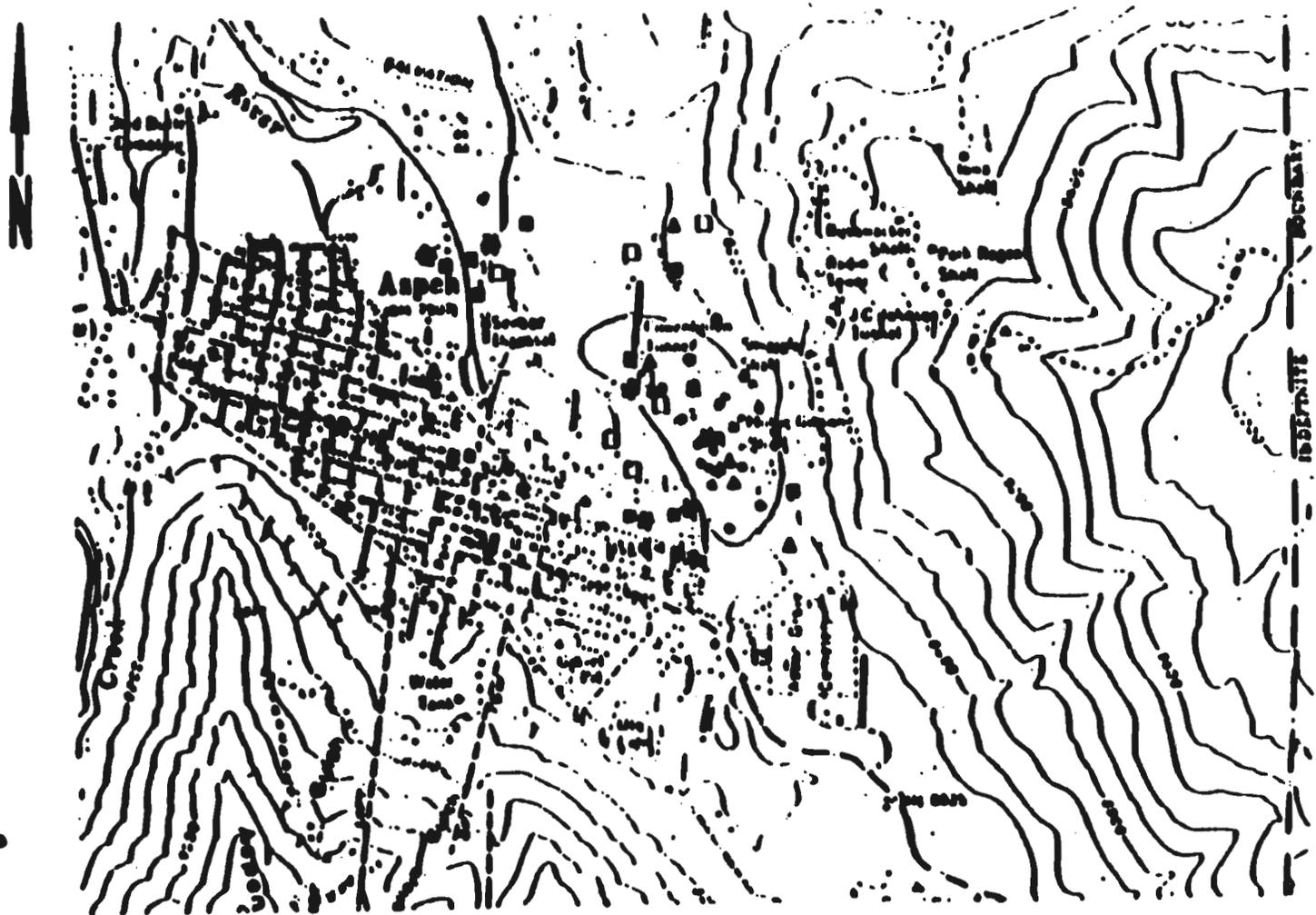
OVERVIEW OF HISTORIC DATA COLLECTION ACTIVITIES

Location and Collector	Sampling Period	No. of Samplers or Samples	Remarks
<u>Air Quality/Meteorology</u>			
Site Vicinity, Ecology & Environment (FIT)	8-9/84	7 hi-vols for 19 days, 120 samples; 1 net station	Air quality samples analyzed for TSP, particle size, metals
Pitkin County Courthouse Roof & Site Vicinity, Colorado Department of Health/Aspen/Pitkin Div. Health	1982-84	2 hi-vols	Lead; sporadic data analyses; heavy metals significantly below health criteria
Capital Creek/Snowmass (background), Colorado Department of Health/Aspen/Pitkin Div. Health	1982-83	1 hi-vol	Background, lead
<u>Ground Water</u>			
Site Vicinity, Ecology & Environment (FIT)	9-11/83	6 domestic wells (1 resampled 11/83)	Elevated concentrations of Cd, Cu, Zn
Site Vicinity, Ecology and Environment (FIT)	3-4/85	4 wells (2 sampled, 2 dry); 4 domestic wells re-sampled	Data inconclusive; sampling of two saturated wells continuing by NEM II
<u>Surface Water</u>			
Site Vicinity, Ecology & Environmental (FIT)	9-11/83	7 samples, quality only; some re-sampling 11/83	Generally good water quality; Fe and Mn exceeded health criteria, but not considered a problem
Site Vicinity, U.S. Geological Survey	1950s - present	Roaring Fork River above confluence with Hunter Creek; Hunter Creek above confluence with Roaring Fork River	Flow and quality records; generally very good water quality
Site Vicinity, NEM II Team (preliminary site characterization)		3/85	→ stations for low-flow water quality
			Data indicate from site to be negligible

OVERVIEW OF HISTORICAL SAMPLING ACTIVITIES

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Location and Collector	Sampling Period	No. of Samplers or Samples	Remarks
<u>Sediment</u>			
Site Vicinity, Ecology & Environment (FIT)	9/83	5 sites	No metals concentrations of note identified based on weak acid extraction analysis
Site Vicinity, NEM II Team (preliminary site characterization)	3/85	5 sites	Data indicate that contamination from site to stream sediments in site vicinity is negligible
<u>Soil/Tailings</u>			
Site Vicinity, Ecology & Environment (FIT)	9/83	14 soil, 6 tailings	4000-8000 ppm Pb reported in soil/tailings; 26-56 ppm Cd
Site Vicinity, Aspen/Pitkin Env. Health	1984(?)	3 samples (1 composite)	Mine tailings materials near Smuggler Trailer Court, 3000-21,000 ppm Pb
Aspen Vicinity, Doon	1982	11 garden samples	Soil lead values as high as 11,000 ppm, in upper horizons
Site Vicinity, Doon	1983	27 soil/tailings samples taken throughout Centennial Development project area	AB-DTPA extraction; 40% of 25-acre site (northern 1/3) determined not to be Pb-contaminated; remaining contaminated area recommended to be controlled by surface covering
Hinter Creek Project, Engineering Science	1985	14 surface and subsurface soil/tailing samples taken throughout the Hinter Creek Condominium development	Total lead values up to 5,790 ppm, with an average of 1997 ppm; 9 samples exceeded 1000 ppm total lead



- ▲ Air
- Sediment
- Surface Water
- Ground Water
- Soil/Tailings

Figure 4
Overview of Data Collection Activities

Source: CDM 1988

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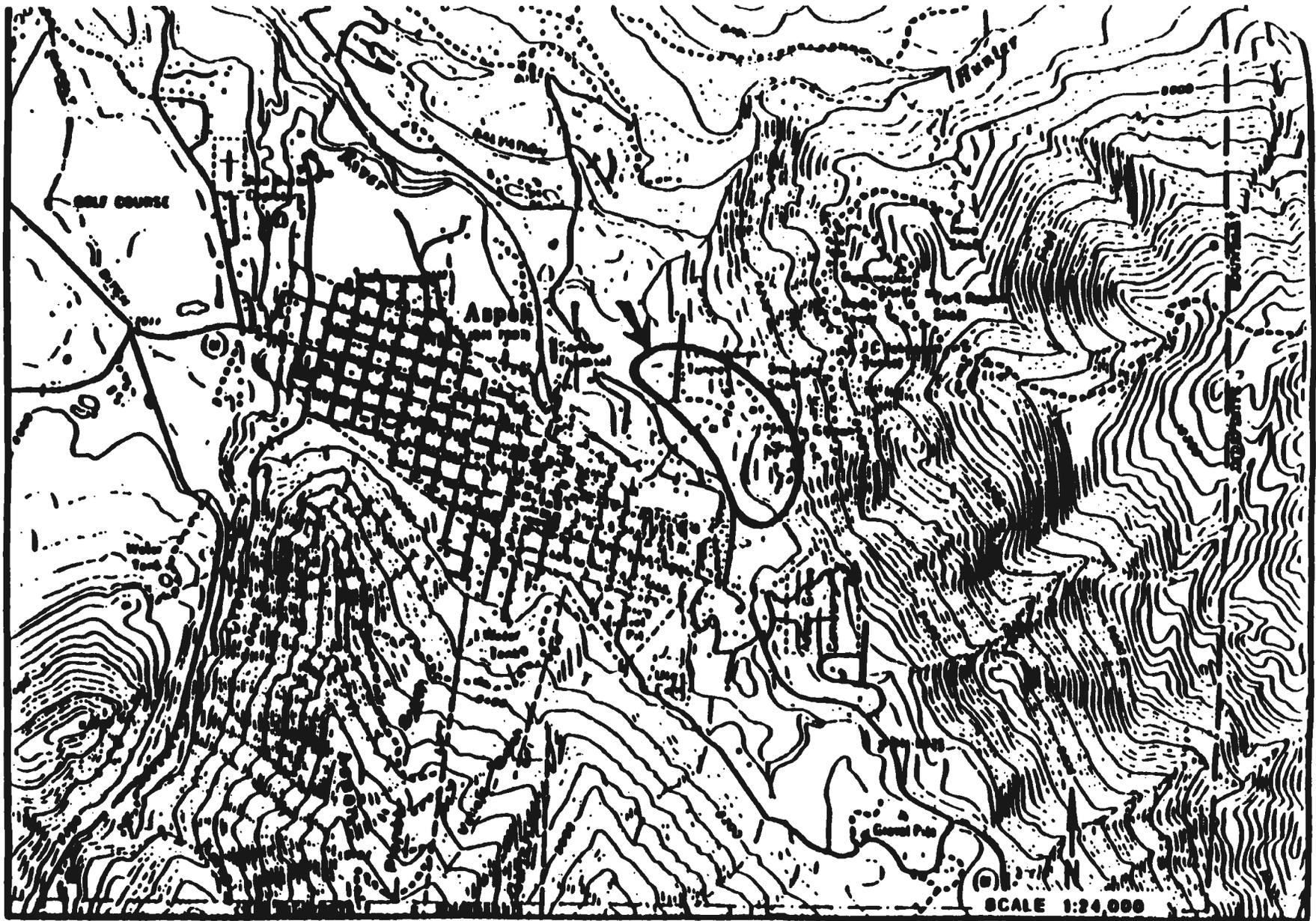


Figure 5
Initial Site Definition Map

Source: E & L 1984

Table 2

SUMMARY OF SOIL SAMPLING ACTIVITIES
SMUGGLER SITE: JULY-AUGUST 1985

<u>Sampling Procedure</u>	<u>Number of Samples Collected</u>	<u>Depth</u>
Surface sampling	34 soil samples collected from each node of gridpoint	0-6 inches
Test pits	7 test pits 15 soil samples collected	10 feet (average) sample collected at each lithologic unit
Test boring	1 borehole 2 soil samples collected	35 feet Sample collected for each unit

Source: Fred C. Hart
1985

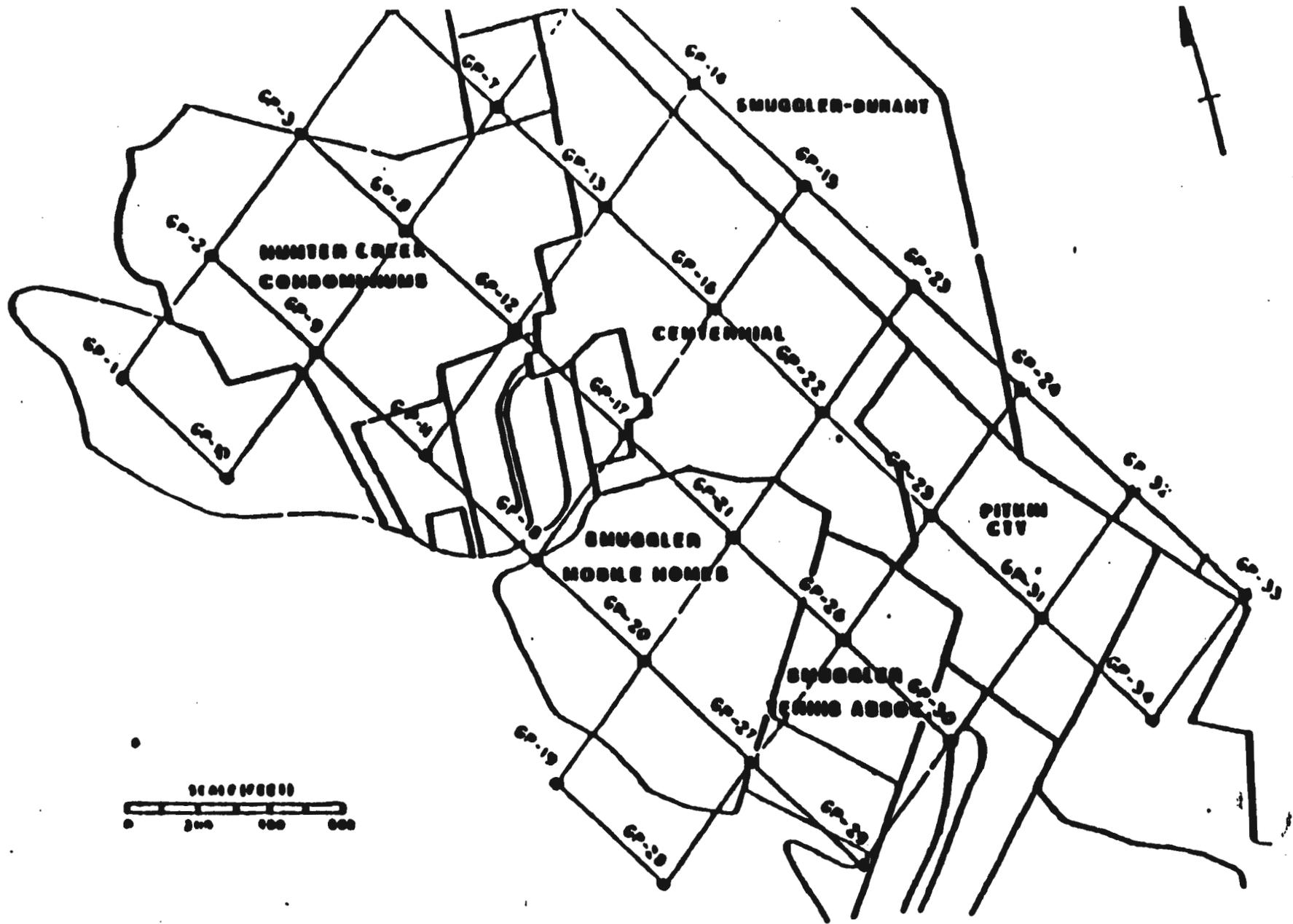
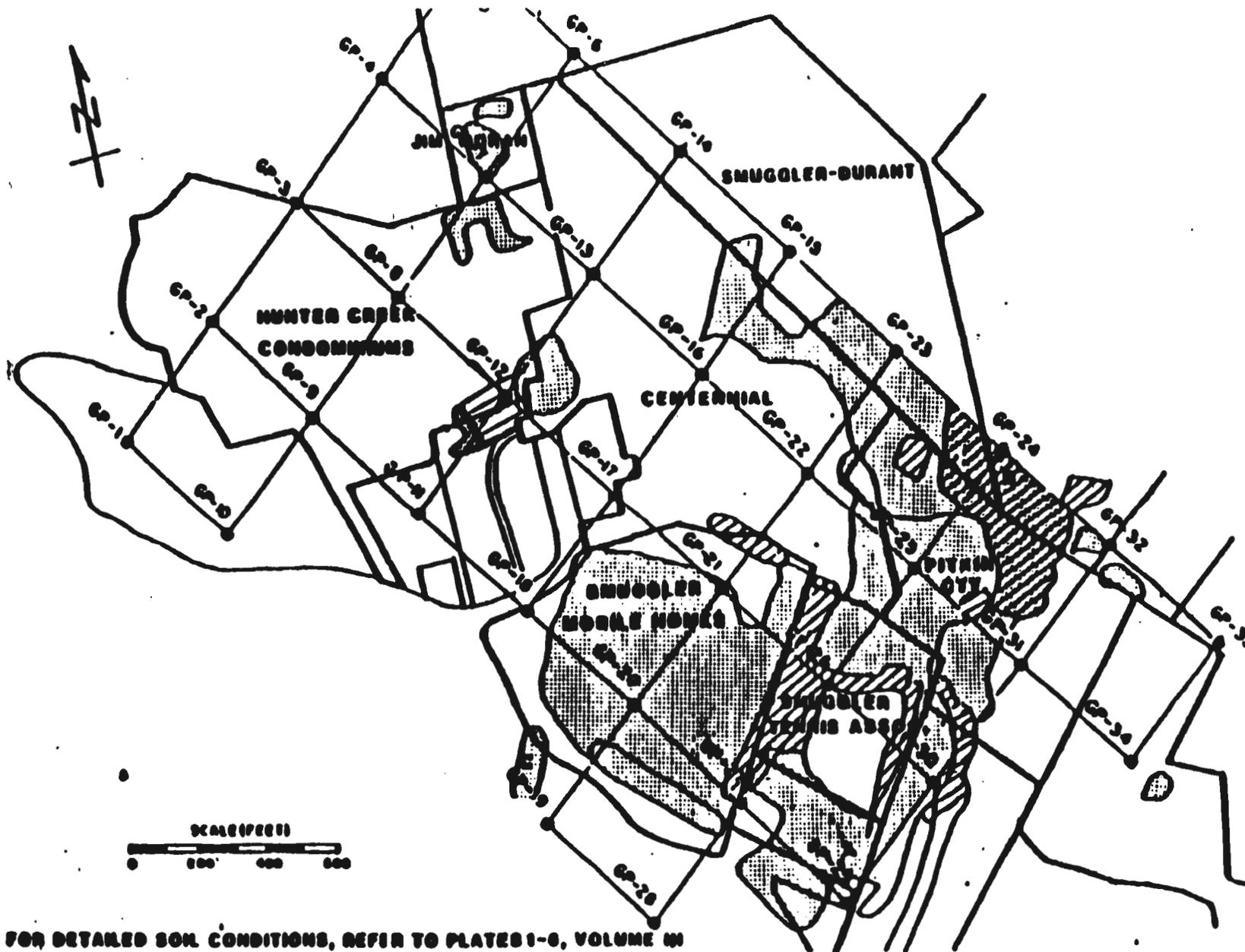


Figure 6
**GRID SYSTEM SHOWING SURFACE
 SAMPLING LOCATIONS**

1971



FOR DETAILED SOIL CONDITIONS, REFER TO PLATES 1-6, VOLUME III

Figure 7
**MAP OF SURFACE SOIL CONDITIONS
 AT THE SMUGGLER MOUNTAIN SITE**

(DOES NOT SHOW SOIL UNITS TYPICALLY UNDER 1000 ppm RANGE)

-  Manmade Fill
-  Mine Tailings
-  Manmade Fill & Mine Tailings
-  Surface Sampling Locations

SOURCE: RWFG Smuggler Mountain Site, F.C. No.

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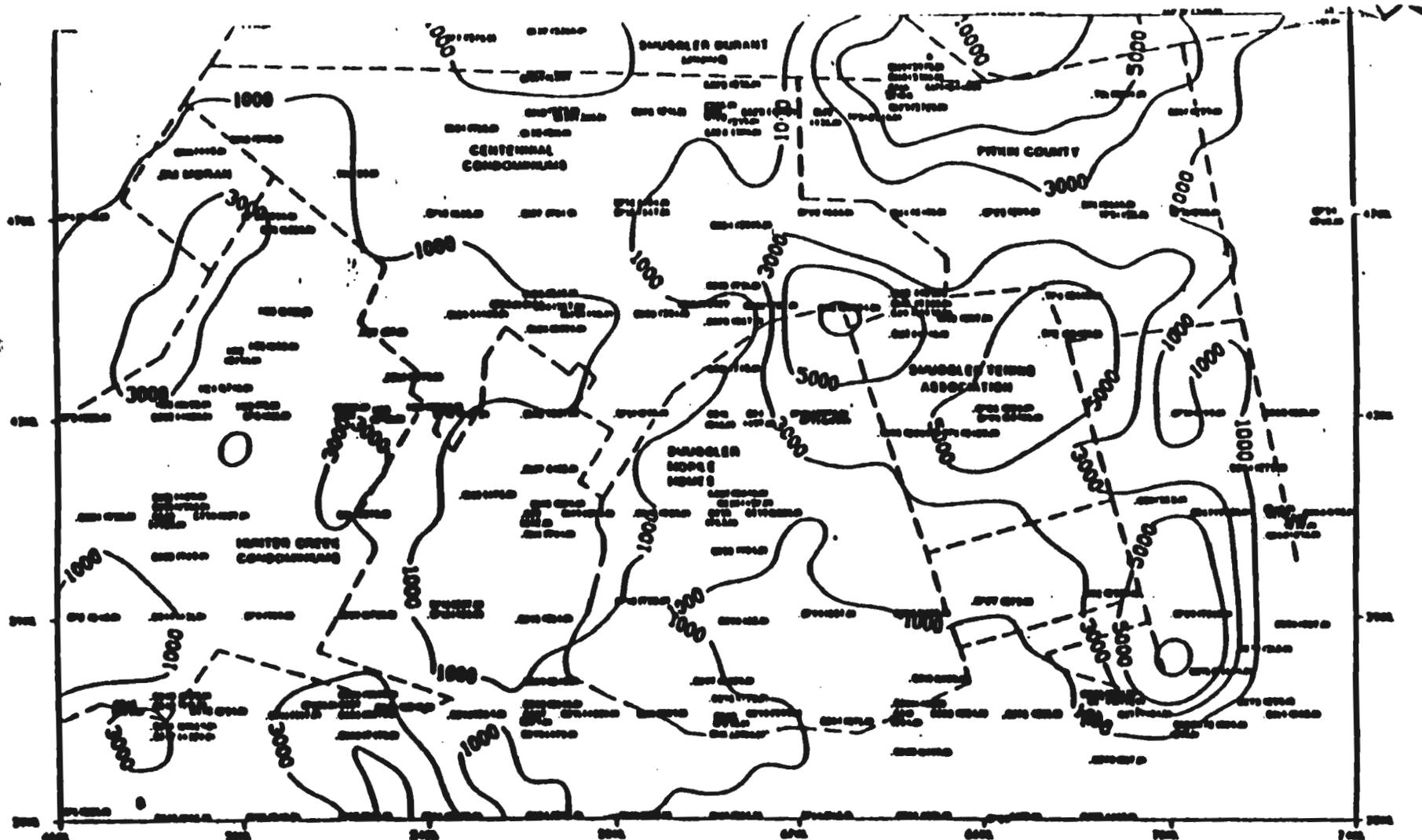


Figure 8
Current Site Definition M.

**LEAD CONTAMINATION
Pb KRIGED ESTIMATES**

CONTOURS IN µg/g
CAMP DESIGN & MAPPING
18 NOV 1999



SCALE 1:500 UNITS/SCALE

SOURCE: SOURCE/CD 1000

**Table 3
LOCATIONS AND RATIONALE FOR SURFACE WATER COLLECTION STATIONS**

Station Designation	Locations	Rationale
<u>Surface Water Samples</u>		
SU-001	Hunter Creek above confluence with Roaring Fork River	Evaluate Hunter Creek water quality previous to influence of Roaring Fork River.
SU-002	Roaring Fork River below confluence with Hunter Creek	Evaluate Roaring Fork water quality after influence of Creek and Suggler Mountain site.
SU-003	Roaring Fork River above confluence with Hunter Creek	Evaluate Roaring Fork water quality prior to influence of Hunter Creek and after influence of Suggler Mountain site.
SU-004	Coverhoven Tunnel Drainage prior to confluence with storm drainage	Evaluate Coverhoven Tunnel drainage prior to discharge into storm water collection system.
SU-005	Mollie Gibson shaft drainage prior to confluence with Roaring Fork River.	Evaluate Mollie Gibson drainage prior to influence of Roaring Fork River.
SU-006	Roaring Fork River above confluence of Mollie Gibson shaft drainage	Evaluate water quality of Roaring Fork River prior to the influence of any mining or milling operations from Suggler Mountain site.

Source: CIM 1985.

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Table 4
Concentrations of Dissolved Metals
in Surface Water Samples

Station	Dissolved Metals							
	Lead	Cadmium	Arsenic	Zinc	Mercury (ug/l)	Barium	Manganese	Iron
SI-001 (Ranter Creek)	ND	ND	ND	ND	ND	ND	ND	78
SI-002 (Roaring Fork below Confluence with Ranter Creek)	ND	ND	ND	ND	ND	ND	17	193
SI-003 (Roaring Fork above Confluence with Ranter Creek)	11 ^a	ND	ND	ND	ND	39	38	727
SI-004 (Overhoven Discharge)	2.7 ^a	ND	ND	278	ND	41	1430	1880
SI-005 (Mollie Gibson Discharge)	ND	ND	ND	377	ND	41	96	150
SI-006 (Roaring Fork above Confluence with Mollie Gibson)	ND	ND	ND	ND	ND	ND	29	327

were within the compliance range for ambient water quality standards set by the State and EPA. Stream sediment samples were also collected in the vicinity of the site, the results of which are summarized on Table 5. Based on available data and in consideration of the reducing conditions of tailings piles, it was concluded that on-site contaminants were not mobile enough to lead to a substantial increase in the levels of metals in surface water and surface water sediments.

Ground Water Sampling. Seven existing private wells were sampled and eight monitoring wells were installed to obtain ground water data. Private wells PW-5 and PW-7 are considered to be down-gradient. EPA installed four monitoring wells, two of which were dry. EPA subsequently installed four more monitoring wells. EPA well GW-01 was established as an upgradient well. EPA well GW-05 was established as downgradient, and EPA wells GW-07, GW-08, GW-09, and GW-10 were established as on-site wells. All ground water well locations (private and EPA) are shown on Figure 9. The private wells were sampled by the EPA FIT in 1983, results from those tests are shown on Table 6. Ground-water samples were collected from the six operational EPA monitoring wells in November 1985, and February and May 1986. Results from the dissolved-metals analyses of these samples are presented on Tables 7, 8, and 9. Water-quality trends from these sampling data indicate that lead and arsenic are not present as ground water contaminants. However, elevated levels of cadmium were noted at two private well sampling locations (Table 6) and at two EPA monitoring well locations (Table 9).

Of particular importance to the selection of the recommended remedy was the absence of lead in the well samples and the variable occurrence of cadmium in GW-07 near the Maximum Contaminant Level (MCL) of .01 mg/l as established by EPA. In addition, levels of uranium and gross alpha were found to be elevated in GW-07 and GW-09. Zinc concentrations were also found to be highest in PW-7. The PRPs have postulated that despite the abundance of calcium carbonate in the host rock, localized pockets of mineralized materials could produce leaching conditions if derived from the core of the mineralized zone. Using the results from the Focused Feasibility Study and ground water monitoring, EPA has determined that the potential ground water problem (as indicated by elevated levels of cadmium, zinc, uranium, and gross alpha in GW-07 and GW-09) would most likely be adequately addressed by the prevention of infiltration of surface water through the tailings. Continued long-term monitoring of the ground water was deemed necessary to evaluate the effects of the remedy on the ground water quality.

Air Sampling. EPA took 115 samples of air particulate matter from a background site and four on-site locations in 1985. A compilation of the resulting data is presented on Table 9. Analyses of these data revealed that levels of arsenic, cadmium, lead and zinc in the air on-site were elevated as compared to background. However, only cadmium and arsenic were found to be present at levels above the proposed National Environmental Standards for Hazardous Air Pollutants (NESHAPS).

9/20

Parameter	Station SD-001 (Hunter Creek)	SD-002 (Roaring Fork Below Hunter Creek)	SD-003 (Roaring Fork Above Site)	SD-004 (Opportunistic Runoff Sample)
Aluminum	4,880	5,550	3,810	11,400
Antimony	ND	ND	ND	ND
Arsenic	10	ND	ND	8.6
Barium	1,990 ¹	2,410 ¹	73 ¹	892 ¹
Beryllium	ND	ND	ND	ND
Cadmium	ND	ND	ND	3
Calcium	26,400 ¹	19,800 ¹	2,990 ¹	32,600 ¹
Chromium	16 ¹	8 ¹	ND ¹	15 ¹
Cobalt	ND	ND	ND	12
Copper	18 ¹	10 ¹	ND ¹	33 ¹
Iron	15,600 ¹	18,200 ¹	13,100 ¹	21,600 ¹
Lead	1,070	1,950	18	1,400
Magnesium	13,800 ¹	11,000 ¹	1,680 ¹	10,300 ¹
Manganese	402 ¹	136 ¹	239 ¹	609 ¹
Mercury	ND	ND	ND ^{1,22}	ND ¹
Nickel	ND ¹	ND ¹	ND ¹	12 ¹
Potassium	ND	ND	714	2,880
Selenium	ND	ND	2.1	ND
Silver	ND	ND	ND	ND
Sodium	3,270 ²	3,900 ²	5,050 ²	5,120 ²
Thallium	ND ²	ND ²	ND ²	ND ²
Tin	ND ²	ND ²	ND ²	ND ²
Vanadium	ND	16 ¹	ND ¹	19 ¹
Zinc	450 ¹	462 ¹	32 ¹	538 ¹

¹ Estimated due to matrix interference.

² Estimated - undetected.

ND: Not Detected.

Source: OTH 1985.

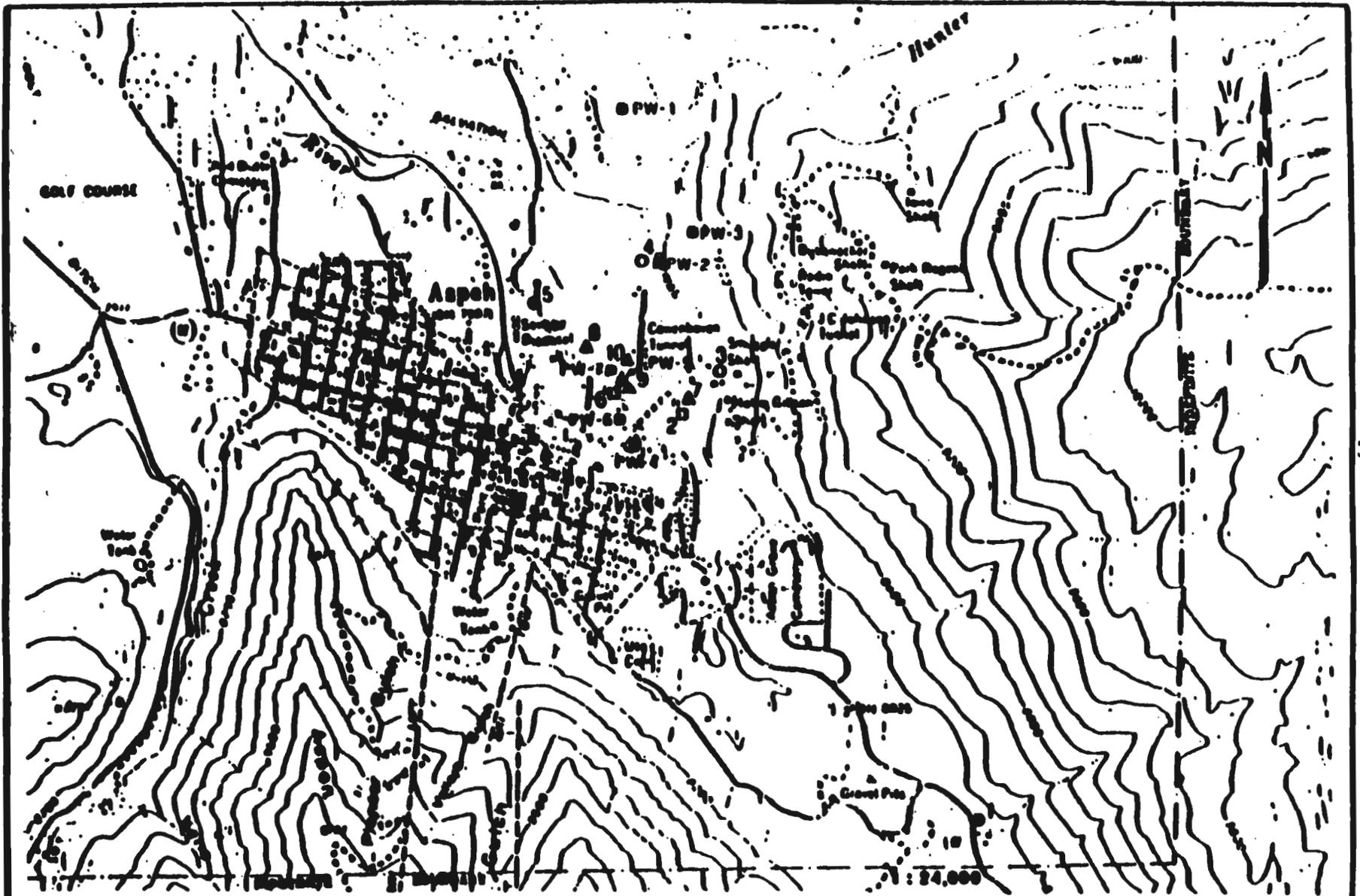


Figure 9
Ground-Water Well Locations

Source: EPA 1985

- FIT Sites Not Completed as Wells
- FIT Wells Not Completed in Saturated Zone
- FIT Wells Completed in Saturated Zone
- ▲ REMB Wells
- Private Wells Sampled by FIT

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Table 6

RESULTS OF DISSOLVED METALS ANALYSIS FOR PRIVATE WELLS
INCLUDED IN P17 SAMPLING EFFORT

Parameter	Drinking Water Standard		Sampling Station						
	Primary ^(a)	Secondary ^(b)	PW-1	PW-2	PW-3	PW-4	PW-5 (9/83)	PW-5 (11/83)	PW-6
Aluminum			ND(30)	ND(30)	ND(30)	ND(30) ³	ND(30)	ND(30)	ND(30)
Antimony			NA ²	NA	NA	NA	NA	ND(100)	NA
Arsenic	50		ND(50) ³	ND(50)	ND(50)	ND(50)	ND(50)	ND(50)	ND(50)
Barium	1,000		130	77	121	79	101	50	92
Beryllium			NA	NA	NA	NA	NA	ND(10)	NA
Cadmium	10		ND(5)	ND(5)	ND(5)	ND(5)	13	0	ND(5)
Calcium			NA	NA	NA	NA	NA	NA	NA
Chromium	50		ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	5
Cobalt			NA	NA	NA	NA	NA	NA	NA
Copper		1,000	35	ND(5)	6	ND(5)	06	160	ND(5)
Iron		300	12	105	30	29	2340	ND(10)	ND(10)
Lead			ND(30)	ND(30)	ND(30)	ND(30)	ND(30)	ND(30)	ND(30)
Magnesium			NA	NA	NA	NA	NA	NA	NA
Manganese		50	ND(5)	0	ND(5)	ND(5)	0	0	ND(5)
Mercury	2		ND(0.5)	ND(0.5)	ND(0.5)	ND(0.5)	ND(0.5)	NA	ND(0.5)
Molybdenum			NA	NA	NA	NA	NA	NA	NA
Nickel			NA	NA	NA	NA	NA	ND(30)	NA
Selenium	10		ND(50)	ND(50)	ND(50)	ND(50)	ND(50)	ND(50)	ND(50)
Silver	50		ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)	ND(5)
Sodium			NA	NA	NA	NA	NA	NA	NA

**RESULTS OF DISSOLVED METALS ANALYSIS FOR PRIVATE WELLS
INCLUDED IN PIT SAMPLING EFFORT (cont.)**

Parameter	Drinking Water Standard		Sampling Station						
	Primary ^(a)	Secondary ^(b)	PW-1	PW-2	PW-3	PW-4	PW-5 (9/83)	PW-6 (11/83)	PW-6
Thallium			NA	NA	NA	NA	NA	NA	NA
Tin			NA	NA	NA	NA	NA	NA	NA
Vanadium			ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)
Zinc		3,000	956	31	652	737	2717	2110	42

¹ All results in ug/l unless otherwise designated.

² Not analyzed.

³ Concentration below minimum detection limits.

ND: Not detected, with detection limits shown in parentheses.

Source: SAS 1986.

^(a) Primary Inorganic Drinking Water Standards (40 CFR 141; 40 FR 39563, December 26, 1975; Amended by 41 FR 28402, July 9, 1976; 44 FR 60601, November 1979; Corrected by 45 FR 13542, March 11, 1980; 45 FR 57142, August 27, 1980).

^(b) Secondary Drinking Water Standards (40 CFR 143; 44 FR 42198, July 19, 1979, Effective January 10, 1981).

Table 7
GROUND WATER ANALYSES FOR NOVEMBER 1985

Parameter	Well No.					
	GW-1	GW-5	GW-7	GW-8	GW-9	GW-10
Arsenic	ND	ND	ND	ND	ND	ND
Cadmium	ND	0.004	0.007	ND	ND	ND
Calcium	4.59	136	143	20	119	128
Iron	ND	ND	ND	ND	ND	ND
Lead	ND	ND	ND	ND	ND	ND
Magnesium	14.1	23.8	52.5	5.74	38.5	36.8
Manganese	0.017	ND	0.052	ND	ND	0.043
Potassium	ND	ND	1.92	ND	ND	ND
Sodium	20.5	9.69	6.68	4.16	ND	6.35
Zinc	0.062	0.060	1.00	0.018	0.413	0.053

Notes:

Concentrations in mg/L; metals are dissolved.

Validation criteria qualifiers pertain to some data; details are included in REM II files.

Source: CDM 1986.

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Table 8
GROUND WATER ANALYSES FOR FEBRUARY 1986

Parameter	Units	Well No.					
		GM-1	GM-5	GM-7	GM-8	GM-9	GM-10
Arsenic	mg/l	ND	Dry	ND	ND	ND	ND
Cadmium	mg/l	ND	Dry	0.010	ND	ND	ND
Calcium	mg/l	46.5	Dry	168	22.3	120	136
Iron	mg/l	0.034	Dry	0.121	0.026	0.022	0.086
Lead	mg/l	ND	Dry	ND	ND	ND	ND
Magnesium	mg/l	14.5	Dry	53.9	6.2	41.2	39.5
Manganese	mg/l	0.025	Dry	0.226	0.05	ND	0.174
Potassium	mg/l	0.95	Dry	2.43	ND	1.49	1.64
Sodium	mg/l	19.4	Dry	4.95	0.93	3.97	6.19
Zinc	mg/l	0.020	Dry	1.44	0.065	0.460	0.066
Oil and Grease	mg/l	1.1	Dry	2.2	1.4	ND	ND
TOC	mg/l	15	Dry	2.1	4.6	4.9	1.7
Chloride	mg/l	29	Dry	ND	ND	ND	30
Sulfate	mg/l	111	Dry	215	30	313	220
Bicarbonate	mg/l	54	Dry	100	49	162	199
TDS	mg/l	200	Dry	905	95	625	625
Radium-226	pCi/l	0.45 ± 0.02	Dry	0.45 ± 0.02	0.21 ± 0.01	0.34 ± 0.02 ^a	0.37 ± 0.02
Gross alpha	pCi/l	3	Dry	140	4	120	17
Uranium	mg/l	0.0024	Dry	0.310	0.00021	0.230 ^a	0.036

Validation criteria qualifiers pertain to some data and are included in REM II files.

^a Duplicate values:
 Radium-226 0.36 ± 0.02
 Gross Alpha 100
 Uranium 0.210

Source: CDM 1986.

TABLE 9

GROUND WATER ANALYSES FOR METALS
MAY, 1986 SAMPLING

Parameter	Ground Water Wells						
	01	05	07	08	09	09	10
Lead	[40.]	[17.]	[36.]	[29.]	[18.]	17.u	[28.]
Cadmium	25.u	25.u	25.u	25.u	27.	25.u	25.u
Copper	10.u	10.u	10.u	10.u	10.u	10.u	10.u
Iron	[62.]	[81.]	[33.]	[40.]	[28.]	[30.]	[62.]
Chromium	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u	1.0u
Manganese	4.0u	4.0u	18.*	4.0u	5.4	4.0u	4.0u
Barium	47000.	124000.	29500.	192000.	138000.	137000.	131000.
Strontium	4.0u	4.0u	4.0u	4.0u	4.0u	4.0u	4.0u
Selenium	3.0u	3.0u	3.0u	3.0u	3.0u	3.0u	3.0u
Zinc	[11]	3.0u	[5.5]	3.0u	[5.2]	3.0u	3.0u
Vanadium	[17]	[7.7]	[72.]	[25.]	[9.8]	[5.8]	[3.2]
Chloride	5.0u	5.0u	25.u***	5.0u	5.0u	5.0u	5.0u
Fluoride	146000	21800.	99800.	5540.	49200.	462000.	356000.
Nitrate	[14.]	[4.6]	23	[6.1]	[3.5]	[4.7]	16
Ammonia	0.2u	0.2u	0.2u	0.2u	0.2u	0.2u	0.2u
Phosphate	8.0u	8.0u	8.0u	8.0u	8.0u	8.0u	8.0u
Sulfate	[1030.]	[1730.]	[2190.]	[602.]	[1760.]	[1480.]	[1250.]
Calcium	7.9	7.9	25.u	5.0u	5.0u	2.5u	5.0u
Magnesium	3.0u	3.0	3.0u	3.0u	3.0u	3.0u	3.0u
Total Hardness	20600.	7920.	6210.	2250.]	5080.	[4730.]	5430.
Silica	10.	10.u	10.u	10.u	10.u	10.u	10.u
Aluminum	17.u	17.u	170.u**	17.u	170.u	170.u	17.u
Chloride	2.0	2.0u	2.0u	2.0u	2.0u	2.0u	2.0u
Fluoride	87.	48.	2510.	25.	590.	596.	35.

result is value greater than or equal to the instrument detection limit but less than the contract required detection limit.

element was analyzed for but not detected. Detection limit is reported.

exceeds Maximum Contaminant Level (Primary Drinking Water Standards)

estimated due to split-recoveries outside limits.

dilution Factor of 5

all values are expressed in micrograms per liter (ug/l)

Source: CDM 1986

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**AIRBORNE CONCENTRATIONS OF HEAVY METALS AND PARTICULATES IN THE VICINITY
OF THE SHOULDER MOUNTAIN SITE ($\mu\text{g}/\text{m}^3$)**

	Concentrations On site			Respirable Size Particulates ($<10\mu$ diameter)			Background Concentrations from Environment			Maximum Recommended Air Concentrations
	No. Sampled	Mean	Maximum	No. Sampled	Mean	Maximum	No. Sampled	Mean	Maximum	
Total suspended particulates	66	43.5	160	10	17	44	10	36	160	260 ^a
Arsenic	37	0.0003	0.0071	10	<0.0001	0.0009	10	<0.0001	0.0002	0.0001 ^b
Cadmium	37	0.0012		10	0.0014	0.0043	10	0.0002	0.0010	0.0004 ^b
Iron	37	1.4	7.5	10	0.50	1.0	10	0.79	1.5	30 ^c
Lead	37	0.19	0.81	10	0.10	0.29	10	0.057	0.10	1.5 ^d
Manganese	37	0.054	0.22	10	0.023	0.067	10	0.026	0.091	1.1 ^e
Zinc	37	0.16	0.54	10	0.090	0.29	10	0.076	0.16	15 ^c

^aUSEPA primary air standard.

^bBased on a 10^{-6} cancer risk (ICF 1985), assuming a 70-kg person inhales 20m^3 of air per day.

^cNoncarcinogens: Allowable chronic intake level from the MCL (ICF 1985), assuming a 70-kg person inhales 20m^3 of air per day.

SOURCE: E & E 1985

Operable Unit 1: Site Remedy

Operable unit 1 is separated into five components as follow:

A. Source Isolation of High-Level Wastes. Isolate soils and tailings with levels of lead at or above 5,000 ppm by excavation and removal to a secure repository. This alternative could involve either the removal of such material by shipping it to a RCRA certified facility, or by depositing it in a secure repository on-site, as defined by EPA. EPA has identified a suitable repository on the site, the County-owned Mollie Gibson Park. If the repository is chosen for deposition of the high-level wastes, it will be excavated to the extent necessary to accommodate the entire volume of high level waste on the site. It will then be prepared to specifications set by EPA that adequately address the issues of surface run-on and stability. All high-level wastes from the site (other than the mine site, itself) will be consolidated and placed in the repository. The repository will be graded and capped in accordance with the appropriate and relevant RCRA standards for landfills (capped with a multi-layer cap possessing a permeability of at least 10^{-7}). A drainage system will be designed according to EPA specifications (designed to pass the 100-year runoff event with a minimum of erosion). The repository will be under the perpetual care of a permanent entity, Pitkin County, to assure the permanent disposition and zero mobility of the contaminants.

B. Source Isolation of Low Level Wastes. Confine soils with levels of lead below 1,000 ppm in such a manner that direct contact, surface water erosion, and wind dispersal are precluded. This operable unit involves the identification of the affected areas using the geostatistical isopleth map. After identification and possible further sampling to more clearly define the contaminated areas, the low level areas will either be covered by six inches of topsoil, graded, and revegetated, or covered with six inches clean fill plus six inches of topsoil and graded. Areas needing further identification will be defined by additional sampling. If such sampling is performed by the PRPs, EPA will verify such sampling. Areas already remediated by property owners will be examined by EPA to determine compliance with design standards.

C. Increased Ground Water Monitoring. Because the ground water system in the area of the site is so uncertain, groundwater monitoring is necessary to confirm the effectiveness of the remedy. Additional wells will be installed as deemed necessary by EPA. A monitoring grid and monitoring schedule will be established. Quarterly reports to EPA will describe the results of monitoring and any trends observed. Ground water in the vicinity of the site will be monitored for a period of five (5) years quarterly to determine efficacy of the capping in enhancing ground water quality. After the close of the monitoring period, the decision must be made by EPA to either implement plume capture and treatment, select alternate concentration limits, or take no further response action.

D. Alternate Water Supply. This operable unit involves the identification of domestic water wells immediately downgradient of the site. After identification, such wells will be replaced by hook-ups to the City water supply and will no longer serve as domestic-use wells.

E. Operation and Maintenance of Low and High Level Waste Caps. The purpose of cap inspections is to note and repair any deterioration, disturbance, or discontinuity before it can impact cap integrity. Weekly inspections are anticipated during the first year. Bi-monthly inspections will take place for the second year. After two years, inspections will be conducted monthly, and from the beginning of the fourth year, quarterly inspections will be conducted for the following twenty-six years.

Operable Unit 2: Mine Reclamation and Ground Water Corrective Action

A. Mine Reclamation. The Smuggler-Durant Mine site will be remediated separately from the remainder of the site. The current extent of toxicity and mobility of the contamination at the mine site is unknown. An addendum to the existing Remedial Investigation and Feasibility study will be prepared to characterize the wastes and determine the appropriate extent of remedy at the Smuggler-Durant Mine site in accordance with the National Contingency Plan and in accordance with the applicable or relevant and appropriate requirements necessary to meet Federal public health and environmental requirements. The Smuggler Mine RI/FS will be subject to public comment and a recommended remedy will be presented. The appropriate extent of remedy, consistent with the NCP, would address the possible historic value of the mine site. The plan for mine site remediation, consistent with the goals and objectives of the RI/FS and NCP, will be prepared by the owners of the mine site and submitted to EPA for approval, or would be prepared by EPA. In accordance with the requirements of the National Environmental Policy Act (NEPA), if the mine site is declared a National Historic Site, the buildings and other structures on the mine site would be adequately maintained for their historic value. Applicable and relevant or appropriate standards and requirements for the safety of workers and visitors to the mine site would be complied with. At the same time, wastes on the mine site will be treated or remedied so as to prevent and/or mitigate the present or future threat of release in a manner that is protective of public health, welfare and the environment. Such remedy would provide a level of protection of public health and environment comparable to the remedy on the remainder of the site.

B. Ground Water Corrective Action. If the results of ground water monitoring conducted during the first operable unit indicate that corrective action is necessary, alternatives will be developed to address the situation and possible response actions will be considered.

C. Performance of Mine Reclamation and Ground Water Corrective Action as Approved by EPA.

A conservative estimate of the total capital and operation and maintenance costs for the recommended remedial alternative is 1.5 to 2 million dollars.

Reference 2

**Excerpts From Remedial Investigation/Feasibility Study,
Smuggler Mountain Site; Fred C. Hart Associates, Inc.;
March 1986**

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SF FILE NUMBER

4.8

ADMINISTRATIVE RECORD

**REMEDIAL INVESTIGATION/FEASIBILITY STUDY
SMUGGLER MOUNTAIN SITE**

Aspen, Pitkin County, Colorado

March 1986

Prepared by:

**Fred C. Hart Associates, Inc.
530 Fifth Avenue
New York, New York 10036**

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1.0 EXECUTIVE SUMMARY

The Smuggler Mountain site is located in an old silver and lead mine area which is located immediately northeast of the City of Aspen, Colorado. Mine tailings produced during the peak mining years, between 1879 and 1920, were piled outside of the mine shafts in the vicinity. Over the course of the years, the tailings have been moved, used for fill material, or have been mixed with man-made materials. At the present time, the site is almost completely covered with residential developments and recreational facilities. Some construction is still underway at the Centennial Development. On a portion of the site owned by Pitkin County, a public park is planned.

A number of investigations have been undertaken at this site. Ecology and Environment, Inc. ("E&E") Field Investigation Team performed a sampling investigation at the site in 1983. The investigation was the result of a request by Pitkin County to characterize any human or environmental threat posed by abandoned mine tailings in the northeast quadrant of Aspen, Colorado. The county became concerned following the analyses of soil and plant samples taken from the Aspen area which indicated elevated levels of trace metals, specifically lead and cadmium (Boon, 1982). An initial report of the results of the E&E sampling was drafted in response to a Technical Directive from the Environmental Protection Agency ("EPA") and was distributed in March 1984 (E&E, 1984a). E&E was subsequently directed to perform a limited groundwater investigation at the site following a proposed ranking on the National Priority List of Hazardous Waste Sites. The results of this groundwater investigation were inconclusive as to the presence of groundwater contaminants originating from mine wastes on the site, but did not eliminate concern over possible groundwater contamination.

Recently, Engineering-Science performed a study sponsored by Western Slope Development Company, and a plan for surface covering and revegetation was developed for certain areas surrounding the Hunter Creek condominium development (Engineering-Science, 1985). Similarly, studies sponsored by Centennial-Aspen, a Limited Partnership, analyzed the distributions of contaminants on the Centennial development site and recommended

topsoil covering and landscaping to isolate contaminated materials (Boon 1983).

In July 1985, discussions between the EPA and a number of "potentially responsible parties" associated with the site culminated in the signing of a Consent Order under which these parties agreed to perform certain studies for the EPA. There is not agreement as to whether groundwater is affected by contaminants at the site. Nonetheless, for purposes of reviewing remedial technologies, groundwater impacts were assumed. Consequently, an initial "focused feasibility study" of remedial options for groundwater protection was performed, followed by this remedial site investigation and final feasibility study ("RI/FS"). Fred C. Hart Associates was retained by the group of "potentially responsible parties" to carry out these studies.

The focused feasibility study for groundwater remediation (HART, 1985), which preceded the RI/FS, examined a range of possible remedial alternatives for the site. This study concluded that many remedial alternatives aimed at groundwater protection were not technically feasible for a number of reasons, including technological infeasibility, unreliability, and significant environmental impact. Several remedial alternatives were found to warrant further investigation, including surface grading and revegetation, removal of contaminated materials from the site, and extraction and treatment of groundwater leaving the site.

The initial screening of remedial alternatives performed by the focused feasibility study allowed a more cost-effective remedial investigation study plan to be devised. This report contains the results of the RI/FS program.

A. Surface Contamination

Because of the highly modified nature of the site, a result of years of residential construction activity, the remedial investigation was

designed to carefully examine the lead concentrations in the soils and present surface distribution of different soil types containing tailings which could be related to the lead contamination.

The application of geostatistics to vastly different sample populations can be misleading, particularly in instances where materials have been relocated. Mine tailings possessing high levels of lead have been relocated, seemingly at random, over the surface of the site. Tailings and fill materials with relatively high lead concentrations and used in small, distinct areas such as driveways or lawns would probably not be identified by geostatistics. Conversely, it might be assumed that an area between several widely spaced points which reported high lead levels would also contain high concentrations of lead; the reality, though, might be that the area contains native soil with only background concentrations of lead. Sampling programs could be devised through geostatistical techniques, such as analysis of variance, to examine for such variations. Such analyses would suggest an appropriate sampling interval.

The EPA decided that, for purposes of action under CERCLA, the site was to be defined as including those areas with surface contaminations of over 1,000 ppm of lead. In order to assess contaminant concentrations and distributions at the site, extensive surface and subsurface soil sampling and testing was performed. Aerial photography and ground surveys of the site established an accurate soil classification system upon which soil mapping could proceed. The soil mapping methodology was confirmed by chemical analysis of the soil samples, which indicated that all tailings materials or materials which contained mine tailings had lead levels in excess of the EPA's action level of 1,000 ppm, while soil types which did not contain tailings were found to contain less than 1,000 ppm in every case. This relationship was demonstrated statistically to a 99% confidence level. A series of detailed maps describing the distribution of these soils is contained in the report.

B. Groundwater Protection

In the initial conversations with the sponsors of the RI/FS, EPA expressed concern over the potential of the tailings material to generate leachate, a possible source of groundwater contamination on and off the site. Acid/base analyses in the RI/FS were designed to address these concerns. The acid/base balance studies demonstrated that acid mine drainage problems probably could not exist at the site, given the buffering capacity of the natural soils.

Water balance studies, analyzing drainage characteristics of the site, showed low permeabilities and percolation rates over most of the area which would prevent most leachate generation, although a small potential was found for generation of leachates containing lead. (This potential may be present in the Molly Gibson and Cowenhoven Tunnel mine drainage ditches which could be losing water over areas which contain mine tailings, possibly recharging groundwater with potentially contaminated leachates.)

C. Analysis of Remedial Technologies

Environmental protection goals and remedial objectives used to analyze potential remedial alternatives called for an isolation of the source of contamination (lead in mine wastes) to prevent direct contact and the distribution of windblown dusts, along with the protection of potential groundwater receptors.

Potential remedial technologies screened prior to use in the development of alternatives included capping, grading, revegetation, surface water diversion, alternate water supply, groundwater collection and treatment and complete excavation, removal and disposal of contaminated materials. All of these technologies were evaluated and retained for use in developing remedial action alternatives for the Smuggler Site. Three technologies -- incineration, groundwater barriers and flood control -- were evaluated and considered to be not appropriate for use at the site.

2.0 BACKGROUND INFORMATION

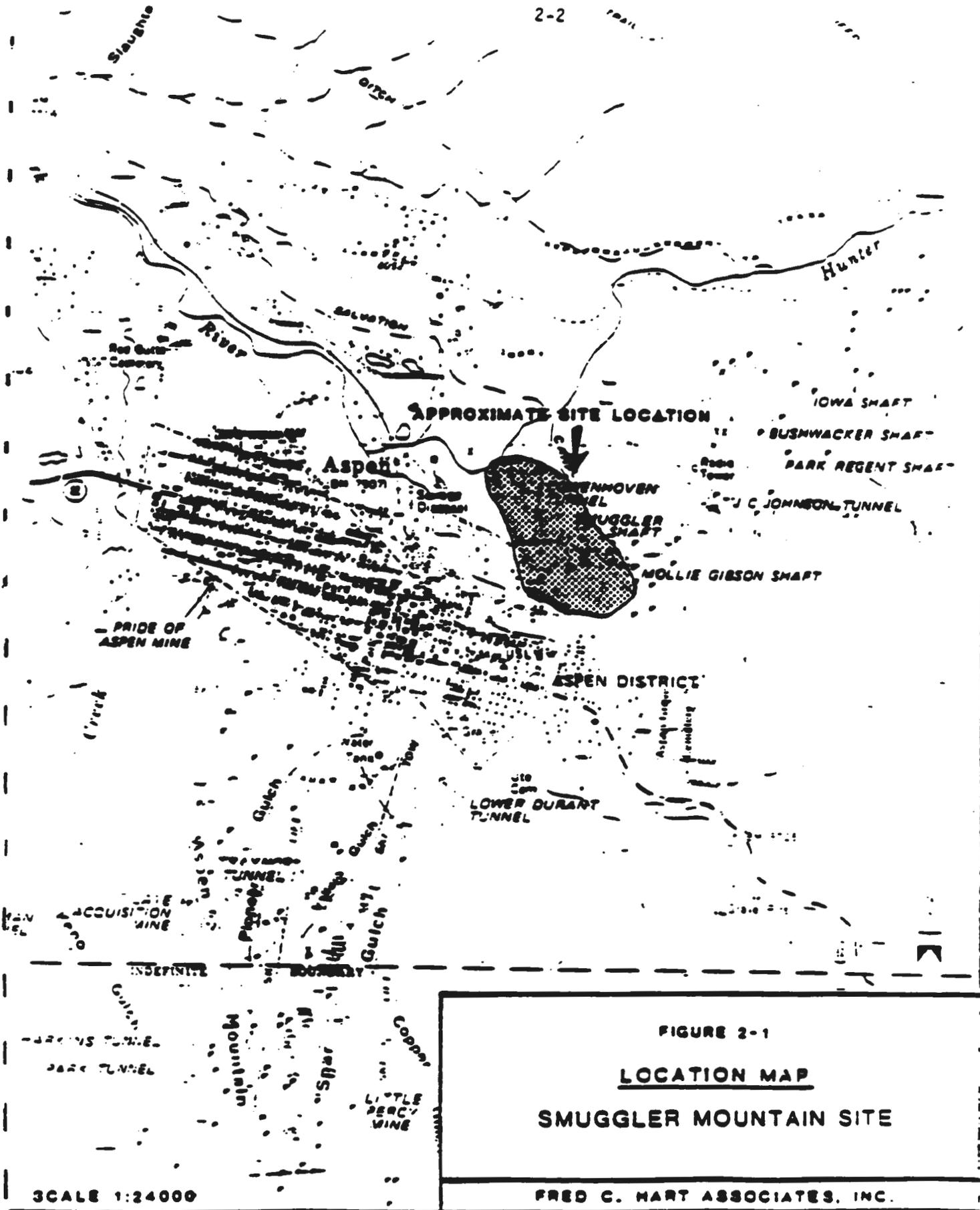
This chapter of the Remedial Investigation at the Smuggler Mountain Site presents a brief overview of background information. Section 2.1 discusses site background information including the location of the site, waste disposal practices at the site, and site geology and hydrology. Section 2.2 briefly discusses previous investigations of the nature and extent of contamination problems at the site. Section 2.3 discusses previous response actions at the site.

2.1 Site Description

2.1.1 Location. The site is located immediately northwest of the City of Aspen in Pitkin County. The tailings area is situated in the northwesterly trending valley of the Roaring Fork River at the base of Smuggler Mountain. A location map is presented in Figure 2-1.

2.1.2 Waste Disposal Practices. The area encompasses approximately 75 acres of developed and undeveloped properties. Tailings from the Smuggler, Mollie Gibson, Free Silver and perhaps other mines, the Cowenhoven Tunnel and from past smelting and milling operations related to these mines and tunnels have been deposited in the area. In some places, tailings have been mixed with native soil. Native soil also comprises part of the surface of the area, with fill material derived from native soil which does not contain tailings.

The deposited tailing material was a result of the mining and milling of silver, lead and zinc. The distribution of the tailings, as well as their reworking since their original distribution, was not well-defined. Past records indicate that tailings on the Smuggler Mountain site were placed there from 1880 to 1915. The tailings piles from the Cowenhoven Tunnel were leveled and scattered when the Hunter Creek condominiums were built. Recent investigations indicated that some of the tailing piles were leveled and tailings were scattered over the present sites of the Smuggler Trailer Court, Smuggler Racquet Club, Hunter Creek Condominiums and the Centennial-Aspen Condominiums. One objective of this Remedial



SCALE 1:24000

FIGURE 2-1
LOCATION MAP
 SMUGGLER MOUNTAIN SITE

FRED C. HART ASSOCIATES, INC.

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Investigation was to define the extent of tailings and fill related soil types for potential remedial actions.

2.1.3 Topography. Topographically, the overall site slopes moderately toward the west and southwest, with an overall gradient on the order of approximately 10 to 15 percent. However, at isolated locations throughout the site and along the southeastern boundary, gradients on the order of 100% occur. The ground surface elevation ranges from approximately 7930 to 8160 feet above mean sea level.

Throughout the years, parts of the land surface at the site have been altered as a result of mining and earth-moving activities. Characteristics of the site include some small closed depressions. Several of these areas of interior drainage are located above abandoned mine shafts and tunnels. Some of these closed depressions are the result of ground subsidence, particularly over the old Mollie Gibson Mine shaft, the Free Silver Mine shaft and Cowenhoven Tunnel. A depression approximately 12 to 15 feet deep is evident at the Free Silver shaft. As mentioned, the topography on the site has changed due to miscellaneous grading (both cutting and filling) through the years. It appears that portions of the site have been either borrowed from, filled on, or disturbed by grading.

2.1.4 Hydrology. The Roaring Fork River passes the site at a distance of approximately 1000 feet to the southwest. In this reach, the river elevation is about 7870 to 7920 feet above mean sea level. There are no major natural drainage channels crossing the site. However, site drainage is affected by two small to moderate-sized basins located to the east and northeast. Hunter Creek passes approximately 500 feet north of the site. The Salvation Ditch, an irrigation canal, surfaces on the northern part of the site from a buried 45 inch concrete pipe, and traverses the site at an elevation of approximately 8000 feet.

Any drainage from the site occurs largely as runoff although channelization is apparent from mine discharge water. Specifically, drainages from the Mollie Gibson Mine shaft and Cowenhoven Mine access tunnel traverse the site. Each discharge is in the range of 1 cubic foot per second

(cfs) or less. Existing water quality data from each channel show the discharge to be moderately laden with dissolved constituents, including iron, manganese and zinc. Based on samples collected in 1983, total dissolved solids (TDS) concentrations range from 540 mg/l for the Mollie Gibson discharge to 918 mg/l for the Cowenhoven Tunnel. The Mollie Gibson and Cowenhoven drainages discharge to the Roaring Fork River and Hunter Creek, respectively. Discharge in both streams is seasonally variable. For the Roaring Fork River, low flows of 15-20 cfs occur during the January through early March period, and high flows of typically 400 to 800 cfs occur during the mid-May through early July period. As for Hunter Creek, flows generally range from 5 to over 400 cfs during similar periods (CDM, 1985).

2.1.5 Hydrogeology. Generally, the groundwater system underlying Smuggler Mountain is dominated by extensive honeycombed mine workings. These workings serve as conduits transporting groundwater from within the mountain to the level of the Roaring Fork River. Groundwater in mountains such as those surrounding the Roaring Fork River Valley discharges into the center of the valley towards the river valley deposits (Freeze and Cherry, 1979; Todd, 1983). Flow in the valley deposits would be down valley, in the direction that the Roaring Fork River flows.

The investigation performed by Ecology and Environment, Inc. in March 1984 indicated there was no alluvial groundwater system underneath the tailings at the site. Recent groundwater investigations by Camp, Dresser and McKee, however, indicated that water-bearing medium grain sand was present underneath tailings in 3 of 4 monitoring wells (Appendix G). The hydrogeology of the Smuggler Site is complex for several reasons. First, because of the position of the site on a valley wall, it is difficult to determine the discharge of groundwater from the bedrock aquifer into the alluvial aquifer at that point. Secondly, since the area had been extensively mineralized and mined, the generation of heavy metal contamination in groundwater from the bedrock aquifer would be expected. It is important to note that it is not possible to install a well in alluvium to monitor upgradient background water quality conditions. For these

reasons it is extremely difficult to determine the groundwater flow and chemical background conditions at the site and the potential impacts of the site on the groundwater. The recent well drilling effort by CDM did not aid in identifying groundwater flow directions at the site.

The site is underlain by various surficial deposits which include alluvial deposits, glacial moraine and glacial outwash deposits. These deposits are characteristic of valley fill deposits. It is estimated that the valley fill deposits are several hundred feet thick in the Roaring Fork River Valley (Lincoln DeVore, 1983). Depending on their extent and thickness, as well as permeability, these deposits could yield anywhere from 5 to 1,000 gallons of water per minute.

Underlying the aforementioned surficial deposits, the bedrock aquifer is comprised of the Gothic Shale, Belden Shale and Leadville Limestone Formations. The occurrence of water is a characteristic of fractures and solution conduits found in the aquifer. The Leadville Limestone, which may be up to 200 feet in thickness, has been reported to yield as much as several thousand gallons of water per minute.

2.2 Previous Investigations

Various studies have been conducted in the recent past to characterize the tailings around the Smuggler area (Boon 1982; Lincoln DeVore, 1983; Boon 1983; E&E 1984a; Clement 1985; McIntosh 1985; Engineering-Science, 1985). Results of these studies show that several metals were detected in the soils and tailings. Concentrations of arsenic, barium, cadmium, copper, lead, manganese, mercury and zinc in the mine tailings and soil were considered elevated compared to a selected soil background sample (E&E 1984a). The concentrations of these metals in the samples also exceeded the expected concentration of those elements found in similar native soils throughout the United States. These soil and tailing areas and their constituents noted to date are described briefly below.

2.2.1 Tailings. Six tailing samples were collected in September 1983 (E&E 1984a). E&E reported that chemical analysis of these samples show elevated concentrations of arsenic, barium, cadmium, copper, lead, manganese, mercury and zinc. Arsenic, cadmium, copper, mercury, lead and zinc were reported, by E&E as being above background levels expected for these types of soils as generally described in the literature by Connor and Shackletter (1975).

2.2.2 Soils. Preliminary soil samples were collected downslope from the tailings piles during September 1983, at an area underlain by graded tailings and covered with transported topsoil (E&E 1984a). Chemical analysis of these samples indicated that, on the average, at some distance downslope of the tailings soil showed elevated levels of arsenic, barium, cadmium, copper, lead, manganese and zinc.

Results from other sampling events conducted by Boon (1983) and the Aspen/Pitkin Environmental Health Department have shown some elevated metal concentrations when compared to Connor and Shackletter (1975). It should be noted, however, that Connor and Shackletter (1975) did not refer to background in areas near mines which may have naturally occurring elevated levels of lead. Boon's data showed elevated levels of cadmium, copper, lead and zinc. Three samples were collected at the Smuggler Trailer Park by the Aspen/Pitkin Environmental Health Department and analyzed for lead and cadmium (CDH 1982). The average and maximum concentrations reported were 90 and 223 ug/g for cadmium and 11,723 and 21,700 ug/g for lead. Whether these samples were of soil or tailings is unclear (Clement 1985); however, subsequent work by Camp, Dresser and McKee, Inc., suggests they were either man-made fill material or tailings (1985 written communication).

In June 1985, Engineering-Science (1985) tested eleven surface samples and three subsurface samples in the Hunter Creek area for concentrations of heavy metals and the EP toxicity of those metals. This is included as Appendix A. Although these soils are not able to generate acid conditions

similar to those in the EP Toxicity analyses, Engineering-Science concluded that the levels of cadmium, zinc and lead were found to be elevated in some soils on the Hunter Creek property.

2.2.3 Toxicity of Contaminants. The site contains elevated concentrations of heavy metals in tailings and contaminated soils. Concentrations for these metals could exceed levels at which toxic effects have been observed in plants, wildlife, domestic animals and man. EPA has performed a risk assessment and has set action levels for soil cleanup at 1,000 ug/g lead.

Lead and cadmium are the two metals of most concern at the site because of their concentrations and acute toxicities. Lead concentrations in some types of soils in the area could exceed the 1,000 ug/g action level set by EPA. Lead exposure related toxicity has been reported for children. Children of the 1-5 age group are at greatest risk because of their soil ingestion habits and greater susceptibility to blood lead poisoning.

It is important to note that the blood lead studies conducted to establish the 1,000 ug/g soil lead concentration were based on atmospherically deposited lead from automobile emissions and smelters. While toxic effects of lead ingestion in children from lead based paints has been documented, it has not been shown that exposure to lead in tailings and soil such as that at the Smuggler site will produce elevated blood levels (CDM, 1985).

Various forms of cadmium are acutely toxic, and cadmium compounds are generally more bioavailable than lead compounds. A groundwater sample of 13 ug/l cadmium exceeded the ambient water quality standard of 10 ug/l, in one well on one occasion. This well was checked again and found to be less than 10 ug/l.

Due to the relatively neutral pH (6.38-7.22) of the tailings, soil and bedrock materials, the metals on the site are in relatively insoluble

forms. The insolubility of the metals decreases their bioavailability and, therefore, toxicity. None of the metals are volatile, and, thus, they are expected to persist for an extended period of time (CDM, 1985).

2.3 Previous Response Actions

A number of investigations have been undertaken at the site. Pitkin County became concerned following analyses of soil and plant samples taken from the area. Analyses indicated elevated levels of trace metals, specifically lead and cadmium (Boon, 1982). The Ecology and Environment, Inc. (E&E) Field Investigation Team performed a sampling investigation at the site in 1983. The investigation was conducted resulting from a request by the county to characterize any human and environmental threats posed by abandoned mine tailings in the northeast quadrant of Aspen, Colorado. An initial report of the results of the E&E sampling was drafted in response to a Technical Directive from the Environmental Protection Agency (EPA) and distributed in March 1984 (E&E, 1984a).

EPA requested Camp, Dresser & McKee, Inc. (CDM), to prepare a Draft Work Plan for the Remedial Investigation/Feasibility Study (RI/FS) of the site. A group of potentially responsible parties retained Fred C. Hart Associates, Inc. (HART) to provide technical support. Because gaps existed in the database used for the ranking, EPA, through its subcontractor Ecology and Environment (E&E), performed a hydrogeologic assessment at the site to address the appropriateness of the ranking of the site. The assessment was inconclusive. EPA, in a Consent Order and Agreement with the group, has worked with Fred C. Hart Associates to develop and carry out a Remedial Investigation at the Site. This report contains the results of that investigation.

3.0 SUMMARY OF FIELD INVESTIGATION ACTIVITIES

A group of potentially responsible parties retained HART to perform a remedial investigation at the Smugglers Mountain Site. The scope of work contained in the remedial investigation was agreed to between EPA and the group of potentially responsible parties prior to the initiation of any work activities at the site. This agreement took the form of a consent order. To insure that the scope of work was adequate, EPA required the submission of a Focused Feasibility Study (FFS). The FFS examined the various options for the remediation of groundwater at the site. The FFS found that subsurface technologies for groundwater remediation at the site were not feasible for technical reasons. The results of the FFS enabled a more cost-effective remedial investigation and feasibility study to be undertaken. The investigation was conducted in July-August of 1985. The sampling program consisted of three phases: surface mapping and sampling; subsurface sampling activities, and surface water studies. Table 3-1 summarizes the sampling program.

Because of the suspected lead contamination, the emphasis of the surface sampling programs was to define the horizontal distribution of lead in the soil. Samples were obtained using three different techniques. During the sampling program, 34 samples were collected at the surface using a clean plated steel trowel. In addition, soil samples were obtained from 7 test pits dug with a backhoe. Finally, soil samples were obtained using a solid stem auger and split spoon sampler.

3.1 Surface Sampling

The surface field activities were designed to determine the lateral extent of the mine tailings and other soil types at the Smuggler site and to define the lateral extent of heavy metal contamination and its association to soil type. This work involved the development of a reference grid, soil sampling and soil mapping.

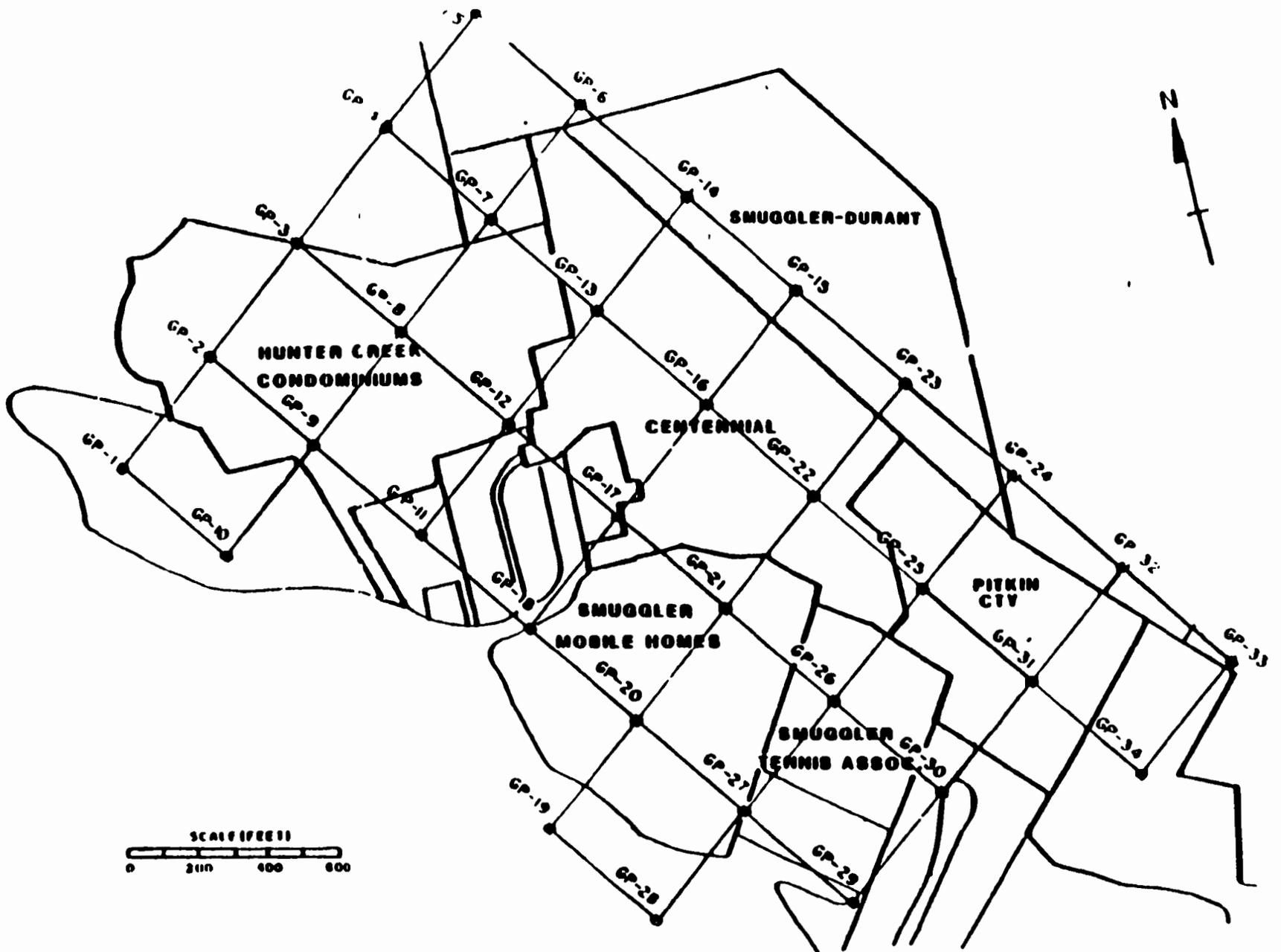
3.1.1 Procedures. A grid system was needed to provide a field reference for sample locations (Figure 3-1). This was established through the

TABLE 3-1

SUMMARY OF SOIL SAMPLING ACTIVITIES
SMUGGLER SITE, JULY - AUGUST 1985

<u>Sampling Procedure</u>	<u>Number of Samples Collected</u>	<u>Depth</u>
Surface sampling	34 soil samples collected from each node of gridpoint	0-6 inches
Test pits	7 test pits 15 soil samples collected	10 feet (average) sample collected at each lithologic unit
Test boring	1 borehole 2 soil samples collected	35 feet Sample collected for each lithologic unit

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3-3

FIGURE 3-1
GRID SYSTEM SHOWING SURFACE
SAMPLING LOCATIONS

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use of aerial photographs and the Centennial site construction map. Two baselines were developed from the existing Centennial Project Grid and perpendicular lines marked at 400' intervals. Each grid point was marked using survey tape and the correct coordinants. The grid covered the entire acreage owned by the named PRPs, plus the immediate surrounding areas.

Significant landscape points noted on both aerial photographs and established reference objects on the site and in surrounding areas were correlated to develop the baselines. The accuracy of the established baselines was assessed by using the standard land surveying technique of measuring tape and compass. The sampling program took place July 22 through August 1, 1985.

Soil samples were collected and tested for heavy metals in order to determine the lateral extent of the affected areas. The samples were collected from each node on the grid, producing a total of 34 samples. Samples were collected from the surface to a depth of six inches using a plated steel trowel. The samples were placed directly into sample jars and analyzed on-site.

In order to avoid cross-contamination between sampling, strict decontamination procedures were followed. All trowels were decontaminated using a detergent and water wash, tap water rinse and distilled water rinse.

On-site analyses were provided by EPA subcontractors, Camp Dresser McKee. This involved the utilization of a Columbia Scientific X-Met 840 portable x-ray analyzer. Lead values were determined for all 34 grid point samples. In addition, 15% (six) of the surface samples collected had duplicates sent to Rocky Mountain Analytical Laboratories (RMAL) of Arvada, Colorado, for verification of the technique. Appendix A presents the analyses performed by RMAL, including Quality Control Data. The samples were analyzed at RMAL an EPA contract laboratory for metals, according to EPA approved analytical techniques. Sample analysis were deemed to have an acceptable level of Quality Control. As requested by

EPA, the samples were tested for arsenic, barium, cadmium, copper, zinc, manganese, iron, lead and mercury. See Table 4-1 for a comparison of the data.

Concurrently with the sampling, the lithology of the soil sample was described. The soils were classified in a two-fold process. The initial determination as to the soil type was made at the sample location. The sample was described by its color, grain size and the presence of man-made artifacts. The general setting of the sample, including the distribution and age of types of vegetation were also recorded given the intimate relationship which exists between the soil and the root system (Alexander, 1965). For example, if the type of vegetation natural to the area was found, the soil most likely would be considered Native Soil, usually reinforced by the presence of a combination of other indicative factors. It is likely, however, that mine waste may have affected the soil type but not the natural vegetation and for this reason careful consideration of each soil sample was given in the office looking at all the samples together, under the same lighting conditions. It was this second descriptive process upon which the final classifications were based. Four generalized soil classifications were delineated for the site. A hypothetical stratigraphic column was developed based on existing soil relationship at the site. The soils can be described as follows:

1. Native Soil (NS): Undisturbed natural soil, native to a particular area and not brought in from anywhere else. Varies from alluvial terrace deposits, to glacial drift and colluvium.
2. Fill (F): Soil used as fill, may include dirt, stone, brick, slag, glass, etc., but does not contain mine tailings.
3. Mine Tailings (MT): By-product of Smuggler silver/lead mine operations. Lithology is usually silty sand, fine to coarse grained, trace cinders, silt, gravel, pebbles, cobbles, gray to black.

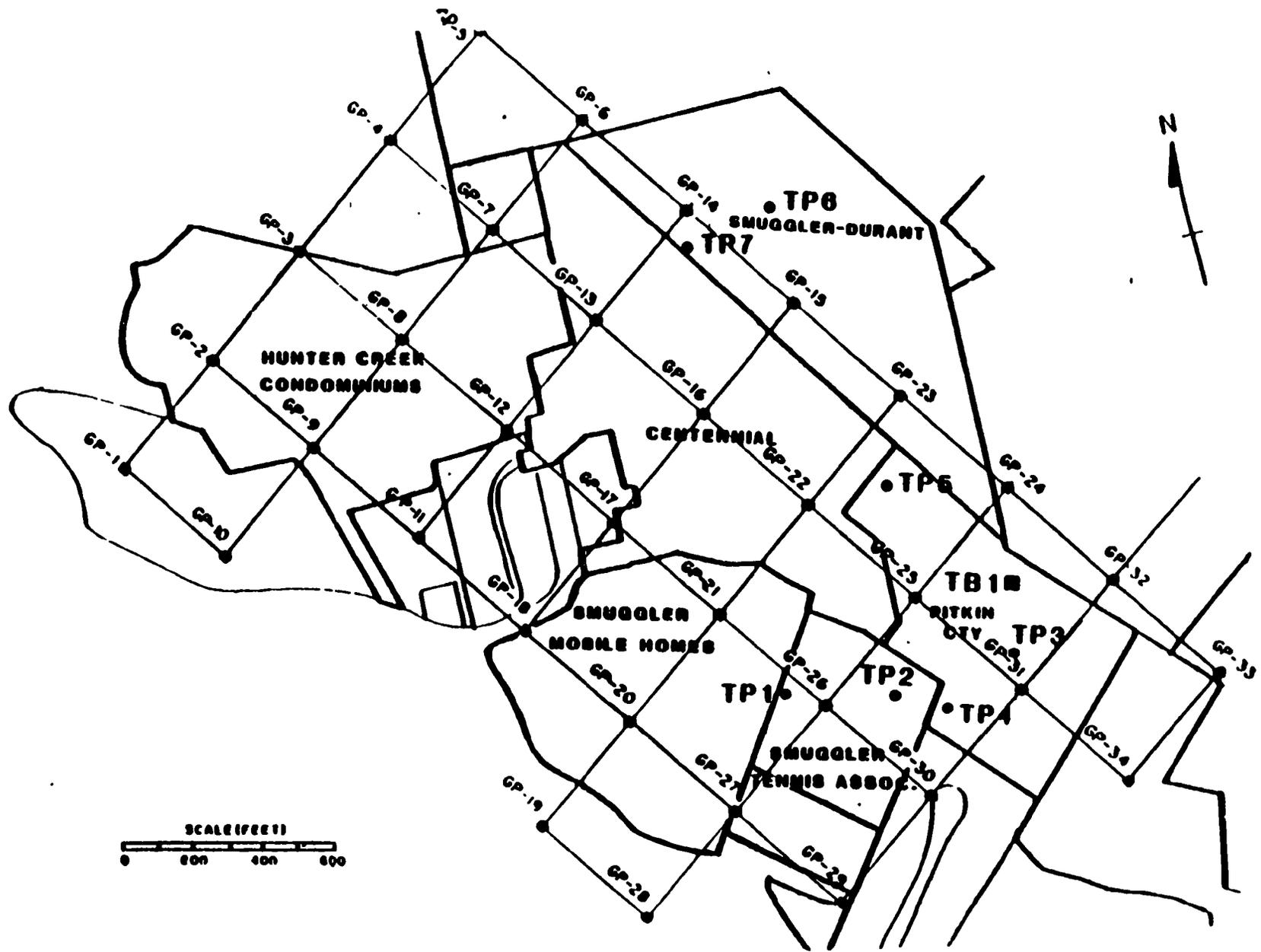
4. **Man-made Fill (MMF):** Material used as fill, may include dirt, stone, bricks, slag, glass, etc., and contains some mine tailings usually identified by their gray to black color.

Mapping of the surface soil conditions around the site was critical to determine the lateral distribution of contaminated materials. Soil types were characterized and defined in the field and mapped on 1"=50' aerial photos. Because of the construction activities and associated landscaping around the area of the site, a low altitude fly-over was conducted as part of this investigation. Color aerial photos were taken at different angles for use in updating the soils maps to reflect changes at the site. The individual photos were used to reconstruct a panorama view of the site at a scale of approximately 1"=280'. Finally, all maps were field checked for accuracy during and after the sample collection. This map series is presented as Volume III. It is important to note that contacts between soil units are often gradational. The existing contact lines reflect areas where one soil type predominates over another. A slash line between soil types indicates that both units are present.

3.2 Subsurface Sampling

The subsurface field activities were needed to provide access to the materials underlying the site. Visual observation along with chemical analysis allowed the determination of the vertical extent of the mine tailings and heavy metal contamination.

3.2.1 Procedures - Test Pits. Seven test pits were dug to sample and identify the subsurface conditions (Figure 3-2). The test pits were dug with a backhoe and a professional operator provided by Ram Excavation, Woody Creek, Colorado and were made under the direct supervision of a HART hydrogeologist. Test pits were excavated to a depth of 10' to reach natural materials. Test pit logs and stratigraphic columns were prepared for each pit describing lithology and stratigraphy (Appendix D). The selection of the specific location for each test pit was based on various combination of stratigraphic relationships of the different materials. TP-1 represented mine tailings over man-made fill over native soil. TP-2



3-7

FIGURE 3-2
TEST PIT LOCATIONS
BOREHOLE LOCATION

- Test Pit Locations
- Test Borehole Location
- ⊕ Surface Sampling Locations

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the values obtained in the laboratory. Since the XRF may appear to exaggerate lead values, application of the 1,000 ppm lead action level in this case would insure that any error would be on the side of safety.

4.2 Distribution of Contaminated Soils

Table 4-2 shows the results of the surface sample analyses. Lead values ranged from a high total of 15,925 ppm at GP-24 to a low total of 185 ppm at GP-21. Two other samples, taken from GP-7 and GP-29, show lead values in excess of 7,000 ppm. Values were 7,890 ppm at GP-7 and 7,615 ppm at GP-29. Six samples, other than GP-21, had lead concentrations less than 300 ppm; GP-17 (290 ppm), GP-19 (218 ppm), GP-25 (209 ppm), GP-30 (299 ppm), GP-31 (208 ppm) and GP-34 (282 ppm).

Over the entire site, the four soil types of native soil, fill, man-made fill and mine tailings were mapped extensively on aerial photographs (Figure 4-1) (Plates 1-6). It was not possible, however, to delineate every area in specific detail due to inaccessibility and/or complexity of soil types. This was the case in the trailer park, where every yard or driveway may have had a different soil type used as fill. Other areas where complete mapping was not possible was in much of Hunter Creek Development and other landscaped areas. The mapping performed was surficial mapping and when an area was landscaped, the area was defined with a soil type, such as fill, but given a qualifier of "P", for "Probably". These types of areas were generally clean on the surface, however at a depth of several inches, contaminated material could be encountered. Further investigation can positively define these "probable" areas.

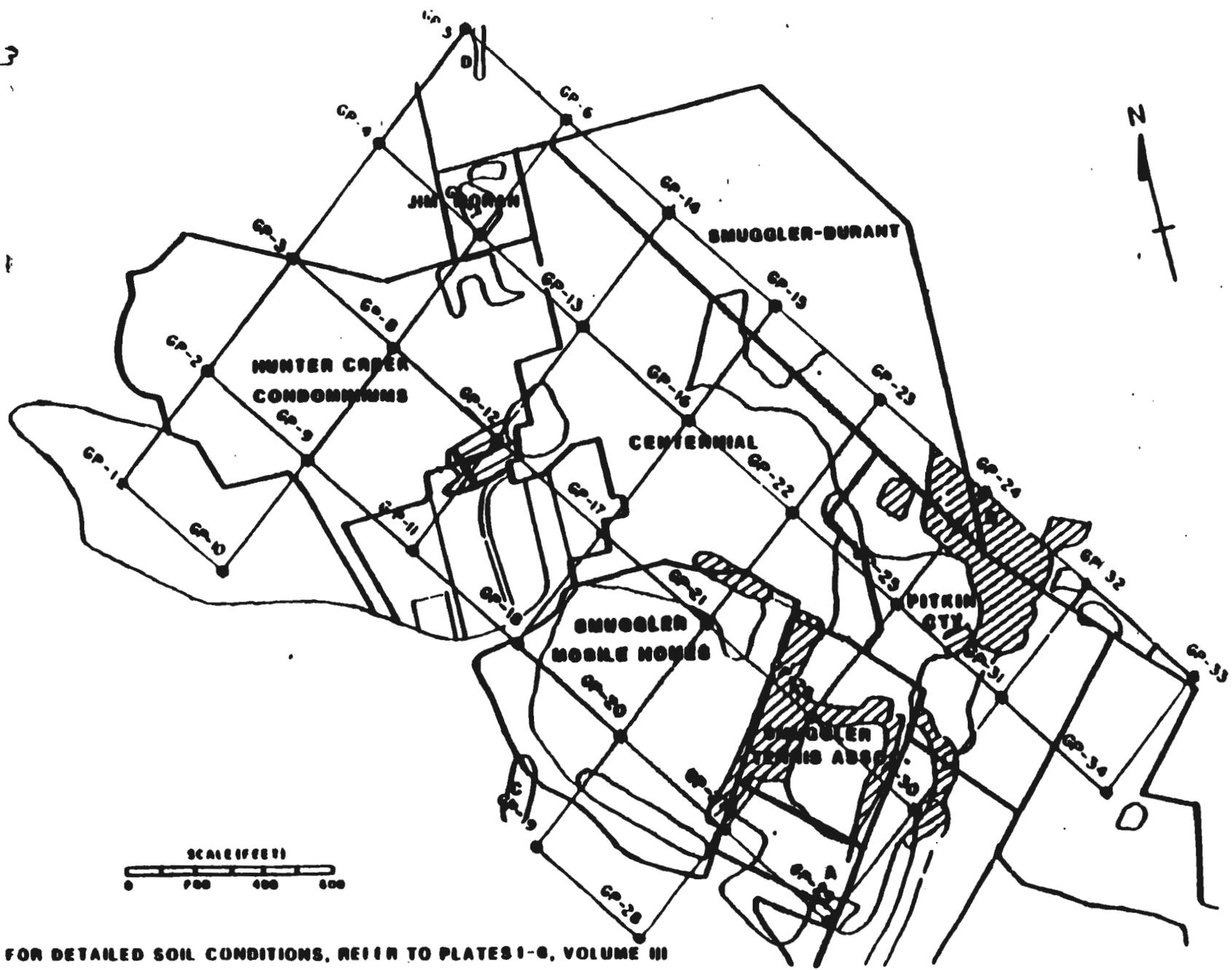
A composite map has been included in a pocket at the end of this report volume. The map shows the detailed soils mapping, HART sampling results, and CDM sampling results, all referenced to the site grid. Soil units containing mine tailings are shown in green, and soil units not containing mine tailings are shown in red. This map provides the most complete summary of all soil mapping and sampling done at the site. For blueprint copies, hatch marks can be used to identify different soil types. A summary of the results of EPA's geostatistical analyses is presented in Appendix H.

TABLE 4-1

COMPARISON OF XRF AND ROCKY MOUNTAIN LABORATORIES DATA

<u>Sample Number</u>	<u>Sample Type</u>	<u>CDM</u>	<u>RML</u>
GP-7	Grid Point	7,890	3,770
GP-9	Grid Point	909	962
GP-19	Grid Point	218	201
GP-24	Grid Point	15,925	19,700
GP-27	Grid Point	879	718
GP-31	Grid Point	208	90
TP6-1	Test Pit	298	9
TP3-2	Test Pit	5,540	1,800

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4-5

FOR DETAILED SOIL CONDITIONS, REFER TO PLATES I-G, VOLUME III

FIGURE 4-1

MAP OF SURFACE SOIL CONDITIONS

-  Manmade Fill
-  Mine Tailings
-  Manmade Fill & Mine Tailings

TABLE 4-2
RESULTS OF XRF LEAD ANALYSIS

<u>Sample Number</u> <u>Gridpoints</u>	<u>Lead Concentration</u>
GP1	560
GP2	648
GP3	553
GP4	348
GP5	802
GP6	391
GP7	7,890
GP8	611
GP9	909
GP10	553
GP11	483
GP12	767
GP13	636
GP14	380
GP15	368
GP16	347
GP17	290
GP18	732
GP19	218
GP20	657
GP21	185
GP22	660
GP23	709
GP24	15,925
GP25	209
GP26	539
GP27	879
GP28	450
GP29	7,615
GP30	299
GP31	208
GP32	540
GP33	481
GP34	232

(0239F)

Mapping was accomplished through physically walking over the area and correlating soil units with high altitude aerial photographs and recent low altitude color aerial photos taken during the course of the Field Studies. Composition, texture and color defined the soil unit to which a particular sample belonged.

Each sample was assigned a soil unit based on composition, texture and color. Table 4-3 shows that each soil type has a characteristic lead level. Average levels of lead concentration in mine tailings and manmade fill were above the 1,000 ppm level. In every sample of fill and native soil, lead levels were below the 1,000 ppm level (Table 4-3).

In samples GP-19, GP-20, and GP-23, Manmade fill was present together with mine tailings which contained less than 1000 ppm concentration of lead. The reason for this is that these samples of fill containing tailings did not possess enough tailings to reach the action level. This is not a problem if that mapped unit is treated as contaminated.

Calculation of the Spearman rank correlation coefficient indicated that the correlation between lead concentrations and soil type has not arisen by chance (Table 4-4). Since each soil type can be mapped by visual classification and its typical concentration is known, the site could be mapped at the 1,000 ppm isopleth by the definition of tailings and manmade fill soil types with an accuracy of 99%. Rank values for soil types were determined by assigning each of the 4 soil groups the same average rank, depending on the number of values in that soil group. For example, native soil was assigned the lowest rank of 10.5. The value of 10.5 was calculated by averaging the sum of $1 + 2 + 3 \dots + 20$. The value of 30 for fill was calculated by averaging the sum of $21 + 22 + 23 \dots + 38$, etc.

Wherever samples were collected from an area with high mine tailing content, lead values were the highest. At GP-7, an area of manmade fill containing mine tailings, lead values were 7,890 ppm. At GP-24, also an area of manmade fill containing mine tailings, values were 7,890 ppm. Again at GP-29, an area of mine tailings, lead concentration was 7,615

Table 4-3

LEAD VALUE/SOIL TYPE COMPARISON

<u>Sample Number</u>	<u>Sample Type</u>	<u>Mapped Soil Type</u>	<u>Lead Concentration (ppm)</u>
GP-7	Grid Point	Mine Tailings	7,890
GP-24	Grid Point	Mine Tailings	15,925
GP-29	Grid Point	Mine Tailings	7,615
TP1-1	Test Pit	Mine Tailings	3,425
TP2-1	Test Pit	Mine Tailings	13,400
TP3-2	Test Pit	Mine Tailings	5,540
TB1-1A	Test Boring	Mine Tailings	8,514
TP4-1	Test Pit	Manmade Fill	3,600
TP5-1	Test Pit	Manmade Fill	2,370
GP-12	Grid Point	Manmade Fill	767
GP-20	Grid Point	Manmade Fill	657
GP-23	Grid Point	Manmade Fill	709
GP-25	Grid Point	Manmade Fill	209
GP-1	Grid Point	Fill	560
GP-2	Grid Point	Fill	648
GP-8	Grid Point	Fill	611
GP-9	Grid Point	Fill	909
GP-13	Grid Point	Fill	636
GP-15	Grid Point	Fill	368
GP-16	Grid Point	Fill	347
GP-17	Grid Point	Fill	290
GP-18	Grid Point	Fill	732
GP-19	Grid Point	Fill	218
GP-21	Grid Point	Fill	185
GP-22	Grid Point	Fill	660
GP-26	Grid Point	Fill	539

Table 4-3
(Continued)

LEAD VALUE/SOIL TYPE COMPARISON

<u>Sample Number</u>	<u>Sample Type</u>	<u>Mapped Soil Type</u>	<u>Lead Concentration (ppm)</u>
GP-27	Grid Point	F111	379
GP-28	Test Pit	F111	450
TP1-2	Test Pit	F111	807
TP3-1	Test Pit	F111	455
TP6-1	Test Pit	F111	298
GP-5	Grid Point	Native Soil/F111	802
GP-3	Grid Point	Native Soil	553
GP-4	Grid Point	Native Soil	348
GP-6	Grid Point	Native Soil	391
GP-10	Grid Point	Native Soil	553
GP-11	Grid Point	Native Soil	483
GP-14	Grid Point	Native Soil	380
GP-30	Grid Point	Native Soil	299
GP-31	Grid Point	Native Soil	208
GP-32	Grid Point	Native Soil	540
GP-33	Grid Point	Native Soil	481
GP-34	Grid Point	Native Soil	282
TP1-3	Test Pit	Native Soil	433
TP2-2	Test Pit	Native Soil	600
TP3-3	Test Pit	Native Soil	345
TP4-2	Test Pit	Native Soil	894
TP5-2	Test Pit	Native Soil	260
TP6-2	Test Pit	Native Soil	289
TP7-1	Test Pit	Native Soil	370
TB1-2A	Test Boring	Native Soil	427

(0239F)

TABLE 4-4

SPEARMAN RANK CORRELATION COEFFICIENT

<u>x</u>		<u>y</u>			
<u>Ph Concentration (ppm)</u>	<u>Rank</u>	<u>Soil Type</u>	<u>Rank</u>	<u>d</u>	<u>d²</u>
185	1	F	30	-29	841
208	2	NS	10.5	-8.5	72.25
209	3	F	30	-27	729
218	4	F	30	-26	676
260	5	NS	10.5	-5.5	30.25
282	6	NS	10.5	-4.5	20.25
289	7	NS	10.5	-3.5	12.25
290	8	F	30	-22	484
298	9	F	30	-21	441
299	10	NS	10.5	.5	.25
345	11	NS	10.5	.5	.25
347	12	F	30	-18	324
348	13	NS	10.5	2.5	6.25
368	14	F	30	-16	256
370	15	NS	10.5	4.5	20.25
379	16	F	30	-14	196
380	17	NS	10.5	6.5	42.25
391	18	NS	10.5	7.5	56.25
427	19	NS	10.5	8.5	72.25
433	20	NS	10.5	9.5	90.25
450	21	F	30	-9	81
455	22	F	30	-8	64
481	23	NS	10.5	12.5	156.25
483	24	NS	10.5	13.5	182.25
539	25	F	30	-5	25
540	26	NS	10.5	15.5	240.25
553	27	NS	10.5	16.5	272.25
553	28	NS	10.5	17.5	306.25
560	29	F	30	-1	1

TABLE 4-4 (Continued)

SPEARMAN RANK CORRELATION COEFFICIENT

<u>x</u>		<u>y</u>			
<u>Ph Concentration (ppm)</u>	<u>Rank</u>	<u>Soil Type</u>	<u>Rank</u>	<u>d</u>	<u>d²</u>
600	30	NS	10.5	19.5	380.25
611	31	F	30	1	1
636	32	F	30	2	4
648	33	F	30	3	9
657	34	MMF	42	-8	64
660	35	F	30	5	25
709	36	MMF	42	6	36
732	37	F	30	-7	49
767	38	MMF	42	4	16
802	39	NS	10.5	28.5	812.25
807	40	F	30	10	100
894	41	NS	10.5	30.5	930.25
909	42	F	30	12	144
2370	43	MMF	42	1	1
3425	44	MT	48	-4	16
3600	45	MMF	42	3	9
5540	46	MT	48	-2	4
7615	47	MT	48	-1	1
7890	48	MT	48	0	0
8514	49	MT	48	1	1
13400	50	MT	48	2	4
15925	51	MT	48	3	9
				<u>d = 0.0</u>	<u>d² = 8314.0</u>

509
(0239F)

TABLE 4-4 (Continued)

SPEARMAN RANK CORRELATION COEFFICIENT

<u>x</u>		<u>y</u>			
<u>Ph Concentration (ppm)</u>	<u>Rank</u>	<u>Soil Type</u>	<u>Rank</u>	<u>d</u>	<u>d²</u>

$$r = \frac{1 - 6 \sum d^2}{n(n^2 - 1)}$$

$$r = \frac{1 - 6(8314)}{51(51^2 - 1)} = 1 - \frac{49884}{132600} = .62$$

$$N = 51 \quad DF = N - 2 = 49$$

H₀: $\rho_s = 0$ the correlation between x and y, i.e. their tendency to vary together, has arisen by chance.

$$t = \frac{rs}{\frac{1-rs^2}{N-2}} = \frac{.6}{\frac{1-(.62)^2}{49}} = \frac{.6}{\frac{.62}{49}} = 5.36$$

Reject H₀

$$t_{.05} = 2.0$$

$$t_{.01} = 2.68$$

The correlation between lead concentration and soil type has not arisen by chance.

ppm. Areas of native soil contained the lowest concentrations of lead, while areas of fill and then manmade fill (containing tailings) show respectively higher values, with mine tailing areas having the highest values. Average lead values for surface samples taken in areas of native soil were 443 ppm, 546 ppm when taken in areas of fill, and 10,477 ppm in areas of mine tailings.

This trend also applied to subsurface sampling. Table 4-6 shows the stratification of soil types and lead contents in each Test Pit. The highest lead concentration values were found where samples were taken from soil layers containing mine tailings only, or from manmade fill which contained a large percentage of mine tailings. Other high lead values were found in TP-1, TP-3 and TB-1, where samples were also taken from areas rich in mine tailings. These values were 3,425 ppm in TP1-1, 5,540 ppm in TP3-2 and 8,514 ppm in TB1-1A. The lowest lead concentrations were found in areas of native soil, the lowest reading being 260 ppm at TP5-2. Lead values were slightly elevated in the native soil below surface mine tailings in one sample, TP2-2. The Mann-Whitney U statistical test was used to determine if a significant difference in lead concentration exists between the surface native-soil and the subsurface native soil. The U-test is used as an alternative to the t-test when the parent population is not known to be a normal distribution (Till, 1982). Calculation of the Mann-Witney U statistic indicated that lead concentrations in surface native soil are not significantly different from lead concentrations in subsurface native soil (Table 4-5). This would preclude the possibility of extensive leaching to the groundwater, and is in agreement with the Hunter Creek Soils Investigation performed by Engineering-Science (Appendix F). In addition, it is unlikely that leaching is a concern on the site due to the low permeability of mine tailings (Section 4.4) combined with slow percolation rates.

Concentrations of lead increased from native soil, to fill, to manmade fill (containing mine tailings), to mine tailings. Averages were 452 ppm, 520 ppm, 2,985 ppm and 7,923 ppm, respectively.

5.0 CONTAMINATION ASSESSMENT

Determination of the nature and extent of remedial actions needed at a site requires an understanding of the hazards posed by the site under investigation. This chapter presents an assessment of contamination at the Smuggler Mountain site based on this and other studies.

Once the type and extent of contamination has been defined, exposure routes and migration pathways can be identified. Endangerment scenarios based on this data can be envisioned and examined to determine the risks posed by contamination at the site to public health and the environment. The appropriate level of risk reduction necessary for the protection of public health and the environment can then be quantified into an environmental protection goal. The environmental protection goal is used to assess the adequacy of the remedial alternatives examined in the feasibility study contained in subsequent chapters of the report.

5.1 Type and Extent of Contamination

EPA has defined the boundaries of the Smuggler Mountain site as the 1,000 ppm lead isopleth. Areas with soils containing higher than 1,000 ppm lead are considered as part of the site. It was shown that lead concentrations are related to soil types. Further, it was demonstrated statistically at a high confidence level that two mapped soil units consistently contained higher than 1,000 ppm lead and two did not. The two mapped units which contained concentrations of lead which were generally close to or over 1,000 ppm were the mine tailings and the man made fill. Since these two units reported lead concentrations generally over 1,000 ppm, they are defined as the site, and will need to be considered for remediation. The other two mapped units were consistently under the 1,000 ppm lead concentration level and will not be considered further.

It should be noted that cadmium is also of concern due to its toxicity. Laboratory analyses showed that all samples with a high lead content also contained significant amounts of cadmium and samples which exhibited low lead also exhibited low cadmium. This finding suggests that

lead can be used as the indicator parameter which determines if the soil is significantly contaminated with cadmium or not.

Treatment of the theory of lead concentration in soil as a function of the mapped soil unit is critical in this case. A composite map showing grid points, analytical data and mapped soil units are shown in the map contained in a pocket at the end of this report volume. CDM's pollutant contour map is presented in Appendix H. Since the surface area of the site is not homogeneous, contour maps showing the 1,000 ppm lead isopleth which did not consider areal changes in soil type would not be accurate. This is critical to a proper understanding of the areal extent of contamination at the site. Contaminated soils have been moved and scattered at random all over the site as lawns, driveways, and road base, an important consideration for remediation. Problems of misleading boundaries were avoided by careful soil mapping. The series of six detailed maps which cover the soil conditions at the site are presented in Volume III (Plates). Common statistical analyses shows that an accurate delineation of contamination can then be related to the mapped soil types. Remediation can focus on those units which are generally over 1,000 ppm lead, and the individual outcrops of those units.

5.2 Exposure Routes and Migration Pathways

Several routes of exposure presently exist at Smuggler Mountain which could cause adverse effects if contamination reaches receptors. Direct contact with the waste could permit exposure. Contaminant laden dusts could be inhaled. Wind could carry fugitive dust particles potentially laden with contamination to nearby residential areas. Soil and pollutant characteristics are an effective barrier to groundwater pollution from site soils (tailings and manmade fill). The risk to groundwater from the site, then, is minimal. Consequently, there is a theoretical risk to public health through ingestion of drinking water contaminated by site soils, but existing site conditions reduce this risk significantly. Since

previous studies have shown no contamination of surface water, surface water will not be considered here.

Studies to determine whether there may be groundwater contamination in domestic wells near the site have been inconclusive. The possibility of contaminated groundwater, if any, emanating from the site may exist. Although elevated levels of metals in wells could be indicative of ore deposits, mining operation, or well construction materials, they may also be associated with the Smuggler Mountain site. Future groundwater development in the area could be limited by the occurrence of this contamination; however, future use of this aquifer is inhibited by the control of development in Pitkin County.

5.3 Endangerment Scenarios

Having enumerated the threats of contamination posed by the uncovered, unstabilized tailings and mixed soils at the Smuggler Mountain site, this section will proceed on the assumption that the site poses routes of exposure through air and direct contact, and a potential threat through the medium of groundwater. A complete discussion of the difficulties with evaluating the potential contamination of groundwater was developed in the FFS. This discussion is reiterated below.

As the geological description of the site indicates, the fractured bedrock underlying much of Smuggler Mountain contains mineralized zones, several of which were mined. Regionally, rain and snowmelt percolating down the interior of the mountain forms a horizontal flow downgradient in the direction of the alluvial aquifer in the valley. It is likely that water in the bedrock aquifer percolates through the mineralized zones and through the abandoned mining areas as it travels to discharge into the alluvial aquifer below and downslope of the Smuggler Mountain site. Hence, any metals found in the alluvial aquifer may be due to the transmission of heavy metals from the bedrock inside Smuggler Mountain, a plume of contamination from the Smuggler Mountain site, or some combination of

the two. At best, this combination would be impossible to evaluate due to the inability to obtain data regarding upgradient background conditions.

Potentially, as rain and snowmelt continue to percolate vertically through the Smuggler Mountain site, the site could eventually have at least some role in contaminating the alluvial aquifer downgradient of the site. It should be noted, however, that acid-base studies showed no potential for acid mine drainage, indicating that leachate percolation at the site would not become worse than it is now.

5.4 Environmental Protection Goals

The overall goal is to minimize the actual or potential release of hazardous substances into the environment from the site. Where direct study allows for a precise identification of those threats, both actual, and potential, precise remedial steps can be taken to arrest contamination through available media, as in the case of air direct contact. Where such identification is confounded by geological ambiguities, as in the case of groundwater, means of abatement must be undertaken commensurate with reasonably established parameters of potential harm.

The specific environmental goal for the Smuggler Mountain site is to insure the protection of the health of residents in the area. Goals for the mitigation of surface releases have been established by EPA in the form of a risk assessment. EPA has defined the site boundary as the 1,000 ppm isopleth. All soil containing higher than 1,000 ppm lead must be isolated such that human health and the environment will be protected. Specific environmental goals with respect to groundwater are to mitigate the threat of exposure to present and future users of the groundwater supply.

Reference 3

Excerpts From Soil Clean-up of Smuggler Mountain Site,
Aspen-Pitkin County, Colorado, Explanation of Significant Differences;
EPA Region VIII; March 1989

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SOIL CLEANUP OF SMUGGLER MOUNTAIN SITE

ASPEN-PITKIN COUNTY, COLORADO EXPLANATION OF SIGNIFICANT DIFFERENCES

Region VIII
Superfund Program

MARCH 1990

OVERVIEW

Portions of the Smuggler Mountain Site in Aspen, Pitkin County, Colorado, are contaminated with mining wastes, which contain high concentrations of lead and cadmium. These concentrations pose a potential health risk to humans, especially small children and pregnant women. Consequently, the site was placed on the Environmental Protection Agency's (EPA) National Priorities List for clean up under the Comprehensive Environmental Response, Compensation, and Liability Act (better known as CERCLA or Superfund). Under the Superfund law, EPA is charged with the responsibility of developing and implementing cleanup remedies that protect human health and the environment.

After thorough study and evaluation, EPA issued a Record of Decision in September 1986, describing the remedy chosen to clean up the site. This remedy was subsequently changed because additional sampling results caused EPA to question the implementability of the clean-up plan. Changes were reflected in EPA's March 1989 Explanation of Significant Differences, a document which described differences between the remedy proposed in the Record of Decision and the remedy to be implemented at the site.

Aspen residents and local officials expressed concern with the changes and submitted to EPA an alternative proposal for site cleanup. Given these concerns and the results of additional soil sampling,

EPA decided to make further revisions to the remedy. The revisions affect four primary components: (1) on-site repository, (2) clean up on individual residential properties, (3) remedial action at Hunter Creek and Centennial Condominiums, and (4) institutional controls.

The community is invited to attend one of the scheduled meetings describing the 1990 draft Explanation of Significant Differences to be held the week of March 19, 1990, in Aspen. The community is also invited to submit written comments to EPA by Friday, March 30, 1990.

Major changes to the remedy proposed in this draft Explanation of Significant Differences are as follows:

1. The number and size of the on-site repositories needed for the disposal of contaminated soil may be reduced.
2. For individual properties, the protective cover of clean soil to be placed over contaminated areas will be reduced from 2 feet to a geo-textile liner overlain with 1 foot of clean soil.
3. For the Hunter Creek and Centennial Condominiums, the protective cover of clean soil to be placed over contaminated areas will be reduced from 2 feet to 6 inches.
4. More stringent institutional controls will be implemented to ensure the effectiveness and permanence of the remedy.

These changes are described in detail in this Explanation of Significant Differences.

**SOIL CLEANUP OF SMUGGLER MOUNTAIN SITE
ASPEN-PITKIN COUNTY, COLORADO**

**DRAFT EXPLANATION OF SIGNIFICANT DIFFERENCES
March 1990**

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INTRODUCTION

This is a draft Explanation of Significant Differences (ESD) on which the Environmental Protection Agency (EPA) will be taking comments from March 8 through March 30, 1990. EPA will consider written comments from the public and will respond to significant comments received in a summary report to be issued at the time the ESD is made final. The final ESD is scheduled to be published by April 15, 1990.

The purpose of this document is to explain the significant differences between the Record of Decision (ROD) signed by the EPA in 1986 (which was subsequently modified by a previous Explanation of Significant Differences in March 1989) and the remedy as proposed herein, which will be implemented at the site.

The ROD divided the site into two operable units (OU) #1 - Residential areas including the site of the repository at the Mollie Gibson Park and #2 - Smuggler Mine site. The ROD selected a remedy only for OU #1. The previous ESD and this ESD only address changes to the remedy selected for OU #1. A remedy will not be selected for OU #2 until a remedial investigation and feasibility study (RI/FS) is completed for the mine site.

Under Section 117 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), EPA is required to publish an explanation of significant differences when significant, but not fundamental, changes are proposed to the previously selected remedy. This document provides a brief history of the site, describes the remedial action to be undertaken at the site, and explains the ways in which this remedial action differs from the remedy selected by EPA in 1986 and subsequently modified in 1989.

This ESD presents only a synopsis of information on the site. The final ESD will be incorporated into the administrative record file. The reader may wish to refer to the previous ESD issued in March 1989, which is available at the Pitkin County Library and

at the Aspen-Pitkin County Environmental Health Department.

SUMMARY OF SITE HISTORY AND CONTAMINATION PROBLEM

Site History

The Smuggler Mountain Site (the site) is located in Aspen, Pitkin County, Colorado. The old Smuggler mine workings are located at the base of the western side of Smuggler Mountain.

Waste rock, tailings, and slag from Smuggler mine cover much of the site. The mine wastes are either exposed, covered, or, in many instances, mixed with native or imported soil. Due to its location in the resort town of Aspen, some residential development has taken place immediately on top of these waste piles. In addition, some piles have been leveled or moved to the edge of the developed areas where they now remain as berms of contaminated soil.

The site is approximately 90 percent developed. Development includes two large condominium complexes, approximately 160 individual homes, several small or condominium developments (4-12 units), and a tennis club.

Soil analyses in the early 1980s, conducted first by residents, later by EPA and the potentially responsible parties (PRPs), identified concentrations of lead up to 46,000 parts per million (ppm). Elevated levels of cadmium, as well as other metals, were also found in the soils. The potential for ground water contamination was also identified during the investigations. The site was proposed for the National Priorities List (NPL), the Superfund list, in October 1984. Listing was final in 1986.

In 1986, EPA selected a remedy for soil cleanup at the site. During the design of the remedy, EPA conducted additional soil sampling at the site to determine the necessary capacity for the on-site repository. The results of this additional soil sampling, which was conducted in the summer of 1988, indicated that the remedy selected in 1986 needed to be changed.

In March 1989, an initial ESD was drafted and presented to the Aspen community. The residents had major concerns regarding the extent and magnitude of the remedial action. Their concerns related to the actual design and implementation of the remedy, the estimated cost, evidence of an actual health risk, and their potential liability, as defined under CERCLA.

Throughout the spring and summer of 1989, EPA met with local officials and citizens in an effort to address their concerns. EPA received a citizens' proposal through Pitkin County dated June 28, 1989, which proposed an alternative remedy which differed from the one presented in the 1989 ESD. This proposal also included a request for assurances from EPA regarding the residents' potential liability. Discussions occurred between EPA and the County concerning the citizens' proposal. The remedy proposed in this ESD addresses both EPA's concerns about the impracticality of the 1986 remedy and, to the extent practicable, concerns expressed by the citizens about the remedy.

In the discussions between EPA and the community, other issues were identified which will not be addressed in this ESD. Design issues, such as preservation of trees or the soil sampling of individual properties, will be addressed in more detail during the design phase of the project after the ESD is final. Other issues of concern to the residents, such as statutory contribution protection and the potential deletion of statutory reopener clauses, would be addressed as part of any settlement between EPA and the property owners. Finally, delisting of the site from the NPL will be addressed in more detail after completion of the remedy.

Background on Lead and Cadmium Contamination

The primary health risk at the site is the potential for human exposure to lead and cadmium through direct contact with mine wastes and contaminated soils.

Lead is a heavy metal that is associated with the mine wastes found at Smuggler Mountain. Lead can be absorbed by humans either through breathing dust in the air or inadvertently. Because small

children tend to put things in their mouths, children who live near a source of lead pollution are more likely to be exposed to lead than adults.

Exposure to lead may cause long-term and possibly permanent damage to the nervous system, which may result in learning disabilities and behavioral problems in children. Even at very low levels, lead exposure can cause harmful effects to the nervous system in children.

Lead exposure may also cause long-term damage to the cardiovascular system, the reproductive system, the kidneys, and the liver. Lead has been shown to be carcinogenic in animal studies.

Cadmium is a heavy metal that is also associated with the mine wastes found at Smuggler Mountain. Studies have shown that cadmium may be carcinogenic to humans. Exposure to cadmium can cause long-term effects on the kidneys, bones, liver, and respiratory and immune systems. Cadmium may also adversely affect human reproduction.

Plants, including leafy green vegetables and root crops, may uptake cadmium from contaminated soils. In addition, vegetables collect dust, which is not easily removed. Vegetables grown in contaminated soils may present an exposure to humans who consume those vegetables.

SUMMARY OF THE 1986 RECORD OF DECISION (ROD)

The objectives of the remedy selected in the 1986 ROD were to isolate waste materials with lead concentrations greater than 1000 ppm by requiring: 1) excavation and disposal of soils/tailings with lead concentrations greater than 5000 ppm in an on-site repository, 2) capping of soils with lead concentrations between 1000 and 5000 ppm with 6 to 12 inches of clean soil and revegetation, 3) continue monitoring of the groundwater, 4) provision of an alternate water supply for residences with domestic wells, and 5) operation and maintenance of the remedy through regular inspections as well as through institutional controls. The 1986 ROD selected a soil cleanup level for lead concentrations of 1000 ppm based on the

information in the Endangerment Assessment and the RLFS report and on the recommendation by the Agency for Toxic Substances and Disease Registry (ATSDR) to EPA.

The reader may refer to the ROD for a more detailed discussion of the remedy selected in 1986. The ROD is available at the Pitkin County Library and at the Aspen-Pitkin Environmental Health Department.

changed from the previous remedies. The changes will be noted at the end of a paragraph by brackets () and highlighting.

Before describing the components of the proposed remedy, an explanation of how the site boundary in Exhibit I was determined and a discussion of the factors that led EPA to make changes to the selected remedy will be provided.

SUMMARY OF THE PROPOSED 1990 REMEDY

The 1989 ESD has been superseded by the remedy proposed in this ESD. Many components of the remedy proposed in this ESD have not changed from the 1989 ESD. It will be noted in the discussions below whether a component has

Site Boundary

The proposed remedy addresses the residential areas within the site boundary for OU #1 which also includes the Mollie Gibson Park repository. Exhibit I of this ESD shows the site boundary which has been drawn to conform to the property boundaries of those properties on the border of the contaminated area. The site boundary is considered an administrative boundary that defines the area subject to the institutional controls adopted by the County.

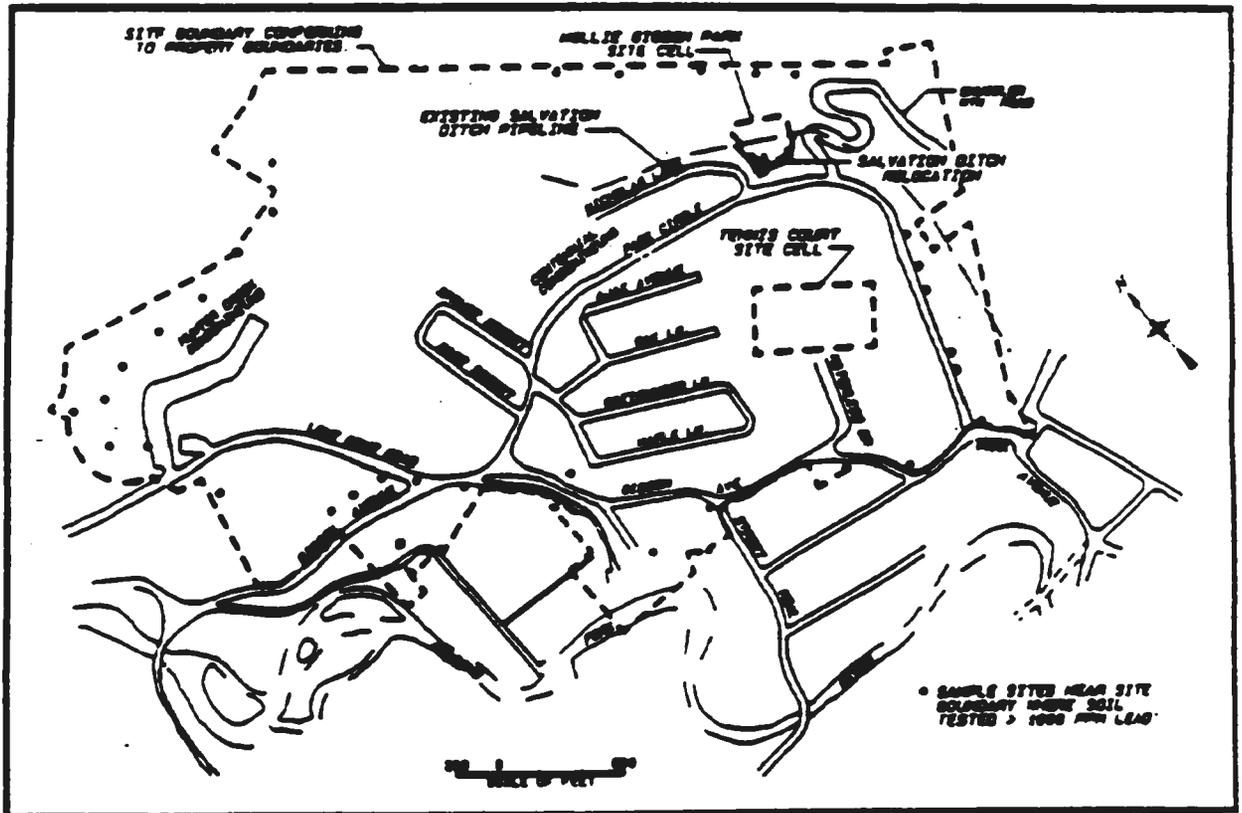


Exhibit #1 Site Boundary Map

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Sampling has shown lead contamination greater than 1000 ppm in the soils on the properties at the edge of the site. These properties have been included within the site boundary. Because the site boundary has been drawn to conform to the boundaries of these properties, it may appear that the original site boundary has expanded in some areas. Additional soil sampling during the design phase may be necessary for some properties to identify the contaminated portion of the property that would require remediation.

Justification for Changing the Remedy

Previous investigations conducted at the site did not clearly identify the exact areas of soil contamination. In addition, the volume of material to be excavated and buried in an on-site repository (i.e., soils with lead concentrations greater than 5000 ppm) was not fully known, since previous investigations had not sampled at depth.

The results of the pre-design sampling conducted by EPA in 1988 indicated that the volume of material with lead concentrations higher than 5000 ppm was significantly greater than the capacity of the Mollie Gibson Park repository. The results also indicated that both the areal and vertical distribution of lead concentrations in the soils/tailings are highly variable. This variability in lead concentrations made it impractical to calculate exact volumes needing to be excavated. The variability also made it extremely impractical to implement two different approaches for soil cleanup, (i.e., total excavation for soils 5000 ppm vs. soil capping for soils 1000-5000 ppm).

The 1989 ESD required 2 feet of clean soil with a vegetative cover for areas where lead concentrations were greater than 1000 ppm. In many situations, achievement of the 2-foot soil cover would have required excavating 2- feet of contaminated material first, before placing 2- feet of clean fill and topsoil. Based on the 1988 soil sampling results and the requirement for a 2- foot soil cover, EPA estimated that the volume of material to be excavated and buried in an on-site repository ranged from 35,000 to 85,000 cubic yards. A second on-site repository would have been required to accommodate this volume of material.

The residents and local officials expressed concern about several components of the 1989 remedy. Their major concerns included the amount of excavation, the resulting disturbance to the community, and the need for two on-site repositories. EPA considered the 2-foot soil cover in the 1989 remedy a necessary balance between engineering controls and institutional controls, because some contamination would be left on-site. The citizens' proposal submitted to EPA in June 1989 suggested an alternative balance that would 1) still provide protection of human health and the environment, 2) minimize the need for a second on-site repository, and 3) provide more certainty in calculating the volume of excavated material requiring on-site disposal.

EPA is proposing revisions to the selected remedy given the findings of the soil sampling, the need to address the impracticality of the 1986 remedy, and the concerns expressed by the citizens about the remedy in the 1989 ESD. EPA is proposing the following changes to the remedy. The proposed remedy consists of four major elements.

1. **On-site Repository**
2. **Cleanup on Individual Residential Properties**
3. **Remedial Action at Hunter Creek & Centennial Condominiums**
4. **Institutional Controls**

1. On-site Repository

- An on-site repository will be constructed at the Mollie Gibson Park Site with a design capacity of approximately 35,000 cubic yards. This repository will serve as the primary location for disposal of contaminated soil/tailings excavated during the residential cleanup. Access to the repository will be controlled by the County.
- The Mollie Gibson Park repository will also serve as the "open" repository for disposal of contaminated soil/tailings displaced due to any kind of development of the properties within the site boundary after completion of cleanup. A repository at the Mollie Gibson Park Site was envisioned in the remedy in the 1989 ESD. However, the primary purpose of a

repository at the Mollie Gibson Park was for future disposal after completion of the remedial action.]

- The Salvation Ditch Irrigation pipeline, which currently passes directly through the Mollie Gibson Park site, will be relocated. (See Exhibit 2 in this ESD). The pipe itself will be upgraded to withstand the expected additional weight from the materials placed in the repository and the pipeline will be re-aligned along the outer edge of the lower bench of the repository for future access. [The relocation of the pipeline has not changed from the 1989 ESD.]
- The Mollie Gibson Park repository will be constructed to be structurally stable, to minimize surface runoff, and to prevent unauthorized access. The "open" portion of the repository will have a temporary cover to minimize dust and a fence to prevent direct contact with the contaminated materials.

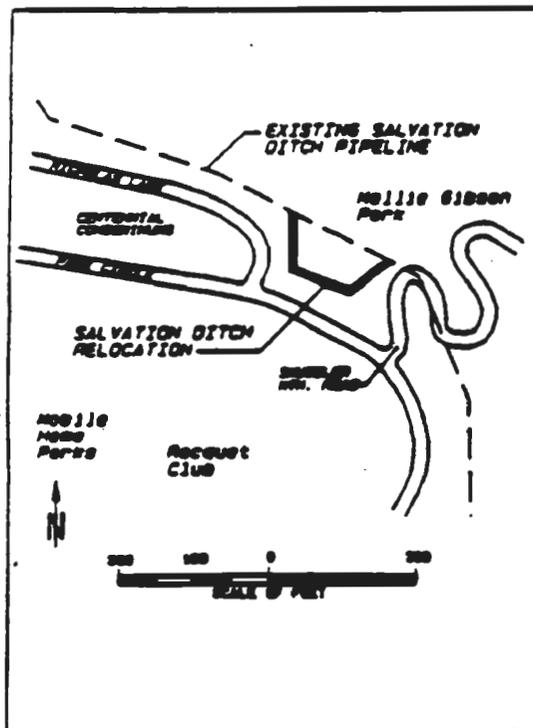


Exhibit 2 Proposed Relocation of Salvation Ditch

- The clean fill and topsoil used as cap material for the repository will have lead concentrations of 250 ppm or less. [This requirement has not been changed from the remedy in the 1989 ESD].
- To conserve the capacity of the "open" portion of the repository, the County will encourage the containment of contaminated soil/tailings on as many properties being developed as possible by administering local ordinances.
- Containment of contaminated soil/tailings on future properties will be accomplished through one of the following approaches:
 - 1) Designing the development project to minimize the displacement of contaminated materials, or
 - 2) Relocating the contaminated materials on the property being developed and covering the materials with an approved cover that is in compliance with the remedy. Any decision to dispose of contaminated materials on the property will include consideration of the amount of material being relocated, the surrounding topography, surface runoff patterns and the effect on adjacent properties.
- A second on-site repository may be necessary depending on the amount of contaminated soil/tailings to be excavated during cleanup. The proposed location of the second repository is the Smuggler Racquet Club property. A major design goal during the cleanup will be to minimize the volume of soil to be excavated and moved, thereby reducing or even eliminating the need for a second repository.
- The decision for a second on-site repository will be based on the number of properties to be remediated and the volume of material to be excavated from those properties. This decision will be made late in the summer of 1991, when all of the soil sampling and volume calculations have been completed.
- Because of proposed changes to the remedy in this ESD (i.e., the change in the soil cover depth from 2 feet to 1 foot would result in a reduction

of volume of material to be excavated), the likelihood of a second repository is reduced

- If a second on-site repository is necessary, the size and capacity would be significantly less than the repository envisioned in the 1989 remedy. It is hoped that, the second repository would not necessitate disturbances of the tennis courts at the Smuggler Racquet Club
- The berm separating the Racquet Club and the Smuggler Mobile Home Park will be remediated and vegetated whether or not a second on-site repository at the Racquet Club is necessary [Remediation of the berm was always a component of the remedies previously selected].

2. Cleanup on Individual Residential Properties

- Soil sampling will be conducted prior to initiating remedial action on each individual residential property that is not part of the Hunter Creek or the Centennial developments.

- Sampling will be conducted in the top 1 foot of soil to determine if the existing soil cover has lead concentrations greater than 1000 ppm. [Soil sampling will provide EPA with the ability to calculate accurately the volume of soil to be excavated and disposed of in the on-site repository. Additional details on this soil sampling program will be provided to residents early in the Spring of 1990.]
- Properties where sampling shows soil lead concentrations above 1000 ppm would be fully remediated, as described below. The soil cleanup on the individual properties includes the following components. (See Exhibit 3 showing the components of the remedy)
 - A geo-textile liner covered with 1 foot of clean fill and topsoil (settled and compacted) and a vegetative cover to minimize erosion is required for all areas not paved or covered by permanent structure. A geo-textile liner is a porous

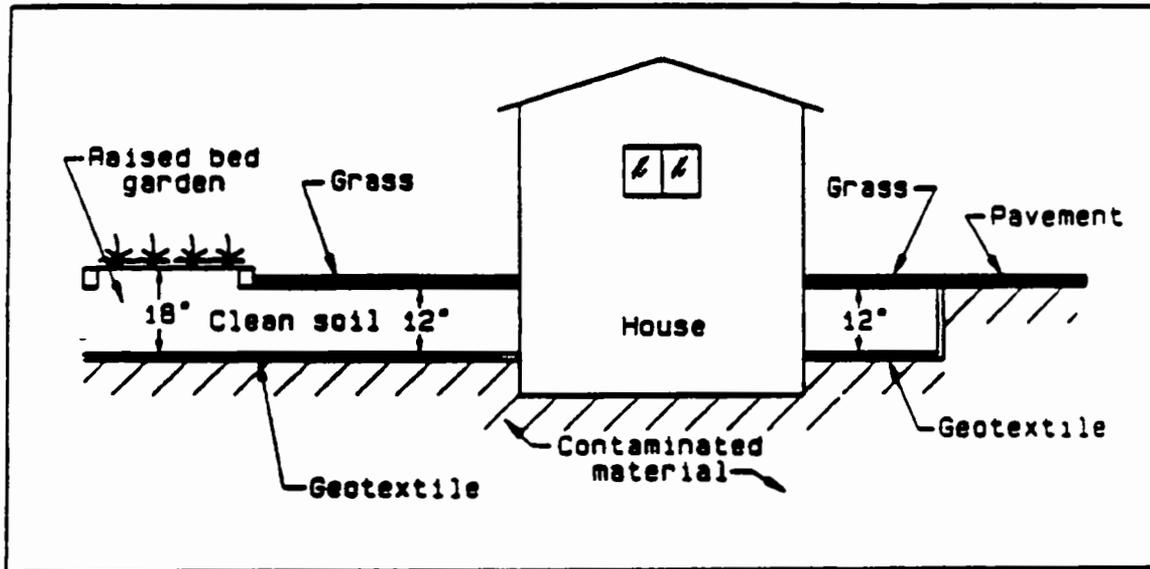


Exhibit 3 Typical Remedy Components

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man-made material (similar to felt) that will be laid over the contaminated soils/tailings [The geo-textile liner was not a component of the remedies previously selected. The requirement for the 1-foot soil cover is a change from the 1989 remedy which required a 2-foot soil cover. The original 1986 remedy required 6-12 inches of clean topsoil for soils with lead concentrations ranging from 1000-5000 ppm.]

- The purpose of the geo-textile liner is to prevent mixing of the contaminated materials with the clean fill. Also, the liner will serve to alert property owners that excavation below this liner would require approval from the County. The geo-textile liner with the 1-foot soil cover functions as a barrier to break exposure pathways and to prevent direct contact with contaminated materials, thus protecting human health. [EPA believes that the geo-textile liner plus a 1-foot soil cover will achieve the same goal of preventing the mixing of clean soil with contaminated soil that would be achieved with a 2-foot soil cover.]
- All clean fill and topsoil used as backfill in the residential areas will have lead concentrations of 250 ppm or less. [This requirement has not changed from the 1989 remedy.]
- Paved areas such as streets, driveways, patios, parking areas, and sports facilities provide an adequate cover to prevent direct contact with any underlying contaminated soil/tailings. Driving areas on the site, such as streets and driveways, that are currently not paved will be paved to prevent direct contact. [The 1989 remedy allowed gravel as well as paving. However, gravel is not as permanent as paving. Dust levels are usually greater with gravel surfaces.]
- Permanent structures such as single family homes, condominiums, modular homes, garages and other structures with a floor and foundation provide adequate cover for

preventing direct contact with contaminated materials. Future modifications to these structures that might increase the risk for direct contact with contaminated materials would require prior approval by Pitkin County as part of the institutional controls to be implemented as part of the remedy. [This component has not changed from the 1989 remedy.]

- Access under any home, deck, or similar structure will be limited or the materials adequately covered to prevent the potential for direct contact with contaminated materials. [This component has not changed from the 1989 remedy.]
- Where topographical conditions permit, contaminated materials may be covered in-place with a geo-textile liner, 1 foot of clean fill (settled and compacted), and a vegetative cover to minimize erosion. Practical considerations such as the drainage patterns and preservation of large trees, as well as discussions with affected property owners will determine the appropriate approach during cleanup. [This component has only changed from the 1989 ESD with respect to the required geo-textile and the thickness of the soil cover.]
- Undeveloped lots will be covered with 1 foot of clean fill over a geo-textile liner and revegetated with a natural grass mixture. Other acceptable covers that provide a protective barrier and are approved by EPA may be substituted. During construction of the remedy, EPA will work with property owners to the extent possible to accommodate the owner's plans for development, where those plans conform to the remedy. [This component has only changed from the 1989 ESD with respect to the required geo-textile and the thickness of the soil cover.]
- All flower and vegetable gardens will be replaced with raised-bed gardens that are at least 6 inches above the top of the soil and vegetative cover. The purpose of raised-bed gardens is to provide a total of

at least 18 inches of clean soil that will 1) ensure that an adequate barrier exists between the roots of vegetables and any contaminated materials and 2) minimize frequent digging below the top 1 foot of clean soil [The requirement for raised-bed gardens is a new component in the proposed remedy due to changing the required soil cover depth from 2 feet to 1 foot.]

- All residential areas will be restored to their original condition to the maximum extent possible. Since preserving the large trees is a major concern to the residents on the site, special care will be taken during cleanup in working around the trees. Because replacement in-kind of large trees is very costly and not always possible, efforts will be made to protect the existing trees. For smaller trees and bushes it may be more cost-effective to replace them rather than work around them during construction. [This component of the proposed remedy has not changed from the 1989 remedy.]
- Additional information and design details regarding the treatment of trees will be developed during the design phase with opportunities for residents' input.
- Those properties where sampling of the top 1 foot of soil does not show contamination greater than 1000 ppm may still require some remedial action to meet the minimum requirements of the remedy. In addition to the 1-foot soil cover already in place, the minimum requirements include a healthy vegetative cover; paved driving area; raised bed gardens; and limited access under homes, decks, and similar structures.
- During remedial design, EPA will evaluate each property where sampling does not show contamination in the top 1 foot for compliance with the remedy. If a property is not in compliance with the remedy, those deficiencies will be addressed during the cleanup. For those properties where soil sampling shows no contamination in the top 1 foot of soil, excavation of the property would not be

required, hence, the geo-textile liner would not be part of the remedy on that property.

3. Remedial Action at Hunter Creek & Centennial Condominiums

The proposed remedy at the Hunter Creek and Centennial Condominiums differs somewhat from that at the rest of the site. There are several reasons for these differences in the remedy.

First, property ownership at the Hunter Creek and Centennial Condominiums is unique in that access and usage of the common areas is already limited by the condominium regulations, i.e., declarations, by-laws, and association rules. Second, the grounds at the condominium areas (including the landscaped and paved areas which comprise the cover) are maintained by the property management associations.

Activities such as individual gardening (other than in containers) and use of the lawns for recreational activities (such as soccer or football) that would tend to be detrimental to the sod cover are currently prohibited by the condominium association rules.

Third, although condominium regulations could be changed to allow other uses, making those changes involves the collective decision of the group rather than the decision of one individual owning the property, as is the case with the individual residential property areas.

Finally, maintenance of the common areas by the condominium associations will also be required by the County's proposed ordinances.

- When Centennial Condominiums were constructed, most contaminated materials were relocated to the Mollie Gibson Park site. However, soil sampling results in 1988 and 1989 at Centennial Condominiums show some limited areas where contamination greater than 1000 ppm still exists in the top 6 inches of the soil.
- In 1985, a 6-inch soil cover was applied at the Hunter Creek Condominiums. The 1988 and 1989 soil sampling results at the Hunter Creek Condominiums show that in many areas lead concentrations are greater than 1000 ppm in the top 6 inches of the soil cover.

- The cause for failure of the soil cover is not known since EPA did not conduct oversight during construction at either the Hunter Creek or Centennial Condominiums. The lack of adherence to strict construction standards in construction of the soil cover may be one of the causes for failure of the soil cover.
- Most of the components of the remedy described for the individual residential properties will be the same for the Hunter Creek and Centennial Condominiums. The following discussion of the soil cleanup remedy at the Hunter Creek and Centennial Condominiums will include only those components that differ from the individual residential properties.
 - Six (6) inches of clean topsoil (settled and compacted) and a vegetative cover to minimize erosion will be required for all areas not paved or covered by permanent structures. [This component has changed from the 1989 remedy which required a 2-foot soil cover. The 1986 remedy required 6-12 inches of clean fill and topsoil.]
 - Areas where the soil cover has "failed" will be repaired such that an uncontaminated 6-inch soil cover (after settling and compaction) exists at all times throughout the Hunter Creek and Centennial condominiums properties.
 - Because a 6-inch soil cover is proposed for the condominiums instead of the 1-foot soil cover required at the rest of the site additional institutional controls including certain access restrictions on common areas will be implemented. These additional controls will be discussed in more detail in #4 below. [Although institutional controls were always a component of the remedy, the additional institutional controls for the common areas are a new component in the proposed remedy.]
 - Because children's exposure to lead is a major concern at the site, a geo-textile liner covered with 1 foot of clean soil will be required for all existing and any new play

areas at Centennial and Hunter Creek Condominiums. A vegetative cover will be required to complete the protective barrier in the play areas. In place of the vegetative cover, 1 foot of clean sand over the geo-textile liner and the 1-foot soil cover may be substituted in these play areas. These requirements will provide an extra level of protection in areas where children may play for extended periods of time. [This component of the remedy has changed from the 1989 remedy which required a 2-foot soil cover. Also, the 1989 remedy did not provide for a sand cover as a substitute for a vegetative cover to complete the remedy.]

4. Institutional Controls

- The term "institutional controls" refers to administrative requirements adopted by governing bodies to require or prohibit certain types of activities. Under the proposed remedy, institutional controls will be adopted to ensure the effectiveness and permanence of the remedy. Institutional controls include County or City ordinances, condominium association covenants, by-laws, or rules and regulations.
- A major component of the proposed remedy is the adoption of institutional controls that will ensure the effectiveness and permanence of the remedy. The purpose of the institutional controls is to ensure that any future development or other activity within the boundaries of the site does not interfere with the integrity and effectiveness of the permanent remedy. [Institutional controls have always been a component of the previously selected remedies although they have never been defined in detail as they have been in this ESD.]
- The institutional controls will apply to all properties within the site boundary (as shown on Exhibit 1), whether or not the properties are remediated during the cleanup.
- Institutional controls will include various measures to maintain the integrity of the soil and vegetative cover. Institutional controls may also include notices to future owners on the site

- advising them of the need to maintain the vegetative cover on their property
- The primary measure will be the enactment and enforcement of County ordinances that will require permits for some types of activities and compliance with the remedy for other activities. The performance standards in the County's proposed ordinances are based on the requirements of the remedy as described in the ROD and in this ESD.
 - The County ordinances will include additional requirements for the Hunter Creek and Centennial Condominiums due to the difference in the required thickness of the soil cover. Other measures may include existing regulations and restrictive covenants enforced by the Hunter Creek and Centennial Condominium associations.
 - The County ordinances are being drafted by the County with input from EPA, the State of Colorado, and local elected officials. Residents of Aspen and Pitkin County will have an opportunity to provide input on the ordinances during the County adoption process. A draft of the proposed ordinances will be published in mid-March 1990, as part of the County's formal adoption process.
 - A draft of the County ordinances will be attached to the final ESD. When the ordinances are adopted, a copy of the adopted ordinances will replace the draft and be attached to the final ESD. If the ordinances are not adopted by the County as presented in the draft attached to the final ESD, then EPA will reevaluate the proposed remedy.
 - The County ordinances under development are described in general terms as follows:
 - Permits will be required for activities or developments that will involve excavation of more than 1 cubic yard of soil. For activities that involve no excavation or excavation of less than 1 cubic yard of soil, the property owner will not need a permit, but will have to comply with certain requirements or performance standards.
 - Information regarding the proposed activity or development such as the depth of excavation, the volume of material to be excavated, the duration of the project, etc., will be required for application of a permit.
 - The performance standards or requirements for maintaining and restoring the remedy are briefly summarized below
 - Flowers and vegetables will be planted only in raised bed gardens at least 6 inches above the soil cover for a total of 18 inches of clean soil above contaminated soils
 - Where excavation of the soil cover is necessary for landscaping purposes (trees and shrubs), the property owner must comply with the performance standards discussed below. Excavation for landscaping will be limited to less than a foot where possible.
 - For excavation and construction activities, interim safety measures will be required to minimize dust, to prevent surface runoff and erosion, and to prevent access to contaminated materials throughout the duration of the project.
 - The Director of the Aspen-Pitkin Environmental Health Department will determine through the permitting process the appropriate method for disposal of contaminated soils/tailings displaced due to development activities. Disposal of displaced contaminated soils/tailings will be either: 1) on the property covered by the approved remedy or 2) in the on-site repository. The Director may require soil sampling to determine the lead content of such materials.
 - Containment of contaminated soils/tailings on the property will be encouraged to the maximum extent possible by minimizing their displacement in the project design or by incorporating the material into the existing topography and covering with

the appropriate components of the remedy

- After completion of any activity or development, the property owner will be required to replace or restore the permanent remedy, i.e., geo-textile liner covered by 1 foot of clean topsoil, and a vegetative cover to minimize erosion.
- Because the remedy is different for the Hunter Creek and Centennial Condominium complexes, additional requirements will be included in the County's ordinances. These additional requirements are summarized as follows:
 - Lawns or other landscaped areas may be fenced, as determined to be necessary by the County, to prevent deterioration of the vegetative cover by foot traffic from residents. Such areas would be fenced with wood or other effective fencing materials at a height of 3-1/2 feet. Any fencing would be approved by the County prior to installation.
 - Lawns and other landscaped areas will be posted to notify residents of the restricted use of such areas. The purpose of the signs would be to remind residents to keep to the designated walkways.
 - Vegetated and paved areas will be regularly maintained. Any changes in the use of the vegetated or paved areas will require prior approval from the County.
 - The Condominium Associations will be responsible for maintaining the common areas and will be required to submit an annual budget and maintenance plan to the County for approval.
 - The Condominium Associations will also be required to post a bond with the County to guarantee annual maintenance costs. The County may

draw on the bond should the Condominium Associations fail to meet their maintenance obligations

- The County will conduct monthly inspections of the common areas. The cost of these inspections will be borne by the Condominium Associations
- Restrictive covenants will be placed on the properties governing the use and maintenance of playing fields and recreational areas.
- No new playing fields or recreational areas will be constructed without County approval.
- The implementation and enforcement of the institutional controls by the County is a major component of the remedy. As such, if the institutional controls as envisioned in this document are not adopted by the County, then EPA would need to reevaluate the proposed remedy once again.

Protectiveness of the Remedy

The remedy proposed in this ESD is protective of human health and the environment because it breaks the exposure pathway between the contaminated soils/tailings and the residents living on-site. The geo-textile liner and a 1-foot soil cover proposed in the remedy provide a protective barrier that prevents direct contact with contaminated soils. Paved streets, driving areas, etc., and permanent structures also provide a protective barrier against direct contact.

The geo-textile liner prevents mixing of underlying contaminated materials during the placement of the soil cover and due to frost heave and other natural forces after cleanup. The liner also alerts a property owner of the need for a permit under County ordinances.

A maintained vegetative cover ensures that the soil cover remains intact and does not erode, and expose the underlying contaminated soils. A vegetative cover also minimizes dust, protecting the overall air quality.

The County ordinances and condominium restrictions provide institutional measures that ensure the integrity of the engineering controls in the remedy. Because contaminated soils will remain on-site, institutional controls are necessary to ensure the permanence of the soil cover.

The County ordinances allow for some disturbance of the soil cover, but the institutional controls will ensure that the remedy is restored or replaced upon completion of the activity. Provisions for an "open" repository ensure an appropriate disposal place for contaminated materials.

The County ordinances include additional requirements governing the use and maintenance of the landscaped areas at the Hunter Creek and Centennial Condominiums. The County ordinances also require financial assurances from the Hunter Creek and Centennial Condominiums to ensure proper maintenance of the grounds.

The County has committed to implementation and enforcement of the ordinances described in this ESD. Enforcement of the institutional controls is assured by the County entering into a Consent Decree with EPA.

Additional institutional controls will ensure the maintenance of the vegetative cover. Restrictive covenants currently exist at the Hunter Creek and Centennial Condominiums which govern the use of the landscaped areas. Notices will advise all future owners on the site of the need to maintain the vegetative cover on their property.

Although the 1989 remedy requiring a 2-foot soil cover anticipated institutional controls as a component of the remedy, the breadth and scope of the institutional controls were not as comprehensive as those proposed here. Under the 1989 remedy with a 2-foot soil cover, most "homeowner" activities, i.e., gardening and other yard improvements, would not have involved excavation below the top 2 feet, thus minimizing the permitting requirements under the County ordinances. With the proposed remedy requiring a 1-foot soil cover, permits under the County's ordinances may be required in more instances. A protective barrier against direct contact with contaminated soils would be provided with either a 1- or 2-foot soil cover, as long as either is maintained appropriately.

EXPLANATION OF SIGNIFICANT DIFFERENCES

The 1986 remedy, as modified by the 1989 remedy, and the proposed 1990 remedy remain fundamentally the same. The same waste management practices will be employed. Both remedies have combined the practice of isolating the contaminated wastes with institutional controls to protect human health and the environment. The other elements of the 1986 remedy remain in the proposed remedy.

The major differences between the 1986 remedy, which was subsequently modified by the 1989 ESD, and the proposed 1990 remedy are as follows:

- The proposed remedy requires a geo-textile liner covered with 1 foot of clean soil and a vegetative cover. The previous remedy as modified by the 1989 ESD required 2 feet of clean soil and a vegetative cover. Both remedies are considered protective since both provide a protective barrier to prevent direct contact with contaminated soils. However, a 1-foot cover will likely require more intervention from the County through its permitting program to ensure that the shallow cover is maintained.
- The proposed remedy will require soil sampling on each property to demonstrate contamination within the top 1 foot before soil removal and placement of a geo-textile liner covered with 1 foot of clean topsoil and a vegetative cover. The previous remedy did not require sampling of each property prior to soil remediation. By sampling each property before remediation, EPA will be able to more accurately determine the required capacity for the on-site repository.
- Changing the soil cover requirement from 2 feet to 1 foot will minimize the need for a second on-site repository at the Smuggler Racquet Club. Should a second repository be necessary, the scale of the repository at the Racquet Club will be much smaller.
- Soil sampling will indicate only whether contamination was found in the soil samples.

taken in the top 12 inches. Previous soil sampling results have indicated contamination can exist below the top 12 inches. Since the potential for contamination exists below the top 12 inches at all properties, all properties will be required to have the major components of the remedy, i.e., a vegetative cover and paved driving areas. All property owners will also be required to maintain the equivalent of the remedy and comply with the institutional controls whether or not the property is remediated.

- A major difference between the 1986 remedy as modified by the 1989 ESD is the thickness of the soil cover required for the Hunter Creek and Centennial Condominiums. Because of the difference in uses of the property and the maintenance of the property by the condominium associations, the proposed remedy will consist of 6 inches of clean soil, a vegetative cover and additional institutional controls that will be enforced by the County. The 1989 remedy required 2 feet of clean backfill and topsoil and a vegetative cover.
- Institutional controls are a major component in both the proposed remedy and in the remedy in the 1989 ESD. However, as discussed above under the "Protectiveness of the Remedy", the institutional controls envisioned in this remedy will be more comprehensive. Additional institutional controls will be required for the Hunter Creek and Centennial Condominiums to ensure maintenance of the landscaped areas.
- The design criteria (e.g., cap material, erosional stability, etc.) of the on-site repository(ies) will not significantly change from the 1989 remedy. However, the scale of the second on-site repository, if needed, will be much smaller.
- Institutional controls will become a more integral part of the proposed remedy than was envisioned in the previous remedy. The County's role in the implementation and enforcement of the institutional controls will be crucial to preserving the integrity of the proposed remedy. The County's entry into a Consent Decree with EPA ensures that the institutional controls will be enforced.

- The monitoring requirements outlined in the ROD for ground water quality and the maintenance of the soil cover will be changed to reflect the changes to the remedy as presented in this ESD.

SUPPORTING AGENCY COMMENTS

The Colorado Department of Health has reviewed the proposed 1990 remedy in this ESD and has provided comments to EPA. These comments have been incorporated into this ESD to the maximum extent practicable. The Colorado Department of Health concurs with EPA in the proposed modifications to the remedy.

STATUTORY DETERMINATIONS

The changes to the remedy were made in accordance with all applicable and statutory requirements for hazardous substances remaining on site. Because hazardous substances above recommended levels will remain at the site, periodic review (every 5 years) of the response action will be conducted, pursuant to CERCLA, to ensure that the remedy remains protective of human health and the environment.

The proposed remedy meets the statutory and regulatory evaluation criteria for selection of a remedy. Because treatment of the principal threats at the site was determined to not be practical, this remedy does not satisfy the statutory preference for treatment as a principle element of the remedy. However, the revised remedy utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable for this site.

Considering new and existing information and the changes to the selected remedy, EPA has determined that the remedy remains protective of human health and the environment because it breaks

the exposure pathway by preventing direct contact with contaminated soils/tailings

The remedy complies with the recommended health advisory by the Agency for Toxic Substances and Disease Registry for cleanup of soils contaminated with lead. The remedy requires remediation, where lead concentrations are greater than 1000 ppm in the top 1 foot of soil on the site.

As noted above, contaminated materials will remain on-site after completion of the remedy. The long-term effectiveness of the remedy is ensured by the engineering components of the remedy and the ongoing maintenance of the vegetative cover required by the institutional controls.

During implementation of the remedy, dust levels may increase slightly. Stringent health and safety measures will be implemented to minimize dust levels and ensure the safety of both the workers and the residents, thus ensuring short-term effectiveness of the remedy.

Implementability of the remedy should not be a problem because the technology is a standard engineering practice for preventing direct contact with contaminated soils.

The cost of the proposed remedy is estimated to be between \$4.5 million to \$5.0 million. This is less than the previous cost estimates for 1986 and 1989 remedies, due in large part to the reduction in the soil cover from 2 feet to 1 foot, and the potential for not needing a second repository.

EPA has worked extensively with the community during the past year to understand the residents' concerns regarding the remedy. To the extent practicable, EPA has addressed the community's concerns. Because the changes to the remedy presented in the 1989 ESD raised numerous concerns, EPA is providing this ESI in draft for the community to review and provide comments before a final ESD is issued. EPA will attempt to address the community's comments regarding this draft.

ACTIVITY DESCRIPTION	1988												1989				
	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY
ESD																	
Over ESD by Public Comments																	
Reopen House to Community																	
ESD Revised																	
SOIL SAMPLING																	
Access for Soil Sampling																	
Soil Sampling																	
SOIL PROTECT OPERATIONS																	
Soil Access/Rails to Proceed																	
Soil Construction																	
Soil Excavation & Control Piles																	
CIVILIAN CONSULT SERVICES																	
Civilian Consult Service Reporting																	
Approved ESD by the EPA																	
CALCULATION OF REMEDIATION COSTS																	
Construction of Piles																	
REMOVED/REMOVED MATERIALS																	
Over Remedial Design																	
Phase Remedial Design																	
REVISIONAL LOT PLAN DESIGN																	
Revising Cleanup Contracting																	
Approved Construction to Proceed																	
Revised Construction																	

Exhibit #4 Schedule for Sampling and Cleanup

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ESD to the extent possible. The State of Colorado supports the proposed changes to the remedy

SCHEDULE FOR SAMPLING AND CLEANUP

The schedule for the Smuggler Mountain site soil sampling and cleanup is presented below in Exhibit 4. The relocation of the pipeline is scheduled for the fall of 1990 and the cleanup in the residential areas will begin in the Spring of 1991.

PUBLIC PARTICIPATION

Citizens are invited to attend one of the scheduled informational meetings on the draft Explanation of Significant Differences to the remedy to be held the week of March 19, 1990, in Aspen. The Community is invited to submit written comments on the draft ESD to EPA. Comments should be sent to EPA at the address given below by Friday, March 30, 1990. Questions regarding the Explanation of Significant Differences should be directed to:

Paula M. Schmittziel
Remedial Project Manager
Phone #: (303) 293-1527

or

Sonya Pennock
Community Relations Coordinator
Phone #: (303) 294-1115

Toll-free Number: 1-800-759-4372 (in Colorado)

Written comments on the draft ESD should be addressed to Paula M. Schmittziel at the address given below:

U.S. Environmental Protection Agency,
8HWM-SR
999 18th St., Suite 500
Denver, CO. 80202-2405

The administrative record, which contains the complete documentation for the site and additional copies of the ROD and the 1989 and 1990 ESDs, is

available for public review at the following locations:

Pitkin County Library
120 E. Main Street
Aspen, Colorado 81611
303-925-7124
Hours: M-Th, 10am-9pm, F-Sat,
10am-6pm, Sun, 12pm-6pm

Aspen-Pitkin County Environmental
Health Department
130 S. Galena Street
Aspen, Colorado 81611
303-920-5070
Hours: M-F, 8am-5pm

EPA Superfund Document Control Room
999 18th Street, 5th Floor
Denver, Colorado 80202
303-293-1807
Hours: M-F, 8am-4pm

MAILING LIST ADDITIONS

If you did not receive this update by mail, and you would like to be added to EPA's mailing list for the Smuggler Mountain Site, please send the following information to:

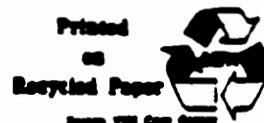
Ms. Sonya Pennock
Office of External Affairs (80EA)
U. S. Environmental Protection Agency
999 18th Street, Suite 500
Denver, Colorado 80202-2405

Name _____

Address _____

City/State _____ Zip _____

Company, organization, or governmental
entity _____





UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
 REGION VIII
 999 18th STREET - SUITE 500
 DENVER, COLORADO 80202-2405

Ref: 80EA

MEETING ANNOUNCEMENT

To: Property Owners and Residents
 Smuggler Mountain Superfund Site

From: Sonya Pennock, Community Involvement Coordinator

Re: Community Meetings on Proposed Explanation of
 Significant Differences, March 19-22, 1990

The U.S. Environmental Protection Agency (EPA) will begin a public comment period on a draft Explanation of Significant Differences (ESD) modifying the cleanup plan for the Smuggler Mountain Superfund Site Friday, March 9, 1990. The public comment period will end Friday, March 30, 1990.

A series of meetings have been scheduled to provide you with information on the ESD. This information will help you decide whether you wish to submit written comments on the proposed changes to the cleanup plan. Because meeting space is limited, EPA encourages you to attend the meeting designated for the area in which you live. If you wish to meet individually with EPA during this time, please call Carolyn Hunka, SRM, 920-4408. For more information on procedures for public comment, please call me at the EPA toll-free number 1-800-759-4372 or at my office number (303) 294-1115 or Diane Sanelli, Community Involvement Coordinator, (303) 294-1139.

MEETING SCHEDULE

March 19:
 7:00 PM - Smuggler Landowner Task Force & County
 Commissioners

March 20:
 11:30 AM - Smuggler Racquet Club
 5:30 PM - Site-wide, Pitkin County Library
 120 E. Main St.
 8:00 PM - Centennial Condominiums
 Community Center - Old Dining Room

March 21:
 1:30 PM - Site-wide, Pitkin County Library
 120 E. Main St.
 6:30 PM - Smuggler Mobile Home Court
 Smuggler Mobile Home Owners Assn. Office

March 22:
 6:00 PM - Hunter Creek Condominiums
 Community Center - Large Dining Room

Reference 4

**Excerpts From Soil Clean-up of Smuggler Mountain Site,
Aspen-Pitkin County, Colorado, Explanation of Significant Differences;
EPA Region VIII; May 16, 1990**

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SOIL CLEANUP OF SMUGGLER MOUNTAIN SITE

Region VIII
Superfund Program

EXPLANATION OF SIGNIFICANT DIFFERENCES

MARCH 1989

ADMINISTRATIVE RECORD
6.7 OF FILE NUMBER

INTRODUCTION

The purpose of this document is to explain the significant differences between the Record of Decision (ROD) signed by the U.S. Environmental Protection Agency (EPA) in 1986 and the remedy which will be implemented at the site. Under Section 117 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), EPA is required to publish an explanation of significant differences. This document provides a brief background of the site, describes the remedial action to be undertaken and explains the ways in which this remedial action differs from the remedy selected by EPA in 1986.

This Fact Sheet will, by necessity, present only a synopsis of information on the site. The administrative record, which contains the complete documentation, is available for public review at the Pitkin County Library and the Aspen-Pitkin County Environmental Health Department in Aspen, Colorado. An additional copy of the administrative record is located at the EPA Region VIII Library in Denver, Colorado.

SITE HISTORY AND BACKGROUND

The Smuggler Mountain Site is located in Aspen, Pitkin County, Colorado. The old Smuggler mine workings are located at the base of the western side of Smuggler Mountain.

Waste rock, tailings and slag cover much of the site. The mine wastes are either exposed, covered, or, in many instances, mixed with native or imported soil. Due to its proximity to the resort city of Aspen, development has taken place immediately on top of the waste piles, or the piles have been leveled

or moved to the edge of developed areas, where they remain as berms of contaminated soil.

The site is approximately 90 percent developed. Development consists primarily of residential properties including two large condominium complexes, two mobile home parks, several small condominium developments (4-12 units), approximately 25-30 individual homes and a tennis club.

Soil analyses in the early 1980s by EPA and the potentially responsible parties (PRPs), identified concentrations of lead up to 46,000 parts per million (ppm). Elevated levels of cadmium, as well as other metals, were also found in the soils. A potential ground water problem was also identified. The site was proposed for the National Priority List (NPL) in October 1984.

The primary concern at the site is the potential for humans to be exposed to lead and cadmium through direct contact by inhalation or ingestion with mine wastes and contaminated soils.

PUBLIC MEETING

EPA representatives will discuss the proposed cleanup design with interested members of the community at a public meeting.

Date: March 14, 1989
 Time: 7 to 9 pm
 Place: Pitkin County Community Center
 Roaring Fork Room
 0100 Lone Pine
 Aspen, Colorado

EPA will also be meeting with the County Commissioners, City Council, and homeowners association groups on March 13 and 14, 1989.

BACKGROUND ON LEAD AND CADMIUM CONTAMINATION

Lead is a heavy metal which is present in the environment from various sources. Lead can be absorbed by humans either through inhalation or ingestion. Because small children tend to put things in their mouths, they are more at risk to lead exposure than adults, if they live near a source of lead pollution.

Lead toxicity affects red blood cells, the nervous system and the kidneys. Lead may also affect human reproduction and has been shown to be carcinogenic in animal studies. Even at very low levels, lead exposure can cause harmful effects to the nervous system in children.

Cadmium is a heavy metal that is also frequently associated with mine wastes, as is the case at the Smuggler Mountain site. Studies have shown that cadmium may be carcinogenic to humans, has chronic effects on the kidneys and may affect human reproduction. Plants, including leafy green vegetables and root crops are subject to uptake of cadmium from contaminated soils. Vegetables grown in such soils may present an exposure to humans through the ingestion of those vegetables.

SUMMARY OF THE 1986 RECORD OF DECISION (ROD)

The objectives of the 1986 ROD were to isolate waste materials with lead concentrations greater than 1000 ppm, to continue monitoring the groundwater, to provide an alternate water supply for residences with domestic wells, and to conduct operation and maintenance of the remedy.

The ROD also divided the site into two operable units (OU): OU 1 - Residential areas including the site of the repository at the Mollie Gibson Park and OU 2 - Smuggler Mine site. This Explanation of Significant Differences will only address changes to the remedy selected for the residential area (i.e., OU 1).

The remedy selected in 1986 consisted of the following elements:

- All soils/tailings with lead concentrations greater than 5000 ppm were to be excavated and placed in an on-site repository under the ownership of Pitkin County. The Mollie Gibson Park, located on Smuggler Mountain below the Smuggler Mine, was proposed as a suitable site for an on-site repository.



AERIAL VIEW OF THE SMUGGLER MOUNTAIN SITE

Reference 5

**Excerpts From Focused Feasibility Study for Ground-water Remediation,
Smuggler Site, Aspen, Colorado; Fred C. Hart Associates, Inc.;
July 5, 1985**

**FOCUSED FEASIBILITY STUDY
FOR GROUNDWATER REMEDIATION
Smuggler Site
Aspen, Colorado**

Prepared by:

**Fred C. Hart Associates, Inc.
530 Fifth Avenue
New York, New York 10036**

July 5, 1985

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1.0 Executive Summary

The Smuggler site is an old silver-lead mine area which is located approximately one mile northeast of the city of Aspen. Mine tailings produced during the peak mining years 1879 to 1920 are piled outside of the mine shafts. Over the course of the years, the tailings have been moved, used for fill material, or have been mixed with man-made materials.

The exact extent of the site area is not yet defined. A study is currently planned to define these limits. Several tunnels and shafts exit Smuggler Mountain within the site area, namely the Cowenhoven Tunnel, Smuggler Shaft and the Mollie Gibson Shaft.

The site is topographically located on the northeast slope of the Roaring Fork River Valley. Coarse-grained unconsolidated glacial outwash, poorly sorted glacial morainal deposits, and alluvial fan deposits immediately underly the mine tailings. The bedrock underlying the unconsolidated materials is the Belden Formation. This formation is composed of limestone, dolomite, slate and evaporites. The ore body which was mined is a zone of mineral enrichment located along a thrust fault which follows the contact of the Leadville Formation and the unconformably overlying Belden Formation.

A number of investigations have been undertaken at this site. The Ecology and Environment, Inc. (E & E) Field Investigation Team performed a sampling investigation at the site in 1983. The investigation was the result of a request by Pitkin County to characterize any human or environmental threat posed by abandoned mine tailings in the northeast quadrant of Aspen, Colorado. The county became concerned following the analyses of soil and plant samples taken from the Aspen area which indicated elevated levels of trace metals, specifically lead and cadmium (Boon, 1982). An initial report of the results of the E & E sampling was drafted in response to a Technical Directive from the Environmental Protection Agency (EPA) and was distributed in March 1984 (E & E, 1984a).

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During this time, EPA requested Camp, Dresser & McKee, Inc. (CDM), to prepare a Draft Work Plan for the Remedial Investigation/Feasibility Study of the site. EPA is currently reviewing all submittals to determine whether the site should be formally listed or removed from NPL consideration.

Currently, the RI/FS work plan proposed to EPA by CDM notes that the short term risks posed by the site are primarily due to the uncontrolled tailings. Direct contact with dusts may lead to dermal ingestion, and potentially contaminated wind blown dusts could lead to ingestion through inhalation. Surface water transport of heavy metals originating from the site could also be responsible for contaminant dispersion.

The currently planned Field Study proposes to provide data to help mitigate these risks. All areas of tailings, mixed tailings and fill material, and contaminated soils which exceed toxic action levels will need to be covered, and surface drainage controls such as culverts, toe drains, or settling basins will need to be implemented to mitigate the problem of dispersion of contaminants by surface water.

Chapter 3 indicated the need for implementation of remedial actions for the protection of the public health. This Feasibility Study was prepared in response to those needs with respect to groundwater. The Feasibility Study evaluated alternative technologies and alternatives that could be implemented at the Smuggler site for mitigation and/or elimination of potential endangerment mechanisms.

Five categories of remedial actions were evaluated for implementation at the site, including monitoring, source removal, source isolation, plume capture and water supply replacement. Sixteen remedial technologies were initially evaluated for applicability to the Smuggler site. Nine technologies were found to be applicable and combined into twelve remedial actions. These twelve remedial actions were initially screened based on an evaluation of their environmental effects, environmental protection, and implementability/reliability. Nine alternatives survived the initial screening process and were subjected to detailed evaluation.

Nine criteria were used to perform a detailed evaluation of each alternative. These criteria included: reliability, implementability, technical effectiveness, environmental concerns, safety, operation and maintenance, costs, regulatory requirements, and public acceptance. Using these criteria, it was possible to assess and identify the most appropriate alternative for the Smuggler site.

Based on the detailed evaluation of the nine alternatives, a combination of alternatives 3, 5, and 9 appears to be the proper the lowest cost alternative that is technologically feasible and reliable; and which effectively mitigates risks posed by the Smuggler site.

Additional studies may be required for the analyses of slope stability, leachability (acid/base potential) and permeability in order to determine the need for surface sealing (alternative 4) and/or subsurface drains (alternative 8). These studies could be performed during the currently planned field studies.

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2.0 BACKGROUND INFORMATION

This chapter of the Focused Feasibility Study for groundwater remediation at the Smuggler Site presents a brief overview of background information. Section 2.1 discusses site background information including the location of the site, waste disposal practices at the site, and site geology and hydrology. Section 2.2 briefly discusses the nature and extent of contamination problems at the site. Section 2.3 discusses previous response actions and investigations at the site. For additional detailed background information concerning the site, the reader is referred to the following documents:

- a. Lincoln DeVore, Inc. 1983. "Interim Report on the Surface Geology and Mine Study, Centennial Project, Aspen, Colorado" Prepared for Centennial Partners Ltd.
- b. Ecology and Environment, Inc. 1984a. "Interpretive Report and Health Risk Assessment of the Smuggler Mine, Aspen, Colorado".
- c. Camp, Dresser, and McKee Inc. 1985. "Draft Work Plan for Smuggler Mountain RI/FS, Pitkin County, Colorado." U.S. Environmental Protection Agency Region VIII, Denver, Colorado.

2.1 Site Description

2.1.1 Location. The site is located immediately northwest of the City of Aspen in Pitkin County. The tailings area is situated in the northwesterly trending valley of the Roaring Fork River at the base of Smuggler Mountain. A location map is presented in Figure 2-1.

2.1.2 Waste Disposal Practices. The area encompasses approximately 75 acres of developed and undeveloped properties. Tailings from the Smuggler, Mollie Gibson, and Free Silver Mines, the Cowenhoven Tunnel, and from past smelting and milling operations related to these mines and tunnels, have been deposited in the area. In most places, tailings have been mixed with other materials. However, some tailings used as fill have remained uncovered (E&E 1984a). It is estimated that undisturbed mine tailings make up

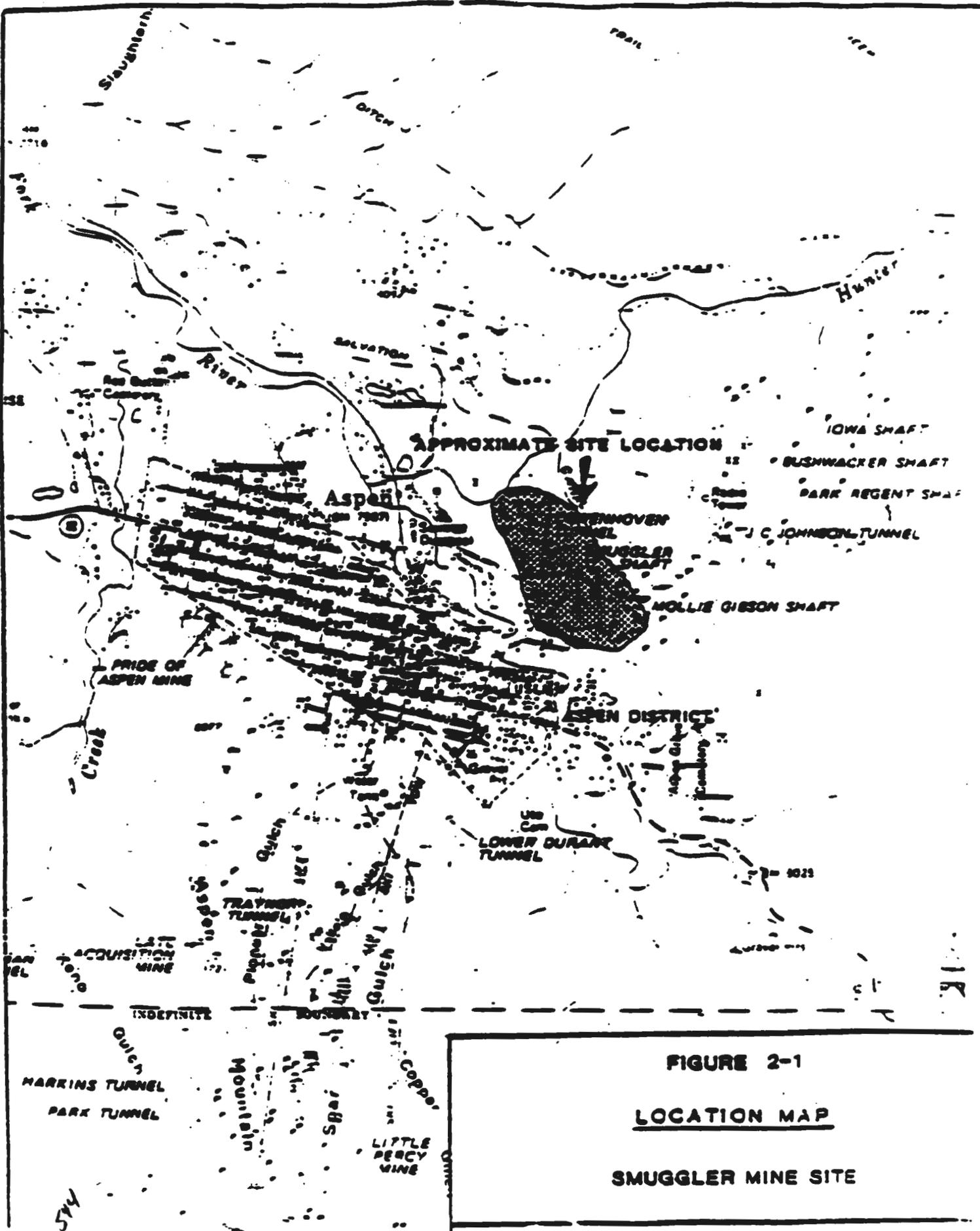


FIGURE 2-1

LOCATION MAP

SMUGGLER MINE SITE

approximately 25 percent of the 75 acre area while undisturbed soils comprise another 25 percent (E&E 1984a). The remaining 50 percent is primarily a complex mixture of mine and mill tailings, native soil, and fill.

The deposited tailing material was a result of the mining and milling of silver, lead, and zinc. Quantities of the tailing materials have been established at approximately 2.4×10^6 cubic yards (E&E 1984b). The distribution of the tailings, as well as their reworking since their original distribution, is not well-defined. Past records indicate that tailings on the Smuggler site were placed there from 1880 to 1915. The tailings piles from the Cowenhoven Tunnel were leveled and scattered when the Hunter Creek condominiums were built. Recent investigations indicate that some of the tailing piles were leveled, and tailings were scattered over the present sites of the Smuggler Trailer Court, Smuggler Racquet Club, Hunter Creek Condominiums, and the Centennial-Aspen Condominiums (McIntosh 1985). There is currently an active permitted mining operation with tailing piles upslope of the site which, due to permitting, is not considered as part of the site.

2.1.3 Topography. Topographically, the overall site slopes moderately toward the west and southwest, with an overall gradient on the order of approximately 10 to 15 percent. However, at isolated locations throughout the site and along the southeastern boundary, gradients on the order of 100% occur. The ground surface elevation ranges from approximately 7936 to 8164 feet above mean sea level.

Throughout the years, parts of the ground surface at the site have been altered as a result of mining and earthmoving activities. Characteristics of the site include numerous small closed depressions. Several of these areas of interior drainage are located above abandoned mine shafts, tunnels, and stopes (cavernous mined-out areas). Some of these closed depressions are the result of ground subsidence, particularly over the old Mollie Gibson Mine shaft, the Free Silver Mine shaft and Cowenhoven Tunnel. A depression approximately 12 to 15 feet deep is evident at the Free Silver shaft. As mentioned, the topography on the site has changed due to miscellaneous grading (both cutting and filling) through the years. On more than one occasion, it appears that portions of the site have been either borrowed from, filled on, or disturbed by grading.

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2.1.4 Hydrogeology. Generally, the groundwater system underlying Smuggler Mountain is dominated by extensive honeycombed mine workings. These workings serve as conduits transporting groundwater from within the mountain to the level of the Roaring Fork River. Groundwater levels are affected only slightly by the stage of the river, moderately by the amount of rainfall and snowmelt runoff available on the mountain, and greatly by the efficiency of the drainage network formed by the mines. Cave-ins and other blockages in the old workings may impede drainage, generating large rises in water levels. Conversely, "blow-outs" of blocked tunnels resulting from high water pressure can produce large water discharges at the ground surface, with consequent falls in groundwater levels. Variations in pore water pressures caused by changes in the groundwater regime may have a significant effect on the overall stability and subsidence potential of the shallow mine workings.

The site is underlain by various surficial deposits which include alluvial deposits, and glacial moraine and glacial outwash deposits. These deposits are characteristic of valley fill deposits. It is reported that the valley fill deposits are several hundred feet thick in the Roaring Fork River Valley. Depending on their extent and thickness, as well as permeability, these deposits will yield anywhere from 5 to 1000 gallons of water per minute. However, it should be noted that the investigation performed by Ecology and Environment, Inc. in March 1984 indicated there was no alluvial groundwater system underneath the tailings at the site.

Underlying the aforementioned surficial deposits, the bedrock is divided into the Gothic Shale, Belden Shale, and Leadville Limestone Formations. The Leadville aquifer, which may be up to 200 feet in thickness, has been reported to yield as much as several thousand gallons of water per minute. The occurrence of water is a characteristic of fractures and solution conduits found in the aquifer.

2.1.5 Hydrology. The Roaring Fork River passes the site at a distance of approximately 1000 feet to the southwest. In this reach, the river elevation is about 7870 to 7920 feet above mean sea level. There are no major

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natural drainage channels crossing the site. However, site drainage is affected by two small to moderate-sized basins located to the east and northeast. Hunter Creek passes approximately 500 feet north of the site. The Salvation Ditch, an irrigation canal, crosses the southern part of the site at an elevation of approximately 8000 feet.

Any drainage from the site occurs largely as unconcentrated overland flow, although channelization is apparent from mine discharge water. Specifically, drainages from the Mollie Gibson Mine shaft and Cowenhoven Mine access tunnel traverse the site. Each discharge is in the range of 1 cubic foot per second (cfs) or less. Existing water quality data from each channel show the discharge to be moderately laden with dissolved constituents, including iron, manganese, and zinc. Based on samples collected in 1983, total dissolved solids (TDS) concentrations range from 540 mg/l for the Mollie Gibson discharge to 918 mg/l for the Cowenhoven Tunnel. The Mollie Gibson and Cowenhoven drainages discharge to the Roaring Fork River and Hunter Creek, respectively. Discharge in both streams is seasonally variable. For the Roaring Fork River, low flows of 15-20 cfs occur during the January through early March period, and high flows of typically 400 to 800 cfs occur during the mid-May through early July period. As for Hunter Creek, flows generally range from 5 to over 400 cfs during similar periods.

2.2 Nature and Extent of Problems

As was previously described, the area under consideration encompasses approximately 75 acres of developed and undeveloped properties. It is estimated that 2.4×10^6 cubic yards of mine tailings materials have been generated at the site (E&E 1984a).

Various studies have been conducted in the recent past to characterize the tailings around the Smuggler area (Boon 1982; Lincoln Devore, 1983; Boon 1983; E&E 1984a; Clement 1985; McIntosh 1985). Results of these studies show that several metals were detected in the soils and tailings. Concentrations of arsenic, barium, cadmium, copper, lead, manganese, mercury, and zinc in the mine tailings and soil were elevated compared to a selected

soil background sample (E&E 1984a). The concentrations of these metals in the samples also exceeded the concentration of those elements found in native soils throughout the United States (Clement 1985). These soil and tailing areas and their constituents noted to date are described briefly below.

2.2.1 Tailings. Six tailing samples were collected in September 1983 (E&E 1984a). Chemical analysis of these samples show elevated concentrations of arsenic, barium, cadmium, copper, lead, manganese, mercury, and zinc. Of these metals, arsenic, cadmium, copper, mercury, lead, and zinc were reported as being above background levels as described by Connor and Shackletter (1975).

2.2.2 Soils. Soil samples were collected downslope from the tailings piles during September 1983, at an area underlain by graded tailings and covered with transported topsoil (E&E 1984a). Chemical analysis of these samples indicated that, on the average, soil downslope of the tailings showed elevated levels of arsenic, barium, cadmium, copper, lead, manganese, and zinc.

Results from other sampling events conducted by Boon (1983) and the Aspen/Pitkin Environmental Health Department have shown some elevated metal concentrations when compared to Connor and Shackletter (1975). Boon's data showed elevated levels of cadmium, copper, lead, and zinc. Three samples were collected at the Smuggler Trailer Park by the Aspen/Pitkin Environmental Health Department and analyzed for lead and cadmium (CDH 1982). The average and maximum concentrations reported were 90 and 223 ug/g for cadmium and 11,723 and 21,700 ug/g for lead. It is uncertain whether these samples were of soil or tailings (Clement 1985).

2.2.3 Toxicity of Contaminants. The site contains elevated concentrations of arsenic, barium, copper, manganese, and mercury, and high concentrations of cadmium, lead, silver, and zinc in tailings and contaminated soils. Concentrations for these metals may exceed levels at which toxic effects have been observed in plants, wildlife, domestic animals, and man. EPA has performed a risk assessment and has arbitrarily set action levels for soil

cleanup. A study is planned to collect and analyze data to determine the extent of surface remediation necessary at the site to mitigate risks posed by the dermal ingestion or direct contact exposure routes.

Lead and cadmium are the two metals of most concern at the site because of their concentrations and acute toxicities. Mean lead concentrations in soil throughout the site area (4,060 ug/g) and tailings (8,120 ug/g) exceed the 1,000 ug/g soil concentration in which significant lead exposure-related toxicity has been reported for children. Children of the 1-5 age group are at greatest risk because of their soil ingestion habits and greater susceptibility to blood lead poisoning. Studies in lead-contaminated environments show that children's blood lead levels increase proportionately to soil lead concentrations. When soil lead concentrations exceed 1,000 ug/g, children's blood lead concentrations exceed could 25 ug/dl, a level above which toxic effects of lead poisoning have been observed in children. (Blood lead levels for children not exposed to lead are usually in the range of 12.7 ug/dl or less. The primary effect of lead exposure is the inhibition of hemesynthesis in the biosynthesis of hemoglobin.)

It is important to note that the blood lead studies conducted to establish the 1,000 ug/g soil lead concentration were based on atmospherically deposited lead from automobile emissions and smelters. It is not known whether exposure to lead in tailings and soil such as that at the Smuggler site will produce elevated blood levels.

Cadmium is of concern for three reasons. First, its reported concentrations in tailings and soils throughout the site area (means of 56 ug/g and 26 ug/g respectively). Second, various forms of cadmium are acutely toxic. Third, cadmium compounds are generally more bioavailable than lead compounds. Phytotoxic reactions to cadmium have been observed at soil concentrations of 5-10 ug/g (background normally 0.1 to 1.0 ug/g). Feed concentrations of 1-5 ug/g have also resulted in cadmium toxicity. Increased cadmium uptake normally results in increased tissue concentrations, particularly in the liver and kidneys. As tissue levels increase, disfunctions of these organs can occur. Cadmium is also of a concern at the site, one

groundwater sample of 13 ug/l exceeded the ambient water quality standard of 10 ug/l. Elevated atmospheric cadmium concentrations were also observed. Exposure to cadmium through water, dust, and direct contact could increase concentrations to toxic levels.

Due to the relatively neutral pH (6.38-7.22) of the tailings, soil and bedrock materials, the metals on the site are in relatively insoluble forms. The insolubility of the metals decreases their bioavailability and, therefore, toxicity. None of the metals are volatile, and, thus, they are expected to persist for an extended period of time. Evidence suggests that heavy metals in domestic wells downgradient of the site could be a problem. It is unknown whether compounds detected in these wells to date could cause a health related problem in these wells. These immediate concerns lead to an impending concern of further future impacts from the tailings to the groundwater system. This Focused Feasibility Study acknowledges the potential for future contamination of groundwater supplies, and therefore looks specifically at alternatives to mitigate these problems. However, any alternatives proposed for groundwater remediation in this Focused Feasibility Study would also contain components of cleanup to address the other issues of potential exposure from unstabilized surface wastes via the direct contact or inhalation routes.

2.3 Previous Response Actions

A number of investigations have been undertaken at the site. Pitkin County became concerned following analyses of soil and plant samples taken from the area. Analyses indicated elevated levels of trace metals, specifically lead and cadmium (Boon, 1982). The Ecology and Environment, Inc. (E&E) Field Investigation Team performed a sampling investigation at the site in 1983. The investigation was conducted resulting from a request by the county to characterize any human and environmental threats posed by abandoned mine tailings in the northeast quadrant of Aspen, Colorado. An initial report of the results of the E&E sampling was drafted in response to a Technical Directive from the Environmental Protection Agency (EPA) and distributed in March 1984 (E&E, 1984a).

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EPA requested Camp, Dresser & McKee, Inc. (CDM), to prepare a Draft Work Plan for the Remedial Investigation/Feasibility Study (RIFS) of the site. The committee of Potentially Responsible Parties (PRPs) retained Fred C. Hart Associates, Inc. (HART) to provide technical support to the committee. Because gaps existed in the data base used for the ranking, EPA, through its subcontractor Ecology and Environment (E&E), performed a hydrogeologic assessment at the site to address the appropriateness of the ranking of the site. EPA is currently reviewing all submittals to determine if the site should either be formally listed or removed from NPL consideration.

3.0 CONTAMINATION ASSESSMENT

Determination of the nature and extent of remedial actions, if any, needed at a site requires an understanding of the hazards posed by the site under investigation. This chapter presents a brief assessment of the contamination at the Smuggler site. Section 3.1 discusses the groundwater pathway by which the contaminants present at the site may migrate to impact groundwater receptors. Section 3.2 summarizes the groundwater endangerment scenarios developed at the Centennial site. Section 3.3 discusses establishment of an environmental protection goal, based on the results of the groundwater contamination assessment. The environmental protection goal is used to assess the adequacy of the no-action alternative as well as any recommended remedial action alternatives.

3.1 Groundwater Contaminant Migration Pathways

The source of contamination at the Smuggler site is solid wastes. The solid wastes include mine wastes, mill tailings, and smelter wastes that were generated from silver, lead, and zinc mining. As previously mentioned, it is estimated that undisturbed mine tailings make up approximately 25 percent of the 75 acre area, and 50 percent is comprised of a complex mixture of mine and mill tailings, native soil, and fill material (E&E 1984a). Potential migration pathways for these wastes include: air, surface water, groundwater, and there is some potential for direct contact with the contaminants at the site.

A study is currently planned address the type and amount of surface remediation necessary to mitigate risks caused by the occurrence of heavy metals at the site. A final feasibility study will set cleanup criteria at the stated action levels from EPA's risk assessment.

Bioavailability and acute toxicity posed by heavy metals and soils at the site via direct contact or inhalation exposure routes, however, are not the only concerns for proper remediation. Since heavy metals could leach

into local aquifers, groundwater users could be at risk, and regional groundwater supplies could be damaged. There has been in conclusive evidence of current contamination of local receptor wells, although, it is generally agreed that future risks to groundwater and groundwater users have not been identified or characterized.

Based on previous work, the concept of groundwater flow is well understood at the site. Due to the complex geologic conditions at the site caused by the occurrence of groundwater through fractured bedrock flow systems, and extensive mining, it is doubtful that any study regardless of cost could ever provide reliable local data to support groundwater remediation alternative designs.

The purpose of this Focused Feasibility Study is to determine the alternatives available for groundwater remediation at the site. In the event that the present data base will not technically support attractive alternative remedial designs, this study will outline data gaps and propose additional study requirements which could be performed during the study planned to define the limits of the site. A final Feasibility Study will be included in that study to recommend a conceptual design for mitigation of risks posed by all media at the site.

The risk associated with the groundwater media is considered to be moderate. There is some potential for largely insoluble heavy metals to be leached by infiltrating rainfall. In addition, the groundwater media could contribute to the contamination of surface water through the interface between alluvial groundwater and the surface waters in the Roaring Fork River and Hunter Creek. Potential receptors include human and animal populations ingesting surface waters from Roaring Forks and Hunter Creek Rivers and persons ingesting contaminated groundwater obtained from the alluvial aquifer. Domestic wells subject to potential contamination include approximately five residential wells located between the site and Roaring Fork River.

Off-site groundwater contamination at levels approaching state and federal drinking water standards have been demonstrated by previous studies (Ecology and Environment 1984a). Although elevated levels of metals in these wells could be indicative of ore deposits, mining operations, or well construction materials, they may also, at least in part, be associated with the Smuggler Site. Future groundwater development in the area could be limited by the occurrence of this contamination, however, future use of this aquifer is prohibited in Pitkin County. Future wells drawing on the alluvial aquifer adjacent to the Smuggler site could be endangered by this contamination.

3.2 Endangerment Scenarios

Having enumerated the threats of contamination posed by the uncovered, unstabilized tailings and mixed soils at the Smuggler site, this section will proceed on the assumption that the Centennial site poses a relatively well-established and predictable threat of transmission through air, surface water and direct contact, and a moderate to high threat through the medium of groundwater. Since a site definition study is currently planned, this section will focus on the groundwater media only.

Although concentrations of two heavy metals significantly higher than background have been found in samples of alluvial groundwater, the presence of mineralized zones in the bedrock in the vicinity of the Smuggler site destroys all simple source-pathway-receptor analysis.

As the geological description of the site indicates, the fractured bedrock underlying much of Smuggler Mountain contains mineralized zones, several of which were mined. Regionally, rain and snowmelt percolating down the interior of the mountain forms a horizontal flow downgradient in the direction of the alluvial aquifer in the valley. Water in the bedrock aquifer percolates through the mineralized zones and through the abandoned mining areas as it travels to discharge into the alluvial aquifer below and downslope of the Smuggler site. Hence, the contamination of heavy metals found in the alluvial aquifer may be due to the transmission of heavy metals

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from the bedrock inside Smuggler Mountain, a plume of contamination from the Smuggler site, or some combination of the two.

Further complicating this source-pathway-receptor analysis is the fact that a plume from the Centennial site would have to percolate vertically through alluvial deposits into the bedrock then horizontally out of the bedrock back into the alluvial deposits downgradient to the location of the private wells in the residential area. This is due to the way in which the Smuggler site is situated at the edge of the valley deposits, nestled against the mountain at the point where bedrock is no longer covered by the alluvial deposits.

Potentially, as rain and snowmelt continue to percolate vertically through the Smuggler Site, the site could eventually have at least some role, if it does not already exist, in contaminating the alluvial aquifer used by residents downgradient of the site. Furthermore, as time goes on, chemical changes in the heavy metal laden tailings may render those metals more likely to leach, thus accelerating the above-described process.

Summary. In accounting for the contamination found in the private wells drawing on the alluvial aquifer, it is impossible to distinguish between contamination that may be caused by the natural condition of the nearby bedrock and contamination that may be caused by the heavy metal-laden tailings at the Smuggler site. However a moderate risk of exposure to groundwater receptors can be attributed to the continued presence of Smuggler site in its present state.

3.3 Environmental Protection Goals

The overall goal is to minimize the actual or potential release of hazardous substances into the environment from the site. Where direct study allows for a precise identification of those threats, both actual and potential, precise remedial steps can be taken to arrest contamination through available media, as in the case of air, surface water and direct contact. Where such identification is confounded by geological ambiguities, as in the case of groundwater, means of abatement must be undertaken commensurate with reasonably established parameters of potential harm.

The specific environmental goal for the Smuggler site is to insure the protection of the health of residents in the area. Goals for the mitigation of surface releases have been established by EPA in the form of a risk assessment. Specific environmental goals with respect to groundwater are to mitigate the threat of exposure to present and future users of the groundwater supply.

5/5/84

Reference 6

**Excerpts From Addendum - Remedial Investigation/Feasibility Study,
Smuggler Mountain, Colorado, Document No. 149-WP1-RT-CMYB-1;
Prepared for EPA; Undated**

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SF FILE NUMBER

4.8

ADMINISTRATIVE RECORD

ADDENDUM

**REMEDIAL INVESTIGATION/FEASIBILITY STUDY
SMUGGLER MOUNTAIN, CO**

Document No.: 149-WP1-RT-CMYS-1

INTRODUCTION AND BACKGROUND

This addendum is prepared by the REM II Team as a portion of our technical oversight support for the Smuggler Mountain Site. It will supplement and clarify the RI/FS (Hart 1986) prepared consistent with a consent order. It also will reference the National Contingency Plan where appropriate. The addendum is presented in sections to address (1) additional RI data and analysis, by discipline, and (2) additional FS analysis, by discipline, especially concerning alternatives analysis and applicable or relevant and appropriate requirements. An overall assessment of cost-effectiveness, the comparative cost estimates, and other alternatives analysis criteria is also included.

As background, the REM II Team was initially assigned the RI/FS for this site. Following negotiations with the PRPs, EPA approved PRP plans to conduct the RI/FS, and a final RI/FS report was submitted in early 1986. The REM II Team was assigned a Technical Oversight role. This Addendum is another oversight effort of the REM II Team.

REMEDIAL INVESTIGATION (RI)

Soil/Tailings

EPA has through the endangerment assessment process established a 1,000 ppm Pb action level in soil and tailings to define the site boundaries of Smuggler Mountain. Various schemes have been proposed by the EPA, the REM II Team, and others to define the site, each with its advantages and disadvantages. However, for purposes of the health risk at the Smuggler site, a final endangerment assessment (Clement 1986) has been prepared

TABLE 1
SOIL ANALYSIS FOR RADIOACTIVITY

Parameter	Units	Location									
		71	10	104	37	118	78	16	94	120	43
Radium 226	pCi/g	3.4±0.1	1.5±0.1	5.9±0.1	6.6±0.1	3.8±0.1	4.7±0.1	5.6±0.1	1.8±0.1	1.4±0.1	1.2±0.1
Gross alpha	pCi/g	28	15	56	48	27	31	44	31	22	15
Uranium	ug/g	20	3.2	45	14	9.4	11	15	13	2.0	1.3
Pb ^a	ug/g	21,694	704	9450	3,840	5,300	517	5,210	237	347	225
Description ^b	---	CP	MF	MF	MF	T	F/NS	T	NS	NS	F

a) X-MET value.

b) CDM Field Classification.

MF = Mixed fill w/tailings

T = Tailings

F = Fill w/out Tailings

NS = Native soil

CP = Chemical precipitate

It is apparent that the potential for contamination of the hydrologic system is dependent on the chemical interaction between water and tailings/fill. From existing data, it is likely that such interaction involving surface water is confined to the marshy area adjacent to the Cowenhoven drainage. The potential geochemical implications, as well as the probable role of ground water, is discussed in the following section.

Ground Water

Ground water beneath the Smuggler site occurs in both unconsolidated surficial deposits, and within the underlying sedimentary bedrock strata. As stated in the RI/FS report, the bedrock system is decidedly complex, with extensive faulting and fracturing which controls the occurrence and flow of ground water in undisturbed strata. The aquifer(s) are further complicated by underground mine workings, which probably represent the preferred ground water flow paths. In general, however, the bedrock ground water system is of minor importance, due to (1) limited existing ground water use, (2) limited potential for future development, and (3) significantly greater use, and potential for use, associated with the alluvial aquifer of the Roaring Fork River valley. The importance of bedrock ground water, therefore, is restricted to its role, if any, in recharging the alluvial system. Based on existing knowledge of the site, the majority of such recharge is provided by discharges from the Cowenhoven and Mollie Gibson adits. The unsaturated to slightly saturated conditions in evidence from wells and boreholes between and upslope of these adits indicates that any other bedrock contributions are negligible.

Considerably more is known regarding the surficial unconsolidated aquifer. Monitor wells installed by the FIT in February 1985 (4 wells) and by the REM II team in October 1985 (4 wells) clearly show that saturated deposits beneath the site are in direct communication with ground water in the alluvium of the Roaring Fork Valley, in an unconfined aquifer system. Water levels measured from six of the eight wells during November 1985, February 1986, and April 1986 exhibit a piezometric surface which parallels the Roaring Fork River; i.e. flowing in a down-valley, northwesterly direction. The remaining two wells, located upslope from the valley

bottom, exhibit unsaturated conditions, indicating that ground water occurrence is limited to beneath the lower slope areas comprising the southwest half of the site. As noted above, some recharge to this aquifer may occur from the Mollie Gibson and Cowenhoven adits; the direct infiltration of incident precipitation and surficial runoff undoubtedly also provides some recharge. Based on the piezometric data, however, it is apparent that the large majority of recharge occurs as underflow in the alluvial system from up the Roaring Fork Valley. As such, monitor Well 1 is established as an upgradient well, Well 5 as downgradient, and Wells 7, 8, 9 and 10 are situated within the site itself.

Ground water chemistry data from these six monitor wells have been collected in November 1985 and February 1986; a third sampling effort was performed during the week of May 12, 1986 (data not yet available). These November and February data are presented in Tables 2 and 3. Of particular importance to the RI/FS is the absence of lead in all samples, and the occurrence of cadmium in Well 7 (both sampling rounds) and Well 5 (November 1985 only; the well was unsaturated in February 1986). A slight increase in cadmium, from 0.007 to 0.010 mg/L, occurred between the two sampling periods. Zinc concentrations are also highest in Well 7 for both sampling periods. Given the absence of cadmium in both the upgradient well (No.1) and the Mollie Gibson and Cowenhoven discharges, the data indicate that the occurrence may be a localized phenomenon, potentially as a result of tailings. Data collected for the RI/FS suggest that the acid-forming potential of the soils is negligible, attributable to an abundance of calcium carbonate in the host rock. These conclusions are valid, but based on a very limited number of samples. There may be significant potential, therefore, for localized pockets of tailings to produce acidic conditions if they are derived from the "core" of the mineralized zone with a low percentage of buffering calcium carbonate. Further monitoring is therefore warranted in all wells.

Because of the potential for elevated concentrations of radioactivity, selected ground water samples were analyzed for radium-226, gross alpha and uranium. The samples were split from those collected by REM II personnel and were analyzed by EPA's Region VIII laboratory. The results of the

TABLE 2
GROUND WATER ANALYSES FOR NOVEMBER 1985

Parameter	Well No.					
	GW-1	GW-5	GW-7	GW-8	GW-9	GW-10
Arsenic	ND	ND	ND	ND	ND	ND
Cadmium	ND	0.004	0.007	ND	ND	ND
Calcium	4.59	136	143	20	119	128
Iron	ND	ND	ND	ND	ND	ND
Lead	ND	ND	ND	ND	ND	ND
Magnesium	14.1	23.8	52.5	5.74	38.5	36.8
Manganese	0.017	ND	0.052	ND	ND	0.043
Potassium	ND	ND	1.92	ND	ND	ND
Sodium	20.5	9.69	6.68	4.16	ND	6.35
Zinc	0.062	0.060	1.00	0.018	0.413	0.053

Notes:

Concentrations in mg/L; metals are dissolved.

Validation criteria qualifiers pertain to some data; details are included in REM II files.

Source: CDM 1986.

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TABLE 3
GROUND WATER ANALYSES FOR FEBRUARY 1986

Parameter	Units	Well No.					
		GM-1	GM-5	GM-7	GM-8	GM-9	GM-10
Arsenic	mg/l	ND	Dry	ND	ND	ND	ND
Cadmium	mg/l	ND	Dry	0.010	ND	ND	ND
Calcium	mg/l	46.5	Dry	168	22.3	120	136
Iron	mg/l	0.034	Dry	0.121	0.026	0.022	0.086
Lead	mg/l	ND	Dry	ND	ND	ND	ND
Magnesium	mg/l	14.5	Dry	53.9	6.2	41.2	39.5
Manganese	mg/l	0.025	Dry	0.226	0.05	ND	0.174
Potassium	mg/l	0.95	Dry	2.43	ND	1.49	1.64
Sodium	mg/l	19.4	Dry	4.95	0.93	3.97	6.19
Zinc	mg/l	0.020	Dry	1.44	0.065	0.460	0.066
Oil and Grease	mg/l	1.1	Dry	2.2	1.4	ND	ND
TOC	mg/l	15	Dry	2.1	4.6	4.9	1.7
Chloride	mg/l	29	Dry	ND	ND	ND	30
Sulfate	mg/l	111	Dry	215	30	313	220
Bicarbonate	mg/l	54	Dry	180	49	162	199
TDS	mg/l	280	Dry	905	95	625	625
Radium-226	pCi/l	0.45 ± 0.02	Dry	0.45 ± 0.02	0.21 ± 0.01	0.34 ± 0.02 ^a	0.37 ± 0.02
Gross alpha	pCi/l	3	Dry	140	4	120 ^a	17
Uranium	mg/l	0.0024	Dry	0.310	0.00021	0.230 ^a	0.036

Validation criteria qualifiers pertain to some data and are included in REM II files.

^a) Duplicate values:
 Radium-236 0.36 ± 0.02
 Gross Alpha 100
 Uranium 0.210

Source: CDM 1986.

analyses are provided in Table 3. As shown, higher concentrations of uranium and gross alpha exist in Wells 7 and 9. The current MCL under the Safe Drinking Water Act is 5 pCi/l for the combined total of radium-226 and radium-228. The standard for gross alpha (excluding uranium and radium) is 15 pCi/l. In addition, Colorado has a guidance level of 10 pCi/l (about 0.015 mg/l) for uranium. Comparison of these standards and the values shown in Table 3 indicate that elevated levels of gross alpha and uranium may exist. However, the gross alpha values reported on Table 3 by the laboratory include the radioactivity contributed by all emitters except radon, but including uranium. Therefore, to compare these values with the standard for gross alpha, the contribution of the uranium to the gross alpha radioactivity should be removed. By correcting the reported gross alpha concentration for uranium using the value of 677pCi/mg of uranium, the values do not exceed the standard for gross alpha. However, the uranium values for GW-7, GW-9, and GW-10 do exceed the Colorado guidance level. In addition, substantially higher values for uranium and gross alpha were measured in samples from Wells 7 and 9. This observation is consistent with the wells showing higher TDS and trace metal concentrations. Because radioactivity appears to be only associated with the tailings (see Table 1), the results at Well 7 and 9 may indicate that leaching of tailings is occurring. As previously recommended, these wells should continue to be monitored for radionuclides.

Because of the potential of surface waters to recharge ground water, the interaction of the surface water with minerals contained in the tailings and host rock was modeled using the computer program PHREEQE (Parkhurst 1980). PHREEQE is a thermodynamic based program used to model equilibrium water/rock interactions under a variety of pH and oxidation/reduction conditions. In particular, the interaction of waters from the Cowenhoven and Mollie Gibson drainages with minerals assumed to be present at the Smuggler site were modeled at the following conditions:

pH: 6.4 to 7.1 s.u.
Eh: -200 to +400 mv

4. The proposed county Park area and Smuggler Mine No. 2 tailings pile and vicinity show visually the largest remaining area of tailings and apparent contaminated material, totaling several acres in extent.

Detailed comments on the field visit are included in the trip report (CDM 1986).

Movement of contaminated materials to a repository on-site by the PRPs is yet under negotiation. REM II comments regarding PRP estimated costs for excavation and removal are addressed in a later section of this document. Remedial design for capping and removal efforts will be addressed in a forthcoming Work Plan and Remedial Design Oversight Report prepared by the REM II Team.

Surface Water

Results from the RI indicate that the existing surface water system, including the Cowenhoven and Mollie Gibson drainages, Hunter Creek, and the Roaring Fork River, has not been contaminated by on-site tailings. The latter two streams exhibit consistently low major ionic and trace metal concentrations. The mine drainages are typified by moderate to high concentrations of selected metals, including zinc, manganese, and iron, but these constituents are not attributable to dissolution of the tailings nor are they considered a significant threat to public health. For these reasons, site remediation must focus on ensuring that surface water conditions are consistent with other protective measures; remediation of the surface water drainages themselves is not warranted. This approach is consistent with the findings of the RI/FS. Critical components of the surface water system which may affect site remediation are as follows:

1. Infiltration through tailings and contaminated fill, potentially leaching metals into the ground water system.
2. Erosion of tailings and contaminated fill, either by existing mine drainage channels or overland flow.
3. Instability of the cap and/or other surface remedies due to erosion by surface water.

Reference 7

**Excerpts From Potential Hazardous Waste Site Identification
and Preliminary Assessment, Smuggler Mine Site;
EPA Region VIII;
March 31, 1984**

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PRELIMINARY ASSESSMENT
SITE INSPECTION
HAZARD RANKING EVALUATION
° FOR THE
SMUGGLER MINE
ASPEN, COLORADO
TDD R8-8403-13

SUBMITTED TO: KEITH SCHWAB, FIT, RPO
LINDA BOORNAZIAN, REM, RPO

SUBMITTED BY: GEOFFREY UPSON - PROJECT OFFICER
JEFFREY FOSTER

DATE SUBMITTED: APRIL 5, 1984

567
022745



POTENTIAL HAZARDOUS WASTE SITE
IDENTIFICATION AND PRELIMINARY ASSESSMENT

REGION VIII SITE NUMBER (to be assigned by HQ) COD980806277

NOTE: This form is completed for each potential hazardous waste site to help set priorities for site inspection. The information submitted on this form is based on available records and may be updated on subsequent forms as a result of additional inquiries and on-site inspections.

GENERAL INSTRUCTIONS: Complete Sections I and III through X as completely as possible before Section II (Preliminary Assessment). File this form in the Regional Hazardous Waste Log File and submit a copy to U.S. Environmental Protection Agency; Site Tracking System; Hazardous Waste Enforcement Task Force (EN-JJS); 401 M St., SW; Washington, DC 20460.

I. SITE IDENTIFICATION

A. SITE NAME Smuggler Mine		B. STREET (or other identifier) N/A	
C. CITY Aspen	D. STATE CO	E. ZIP CODE 81611	F. COUNTY NAME Pitkin
G. OWNER/OPERATOR (if known) 1. NAME See Addendum		H. TELEPHONE NUMBER	
I. TYPE OF OWNERSHIP <input type="checkbox"/> 1. FEDERAL <input type="checkbox"/> 2. STATE <input checked="" type="checkbox"/> 3. COUNTY <input type="checkbox"/> 4. MUNICIPAL <input checked="" type="checkbox"/> 5. PRIVATE <input type="checkbox"/> 6. UNKNOWN			
J. SITE DESCRIPTION A lead-silver mining operation (intermittent operation) with adjacent mine and mill tailings from previous local mining operations.			
K. HOW IDENTIFIED (i.e., citizen's complaints, OSHA citations, etc.) Research into crop uptake of trace metals indicated a potentially serious problem with the uptake of lead and cadmium by vegetables grown on regraded mine and mill tailings (Boon)			L. DATE IDENTIFIED (mo., day, & yr.) 1981
M. PRINCIPAL STATE CONTACT 1. NAME County - Mr. Patrick Dobie, Pitkin Cty. Eng. Dept.		N. TELEPHONE NUMBER (303) 925-6527	

II. PRELIMINARY ASSESSMENT (complete this section last)

O. APPARENT SERIOUSNESS OF PROBLEM
 1. HIGH 2. MEDIUM 3. LOW 4. NONE 5. UNKNOWN

P. RECOMMENDATION : A lead biomonitoring study for young children (<10 years) is recommended.
 1. NO ACTION NEEDED (no hazard)
 2. IMMEDIATE SITE INSPECTION NEEDED & TENTATIVELY SCHEDULED FOR _____
 a. WILL BE PERFORMED BY _____
 3. SITE INSPECTION NEEDED & TENTATIVELY SCHEDULED FOR _____
 a. WILL BE PERFORMED BY _____
 4. SITE INSPECTION NEEDED (low priority)

Site Sampling completed September 1983 and November 1983.

Q. PREPARER INFORMATION

1. NAME Geoffrey L. Upson	2. TELEPHONE NUMBER (303) 757-4984	3. DATE (mo., day, & yr.) March 31, 1984
------------------------------	---------------------------------------	---

III. SITE INFORMATION

R. SITE STATUS
 1. ACTIVE (These industrial or municipal sites which are being used for waste treatment, storage, or disposal on a continuing basis, even if in-quantity.)
 2. INACTIVE (These sites which no longer receive wastes.)
 3. OTHER (specify: _____ (These sites that include such incidents like "midnight dumping" where no regular or continuing use of the site for waste disposal has occurred.)

S. IS GENERATOR ON SITE?
 1. NO 2. YES (specify generator's four-digit SIC Code: N/A)

T. AREA OF SITE (in acres) 75+ acres

U. IF APPARENT SERIOUSNESS OF SITE IS HIGH, SPECIFY COORDINATES
 1. LATITUDE (North-South) 39° 11' 30" North
 2. LONGITUDE (East-West) 106° 48' 36" West

V. ARE THERE BUILDINGS ON THE SITE?
 1. NO 2. YES (specify: Mine Building on the Smuggler Mine Site. Single family dwellings, Trailer court, Tennis club, Condominiums and Apartments.

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Reference 8

**Personal Communication Concerning Smuggler Mountain;
From Laurie Lamb, SAIC, to Bob Elkington, EPA Region VIII;
May 10, 1991**

PERSONAL COMMUNICATION
SUMMARY REPORT

SAIC Contact: Laurie Lamb

Date: 5/10/91

Time: 9:00 a.m.

Meeting at SAIC Meeting at EPA

Person(s) Contacted (Organization): Bob Elkington, Assistant to Paula Schmittidial

Subject: Discussion of Smuggler Mountain NPL Site Summary, RPM Smuggler Mountain

Summary: Bob displayed a map of Operable Unit 1 boundaries. Operable Unit 2 has no defined boundary at this time. The mine site is up dip from Mollie Gibson Park. Virtually nothing has been done on Operable Unit 2.

Two repositories are in the planning stage. The first to be constructed and used will be the Racquet Club repository, which will have a design capacity of 9,000 cubic yards.

The Salvation Ditch project is currently underway. It requires the redirection of the ditch to make way for the Mollie Gibson repository in Mollie Gibson Park. The expected completion date is June 1. BOR is the prime contractor for the site. Remediation will begin on August 2. Design engineers have been meeting with property owners to work out the details. The Mollie Gibson repository has a design capacity of 45,000 cubic yards. Most remediation will be completed by the end of next summer. Operable Unit 1 is a 116-acre site (90 percent of it is developed).

In 1988, Jacobs Engineering collected 1,000 samples from 0 to 4 feet and analyzed them using XRF. Camp, Dresser and McKee's 1990 sampling included 3,300 samples (1,100 locations and 3 samples at each location at defined depths of 0 to 2 inches; 2 to 6 inches; and 6 to 12 inches. XRF was used to analyze for lead concentrations.

The geometric mean for all lead samples was - 6,577 ppm (all depths); the mathematic lead mean was 2,084 ppm; the lead action level was 1,000 ppm.

The ranges in concentration were from 0 to approximately 107,000 ppm.

- 0 to 500 ppm - 49 percent of samples
- 500 to 1,000 ppm - 16 percent of samples
- Greater than 1,000 ppm - 35 percent of samples.

Mining Waste NPL Site Summary Report

**St. Louis Airport/
Hazelwood Interim Storage/
Futura Coatings Company Site
St. Louis County, Missouri**

**U.S. Environmental Protection Agency
Office of Solid Waste**

June 21, 1991

FINAL DRAFT

Prepared by:

**Science Applications International Corporation
Environmental and Health Sciences Group
7600-A Leesburg Pike
Falls Church, Virginia 22043**

DISCLAIMER AND ACKNOWLEDGEMENTS

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract Number 68-W0-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Greg McCabe of EPA Region VII [(913) 551-7709], the Remedial Project Manager for the site, whose comments have been incorporated into the report.

**ST. LOUIS AIRPORT/
HAZELWOOD INTERIM STORAGE/
FUTURA COATINGS COMPANY SITE
ST. LOUIS COUNTY, MISSOURI**

INTRODUCTION

This Site Summary Report for the St. Louis Airport/Hazelwood Interim Storage/Futura Coatings Company Site is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of the summary by the EPA Region VII Remedial Project Manager for the site, Greg McCabe.

SITE OVERVIEW

The NPL site consists of three areas: the St. Louis Airport location immediately north of the St. Louis International Airport; the Hazelwood Interim Storage area on Latty Avenue .5 mile north of the Airport location; and the Futura Coatings Company property, adjacent to the Hazelwood Storage area. These three properties total 33 acres; (see Figure 1) (Reference 1, pages 10 through 13; Reference 2, page 2). The three areas, located in an industrial section of St. Louis County approximately 15 miles northwest of downtown St. Louis, were used for the storage of residues resulting from offsite uranium processing at a facility located in downtown St. Louis (Reference 2, page 4). Historic management practices resulted in the contamination of soil at the site. In addition, some wastes stored in these areas remain onsite. Constituents of concern at the site are uranium, thorium, radium, and radon.

Operation of the downtown facility and the Airport location was conducted by the Manhattan Engineering District in the 1940's and 1950's. None of the areas are presently owned or operated by the Department of Energy (DOE) (Reference 2, page 4; Reference 3, page 2). All three areas are under investigation through the DOE's Formerly Utilized Sites Remedial Action Program (Reference 1, page 2). An agreement between DOE and EPA was finalized in August 1990, giving DOE authority to conduct all remedial actions and giving the EPA oversight authority (Reference 4). Some remedial actions, described in the next section, were conducted in 1984 and 1986. No further remedial actions are scheduled prior to the signing of a Record of Decision (ROD), expected in 1994 (Reference 3, page 19).

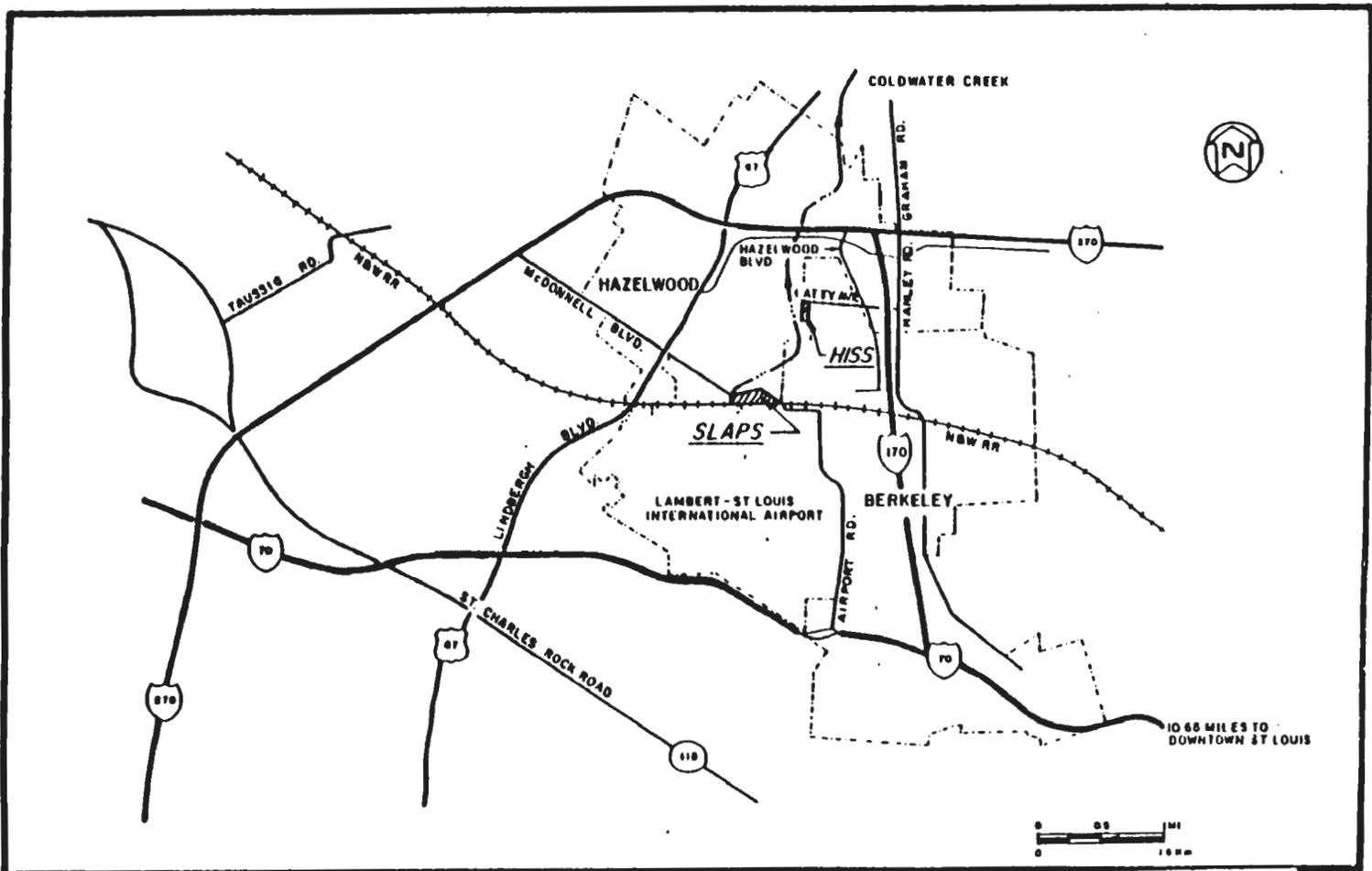


FIGURE 1. LOCATION OF SLAPS

OPERATING HISTORY

Storage of uranium ore processing residues at the St. Louis Airport location began in 1946 by the Manhattan Engineering District (MED) (Reference 2, page 4). The Airport location was used to store residues from a uranium ore processing facility in St. Louis, which operated under a MED and Atomic Energy Commission (AEC) contract until 1957 (Reference 5, pages 5 and 8).

Residues sent to the St. Louis Airport location included pitchblende raffinate residues, radium-bearing residues, barium sulfate cake, Colorado raffinate residues, and contaminated scrap. Most residues were stored (in bulk) as drums or metal scrap on open ground, although some were buried onsite (Reference 5, page 8; Reference 6).

In 1966, residues stored at the Airport location were moved to the Hazelwood Interim Storage area .5 mile north of the Airport location (Reference 2, page 4). Also in 1966, Continental Mining and Milling Company acquired the Hazelwood Storage area property and recovered uranium from wastes. The company sold the property the following year (Reference 6). Residues on the Hazelwood Storage area in 1966 included 74,000 tons of pitchblende raffinate, 32,500 tons of Colorado raffinate, 8,700 tons of leached barium sulfate, and a total of approximately 68 tons of uranium (Reference 7, page 4). Some residues were sold to a Colorado facility from 1967 to 1973, while the leached barium sulfate was transported to a St. Louis County landfill.

Since the 1970's, Futura Coatings has leased the western portion of the Hazelwood Storage area. The facility is used for plastic coatings manufacturing and is unrelated to mining activities.

In August 1979, approximately 13,000 cubic yards of contaminated soil from the Hazelwood Storage area was excavated and stockpiled on the property. In 1984, DOE conducted remedial actions in the area, as directed by the 1985 Energy and Water Appropriations Act (Reference 5, page 8; Reference 6). As a result of remedial actions and construction activities on adjacent properties and at Latty Avenue in 1984 and 1986, an additional 18,600 cubic yards of soil was placed on the property. As of 1986, two piles of contaminated soil, totaling 32,000 cubic yards, were located on the Hazelwood Interim Storage area (Reference 7, page 5). As of 1988, a total of 4,100 tons of contaminated scrap and residues were at the Airport location (Reference 1, page 28).

SITE CHARACTERIZATION

Characterization activities were performed by DOE as early as 1976, but the most extensive characterization of the site was performed by DOE from 1985 to 1987 to determine the extent of offsite soil contamination and to characterize onsite soil and ground water (Reference 7, pages 9 and

10; Reference 2, page 11). Ongoing monitoring activities, consisting of ground-water, surface-water, creek sediment, and air sampling, have been performed at the St. Louis Airport location annually by DOE since 1984. Airborne release of contaminants is the primary exposure route at the site (Reference 1, page 45).

Two ground-water systems underlie the St. Louis Airport location. The first system consists of an upper, unconsolidated glacial deposit at a depth of 11 to 35 feet, and a lower glacial sediment deposit at a depth of 35 to 87 feet. Flow in both deposits is east to west, towards Coldwater Creek. The second system is a bedrock limestone aquifer several hundred feet below the area, of generally poorer quality (Reference 5, pages 4, 5, 13, and 16 through 20). The well nearest the Airport location is approximately 1.5 miles north (Reference 5, page 5). Ground-water flow at the Hazelwood Storage area is reported to be towards Coldwater Creek (Reference 1, page 44). The Airport location is adjacent to Coldwater Creek, while the Hazelwood Storage area and the Futura property are less than 500 feet east of Coldwater Creek (Reference 2, page 7).

Air

Annual average levels of radon-222 were measured at nine perimeter locations at the Airport area in 1988. Average levels of radon-222 at the Futura property were reported from building interiors. Average levels of radon-222 at the Hazelwood Storage area were reported from unknown monitoring locations. Studies were performed by DOE and the results are presented below (in ranges) in Table 1 (Reference 5, pages 27 through 33; Reference 1, pages 42 and 73 through 76).

TABLE 1. ONSITE RADON-222 CONCENTRATION IN AIR pCi/l (IN RANGES)

Airport	Hazelwood	Futura	Background
0.7 - 2.1	0.2 - 1.8	0.3 - 0.7	0.4 - 0.5

A standard of 3 pico Curies per liter (pCi/l) has been established for radon-222 by the Nuclear Regulatory Commission as the maximum permissible concentration for air in unrestricted areas (Reference 1, page 43).

Levels of gamma radiation exposure were measured at perimeter locations at the Airport area. Levels of gamma radiation at the Futura property were reported from building exteriors. Levels of gamma radiation at the Hazelwood Storage area were reported from unknown monitoring locations. Results of these measurements are presented below (in ranges) in Table 2.

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TABLE 2. ONSITE GAMMA RADIATION EXPOSURE, IN AIR (μ R/hr) (IN RANGES)

Airport	Hazelwood	Futura	Background
9-261	13-55	8-27	8

Based on data collected annually from 1984 to 1988, levels of radon and exposure to gamma radiation in the air have remained constant at the Airport location (Reference 5, pages 43 through 46). No information concerning trends at the other locations was provided.

Surface Water

Annual average radioactive constituent concentrations of Coldwater Creek water were measured 15 meters north (downstream) of the St. Louis Airport location boundary and at an upstream location in 1988. Coldwater Creek water quality was measured at the Hazelwood Storage area in 1986 (Reference 1, page 41; Reference 5, pages 33 through 35). Upstream concentrations were reported to provide background data. Surface-water contaminant levels are near background at the Airport location. Although no conclusions concerning levels of thorium in surface water from the Hazelwood Storage area were provided, results are provided below in Table 3.

TABLE 3. COLDWATER CREEK WATER CONCENTRATION, (IN pCi/l)

Constituent	Airport	Hazelwood	Upstream
Uranium (total)	4	<3 - 5	4
Radium-226	0.3	0.1 - 0.4	0.5
Thorium-230	0.3	<0.1 - 1	0.1

Based on data collected annually from 1984 to 1988, levels of uranium, radium-226, and thorium-230 in surface water have remained constant at the Airport location (Reference 5, pages 43 and 47). No information concerning trends at the other locations was provided.

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Sediments

Annual average contaminant levels of Coldwater Creek sediments were measured at the same upstream and downstream locations as the surface-water samples (Reference 1, page 41; Reference 5, page 39). Upstream concentrations were reported to provide background data. Results are provided below in Table 4. No conclusions concerning levels of thorium in sediments from the Hazelwood Storage area were presented.

TABLE 4. COLDWATER CREEK WATER CONCENTRATION (IN pCi/g) DRY WEIGHT

Constituent	Airport	Hazelwood	Upstream
Uranium (total)	2.6	5.6	1.7
Radium-226	1.0	5.6	1.5
Thorium-230	5.4	200	1.3

Ground Water

At the St. Louis Airport location, an unknown number of ground-water monitoring wells were installed in 1981, 10 wells were installed in 1986, and 27 wells were installed in 1988 (Reference 5, page 9). The ranges of average levels of constituents measured quarterly in 1988 from each of 16 onsite wells are presented below in Table 5 (Reference 5, pages 34 through 38). Data from the Hazelwood Storage area is from the 1986 DOE annual report, while a source of the Futura data was not provided (Reference 1, pages 40 and 47 through 49). High levels of uranium in ground-water monitoring wells at the Airport location reportedly result from subsurface soil contamination (Reference 5, page 38). Conclusions regarding thorium levels at the Airport location, as well as conclusions regarding uranium and thorium levels at the Hazelwood Storage area, were not given. Levels of all three constituents at the Futura property are near background.

TABLE 5. GROUNDWATER CONCENTRATION (IN pCi/l) (IN RANGES)

Constituent	Airport	Hazelwood	Futura	Background
Uranium (total)	<3 - 5,590	<3 - 33	<3 - 6	3 - 4
Radium-226	0.3 - 0.9	0.1 - 0.7	0.6 - 1.3	0.6 - 1.1
Thorium-230	0.3 - 52	<0.1 - 1	0.1 - 0.4	0.2

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Based on data collected annually from 1984 to 1988, levels of radium-226 and thorium-230 have remained constant. Levels of uranium in two wells increased in 1988 while remaining stable in five others (Reference 5, pages 43 and 48 through 50). No explanation for the increase in these wells was provided. No information concerning trends at the other locations was presented.

Conventional parameters were also measured at the Airport location. Levels of pH and total organic carbon in onsite ground-water monitoring wells were found to be similar to background levels, while levels of specific conductance and total organic halogens were found to be above background levels (Reference 5, page 51). Explanations for elevated levels of total organic halogens were not available (Reference 5, page 51).

Soils

Data on concentration of uranium 238, radium 226, and thorium 230 from unspecified studies were presented in the Hazard Ranking System Scoring Package (Reference 1, pages 73 through 76) (see Table 6). EPA standards for radium-226 and DOE clean-up criteria for thorium-230 have been established at 5 pico Curies per gram (pCi/g).

TABLE 6. SURFACE SOIL CONCENTRATION (IN pCi/g)

Constituent	Airport	Hazelwood	Futura	Background
Uranium-238	< 3 - 1,600	4 - 800	< 3 - 2,500	1.0
Radium-226	0.5 - 5,600	0.5 - 700	0.4 - 2,300	0.5
Thorium-230	0.6 - 2,600	1 - 790	< 1.1 - 2,000	0.2

Characterization activities at the NPL site were conducted from 1985 to 1987 by DOE. Soils for the Airport location revealed levels of molybdenum and cobalt, while levels of other metals were not provided. Soil contamination at the Airport location was found up to 18 feet below the surface; contamination at the Futura property was found at depths of up to 15 feet; and contamination at the Hazelwood Storage area was found at depths of up to 6 feet (Reference 2, pages 12 and 13; Reference 7, page 10). DOE guidelines for determining thorium-230 and radium-226 contamination is 5 pCi/g (average) for surface soil and 15 pCi/g (average) for subsurface samples (Reference 2, page 12).

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ENVIRONMENTAL DAMAGES AND RISKS

Although contamination of surface water and ground water has been documented, these routes were not considered in the Hazard Ranking System scoring because of the lack of exposure targets. Ground water is of poor quality. The nearest well is approximately 1.5 miles north of the Airport location; its function was not specified (Reference 1, page 45). No uses of Coldwater Creek are known. The primary exposure route is air due to the emission of radon-222 and the proximity of people working near the sites (Reference 1, page 45). An estimated 7.5 millirem per year was determined to be the exposure to the maximally exposed individual from the Airport location. The DOE radiation protection standard is 100 millirem per year (Reference 5, pages 41 and 42).

Uses of nearby property are predominantly commercial and industrial. A 24,000-person commercial building complex is located .25 mile west of the Airport location, while the St. Louis International Airport facilities are 1 mile south of the Airport location (Reference 1, pages 29 through 30 and 37). Numerous industrial facilities are within .25 mile of the Airport location. A park is immediately north of the Airport site. Nearby residential areas include 75 to 100 people living .5 mile west of the Airport location, 1,500 people living 1 mile northwest of the Airport location, and 8,800 people residing more than .75 mile north of the Hazelwood and Futura locations in the City of Hazelwood. Commercial and industrial facilities are located north and east of the St. Louis Airport vicinity properties and the Hazelwood and Futura locations (Reference 1, pages 37 and 38).

An estimated 142,000 cubic yards of contaminated media is present in the St. Louis Airport vicinity properties (Reference 2, page 6). Soil contamination adjacent to the three areas is shown in Figures 2 and 3 (Reference 2, page 17; Reference 7, page 11). DOE guidelines for determining thorium-230 and radium-226 contamination is 5 pCi/g (average) for surface soil and 15 pCi/g (average) for subsurface samples (Reference 2, page 12).

REMEDIAL ACTIONS AND COSTS

Contaminated material was excavated from the Futura property and placed on the Hazelwood Storage area (Reference 1, page 39). This excavation was performed in 1979 (Reference 1, page 6). Offsite remedial excavation was conducted from 1984 to 1986 near the Hazelwood Storage area, adding contaminated soil to the Hazelwood Storage area (Reference 7, page 5).

Additional work to be performed at the site includes Remedial Investigation/Feasibility Study development, Environmental Impact Statement preparation, monitoring, and waste storage. Cost at the Airport location was estimated at \$32 million; at the adjacent Airport properties, it was estimated

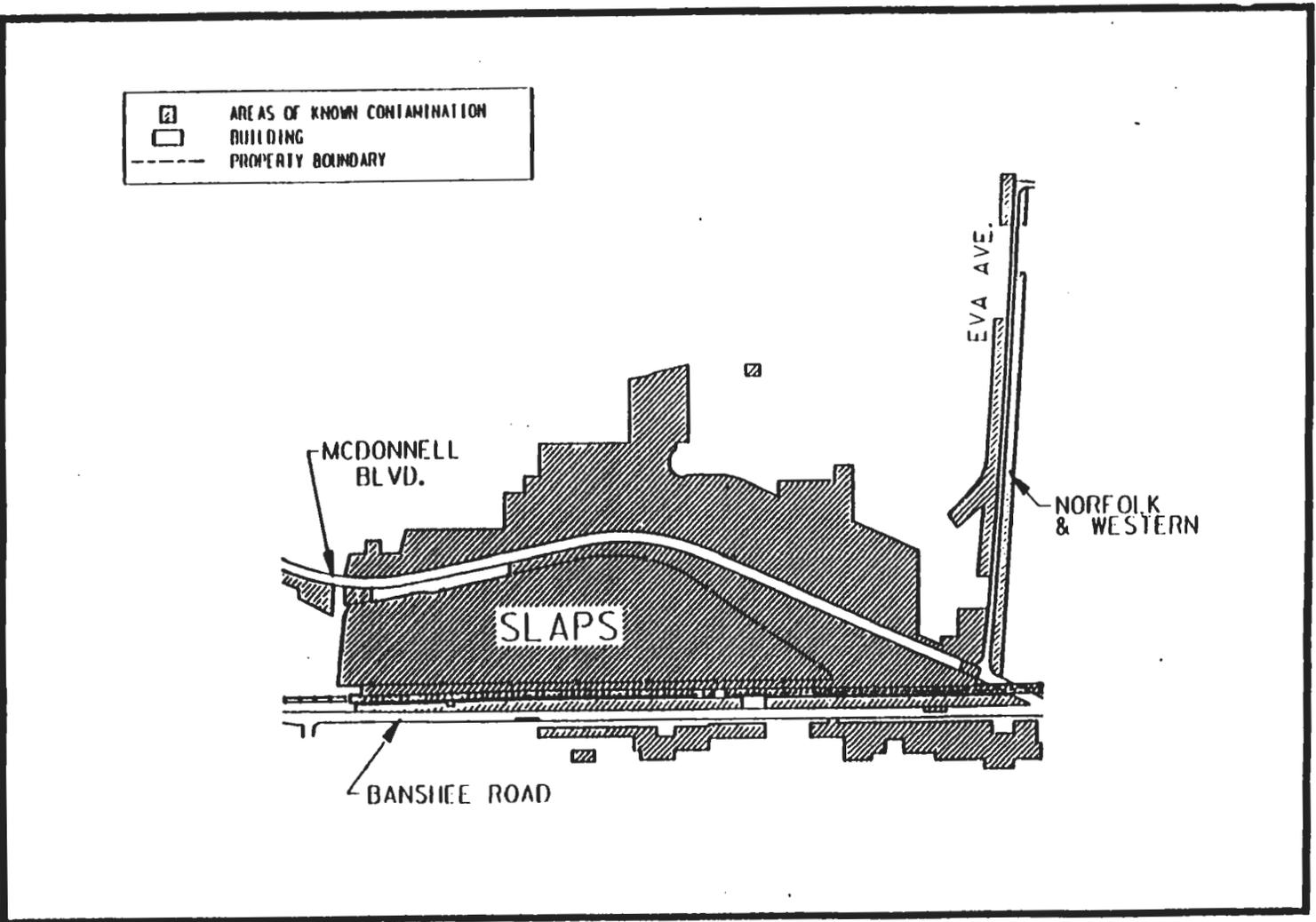


FIGURE 2. AREAS OF CONTAMINATION IN EXCESS OF GUIDELINES AT SLAPS

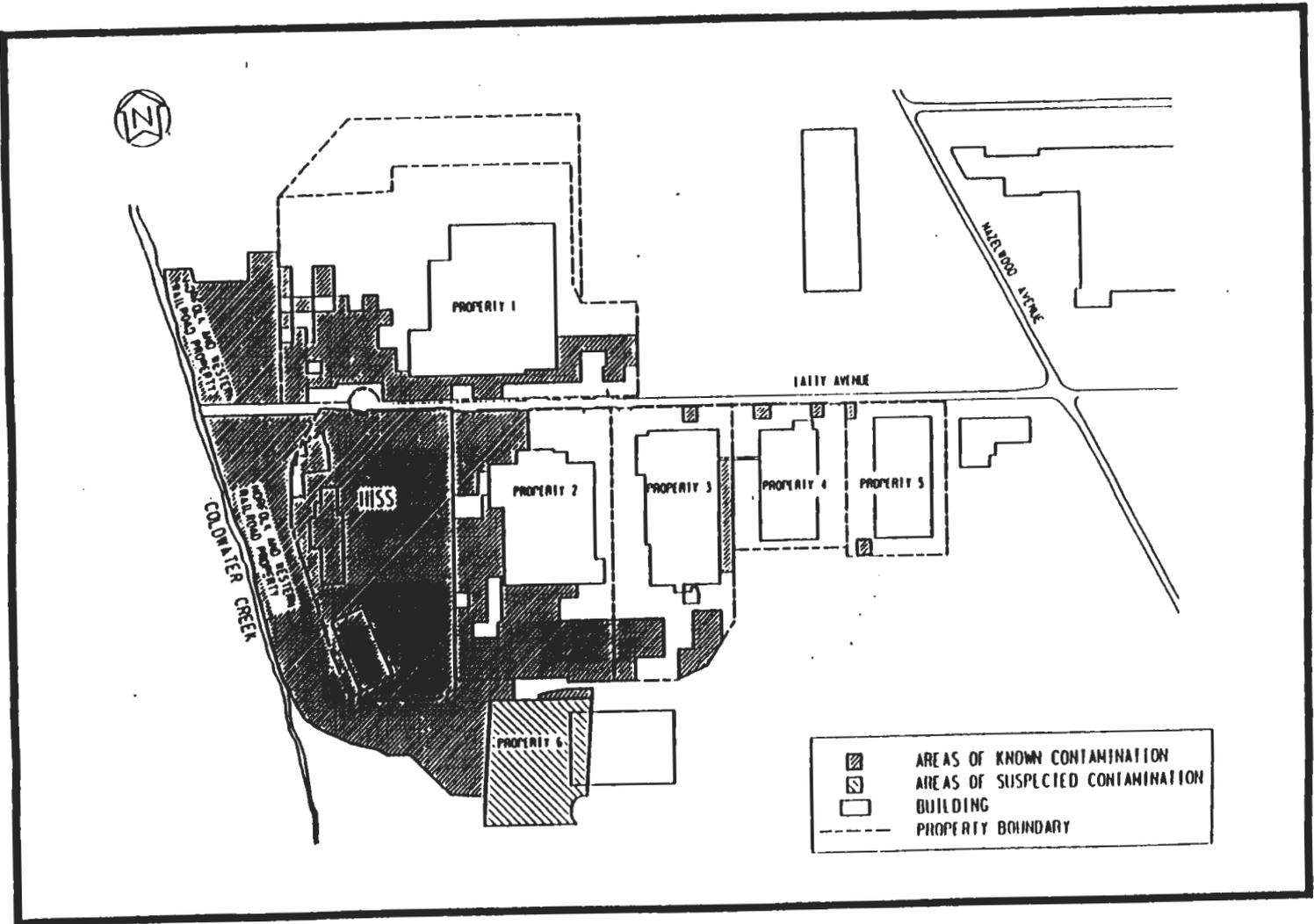


FIGURE 3. RADIOLOGICAL CHARACTERIZATION OF THE LATTY AVENUE VICINITY PROPERTIES

at \$50 million; and at the Latty Avenue properties (which includes the Hazelwood and Futura properties) it was estimated at \$25.5 million. RODs for all areas are scheduled for 1994.

CURRENT STATUS

The Airport, Futura, and Hazelwood areas were added to the NPL in October 1989 (Reference 3, page 6). The Federal Facilities Agreement was signed in late June and became effective August 17, 1990. DOE is the head agency and will be conducting all investigations and remediation, while EPA has oversight authority and must approve the final remedial selections. A ROD is scheduled to be completed in 1994 (Reference 4).

REFERENCES

1. Hazard Ranking System Scoring Package, St. Louis Airport/Hazelwood Interim Storage/Futura Coating Site, St. Louis, Missouri; EPA; June 3, 1988.
2. Site Plan for St. Louis Airport Site and Vicinity Properties, St. Louis, Missouri; Prepared for the U.S. Department of Energy by Bechtel National, Incorporated; November 1989.
3. Environmental Restoration and Waste Management Site-Specific Plan for Oak Ridge Operations Office (Formerly Utilized Sites Remedial Action Program, Missouri); Prepared for U.S. Department of Energy; November 1989.
4. Telephone Communication Concerning the Current Status of the St. Louis Airport Sites; From Sue McCarter, SAIC, to Gene Gunn, EPA Region VII; December 18, 1990.
5. St. Louis Airport Site Annual Site Environmental Report, St. Louis, Missouri, Calendar Year 1988; Prepared for the U.S. Department of Energy by Bechtel National, Incorporated; April 1989.
6. National Priorities List Summary Sheet for the St. Louis Airport/Hazelwood Interim Storage/Futura Coatings Company Site; EPA; Undated.
7. Site Plan for Latty Avenue Properties, Hazelwood, Missouri; Prepared for the U.S. Department of Energy by Bechtel National, Incorporated; November 1989.

BIBLIOGRAPHY

- EPA. Hazard Ranking System Scoring Package, St. Louis Airport/Hazelwood Interim Storage/Futura Coating Site, St. Louis, Missouri. June 3, 1988.
- EPA. National Priorities List Summary Sheet for the St. Louis Airport/Hazelwood Interim Storage/Futura Coatings Company Site. Undated.
- McCarter, Sue (SAIC). Telephone Communication Concerning the Current Status of the St. Louis Airport Sites to Gene Gunn, EPA Region VII. December 18, 1990.
- Prepared for the U.S. Department of Energy by _____. Environmental Restoration and Waste Management Site-Specific Plan for Oak Ridge Operations Office (Formerly Utilized Sites Remedial Action Program, Missouri). November 1989.
- Prepared for the U.S. Department of Energy by Bechtel National, Incorporated. Site Plan for Latty Avenue Properties, Hazelwood, Missouri. November 1989.
- Prepared for U.S. Department of Energy by Bechtel National, Incorporated. Site Plan for St. Louis Airport Site and Vicinity Properties, St. Louis, Missouri. November 1989.
- Prepared for the U.S. Department of Energy by Bechtel National, Incorporated. St. Louis Airport Site Annual Site Environmental Report, St. Louis, Missouri, Calendar Year 1988. April 1989.

Reference 1

**Excerpts From Hazard Ranking System Scoring Package,
St. Louis Airport/Hazelwood Interim Storage/Futura Coating Site,
St. Louis, Missouri; EPA; June 3, 1988**

MITRE

RECEIVED

26 October 1988
W52-398

OCT 31 88

PREP SECTION

Ms. Shelley Brodie
U.S. Environmental Protection Agency
Region VII
726 Minnesota Avenue
Kansas City, KS 66101

Dear Ms. Brodie:

Enclosed is the QA signed package for St. Louis Airport/Hazelwood Interim Storage/Futura Coating Site, St. Louis, Missouri. Please submit the package, in triplicate, to the EPA Docket Clerk, Ms. Tina Maragousis, at EPA Headquarters and retain the original in your program file. In your transmittal letter to Ms. Maragousis, please indicate that this site is being considered for Update 8.

If you have any questions regarding this material, please contact Barry Nash at (703) 883-5843.

Sincerely,



for

L. Sue Russell
Group Leader
Hazardous Waste Systems

LSR/flh

Enclosure

cc: S. Crystall
J. Kruger

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The MITRE Corporation
Civil Systems Division
7525 Colshire Drive, McLean, Virginia 22102-3481
Telephone (703) 883-6000/Telex 248923

SITE AGGREGATION RATIONALE

St. Louis Airport, Hazelwood Interim Storage, and Futura Sites St. Louis County, Missouri

The St. Louis Airport (SLAP) Site and the Latty Avenue properties consisting of the Hazelwood Interim Storage (HIS) Site and the Futura Coatings (FUTURA) Site are located near the Lambert St. Louis International Airport. These sites were used for storing radioactive by-product wastes and other wastes resulting from the activities of the Manhattan Engineering District (MED) under the jurisdiction of the U.S. Army, and the U.S. Atomic Energy Commission (AEC). The responsibility for management of these wastes was ultimately transferred to the U.S. Department of Energy (DOE) in 1977. All three sites are under investigation through DOE's Formerly Utilized Sites Remedial Action Program. (FUSRAP) (Reference 2, p. 1).

The St. Louis Airport Site and the Latty Avenue properties are presented in this HRS package as one aggregated site. The aggregation of these three sites is based on several factors, including the close proximity of all three sites, the storage at each site of radioactive wastes from the same waste source, detected radioactive contamination along roads used to transport the wastes between the sites, similar threats posed by the contaminants from all three sites on the same surface water and groundwater resources, similar threats of air releases posed by contaminants at all three sites, and the historical involvement of the U.S. Department of Energy in the management of wastes at each of these sites (Reference 20). Details pertaining to the location and history of each site and the rationale for aggregation of the sites are presented in the following paragraphs.

The SLAP, HIS, and FUTURA Sites are located within approximately one-half mile of one another, as shown on Figure 1. The SLAP Site is the largest of the three sites (21.7 acres) and is located immediately north of the Lambert St. Louis

Additional wastes stored at the HIS and FUTURA Sites were moved to the West Lake Landfill in St. Louis County at an unknown date (Reference 1).

Radiological surveys of the Latty Avenue properties by the Nuclear Regulatory Commission (NRC) in 1976 and the Oak Ridge National Laboratory (ORNL) in 1977 disclosed the presence of Uranium, Thorium and Radium in on-site buildings. In addition, detected concentrations of these contaminants in soil exceeded NRC and DOE guidelines for a release from unrestricted land areas (Reference 1, Reference 2 p. 17). Cleanup actions at these sites by the property owner resulted in the generation of approximately 13,000 cubic yards of radioactive material. This material was placed on the HIS Site to form the main storage pile. Remedial actions in 1984 resulted in the excavation of an additional 14,000 cubic yards of contaminated soil from the Latty Avenue properties (Reference 1). This material was formed into the secondary storage pile at the HIS Site. Both of these storage piles have remained on the HIS Site to date.

Radiological and/or chemical characterization studies have been performed at all three sites. These studies indicated that a significant volume of the remaining surface and subsurface soils at each site contain elevated concentrations of radioactive contaminants (Reference 2, p. 18). A radiological survey in 1985 of roads used for transporting the contaminated wastes from the SLAP Site to the HIS and FUTURA Sites, indicated elevated levels of radioactive contaminants along Latty Avenue, which forms the northern boundary of the HIS and FUTURA Sites. As a result, the roads between the SLAP Site and the HIS and FUTURA Sites which were used for transporting the contaminated wastes were designated for remedial action under DOE's FUSRAP in 1986 (Reference 3, p. 3). Subsequent to this designation, Thorium-230 was detected at concentrations as high as 600 pico

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NARRATIVE SUMMARY

St. Louis Airport, Hazelwood Interim Storage, and Futura Sites St. Louis County, Missouri

The St. Louis Airport (SLAP) Site and the Latty Avenue properties consisting of the Hazelwood Interim Storage (HIS) Site and the Futura Coatings (FUTURA) Site are located near the Lambert St. Louis International Airport. These sites were used for storing radioactive by-product wastes and other wastes resulting from a U.S. Department of Energy (DOE) uranium processing operation. All three sites are under investigation through DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP).

The St. Louis Airport Site and the Latty Avenue properties are presented in this HRS package as one aggregated site. The aggregation of these three sites is based on several factors, including the close proximity of all three sites, the storage at each site of radioactive wastes from the same waste source, detected radioactive contamination along roads used to transport the wastes between the sites, similar threats posed by the contaminants from all three sites on the same surface water and groundwater resources, similar threats of air releases posed by contaminants at all three sites, and the historical involvement of the U.S. Department of Energy in the management of wastes at each of these sites. Details pertaining to the locations of the sites and the history of radioactive waste disposal at these sites are provided in the following paragraphs.

The SLAP, HIS, and FUTURA Sites are located within approximately one-half mile of one another, as shown on Figure 1. The SLAP Site is the largest of the three sites (21.7 acres) and is located immediately north of the Lambert St. Louis International Airport. The SLAP Site is bounded by the Norfolk and Western Railroad on the south, Coldwater Creek on the west, and McDonnell Boulevard on

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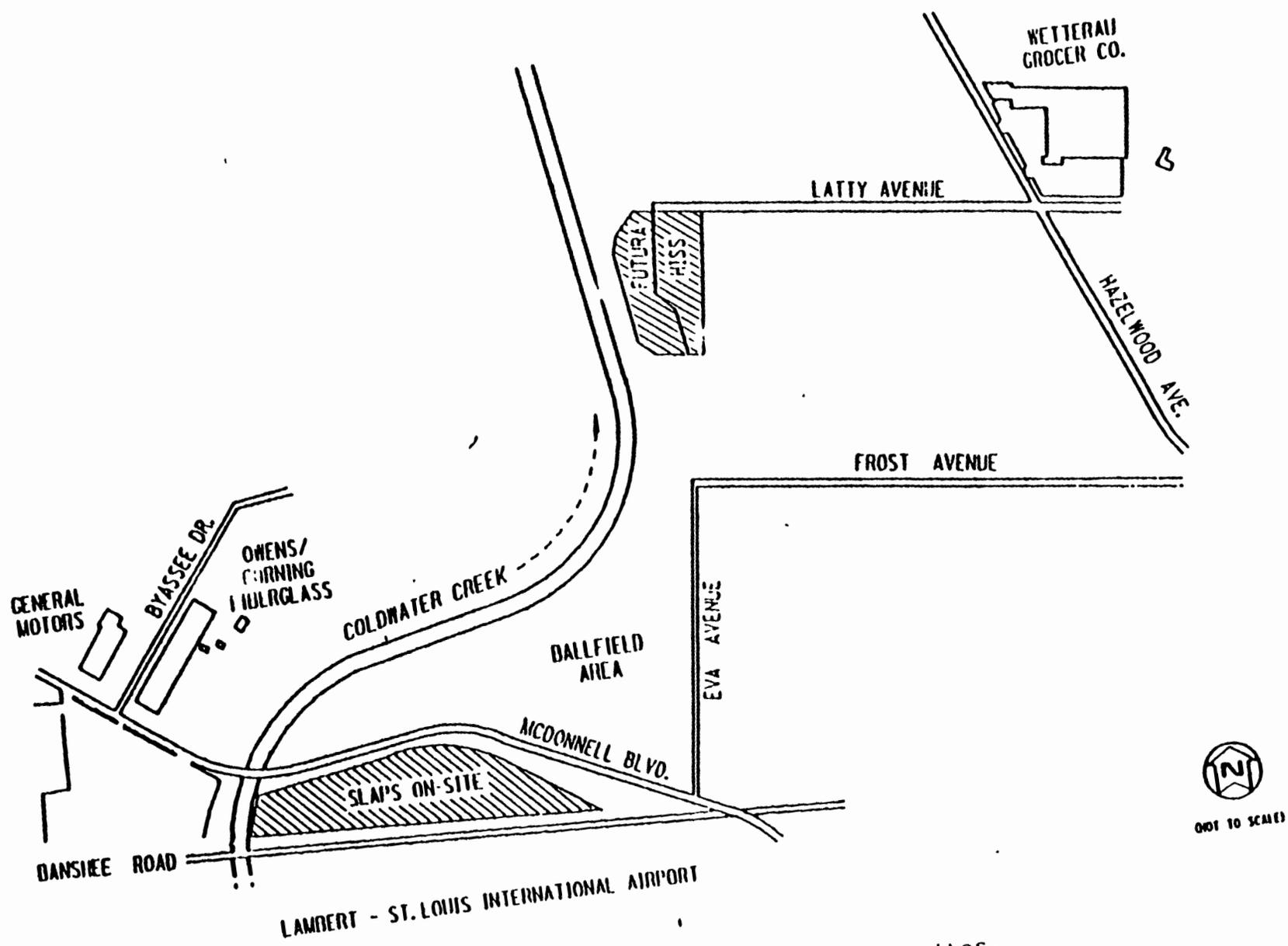


Figure 1. Location of the SLAP, HIS and FUTURA sites.
Reference 2.

the north and east. The McDonnell Douglas Corporation is adjacent to the SLAP Site on the west and southwest. The office buildings of this company are within one-half mile of contaminated surface soil at the SLAP Site. Twenty four thousand employees of this company work at the location adjacent to the SLAP Site. The Latty Avenue properties, consisting of the adjoining HIS Site and the FUTURA Site, span 11 acres along Latty Avenue in Hazelwood, Missouri, as shown on Figure 2. This area is bounded on the north by Latty Avenue, on the east by the Hazelwood city limit, on the west by the Norfolk and Western Railroad and on the south by a tributary to Coldwater Creek.

Wastes from uranium processing operations were stored on the open ground at the SLAP Site from 1947 until 1967. These wastes included: pitchblende raffinate, radium-bearing residues, barium sulfate cake residues, Colorado raffinate residues, used dolomite liner and recycled magnesium fluoride liner generated as slag, and uranium containing sand and scrap metals. In 1957, contaminated scrap metal and miscellaneous radioactive materials were buried in the western end of the property. In 1966 and 1967, most of the wastes stored at the SLAP Site were transported to the Latty Avenue properties (HIS and FUTURA Sites). In 1969, the St. Louis Airport Authority initiated partial remediation of the SLAP Site. At that time, the remaining barium sulfate waste was transported to the Latty Avenue properties and all structures except a security fence were buried on-site. From 1967 to 1973, a portion of the wastes which were previously transported from the SLAP Site to the HIS and FUTURA Sites was shipped to the Cotter Corporation in Canon City, Colorado. Additional wastes stored at the HIS and FUTURA Sites were moved to the West Lake Landfill in St. Louis County at an unknown date (Reference 1).

Cleanup actions by the owner of Latty Avenue properties resulted in the generation of approximately 13,000 cubic yards of radioactive material. This

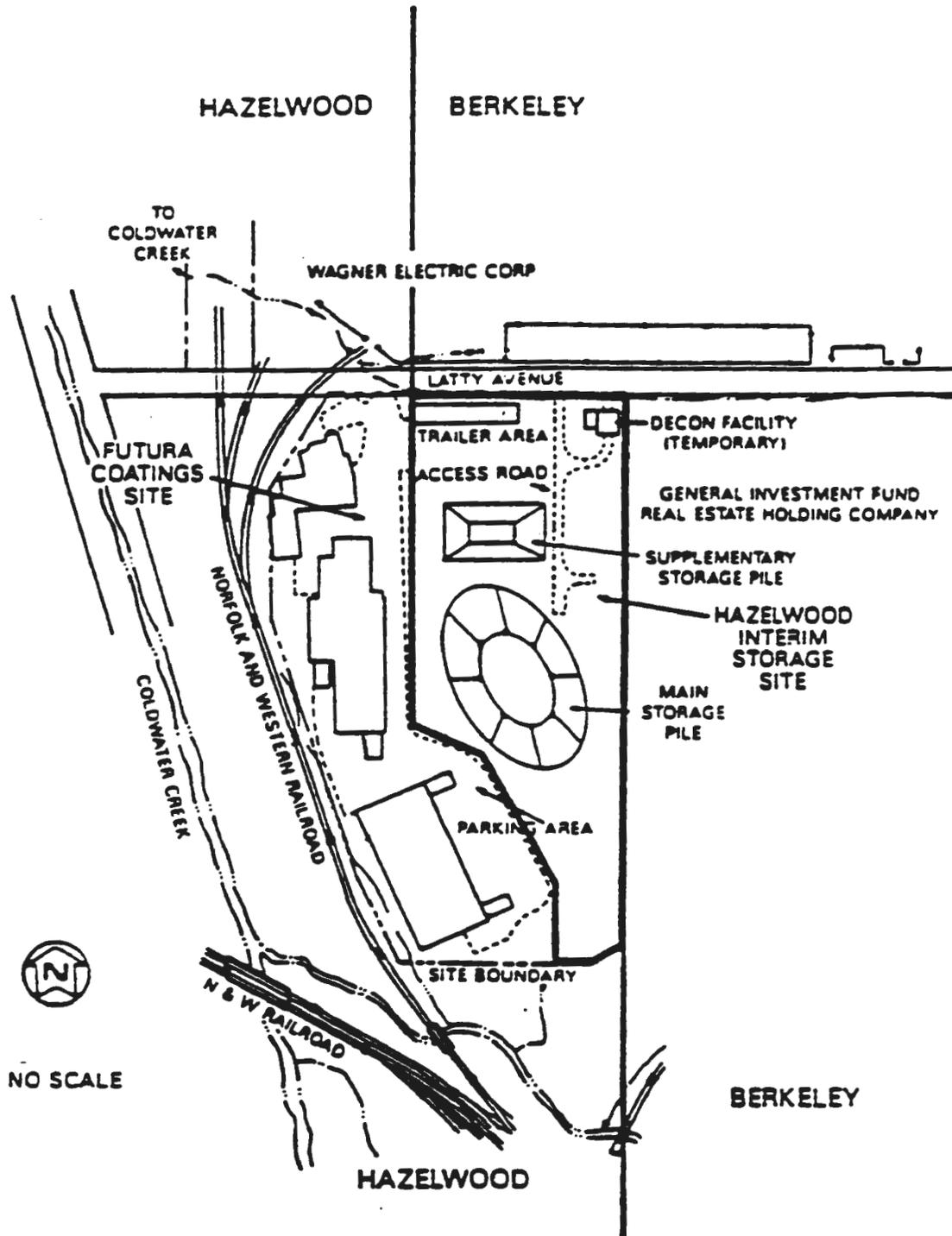


Figure 2. Boundaries of the HIS and FUTURA sites. Reference 9, page 6.

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2. WASTE CHARACTERISTICS

Reactivity and Incompatibility

Most reactive compound:

Radioactive residues present on all three subsites are believed to be relatively stable. It is not known whether the intermixing of these residues poses a threat of a fire or explosion.

SCORE = 0

Most incompatible pair of compounds:

None found

Toxicity

Most toxic compound:

Uranium (Reference 15 page 2711).

SCORE = 9

Hazardous Waste Quantity

Total quantity of hazardous substances at the site (Give a reasonable estimate even if quantity is above maximum):

At least 4,100 tons of hazardous wastes were deposited at the SLAP Site, as documented below:

SCORE = 8

Basis of estimating and/or computing waste quantity:

Basis of Computing Waste Quantity
(Reference 8, p. 7; and Reference 16, pp. 2-1 and 2-4)

Waste Material

(1) Contaminated steel and alloy scrap.

Quantity *
3,500 tons

(2) Drums containing miscellaneous residues, Japanese uranium containing sand, and contaminated scrap metal.

600 tons

(3) 50 to 60 truckloads of contaminated metal scrap, not calculated because of lack of data.

TOTAL 4,100 tons

* Note: All quantities were converted to tons using the conversion factors given in reference 17, p. 19.

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3. TARGETS

Population Within 4-Mile Radius

Circle radius used, give population, and indicate how determined:

0 to 4 mi

0 to 1 mi

0 to 1/2 mi

0 to 1/4 mi

The McDonnell Douglas Corporation borders the SLAP Site on the west and southwest (Reference 16, p. 3-20). The office buildings of this company are within one-half mile of contaminated surface soil on the SLAP Site (Reference 16, pp. 3-19 and 3-27). Twenty four thousand employees (24,000) of this company work at the location adjacent to the SLAP Site (Reference 19).

SCORE = 27

Distance to a Sensitive Environment

Distance to 5-acre (minimum) coastal wetland, if 2 miles or less:

No coastal wetlands exist within two miles of the site.

SCORE = 0

Distance to 5-acre (minimum) fresh-water wetland, if 1 mile or less:

No fresh-water wetlands are known to exist within one mile of the site (Reference 16, pp. 1-2 and 3-18; and Reference 22).

SCORE = 0

Distance to critical habitat of an endangered species or national wildlife refuge, if 1 mile or less:

No critical habitat areas are known to exist within one mile of the site (Reference 16, pp. 1-2, 3-17, and 3-18).

SCORE = 0

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Land Use

Distance to commercial/industrial area, if 1 mile or less:

The McDonnell Douglas Corporation borders the SLAP Site to the west and the southwest (Reference 16, p. 3-20). Thus, the distance to an industrial area is less than one-fourth mile.

SCORE = 3

Distance to national or state park, forest, or wildlife reserve, if 2 miles or less:

No national or state park, forest, or wildlife reserve is known to exist within two miles of the site (Reference 22).

Distance to residential area, if 2 miles or less:

The nearest residential area is in Hazelwood, one-half mile from the SLAP Site. This area of Hazelwood has 75 to 100 residents (Reference 16, p. 3-20).

Distance to agricultural land in production within past 5 years, if 1 mile or less:

No agricultural land is known to exist within one mile of the site (Reference 16, pp. 3-18, 3-19, and 3-20).

Distance to prime agricultural land in production within past 5 years, if 2 miles or less:

No agricultural land is known to exist within one mile of the site (Reference 16, pp. 3-18, 3-19, and 3-20).

Is a historic or landmark site (National Register of Historic Places and National Natural Landmarks) within view of the site?

There are no archaeological or historical sites or districts which are included in the National Register of Historic Places within one mile of the site (Reference 16, p. 3-21).

River. Both the quantity and quality of flow in Coldwater Creek are influenced by surface water runoff from adjacent developed areas (e.g., the airport and industrial and residential areas) and industrial and municipal discharges; there are no known uses of the flow in the creek. Groundwater in the vicinities of the sites is of very poor quality (saline), and the yields from water wells in the local limestones are very low. Consequently, groundwater is not generally used in the area around the sites. Water from the Missouri and Mississippi Rivers is treated to meet the area's water needs; the closest water treatment facility is on the Missouri River upstream of its confluence with Coldwater Creek. There are no records of any producing water wells within a 1-mile radius of the SLAP Site with the nearest water well being approximately 1.5 miles north of the SLAP Site (Reference 3, pp 1-1, 1-2, 3-6 through 3-13, Reference 6, pp. 1, 4).

The observed release of Rn-222 from the SLAP and HIS Sites may present a potential hazard to the population located within the vicinity of the sites. Seventy-five to 100 people reside in an industrially zoned area of Hazelwood approximately 0.5 mile west of the SLAP Site, and approximately 1,500 people reside along Chapel Ridge Drive one mile northwest of the SLAP Site (Reference 3, p. 3-20). The McDonnell Douglas Corporation employs 24,000 people adjacent to the SLAP Site (Reference 7), and Ford Motors maintains a large facility approximately 0.5 mile north of the site. The Lambert-St. Louis International Airport facilities are approximately one mile south of the SLAP Site. Recreational programs are conducted at Berkeley Khoury League Park immediately north of the SLAP Site, and numerous other industrial facilities are located within 0.25 mile of the site (Reference 3, pp. 3-18 through 3-21). Residential areas nearest the HIS and FUTURA Sites are approximately 0.3 mile to the west in Hazelwood; most of Hazelwood's residents (1980 population of 8,819) are north of Interstate Highway

270 approximately 0.75 mile north of the HIS and FUTURA Sites (Reference 3, p. 3-20; Reference 6, p. 4). Residences in the city of Berkeley (1980 population of 16,146) are southeast of the site. Commercial and industrial facilities are adjacent to the HIS and FUTURA Sites to the north and east (Reference 3, p. 3-19; Reference 6, p. 3).

2. INFORMATION ON CONSTITUENTS OF WASTE

Quantity

All of the contaminants evaluated at the SLAP, HIS and FUTURA Sites were constituents, or are decay products of the constituents, of the radioactive wastes that were stored at the sites. The radioactive wastes stored at the sites were the result of uranium processing operations (Reference 5, pp. 2, 3; Reference 2, pp 2, 3, 5) and, therefore, are special study wastes under Section 3001 (b)(3)(A)(ii) of the RCRA. Consequently, all wastes at the sites are special study wastes, and all potential environmental hazards are due to special study wastes.

A total of 125,150 tons of radioactive wastes were stored at the SLAP Site; this total included 106,500 tons of raffinates, 10,200 tons of leached and unleached barium sulfate cake, 4,000 tons of liner slag, 350 tons of miscellaneous residues (Reference 8, p. 32), 3,500 tons of contaminated scrap metal, and 600 tons (2,400 drums) of uranium bearing sand, contaminated scrap materials, and miscellaneous residues. An unknown quantity (50 to 60 truckloads) of contaminated scrap metal and possibly contaminated structures were also buried at the site (Reference 3, pp. 2-1, 2-4). The quantity of wastes that was moved to the HIS and FUTURA Sites cannot be determined from existing documents; consequently, the quantities of wastes still remaining at the SLAP, HIS and FUTURA Sites are unknown. The original storage

pile at the HIS Site contains approximately 13,000 tons (cubic yards) of contaminated materials that were excavated during remediation of the adjacent FUTURA Site (Reference 2, p. 7). The 4,100 tons of special study (radioactive) wastes used for scoring purposes received the maximum hazardous waste quantity factor score of 8 in the HRS scoring.

Concentration

The concentrations of radionuclides in the radioactive wastes originally stored at the SLAP Site are unknown. An inventory of these wastes estimated that the 121,050 tons of raffinates, barium sulfate cake, liner slag, and miscellaneous residues contained approximately 241 tons of uranium (Reference 8, p. 32). Radiological characterizations of the SLAP, HIS and FUTURA Sites in 1977 and 1986 indicated that Ra-226, Th-230, and U-238 are the major radioactive contaminants at the sites. The ranges in concentrations of these radionuclides in soil, groundwater, surface water, stream sediment, and air samples from the sites are provided in Tables 1 through 5.

Reactivity and Incompatibility

Radioactive residues present on-site are believed to be relatively stable. It is not known whether the intermixing of these residues would pose a threat of a fire/explosive hazard. Therefore, the special study wastes received a reactivity factor score of 0.

Table 1

Radionuclide Concentrations In SLAP, HIS and FUTURA Soil Samples
Concentration Range In Soil Samples

Radionuclide	SLAP Site (pCi/g) ^a	HIS Site (pCi/g) ^b	FUTURA Site (pCi/g) ^c	Background (pCi/g) ^{a,b,c}
Ra-226	0.5 to 5,620	0.5 to 700	0.5 to 2300	0.5
Th-230	0.6 to 2,600	0.8 to 790	0.2 to 2000	0.2
U-238	<3 to 1,600	4 to 800	1.0 to 2500	1.0

^a Reference 5, pp. 19, 21. PicoCuries per gram = pCi/g.

^b Reference 2, pp. 16, 19, 43 through 57 PicoCuries per gram = pCi/g

^c Reference 9 PicoCuries per gram = pCi/g.

^d For the St. Louis, Missouri, area.

Table 2

Radionuclide Concentrations In SLAP, HIS and FUTURA Groundwater Samples^a
Concentration Range In Groundwater Samples

Radionuclide	SLAP Site (pCi/l) ^b	HIS Site (pCi/l) ^c	FUTURA Site (pCi/l) ^d
Ra-226	0.2 to 0.5	0.1 to 0.7	0.6 to 1.3
Th-230	0.2 to 1.2	0.6 to 2.6	0.1 to 0.4
Total uranium ^e	16 to 6,570	<3 to 33	<3.0 to 6.0

^a Background radionuclide concentrations in groundwater were not provided in reference documents for the SLAP, HIS and FUTURA Sites.

^b Reference 1, pp. 21, 23. PicoCuries per liter = pCi/l.

^c Reference 6, pp. 22, 23, PicoCuries per liter = pCi/l.

^d Reference 10. PicoCuries per liter = pCi/l.

^e Total uranium is U-234 and U-238 combined.

Table 3
Radionuclide Concentrations In SLAP and HIS Surface Water Samples
Concentration Range in Surface Water Samples

Radionuclide	SLAP Site (pCi/l) ^a	HIS Site (pCi/l) ^b	Background (pCi/l) ^{a,b,c}
Ra-226	0.1 to 0.4	0.1 to 0.4	0.2 to 0.3
Th-230	<0.05 to 0.5	<0.1 to 1.0	<0.2 to 0.2
Total uranium	<3.0 to 6.7	<3.0 to 5.0	<3.0

^a Reference 1, pp 19, 20 PicoCuries per liter = pCi/l

^b Reference 6, pp 19, 20, 21 PicoCuries per liter = pCi/l

^c Range in average background radionuclide concentrations at both the SLAP and HIS Sites as determined from surface water samples taken upstream of both sites

Table 4
Radionuclide Concentrations In SLAP and HIS Stream Sediment Samples
Concentration Range IN Stream Sediment Samples

Radionuclide	SLAP Site (pCi/g dry) ^a	HIS Site (pCi/g dry) ^b	Background (pCi/g dry) ^{a,b,c}
Ra-226	0.9 to 1.7	5.6	0.8 to 1.1
Th-230	0.6 to 2.2	200	1.2 to 6.0
U-238	0.6 to 2.6	5.6	0.8 to 1.2

^a Reference 1, pp 23, 24. PicoCuries per gram = pCi/g.

^b Reference 16, pp 22, 24, 25. PicoCuries per gram = pCi/g.

^c Range in average background radionuclide concentrations at both the SLAP and HIS Sites as determined from sediment samples taken upstream of both sites.

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Table 5

Radon-222 Concentrations In SLAP and HIS Air Samples
Concentration Range In Air Samples

SLAP Site (pCi/l) ^{a,b}	SLAP Average (pCi/l) ^{a,b}	HIS Site (pCi/l) ^{a,c}	HIS Average (pCi/l) ^{a,c}
0.1 to 6.8	0.4 to 3.5	0.1 to 3.4	0.2 to 1.8

^a PicoCuries per liter = pCi/l All concentrations include the background Rn-222 concentration of 0.3 pCi/l

^b Reference 1, pp 14, 15, 16

^c Reference 6, pp 14, 15, 16

Toxicity

The toxic components of the special study wastes include Ra-226, Rn-222, Th-230, and U-238. Ra-226 is a highly radiotoxic element, and inhalation, ingestion, or bodily exposure to Ra-226 can result in lung or bone cancer and skin damage. The chief hazard from Rn-222 is inhalation of the gaseous element and its solid daughters (decay products) that are attached to particulates in the air. Once inhaled, the solid radon daughters attach to the lungs and then decay, transmitting energy (radiation) to the lungs. Inhalation of radon has been considered to be a major cause of the high incidence of lung cancer in uranium miners. On an acute basis, Th-230 has caused dermatitis; however, taken internally as thorium oxide, it has proven to be carcinogenic due to its radioactivity. U-238 is a highly toxic element on an acute basis. Permissible levels for soluble uranium compounds are based on chemical toxicity while the permissible body level for insoluble uranium compounds is based on radiotoxicity. The high chemical toxicity of uranium and its salts is largely shown in kidney damage, and the high toxicity effect of insoluble uranium compounds is largely due to lung irradiation by inhaled particles

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(Reference 11, pp. 2357, 2577, 2711). Due to the toxicities of the radionuclides in the special study wastes, the special study wastes received the maximum toxicity factor score of 9.

The concentrations of Ra-226 and Th-230 in surface and subsurface soils at the SLAP, HIS and FUTURA Sites greatly exceed the DOE's soil (land) guidelines or maximum limits for unrestricted use; these guidelines for radionuclides (Ra-226, Ra-228, Th-230, and Th-232) are 5 pCi/g averaged over the first 15 centimeters of soil below the surface and 15 pCi/g when averaged over any 15-centimeter thick soil layer below the surface (Reference 5, p. 24). Individual and average concentrations of Rn-222 in air samples from the SLAP Site exceed the maximum permissible concentration (MPC) of 3.0 pCi/l for air in unrestricted areas as promulgated by the U.S. Nuclear Regulatory Commission (NRC) in Title 10, Code of Federal Regulations, Part 20 (10 CFR 20). The concentration of radionuclides in groundwater and surface water at the SLAP, HIS, and FUTURA Sites are within the standards and guidelines promulgated by the NRC in 10 CFR 20 and the EPA in 40 CFR 141 (Primary Drinking Water Standards)(Reference 12, p. 4-3).

3. EXPOSURE INFORMATION

Releases

At the present time, contaminants can leach from the SLAP, HIS and FUTURA Sites into groundwater. This type of release is confirmed by the concentrations of radionuclides in on-site monitoring wells (Table 2). Groundwater samples collected at the SLAP Site in 1986 contained average concentrations ranging from 0.2 to 0.5 picoCuries per liter (pCi/l) for Ra-226, 0.2 to 1.2 pCi/l for Th-230, and 16 to 6,570 pCi/l for total uranium (U-234 and U-238 combined) (Reference 1, pp. 21, 22).

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Groundwater samples collected at the HIS Site in 1986 contained maximum average concentrations of Ra-226, Th-230, and total uranium of 0.7, 2.6, and 33 pCi/l, respectively (Reference 6, pp. 22, 23).

As shown in Table 1, soils at the SLAP, HIS, and FUTURA Sites contain concentrations of radionuclides that exceed background soil concentrations. Therefore, surface runoff from the sites could transport contaminants to Coldwater Creek by direct overland flow or in drainage ditches adjacent to the sites. Surface water samples collected in 1986 at locations downstream of the sites had average concentrations of Ra-226, Th-230, and total uranium that exceeded background concentrations in samples collected upstream of the sites (Table 3). Analyses of sediment samples collected at surface water sampling locations produced similar results at both sites (Table 4) and indicated Th-230 contamination at concentrations much greater than background in a drainage ditch north and downstream of the HIS and FUTURA Sites (Reference 6, pp. 20, 22, 24, 25). The direction of groundwater flow at all three sites is toward Coldwater Creek, and groundwater may discharge into the creek allowing contaminants to enter surface water. The surface water monitoring at both sites indicates that this potential contamination mechanism has not affected surface water quality at the sites (Reference 1, pp. 19, 21; Reference 6, p. 19).

A statistical analysis of Rn-222 data in the HRS scoring package (Reference 12) confirmed an observed air release at the SLAP Site. Rn-222 is constantly being emitted as a radioactive decay product of the Ra-226 present at both sites. Air monitoring at the SLAP Site during 1986 revealed annual average Rn-222 concentrations of 0.4 to 3.5 pCi/l (Table 5). Annual average Rn-222 concentrations at the HIS Site during the same time period were 0.2 to 1.8 pCi/l (Table 5). The

annual average Rn-222 concentrations at both sites include the approximate background Rn-222 concentration of 0.3 to 0.5 pCi/l (Reference 6, pp. 14, 15, 16; Reference 1, p. 14; Reference 12). The special study wastes received the maximum observed air release factor score of 45.

Exposures

The groundwater and surface water routes are not primary routes of exposure for the SLAP, HIS and FUTURA Sites. The groundwater in the area of the sites is of very poor quality, and water well yields are very low. There are no known uses of the flow in Coldwater Creek (Reference 3, pp. 1-1, 1-2, 3-6 through 3-13; Reference 6, pp. 1, 4). However, one report (Reference 3, pp. 3-6) indicates that there is a potential water well approximately 1.5 miles north of the SLAP Site. Thus, groundwater is a potential exposure route. The use of this well is not known. Although water is withdrawn from the Missouri and Mississippi Rivers for municipal drinking water, the closest withdrawal points (treatment plants) are on the Missouri River upstream of the Coldwater Creek confluence and on the Mississippi River more than 3 miles downstream of the SLAP, HIS and FUTURA Sites (Reference 3, p. 3-9; Reference 1, p. 5). Due to the lack of targets, the groundwater and surface water routes were not evaluated in the HRS scoring package.

The air route is the primary exposure route for the SLAP, HIS and FUTURA Sites due to the constant emission of Rn-222 from the decay of the Ra-226 at the sites. This exposure route has the potential to affect people residing and working in the vicinity of the sites. There are numerous residences in the cities of Hazelwood and Berkeley within 4 miles of the sites, and several small to large, industrial and commercial facilities are adjacent to and in close proximity to the sites (Reference

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3, pp 3-18 through 3-21; Reference 6, pp. 3, 4). Based on the employment of 24,000 people at the McDonnell Douglas Corporation within 0.5 mile of the SLAP Site (Reference 7), the special study wastes received a population within 4-mile radius factor score of 27. The special study wastes received the maximum land use factor score of 3 because commercial and industrial facilities are immediately adjacent to all three sites.

4. HAZARD TO HUMAN HEALTH AND THE ENVIRONMENT

The SLAP, HIS and FUTURA Sites present a threat to human health and the environment. Radioactive wastes from uranium processing operations, designated as special study wastes in Section 3001(b)(3)(A)(ii) of the RCRA, were stored at the sites. Most of these radioactive wastes have been removed from the sites, but radionuclides from the wastes (i.e., Ra-226, Th-230, and U-238) have been detected in surface and subsurface soils, groundwater, surface water, and stream sediments. Radon gas (Rn-222) from the decay of Ra-226 at the sites is constantly being released into the air. The concentrations of Ra-226 and Th-230 in surface and subsurface soils at the SLAP, HIS and FUTURA Sites are as much as 1,124 times greater than the DOE's soil guidelines for unrestricted use, and concentrations of Rn-222 in air samples from the SLAP and HIS Sites are one to two times greater than the DOE's concentration guide for uncontrolled areas and the NRC's MPC for restricted areas. Groundwater and surface water are generally not used in the area of the sites; however, more than 24,000 people work within 0.5 mile of the sites, and there are numerous residences and commercial and industrial facilities within 4 miles of the sites. Residents and employees in the vicinities of the sites could be exposed to the carcinogenic radon gas.

5. SUMMARY

Radioactive wastes from uranium processing operations were stored at the SLAP, HIS and FUTURA Sites; these wastes were designated as special study wastes by RCRA. In accordance with the SARA and EPA directives, this evaluation was prepared to determine to what extent these special study wastes affected the HRS score for the sites. Toxic radionuclides from the special study wastes have been released to groundwater, surface water, and air. Human exposure to the contaminated waters is not likely, but a large population adjacent and in close proximity to the sites could be exposed to radon gas that is constantly released into the air from the decay of radionuclides at the sites. Therefore, the sites present a threat to human health and the environment due to the presence of the special study wastes. The HRS score for the sites was based solely on the special study wastes.

6. REFERENCES

References from HRS Scoring Package

All references cited in the documentation record for the HRS scoring package were reviewed for this evaluation. The references from the HRS scoring package that were cited in this evaluation are as follows:

1. St. Louis Airport Site, Annual Site Environmental Report, St. Louis, Missouri, Calendar Year 1986, DOE/OR/20722-145, prepared by Bechtel National, Inc., Oak Ridge, Tennessee, for the U.S. Department of Energy, Formerly Utilized Sites Remedial Action Program (FUSRAP), Oak Ridge Operations Office, Oak Ridge, Tennessee, May 1987.

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2. Characterization Report for the Hazelwood Interim Storage Site, Hazelwood, Missouri, DOE/OR/20722-141, prepared by Bechtel National, Inc., Oak Ridge, Tennessee, for the U.S. Department of Energy, Formerly Utilized Sites Remedial Action Program (FUSRAP), Oak Ridge Operations Office, Oak Ridge, Tennessee, June, 1987.
3. "Draft Report, Environmental Impact Assessment of the Former Airport Storage Site of the Atomic Energy Commission, St. Louis County, Missouri," prepared by Roy F. Weston, Inc., Westchester, Pennsylvania, for Oak Ridge National Laboratory Nuclear Division, Union Carbide, Oak Ridge, Tennessee, October 1978.
4. Avel, Andy, U.S. Department of Energy, "Attachment 1, Outdoor Radon Monitoring," personal communication to John Chen, U.S. Environmental Protection Agency, dated September 30, 1987.
5. Radiological and Limited Chemical Characterization Report for the St. Louis Airport Site, St. Louis, Missouri, DOE/OR/20722-163, prepared by Bechtel National, Inc., Oak Ridge, Tennessee, for the U.S. Department of Energy, Formerly Utilized Sites Remedial Action Program (FUSRAP), Oak Ridge Operations Office, Oak Ridge, Tennessee, August 1987.
6. Hazelwood Interim Storage Site, Annual Site Environmental Report, Hazelwood, Missouri, Calendar Year 1986, DOE/OR/20722-143, prepared by Bechtel National, Inc., Oak Ridge, Tennessee, for the U.S. Department of Energy, Formerly Utilized Sites Remedial Action Program (FUSRAP), Oak Ridge Operations Office, Oak Ridge, Tennessee, June 1987.

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7. Copeland, Joe, McDonnell Douglas Corporation, St. Louis, Missouri, personal communication to Jill Biesma, Jacobs Engineering Group Inc., Lenexa, Kansas, dated November 9, 1987.
8. Radiological Survey of the St. Louis Airport Storage Site, St. Louis, Missouri, September 1979, Final Report, DOE/EV-0005/16, prepared by Oak Ridge National Laboratory, Oak Ridge, Tennessee, for the Formerly Utilized MED/AEC Sites Remedial Action Program, U.S. Department of Energy, Assistant Secretary for Environment, Division of Environmental Control Technology, Washington, D.C.
9. Radiological Characterization Report For The Futura Coatings Site, DOE/OR/20722-158, prepared by Bechtel National, Inc., Oak Ridge, Tennessee, for the U.S. Department of Energy, Formerly Utilized Sites Remedial Action Program (FURSAP), Oak Ridge, Tennessee, July 1987.
10. Summary of Radiological Data For SLAP, HIS and FUTURA Sites.
11. Sax, N. Irving, Dangerous Properties of Industrial Materials, Sixth Edition, Van Nostrand Reinhold Company, New York, New York, 1984.
12. Biesma, Jill, "Observed Air Release Statistical Analysis, Hazard Ranking System (HRS) Scoring for the St. Louis Airport and Hazelwood Interim Storage Sites, St. Louis County, Missouri, Jacobs Engineering Group Inc., Lenexa, Kansas, June 3, 1988.

**SUMMARY OF RADIOLOGICAL DATA
FOR SLAPS, HISS AND FUTURA .**

ST. LOUIS AIRPORT SITE (SLAPS)

Ownership: DOE purchase from ST. Louis Airport Authority

Status of Site Characterization: Chemical and hydrological characterization in progress. Radiological characterization complete.

Gamma Exposure Rates: 9-261 microR/hr along the northern site boundary with a mean of 84 microR/hr. No other data presented.

Airborne Concentrations: Annual radon concentrations ranged from 0.4-3.5 pCi/l. The average radon concentration of 0.95 pCi/l is above the single estimate of background levels of 0.45 pCi/l. No gross alpha or air particulate data presented.

Surface and Groundwater: Radionuclide concentrations in pCi/l from 16 on-site monitoring wells and a single Coldwater Creek station are as follows:

	<u>Creek</u>	<u>Wells</u>
Natural uranium	4.3	16-6570
Th-230	<0.2	<0.2-1.2
Ra-226	<0.2	0.3-0.5

Background water concentration data are not presented.

Soil Concentrations: Ranged from background to concentrations greatly exceeding EPA standards for Ra-226 and DOE cleanup criteria for Th-232 and Th-230. Cleanup criteria and EPA standards are as follows:

EPA standard	Ra-226	5 pCi/g surface, pCi/g subsurface
DOE guidelines	Th-232, Th-230	same as for Ra-226

Concentration ranges are as follows:

	<u>Onsite</u>	<u>Background</u>
U-238	<3.0-1600	1.0
Th-232	<0.5	0.4
Th-230	0.6-2600	0.2
Ra-226	0.5-5600	0.5
Pb-210	no data	1.0

Depths of contamination ranged from the surface to 18 feet with an average depth of six feet.

General Comments:

- o Sufficient samples from 102 borehole across the 21.7 acres site have been collected and archived. However, additional sample analyses are needed to adequately determine average concentrations and characterize the source term as a function of depth.
- o Soil concentrations are highly variable with depth and greatly exceed Ra-226 and Th-230 cleanup criteria. No U-238 guideline has been developed.
- o Elevated radon concentrations greater than 3pCi/l exist at some boundary locations and background radon concentrations are not well established.

FUTURA SITE

Ownership: Jarboe Realty and Investment Company

Status of Site Characterization: No chemical characterization. Radiological characterization is complete.

Gamma Exposure Rates: 8-27 microR/hr outside existing structures. The background exposure rate is 8 micro R/hr.

Airborne Concentrations: Radon 0.3-0.7 pCi/l inside buildings. Background radon is limited to one measurement (0.45 pCi/l). Gross alpha concentrations inside buildings ranged from 0.001-0.004 pCi/m³. Removable contamination on building surfaces was minimal and below DOE guidelines.

Surface and Groundwater: Radionuclide concentrations (pCi/l) in Coldwater Creek and from on-site monitoring wells are as follows:

	<u>Creek</u>	<u>Wells</u>
Natural uranium	4.0	<3.0-6.0
Th-230	0.2-0.4	0.1-0.4
Ra-226	0.3	0.6-1.3

Background water concentration data are not presented.

Soil Concentrations: Ranged from background to concentrations greatly exceeding EPA standards for Ra-226 and DOE cleanup criteria for Th-232 and Th-230. Soil concentration ranges in pCi/l are as follows:

	<u>On-site</u>	<u>Background</u>
U-238	<3.0-2500	1.0
Th-232	<1.0-26	0.4
Th-230	<1.1-2000	0.2
Ra-226	0.4-2300	0.5
Pb-210	no data	1.0

Depths of contamination ranged from the surface to more than 15 feet. No Pb-210 or Po-210 data were presented.

General Comments:

- o Airborne concentrations, gamma exposure rates and water concentrations all appear to be well below appropriate standards and guidelines.
- o Soil concentrations are quite variable with depth and can greatly exceed limits for Ra-226 and guidelines for Th-230. Th-232 concentrations are not significantly above background. No U-238 guideline has been developed.
- o Potential impacts to Coldwater Creek need to be investigated by sampling sediments adjacent to the FUTURA/HISS Complex.
- o Additional work needs to be completed to further establish background radionuclide concentrations for radon and water.

HAZELWOOD INTERIM STORAGE SITE (HISS)

Ownership: Leased to Futura Coating, Inc.

Status of Characterization: No chemical characterization and incomplete radiological characterization.

Gamma Exposure Rate: 13-55 microR/hr with a mean of 24 microR/hr. Background exposure is 8 microR/hr.

Airborne Concentration: Radon ranged from 0.3-2.2 pCi/l in 1984, 0.3-0.7 pCi/l in 1985 and 0.2-1.8 pCi/l in 1986. Background radon was determined to be 0.5 pCi/l in 1985 and 0.3 pCi/l in 1986.

Surface and Groundwater: Radionuclide concentration ranges (pCi/l) from four on-site monitoring wells and four surface water stations were as follows:

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	<u>Surface</u>	<u>Groundwater</u>
Natural uranium	<3.0	4-33
Th-230	<0.1-0.4	1-2.6
Ra-226	0.2	0.3-0.7

There is no apparent effect of surface runoff from the site on surface waters of Coldwater Creek. Uranium concentrations in surface waters by HISS have declined since partial remedial action in 1984.

Soil Concentrations: Radionuclide concentrations ranged from background to above EPA standards and DOE guidelines in pCi/g as follow:

<u>On-site</u>	<u>Background</u>	
U-238	4.0-800	1.0
Th-232	0.7-5.0	0.4
Th-230	1.0-790	0.2
Ra-226	0.5-700	0.5
Pb-210	no data	1.0

Depths of Ra-226 ranged for the surface to six feet with a mean depth of three feet. There is evidence that Th-230 is more mobile with concentrations as deep as ten feet. Background Ra-226 concentrations were observed at four feet.

General Comments

- o Additional Th-230 analyses of archived samples are needed to adequately determine the Th-230 content as a function of depth.
- o Adjacent properties need to be characterized to determine extent of off-site contamination along Coldwater Creek and Latty Avenue.
- o Investigation of waste materials sent to the West Lake landfill needs to be conducted.
- o The main and supplementary waste storage piles need to be radiologically and chemically characterized.

OFF-SITE PROPERTIES

Ditches : designated for FUSRAP cleanup in 1982. The primary contamination is Ra-226. Ra-226 is at depth 10-50' adjacent to western half of SLAPS between SLAPS boundary and McDonnell Blvd. Ra-226 on the surface (0-15 cm) ranged from 0.1-656 pCi/g adjacent to the western boundary of SLAPS, extending under McDonnell Blvd.

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Reference 2

**Excerpts From Site Plan for St. Louis Airport Site
and Vicinity Properties, St. Louis, Missouri;
Prepared for the U.S. Department of Energy by
Bechtel National, Incorporated; November 1989**

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**SITE PLAN FOR ST. LOUIS AIRPORT SITE AND VICINITY PROPERTIES
ST. LOUIS, MISSOURI**

NOVEMBER 1989

Prepared for
UNITED STATES DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE
Under Contract No. DE-AC05-81OR20722

By

Bechtel National, Inc.
Oak Ridge, Tennessee
Bechtel Job No. 14501

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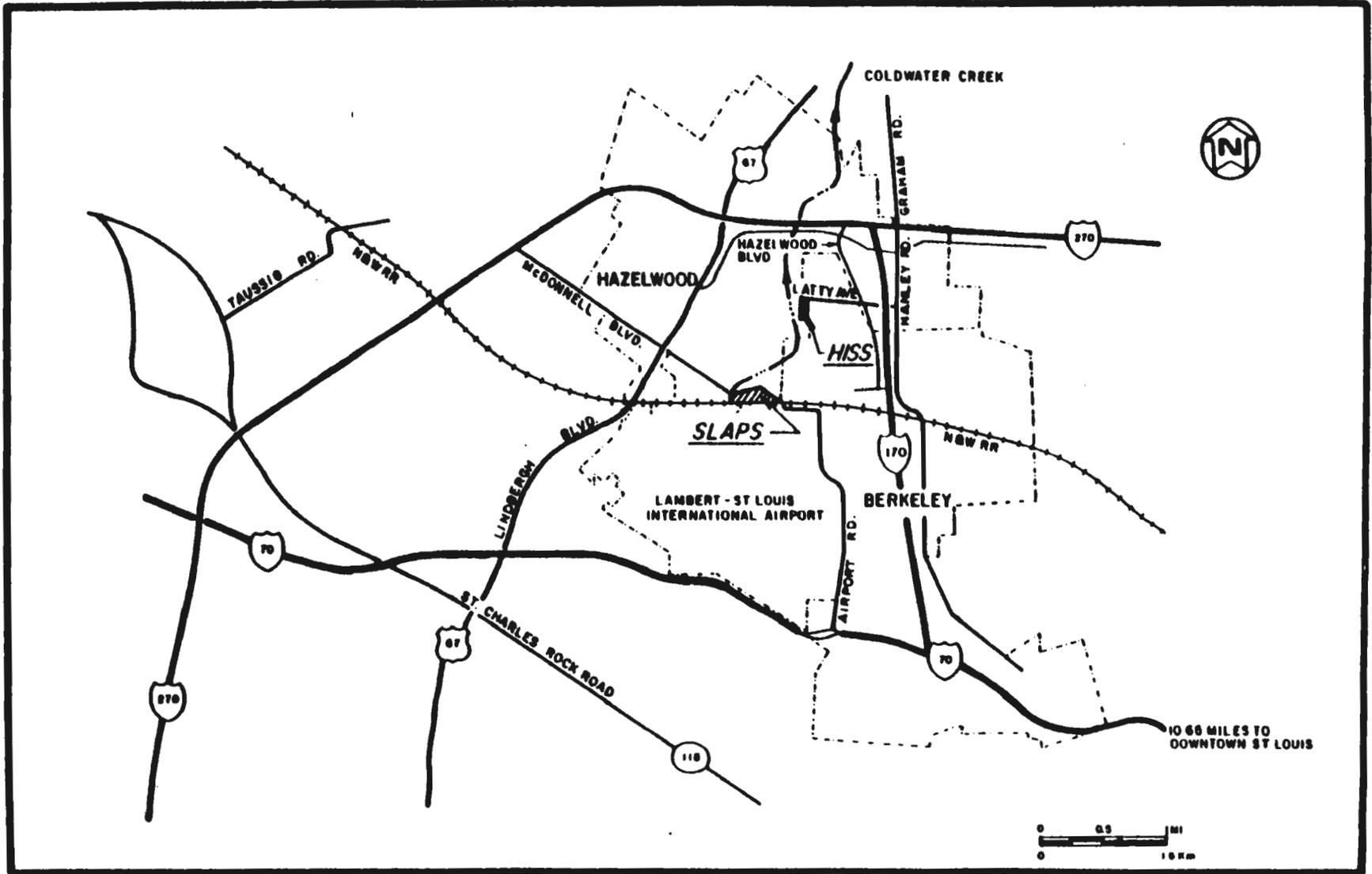


FIGURE I-1 LOCATION OF SLAPS

II. HISTORY

In 1946, the Manhattan Engineering District (MED), a predecessor of the Atomic Energy Commission (AEC), and DOE acquired the 21.7-acre tract now known as SLAPS to store residues resulting from the processing of uranium ores at a facility in downtown St. Louis.

The uranium processing (under a MED contract) continued through 1953; the resulting radioactive residues were stored at SLAPS. These materials included pitchblende raffinate residues, radium-bearing residues, barium sulfate cake, Colorado raffinate residues, and contaminated scrap (Ref. 1). Most of the residues were stored in bulk on open ground. Some contaminated materials and scrap were buried at the western end and in other parts of the site. To limit direct radiation exposure to the public, the site was fenced to prevent casual entry.

In 1966 and 1967, most of the stored residues were sold and removed from the site. These residues were transferred to the the Hazelwood Interim Storage Site (HISS--one of the Latty Avenue Properties) for storage. On-site structures were razed, buried on the site, and covered with 1 to 3 ft of clean fill. Although these activities reduced the surface dose rates to acceptable levels, buried deposits of uranium-238, radium-226, and thorium-230 remained on the site (Ref. 2).

In 1973, at the request of the city, the tract was transferred by quitclaim deed from AEC to the City of St. Louis. The 1985 Energy and Water Development Appropriations Act (Public Law 98-360) authorized DOE to reacquire the property from the city for use as a permanent disposal site for the waste already on site, contaminated soil in the ditches surrounding the site, and the waste from the Latty Avenue Properties, approximately 1 mi to the north (Ref. 1). Actions to transfer ownership of the SLAPS property to DOE have been initiated.

From 1976 through 1978, Oak Ridge National Laboratory (ORNL) conducted a radiological investigation of SLAPS (Ref. 3). This survey indicated the presence of elevated concentrations of uranium-238 and radium-226 in drainage ditches north and south of McDonnell Boulevard. In 1981, the drainage ditches were designated for remedial action under FUSRAP.

Site: VP/SLAPS
WBS: 134/153
Date: 10/06/89

- o Construction of an access road across the site and along the west end of the site
- o Excavation of the slope on the west end of the site abutting Coldwater Creek
- o Construction of a storage pile for the excavated material
- o Construction of gabion (i.e. retaining) wall along Coldwater Creek

Prior to the start of the FY 1986 characterization at SLAPS, BNI prepared a plan to outline the activities necessary to support the long-term management plan and developed the engineering packages necessary for the radiological/chemical and geological/hydrological characterization of SLAPS. This work involved the preparation of detailed cost estimates, design drawings, technical specifications, schedules, and requisitions.

In 1985, ORNL performed a radiological survey of the roads thought to have been used to transport contaminated material from the St. Louis sites (Ref. 6). As a result of this survey, parts of Hazelwood Avenue, Pershall Road, and McDonnell Boulevard were designated for remedial action in 1986. In 1988 and 1989, BNI performed a radiological characterization of the roads, as shown in Figure I-3, and approximately 70 adjacent vicinity properties. Results from this characterization effort indicated thorium-230 contamination was present along the rights-of-way of these roads, extending onto some of the adjacent properties. The contamination is shallow (approximately 1 to 2 ft). The boundaries of contamination for these roads and the vicinity properties have in general been established.

No formal radiological characterization had been performed on the area south of SLAPS until the recent (1986-1989) surveys. This area includes the Norfolk and Western Railroad property, which forms the southern boundary of SLAPS, Banshee Road, and a portion of the St. Louis Airport Authority property south of Banshee Road. Thorium-230 contamination was detected on the railroad property, at two isolated areas on Banshee Road, and on portions of the St. Louis Airport Authority property. The contamination is confined to the top 2 ft of soil.

The estimated volume of waste that will be collected as a result of remedial action at the SLAPS vicinity properties is 142,000 yd³.

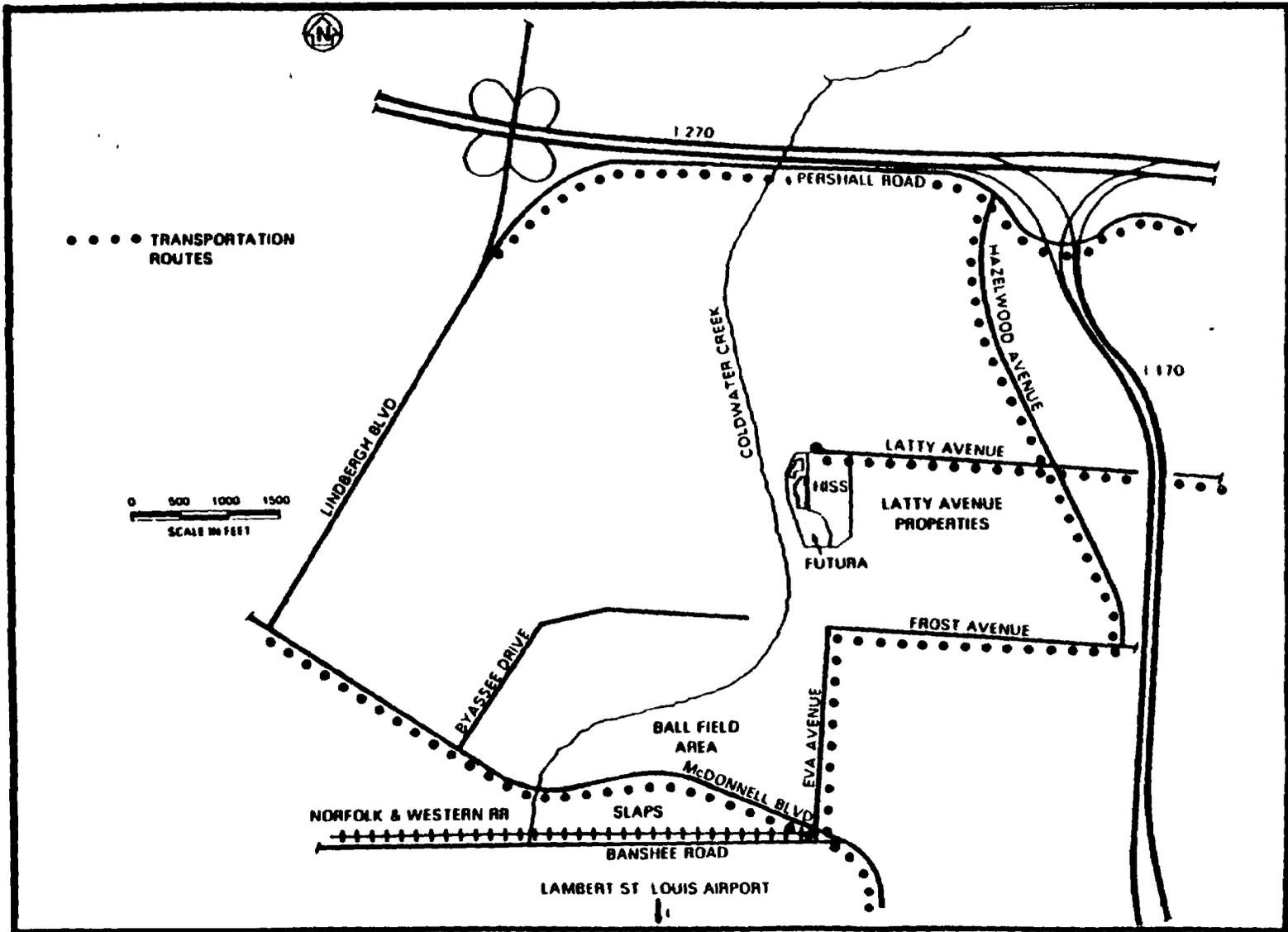


FIGURE I-3 LOCATION OF SLAPS AND THE TRANSPORTATION ROUTES

Site: VP/SLAPS
WBS: 134/153
Date: 10/06/89

IV. REMEDIAL ACTION

A. Site Characterization and Scoping

The following activities were necessary to characterize the site. These activities were completed in FY 1987.

- o Radiological and chemical characterization of the site.
- o Geologic and hydrogeologic characterization of the site.
- o Radiological characterization of vicinity properties, including ditches adjacent to the site, along McDonnell Boulevard, and in and along Coldwater Creek. NOTE: Additional characterization is required on Coldwater Creek to determine the downstream boundaries of contamination.

Radiological characterization was completed along the haul routes and vicinity properties in 1989.

In October 1985, BNI initiated engineering activities to develop the engineering packages necessary for the radiological/chemical and geological/hydrological characterizations of SLAPS. These characterization activities were completed in FY 1987.

Radiological and chemical characterizations were conducted in accordance with FUSRAP project instructions and monitoring plans developed for each characterization. The objective of the characterization was to determine the vertical and horizontal limits of contamination. Parameters measured included, but were not limited to, uranium-238, radium-226, thorium-232, thorium-230, and soil and water parameters specified in the Resource Conservation and Recovery Act (RCRA). All composite samples were subject to multi-element analysis and a total organic carbon analysis. Results of these analyses were compared with those made on background soil samples.

Characterizing the SLAPS ditches involved analyzing archived soil samples from the 1982 BNI survey for thorium-230. The results of these analyses indicated that it was necessary to collect additional surface and subsurface soil samples in FY 1987 to adequately determine the extent of contamination in excess of

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remedial action guidelines. The DOE guideline for thorium-230, thorium-232, and radium-226 contamination is 5 pCi/g averaged over the first 15 cm of soil below the surface and 15 pCi/g when averaged over 15-cm-thick soil layers more than 15 cm below the surface, averaged over 100 m².

Soil sample analyses indicated elevated levels of uranium-238, radium-226, thorium-232, and thorium-230 in surface and subsurface samples. The radiological characterization indicated contamination present on SLAPS to depths as much as 18 ft. Figure IV-1 shows the areas and depths of radioactive contamination at SLAPS.

Sediment samples were collected from Coldwater Creek. Samples were analyzed for uranium-238, radium-226, thorium-232, and thorium-230. Results showed that spotty contamination was present from 50 ft upstream of SLAPS to the Pershall Road intersection underpass, approximately 1.2 mi north of the site.

Soil samples collected from the Norfolk and Western Railroad property south of SLAPS, Banshee Road, and the St. Louis Airport Authority property were analyzed for uranium-238, radium-226, thorium-232, and thorium-230. Results showed that contamination was present south of SLAPS extending to approximately 2 ft in depth in some areas.

Soil samples were collected from the rights-of-way of the haul roads and adjacent vicinity properties. These samples were analyzed for thorium-230 only because previous field work had already identified thorium-230 as the primary contaminant. Results showed that shallow (approximately 1 to 2 ft) contamination was present.

Results of the metals analyses for SLAPS soil samples confirmed the presence of some metals (i.e., molybdenum and cobalt) at concentrations above background.

None of the soil samples analyzed for RCRA characteristics indicated that the soil is hazardous.

Volatile organic analyses confirmed the presence of three compounds in soil including toluene, trichloroethene, and trans-1,2-dichloroethene. Concentrations of these were, in general, in the low parts per billion.

Semivolatile analyses did not identify any Hazardous Substance List compounds.

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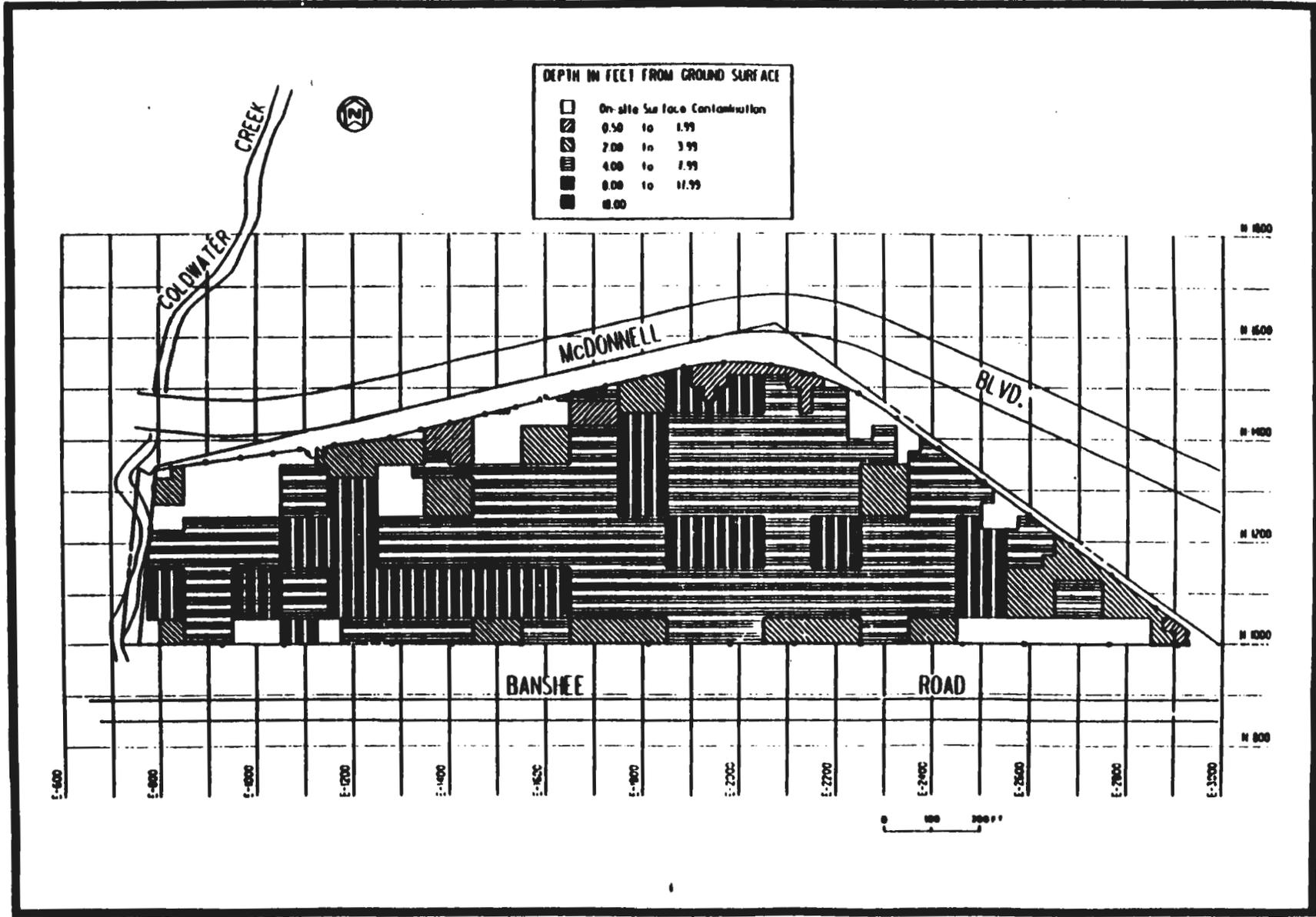


FIGURE IV-1 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT SLAPS

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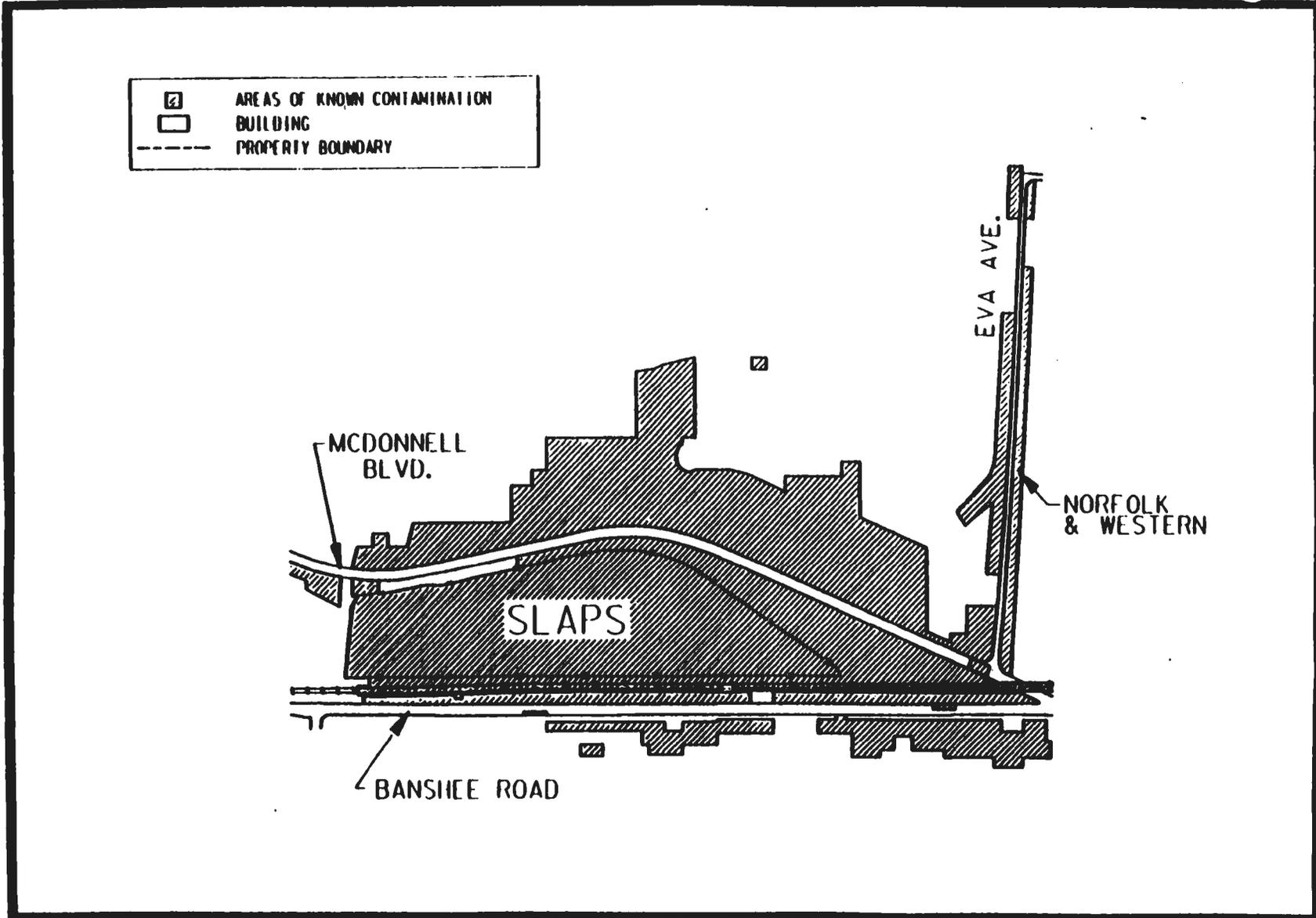


FIGURE IV-2 AREAS OF CONTAMINATION IN EXCESS OF GUIDELINES AT SLAPS

Site: VP/SLAPS
WBS: 134/153
Date: 10/06/89

V. COST AND SCHEDULE

Estimated costs associated with the portion of work specifically addressing SLAPS and its vicinity properties during the time period covered by this plan are listed in Figures V-1, 2, 3, and 4. The schedule of work for FY 91 through FY 95 as illustrated in Figure V-5 and V-6, and the text of this plan are based upon current progress and priorities. Therefore, there may be some discrepancies between cost and schedule.

(\$000)

ACTIVITY	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95
BNI ASSESSMENT (B&R AH-10-05-01)	353	1,552	448	433	343	-
CLEANUP (B&R AH-10-05-02)	-	-	17,270	8,039	14,336	4,895
SUBTOTAL	353	1,552	17,718	8,472	14,679	4,895
ANL	5	25	80	125	100	50
HQ	75	115	930	335	470	150
TOTAL	433	1,692	18,728	8,932	15,249	5,095

NOTE: Dollars are BA

FIGURE V-1 ST. LOUIS VICINITY PROPERTIES SITE BUDGET

(\$000)

ACTIVITY	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95
BNI ASSESSMENT (B&R AH-10-05-01)	716	474	1,268	1,659	1,595	-
CLEANUP (B&R AH-10-05-02)	-	670	-	-	4,313	19,784
SUBTOTAL	716	1,144	1,268	1,659	5,908	19,784
ANL	5	50	120	150	150	50
HQ	150	90	70	70	195	595
TOTAL	871	1,284	1,458	1,879	6,253	20,429

NOTE. Dollars are BA

FIGURE V-2 ST. LOUIS AIRPORT SITE BUDGET

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FY90 DETAIL — ST. LOUIS AIRPORT SITE VICINITY PROPERTIES, MO

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
134 SLAPS VICINITY PROPERTIES HAUL ROADS CHARACTERIZATION REPORT PREPARE SCOPING/PLANNING DOCUMENTS PREPARE COMMUNITY RELATIONS PLAN REMEDIAL INVESTIGATION REPORT EE/CA MEMORANDUM FOR INTERIM REMEDIAL ACTION ALONG HAUL ROADS DESIGN & PROCURE SUBCONTRACTS FOR INTERIM REMEDIAL ACTION ALONG HAUL ROADS ENVIRONMENTAL MONITORING	PUBLISH ▾												
											DOE REVIEW DRAFT ▾		
									DOE REVIEW DRAFT ▾				
							DOE REVIEW DRAFT ▾						
	DOE REVIEW DRAFT ▾				FINAL DRAFT ▾								
						◇							
	ENVIRONMENTAL MONITORING												
FUSRAP	54	34	25	20	25	21	34	28	28	28	28	28	
ANL	—	—	—	—	—	1	1	1	1	1	—	—	
HQ	6	6	6	6	6	6	6	6	6	7	7	7	
TOTAL (\$000-BA)	60	40	31	26	31	28	41	35	35	36	35	35	

FIVE YEAR PLAN FY90 VS. FY90 BASELINE RECONCILIATION: THE RI/FS PROCESS HAS BEEN ACCELERATED AND STARTED IN FY 89 AND WILL CONTINUE IN FY 90. ORIGINALLY FY 90 PLANNED ACTIVITIES FOR THIS SITE WERE INCLUSIVE TO THE COMPLETION OF THE FIELD RI OF PROPERTIES ALONG THE HAUL ROADS

PROPOSED MILESTONES CONTROLLED BY ▽ DOE HQ ▽ ORO TSD ◇ PMC ○ ANL

FIGURE V-3 FY 90 DETAIL

FY90 DETAIL — ST. LOUIS AIRPORT SITE, MO

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
189 SLAPS												
PREPARE SCOPING/PLANNING DOCUMENTS	DOE REVIEW DRAFT ▽											
PREPARE COMMUNITY RELATIONS PLAN	DOE REVIEW DRAFT ▽											
REMEDIAL INVESTIGATION REPORT	DOE REVIEW DRAFT ▽											
ENVIRONMENTAL MONITORING												
FUSRAP	72	53	69	63	68	48	93	50	51	50	51	48
ANL	—	—	—	—	—	1	1	1	1	1	—	—
HQ	12	13	12	13	12	13	12	13	12	13	12	13
TOTAL (\$000-BA)	84	66	81	76	80	62	106	64	64	64	63	61

FIVE YEAR PLAN FY80 VS FY90 BASELINE RECONCILIATION THE RIVS PROCESS HAS BEEN ACCELERATED AND STARTED IN FY 89 AND WILL CONTINUE IN FY 90 ORIGINALLY FY 90 PLANNED ACTIVITIES FOR THIS SITE WERE INCLUSIVE TO SURVEILLANCE AND MAINTENANCE ACTIVITIES

PROPOSED MILESTONES CONTROLLED BY ▽ DOE HQ ▽ ORO TSD ◇ PMC ○ ANL

989 1141 16

FIGURE V-4 FY 90 DETAIL

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ST. LOUIS AIRPORT SITE VICINITY PROPERTIES — 5-YEAR PLAN

	FY 91				FY 92				FY 93				FY 94				FY 95			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
ASSESSMENT																				
R/FS - EIS	<div style="display: flex; justify-content: space-between;"> WORK PLAN TO PUBLIC SIGN ROD </div>																			
CLEANUP																				
HAUL ROADS AND VICINITY PROP.																				
STORAGE OF WASTE AT HISS																				
POST-REMEDIATION ACTION REPORT																				
CERTIFICATION DOCKET																				

FIGURE V-5 FY 91 - 95 SCHEDULE

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ST. LOUIS AIRPORT SITE — 5-YEAR PLAN

	FY 91				FY 92				FY 93				FY 94				FY 95			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
ASSESSMENT																				
RVFS - EIS															SIGN ROD ⊙					
CLEANUP*																				
REMEDIAL ACTION DESIGN															◆					
CONSTRUCT DISPOSAL CELL																			◆	
START CELL OPERATIONS																				◆

*ASSUMES, FOR THE PURPOSES OF THIS SCHEDULE, THAT THE SELECTED REMEDIAL ACTION ALTERNATIVE IS LAND DISPOSAL IN THE ST LOUIS AREA

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FIGURE V-6 FY 91 - 95 SCHEDULE

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Reference 3

**Excerpts From Environmental Restoration and Waste Management
Site-Specific Plan for Oak Ridge Operations Office
(Formerly Utilized Sites Remedial Action Program, Missouri);
Prepared for U.S. Department of Energy; November 1989**

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ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT
SITE-SPECIFIC PLAN FOR
OAK RIDGE OPERATIONS OFFICE
FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM

MISSOURI

NOVEMBER 1989

Prepared for:
U.S. DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE

RECEIVED
NOV 1 1989
REML SECTION

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As of September 1989, 30 sites at which DOE has authority to proceed have been identified as requiring some form of remedial action, and one other site has been identified as requiring radiological surveillance to monitor the effectiveness of past remedial actions conducted by DOE's predecessor agencies. Sites may be added to FUSRAP based on (1) the results of ongoing radiological surveys, health and safety evaluations, and review of authority being conducted by DOE and (2) legislative actions.

FUSRAP activities have been under way since 1974, with remedial actions beginning on a limited basis in 1979. Remedial action has been completed at 10 of the 30 currently authorized sites and has been initiated at 8 other sites. Preliminary engineering has been partially completed for 1 of the remaining 12 authorized sites.

The FUSRAP and SFMP site locations are shown in Figure 1.

This Site-Specific Plan (SSP) pertains to the FUSRAP sites in Missouri, the locations of which are shown in Figure 2. An overview of these sites is provided in Section 1.2.

1.2 ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT OVERVIEW

This SSP addresses the assessment and cleanup activities to be conducted at FUSRAP sites in the State of Missouri. These include:

- o St. Louis Downtown Site
- o St. Louis Airport Site and Vicinity Properties
- o Latty Avenue Properties

None of the sites are owned by DOE, but each site contains radioactive residues from federal uranium processing activities during and after World War II. The sites are described in detail in separate site plans, provided as appendices to this SSP. The site plans provide specific information regarding site locations, histories, and assessment and cleanup activities performed to date.

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2.0 REQUIREMENTS FOR IMPLEMENTATION

DOE has authority under AEA, as amended, to undertake radiological surveys and other research work, including radiological monitoring, at sites formerly utilized to support the nuclear activities of DOE's predecessor agencies. DOE also has authority under that act to conduct remedial actions at 25 of the sites identified to date as requiring some form of remedial action. Public Law 98-50, the FY 1984 Energy and Water Development Appropriations Act, authorized DOE to conduct a decontamination research and development project at four sites: Wayne/Pequannock (New Jersey), Maywood (New Jersey), Colonie (New York), and Latty Avenue (Missouri) properties.

Public Law 98-360, the FY 1985 Energy and Water Development Appropriations Act, authorized DOE to acquire title to the St. Louis (Missouri) Airport Site and to perform necessary remedial action and develop the property as a disposal site for the waste already there, as well as for waste on vicinity properties and the Latty Avenue properties, consistent with appropriate regulatory requirements and in a manner satisfactory to the City of St. Louis. Continued authorization has been provided each year in the passage of the subsequent Energy and Water Development Appropriations Act.

The St. Louis Airport site, Latty Avenue Properties site, and the vicinity properties were added to the National Priorities List (NPL) as one site by the EPA in October 1989. The Wayne/Pequannock and Maywood, New Jersey, sites and their vicinity properties were added to the NPL as two sites by the EPA in December 1982 and September 1983, respectively.

5.0 ENVIRONMENTAL RESTORATION

5.1 TASK DESCRIPTION

The general sequence of events to accomplish environmental restoration at FUSRAP sites is described in Section 3.2. This section of this SSP pertains specifically to the Missouri sites and the actions to be taken there over the next five years.

There are two overall activities to be performed: assessment and cleanup. Assessment activities are considered to be priority 1 because they are ongoing and are designed to reduce health risks that would be associated with uncontrolled exposure of the general public to the contamination.

These assessment activities, including a RI/FS-EIS, are the first steps in the overall process of waste cleanup at the sites. Without completion of these activities, the ROD cannot be reached and cleanup activities cannot start. Therefore, the driving force behind this work is the need to initiate the process of understanding site conditions so eventual cleanup can be undertaken. Discussions with community leaders and officials regarding the disposition of this waste have been ongoing.

The activities that have been initiated and are needed to complete the RI/FS-EIS include: field investigations to complete definition of the nature and extent of the contamination, documentation of the results of these field investigations, and evaluation of cleanup alternatives. The assessment activities will culminate in a ROD in FY 1994 for cleanup of the sites.

Cleanup activities are considered to be priority 1 because they are follow-up actions to ongoing assessment activities. The cleanup is necessary to reduce health risks associated with uncontrolled exposure of the general public and workers to the contamination.

Remedial actions at the FUSRAP sites in Missouri include all actions following the signing of the ROD that formally selects the remedial action alternative to be implemented. The cleanup activities include design engineering for the waste cleanup and disposal, preparation and procurement of subcontracts to implement the design engineering, execution of the cleanup subcontracts, waste management, verification and certification of the effectiveness of the cleanup, and surveillance and maintenance of waste disposal sites. With the completion of a ROD for the sites, cleanup will proceed.

At present the sites represent a potential health hazard to the general public. There is no control of off-site contamination to prevent the further spread of this material. This problem is magnified by the extensive commercial development in this area. Because of the potential health risk that the contamination could pose, the sites were given a priority 1 for cleanup.

Additional information regarding each site is provided in the site plans provided as appendices. Milestones and schedules are provided in Section 5.3, and cost is discussed in Section 5.4.

5.2 RESOURCES

Standard industrial equipment and supplies are generally sufficient for accomplishment of activities at the Missouri sites. Labor intensive efforts are generally subcontracted to qualified local or regional contractors. Any need for special equipment or uniquely trained personnel will be identified as activities progress.

5.3 SCHEDULED MILESTONES

The key milestones for the Missouri sites that fall within the five-year planning period are listed below. For planning and budgeting purposes, a disposal site in Missouri is assumed.

<u>Site</u>	<u>Task/Activity Description</u>	<u>Milestone</u>	
		<u>Level</u>	<u>Date</u>
All	Issue Draft Remedial Investigation Report	1	08/90
	Issue Draft Scoping/Planning Documents to EPA	2	11/90
	Issue Final Draft Scoping/Planning Documents to Public	3	09/91
	Issue Record of Decision and Proposed Plan for Remedial Action	3	03/94
SLAPS	Start Construction of Disposal Cell	1	06/94
	Start Disposal Cell Operations	1	04/95
SLAPS Vicinity Properties	Issue Final Draft EE/CA for Haul Roads Remedial Action	2	03/90
	Publish Certification Docket	3	01/95
Latty Avenue Properties	Acquire Real Estate Interest in HISS Property	3	03/91
	Start Cleanup of Vicinity Properties	1	10/94
St. Louis Downtown Site	Publish Characterization Report, Phase 1 & 2	2	03/90

Milestones: 1-Site; 2-ORO; 3-HQ

The detailed schedules for each Missouri site are provided in the appropriate appendices.

5.4 COST

Figure 5 is provided to show the overall costs for FUSRAP sites, including costs for DOE Headquarters and ANL activities--which pertain to all four site groups. The overall cost for the Missouri sites, excluding Headquarters and ANL costs, is illustrated in this figure. Specific dollar amounts by activity and year are provided in Table 1.

Reference 4

**Telephone Communication Concerning the Current Status
of the St. Louis Airport Sites; From Sue McCarter, SAIC,
to Gene Gunn, EPA Region VII; December 18, 1990**

**TELECOMMUNICATIONS
SUMMARY REPORT**

SAIC Contact: Sue McCarter

Date: 12/18/90

Time: 9:30 a.m.

Made Call X Received Call

Person(s) Contacted (Organization): Gene Gunn, Region VII Remedial Project Manager
(913) 551-7776 [Gene is no longer Remedial Project Manager - contact Greg McCabe at
(913) 551-7709]

Subject: Current Status - St. Louis Airport

Summary: (The majority of Federal sites have been lumped into one unit.) Current Status: Federal Facilities Agreement (IZO IAG CERCLA) was signed and made final in late June. It became effective on August 17, after a public comment period, etc.

This Federal Facilities Agreement establishes DOE as the lead agency. It will be doing all the work, removal actions, etc. ("what they do, they earn.") EPA has oversight authority and has final say over final remedy selection. The agreement is basically a procedural one that sets out requests and schedules for primary documents, which include Remedial Investigation/Feasibility Study, ROD, proposed plan, and remedial action. DOE has submitted a schedule - EPA has approved it. The ROD is scheduled to be completed in 1994.

Reference 5

**Excerpts From St. Louis Airport Site Annual Site Environmental Report,
St. Louis, Missouri, Calendar Year 1988; Prepared for the U.S. Department of Energy
by Bechtel National, Incorporated; April 1989**

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Formerly Utilized Sites Remedial Action Program (FUSRAP)
Contract No. DE-AC05-81OR20722

**ST. LOUIS AIRPORT SITE
ANNUAL SITE ENVIRONMENTAL REPORT**

St. Louis, Missouri

Calendar Year 1988

April 1989



Bechtel National, Inc.

SLAPS is located in the upper half of the Coldwater Creek watershed. Coldwater Creek originates about 5.8 km (3.6 mi) south of SLAPS at a small, spring-fed lake in Overland, Missouri; flows along the western end of the site; and discharges to the Missouri River approximately 6.4 km (4 mi) upstream of its confluence with the Mississippi River. Passing through culverts under the Lambert-St. Louis International Airport, flow in Coldwater Creek is influenced by stormwater runoff from the upstream areas of residential, commercial, industrial, and airport land (Ref. 1) (see Figure 3-1).

Rainwater runoff from SLAPS leaves the site by evaporation, seepage into groundwater, or surface drainage to Coldwater Creek. Surface drainage from the site is intercepted by drainage channels along the northern and southern boundaries of the site that direct flow into Coldwater Creek. To halt erosion of the western end of SLAPS, a gabion wall consisting of rock-filled wire baskets was constructed in 1985 along the section of Coldwater Creek bordering the site.

There are no facilities on Coldwater Creek that withdraw water for human consumption. Coldwater creek empties into the Missouri River, which in turn empties into the Mississippi River. The closest water treatment facility is on the Mississippi River, approximately 12.8 km (8 mi) downstream of the confluence of the Mississippi and the Missouri (Ref. 2).

Groundwater at SLAPS occurs in two basic systems. The first is the groundwater being monitored at the site as the "upper" and "lower" groundwater systems that occur in unconsolidated glacial sediments and are thought to be hydraulically connected. These groundwater systems yield insufficient quantities of water to wells installed at the site to be considered aquifers. The second basic system is the bedrock aquifer located in Paleozoic limestones several hundred feet beneath the site. The groundwater in the bedrock aquifer is typically of poor quality (Ref. 2), containing more than 1,000 ppm of dissolved solids, and is classified as saline (Ref. 3). In addition, yields from wells in this aquifer are very low, with

reported specific yields of less than 7.6 l/min/m (2 gal/min/ft) of drawdown. There are no plans at present to install monitoring wells in the bedrock aquifer at the site. Groundwater is not generally used for any purpose in the SLAPS area, and the nearest well is about 2.4 km (1.5 mi) north of the site. The water needs for the area are met with treated Mississippi River water.

The climate at SLAPS is classified as modified continental. The average annual daily temperature ranges from 7.4 to 18.6°C (45.4 to 65.5°F). The highest average monthly temperature is 31.6°C (89°F) (July) and the lowest is -6.7°C (19.9°F) (January). Normal annual precipitation is slightly over 87.5 cm (35 in.). The average annual snowfall is 65.8 cm (26.3 in.). Prevailing winds tend to be from the south, the northwest, and west-northwest. Average wind speeds range from 12.2 to 18.9 km/h (7.6 to 11.8 mph). Figure 1-3 shows the distribution of wind direction and speed for the SLAPS vicinity (Ref. 4).

There are no sizeable residential population centers within 1.6 km (1 mi) of the site. The nearest population center comprises 75 to 100 people residing about 0.8 km (0.5 mi) west of the site in an industrially zoned area of Hazelwood. The next nearest (about 1,500 people) is about 1.6 km (1 mi) northwest of the site along Chapel Ridge Drive. Most of Hazelwood's population is north of Interstate 270, more than 2.4 km (1.5 mi) north of the site (Ref. 2). Land use immediately adjacent to the site is varied (Figure 1-4, Ref. 2). More than two-thirds of the land within 0.8 km (0.5 mi) of the site is used for transportation-related purposes, primarily Lambert-St. Louis International Airport. Land immediately adjacent to the site is also used for commercial and recreational purposes.

1.2 SITE HISTORY

In 1946, the Manhattan Engineer District (MED), a predecessor of the Atomic Energy Commission (AEC) and DOE, acquired the 8.8-ha (21.7-acre) tract now known as SLAPS to store residues resulting from the processing of uranium ores at a facility in St. Louis.

Uranium processing at this facility was conducted under a contract with MED/AEC until 1957. Processing residues sent to the tract now known as SLAPS included pitchblende raffinate residues, radium-bearing residues, barium sulfate cake, Colorado raffinate residues, and contaminated scrap. Most of the residues were stored in bulk on open ground. Some contaminated materials and scrap were buried at the western end and in other parts of the site. To limit direct radiation exposure to the public, the site was fenced to prevent casual entry.

In 1966 and 1967, most of the stored residues were sold and moved approximately 0.8 km (0.5 mi) north to a site on Latty Avenue. On-site structures were razed, buried on the site, and covered with 0.3 to 1 m (1 to 3 ft) of clean fill. Although these activities reduced the surface dose rates to acceptable levels, buried deposits of residue containing uranium-238, radium-226, and thorium-230 remained on the site (Ref. 5).

In 1973, the tract was transferred by quitclaim deed from AEC to the City of St. Louis, at the City's request. The 1985 Energy and Water Appropriations Act (Public Law 98-360) authorized DOE to take the necessary steps to consolidate and dispose of waste materials from the Latty Avenue site and the nearby St. Louis Airport vicinity properties locally by reacquiring, stabilizing, and using the old 8.8-ha (21.7-acre) AEC airport site in a manner acceptable to the City of St. Louis.

From 1976 through 1978, ORNL conducted a radiological investigation of SLAPS (Ref. 6). This survey indicated the presence of elevated concentrations of uranium-238 and radium-226 in drainage ditches north and south of McDonnell Boulevard. In 1981, the drainage ditches were designated for remedial action under FUSRAP.

In 1982, BNI performed radiological characterizations of the ditches on either side of McDonnell Boulevard and portions of Coldwater Creek (Ref. 7). Neither of these surveys included measuring thorium-230 in soil. During 1986, however, archived soil samples

from the ditches were reanalyzed to determine thorium-230 content, and new samples from the ditches and Coldwater Creek were radiologically and chemically analyzed.

Additional radiological characterization and limited geological and chemical characterization of SLAPS were undertaken during 1986 and included installation of 10 groundwater monitoring wells at the site. Radiological characterization was also performed on three properties immediately adjacent to SLAPS: the ball field property north of the site, the railroad bordering the site on the south, and a triangular-shaped area between the SLAPS fence line and McDonnell Boulevard at the eastern end of the site.

There are no continuing commercial or industrial activities at SLAPS; therefore, no radioactive effluents exist at the site.

1.3 HYDROGEOLOGICAL CHARACTERISTICS OF THE SITE

This section presents data on the hydrogeology at SLAPS. The interpretations are based on groundwater levels measured in calendar year 1988. An early set of monitoring wells at the site was installed by Roy F. Weston, Inc., in 1981 (Ref. 8). These wells are not used for groundwater level measurements but are used to obtain samples for environmental monitoring. The groundwater monitoring wells where water levels were measured to collect data for this report (Figure 1-5) ~~were~~ installed at SLAPS by BNI in mid-1986 (Ref. 9). Twenty-seven additional wells were installed by BNI in 1988 at the adjacent ball field. The ball field wells nearest to SLAPS supplement the groundwater level monitoring presented in this report and are also shown in Figure 1-5. A summary of well construction information is given in Table 1-1. An example of well construction details is included as Appendix E.

In previous reports the two groundwater systems at SLAPS have been referred to as "shallow" and "deep" (Refs. 8 and 9). In this report the two groundwater systems monitored are designated "upper" and "lower" to be consistent with data being reported for the ball field

area (Ref. 10). Background information on site geology, hydrogeology, and well installation methods can be found in Refs. 8-10.

Groundwater levels at SLAPS were measured weekly with an electric downhole probe water level indicator.

1.3.1 Upper Groundwater System

The unconfined upper groundwater system occurs in a zone approximately 3.4 to 10.7 m (11 to 35 ft) below the ground surface (Ref. 8). Wells in this zone are screened in unconsolidated glacial materials at depths from 3.4 to 10.1 m (11 to 33 ft) above a clayey aquitard (Ref. 9). Groundwater surface elevations measured in 1988 for each well are shown as hydrographs (Figures 1-6 and 1-7). Precipitation records for the St. Louis area are presented with the hydrographs in Figures 1-6 and 1-7.

The hydrographs for the upper groundwater system show apparent seasonal fluctuations in groundwater levels. The water levels are highest during late winter-early spring, then slowly fall 0.6 to 2.4 m (2 to 8 ft) until the lowest water levels are reached in the fall. Except during December, the changes in water levels correlate from well to well. In December the water levels for wells M10-8S, M13.5-8.5S, and M11-9 dropped, while the rest of the water levels were relatively steady. This behavior may be associated with discharge of shallow groundwater into the Coldwater Creek channel.

Correlation between precipitation and water levels is not consistent. Apparently, minimal recharge occurs at the site.

The slope and flow direction of the upper groundwater system were determined from potentiometric surface maps. (Potentiometric surface is defined as the level to which water will rise in tightly cased wells. Delineation of the potentiometric surface of an aquifer indicates groundwater slope and flow direction.) The dates for the information shown on these two maps (Figures 1-8 and 1-9)

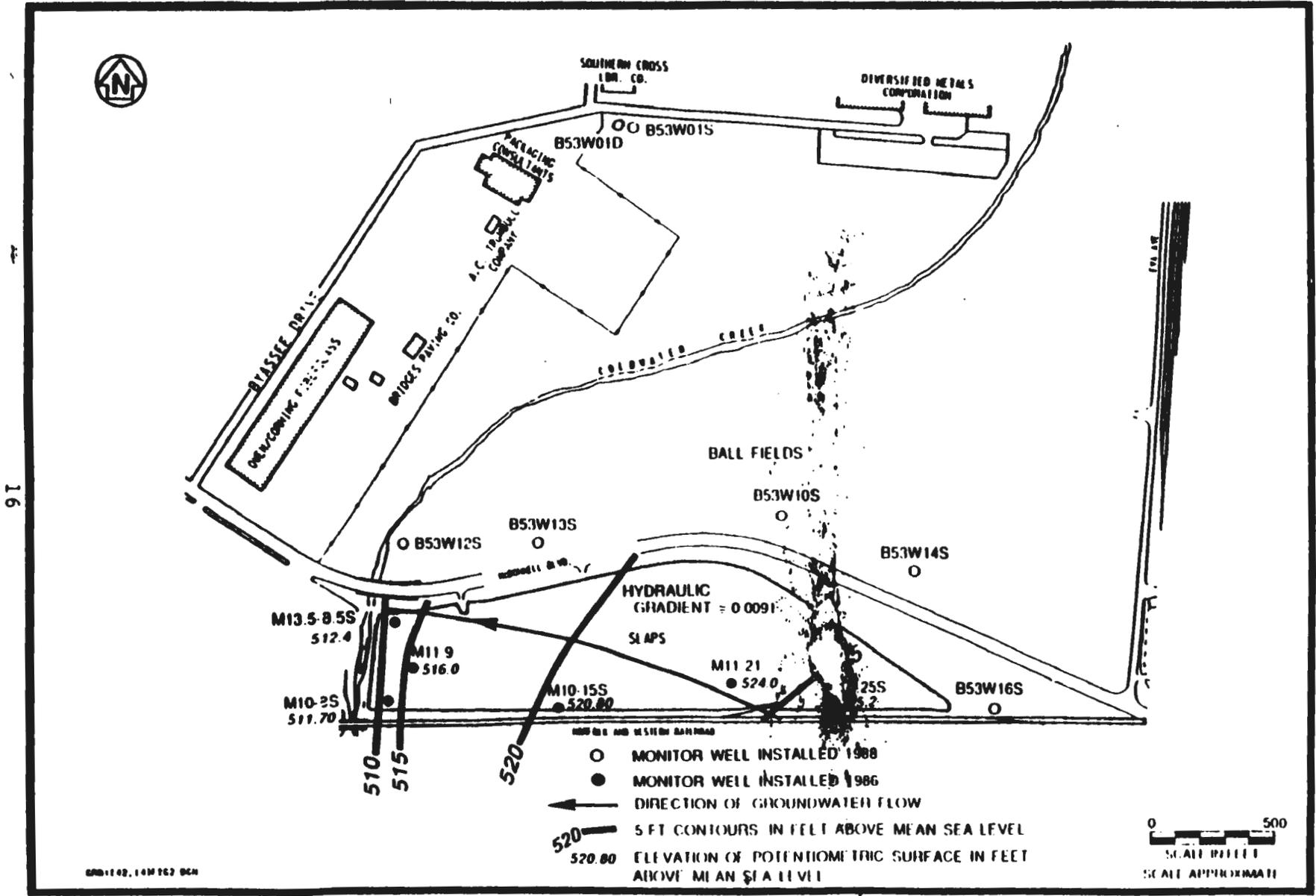


FIGURE 1-8 SLAPS UPPER GROUNDWATER SYSTEM POTENTIOMETRIC SURFACE (3/18/88)

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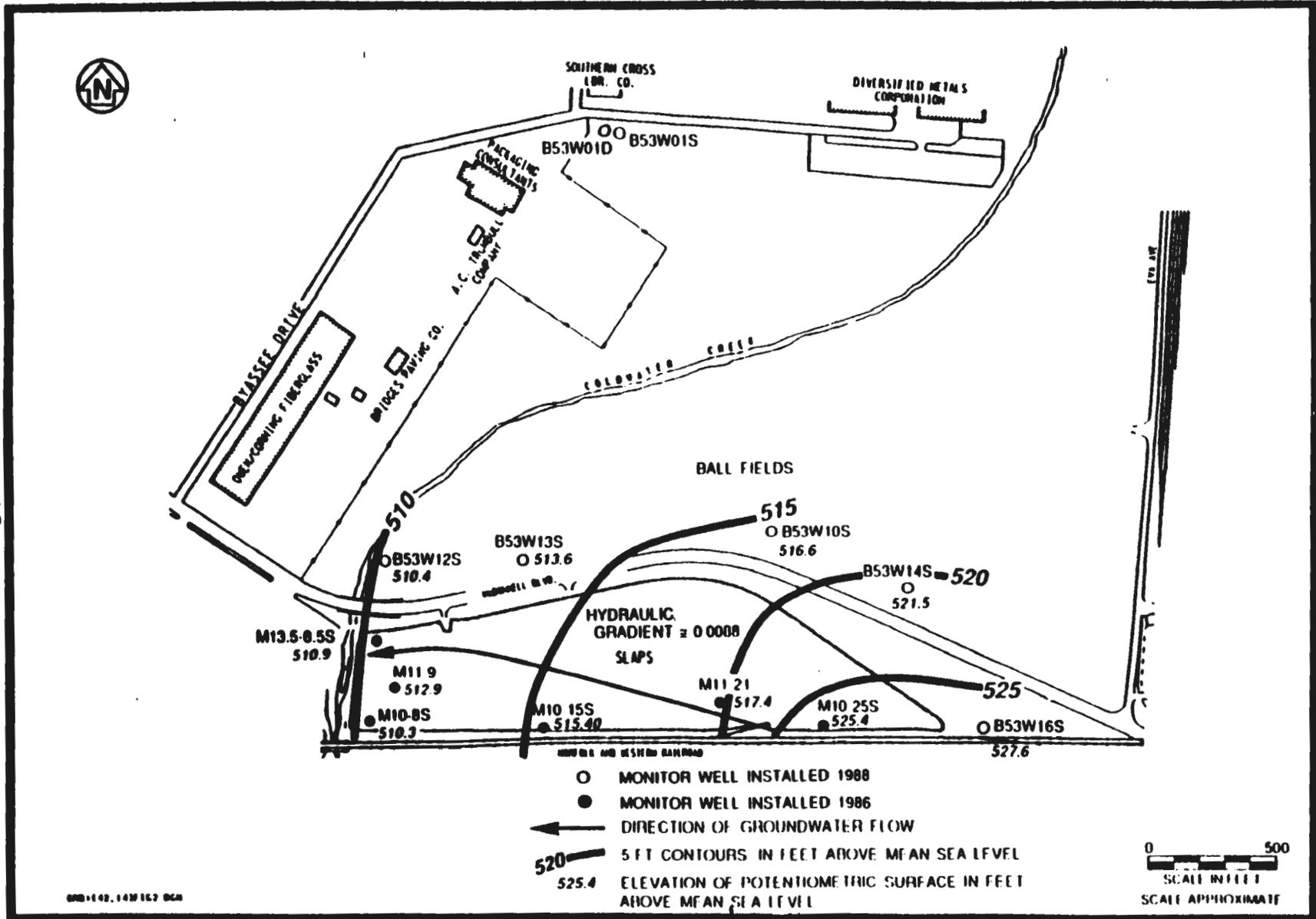


FIGURE 1-9 SLAPS UPPER GROUNDWATER SYSTEM POTENTIOMETRIC SURFACE (11/11/88)

were chosen because they represent seasonal high and low water level periods and are the same dates used to prepare potentiometric surface contour maps for the adjacent ball field area characterization report (Ref. 10). The groundwater flow direction is generally east to west. The contours suggest a flow direction approximately parallel to the site topography (Ref. 8, p. 4-3) with discharge into Coldwater Creek. The hydraulic gradient for both dates is on the order of 0.009.

1.3.2 Lower Groundwater System

The lower groundwater system is located in the glacial sediments below the clayey aquitard and above bedrock (Ref. 9), approximately 10.7 to 26.5 m (35 to 87 ft) below the ground surface. The lower system wells are screened at depths ranging from 11 to 26.5 m (36 to 87 ft). Hydrographs of wells monitoring the lower groundwater system are shown in Figure 1-10. Precipitation records for the St. Louis area collected at the St. Louis Airport are also shown on the hydrographs.

The hydrographs for the lower system (Figure 1-10) show little seasonal variation of water levels. Water levels in wells M10-15D and M10-25D show a slow but steady drop amounting to almost 0.9 m (3 ft) over the course of the year. Well M13.5-8.5D water levels fluctuated 2.4 m (8 ft) during September-October and the year-end level declined 5 ft in 1988, as did those of M10-15D and M10-25D. Water levels in M10-8D rose during 1988, except for the last measurement. The reason for the inconsistent behavior of the lower system wells is not known, but the overall effect of this behavior on hydraulic gradient and flow direction is minimal. Correlation of the water levels with the precipitation record is inconsistent.

Hydraulic gradient and flow direction for the lower groundwater system were determined using two potentiometric surface contour maps (Figures 1-11 and 1-12) from the water level measurements for the same dates as those for Figures 1-8 and 1-9. The potentiometric surface maps show a consistent flow direction from east to west.

6.5)

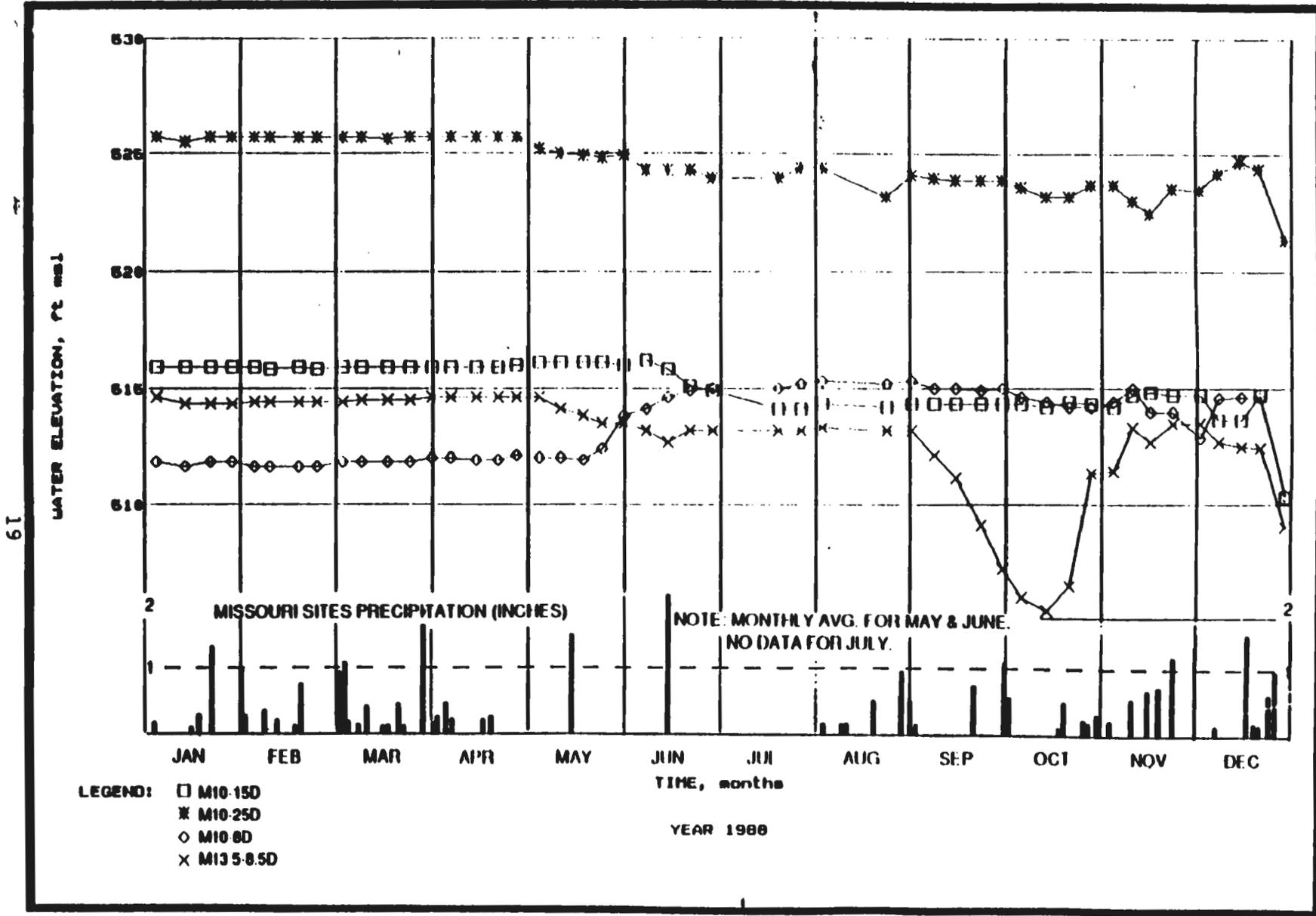


FIGURE 1-10 HYDROGRAPHS OF LOWER GROUNDWATER SYSTEM WELLS M10-15D, M10-25D, M10-8D, AND M13.5-8.5D

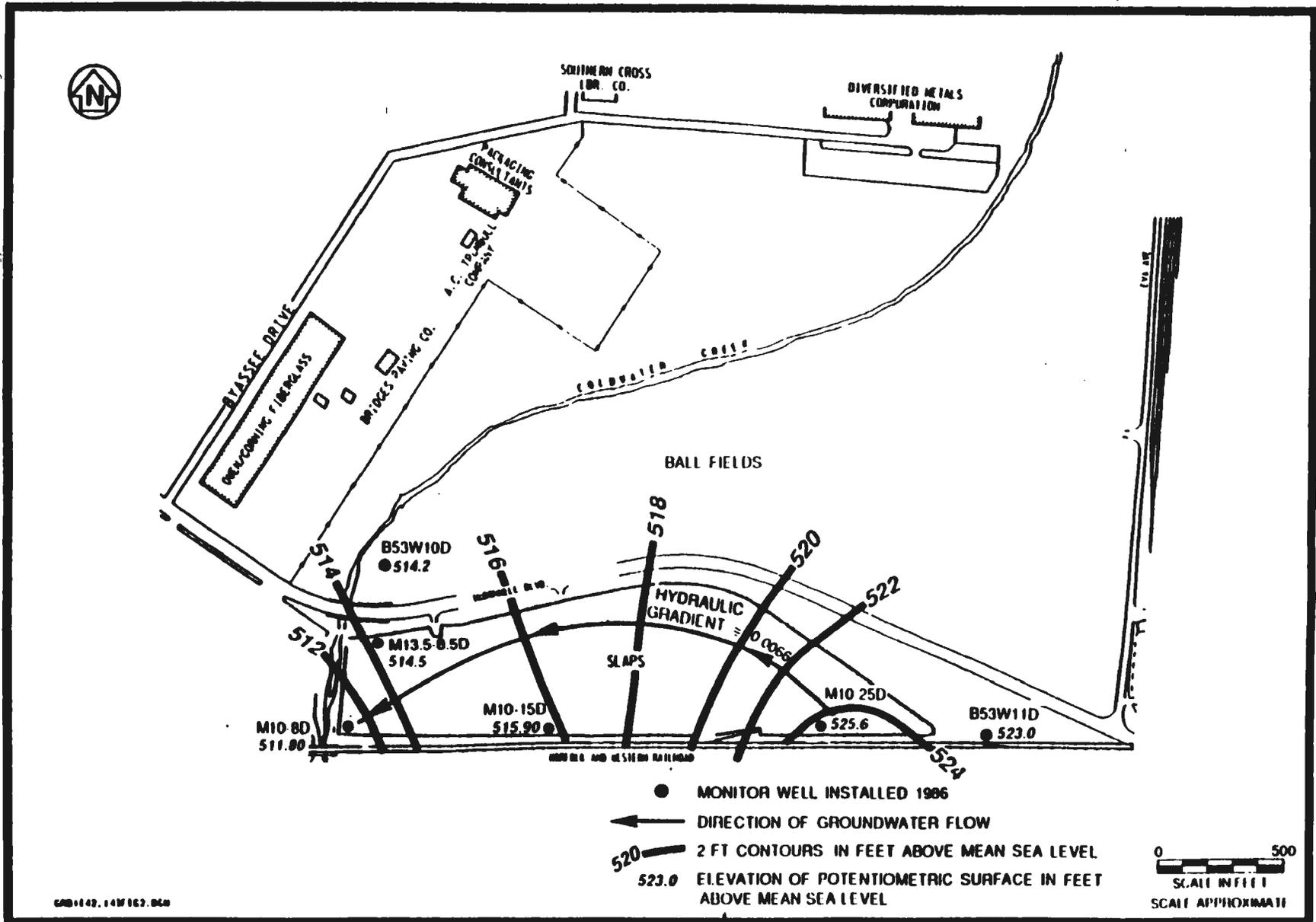


FIGURE 1-11 SLAPS LOWER GROUNDWATER SYSTEM
POTENTIOMETRIC SURFACE (3/18/88)

3.1 RADON SAMPLING

Nine radon detectors are maintained along the site boundary, spaced so as to ensure adequate detection capability under most atmospheric conditions. The locations of the radon monitors are shown in Figure 3-1. Three background detectors are maintained off-site.

Radon concentrations are determined using monitors purchased from the Terradex Corporation. These devices (Terradex Type F Track-Etch) consist of an alpha-sensitive film contained in a small plastic cup covered by a membrane through which radon can diffuse. Radon will diffuse through the membrane (in or out of the cup) when a concentration gradient exists; therefore, it will equilibrate with radon in the outside air. Alpha particles from the radioactive decay of radon and its daughters in the cup create tiny tracks when they collide with the film. When returned to Terradex for processing, the films are placed in a caustic etching solution to enlarge the tracks. Under strong magnification, the tracks can be counted. The number of tracks per unit area (i.e., tracks/mm²) is related through calibration to the concentration of radon in air. Fresh Track-Etch monitors are obtained from Terradex each quarter. Site personnel place these units in each sampling location and return the exposed monitors to Terradex for analysis.

Table 3-1 reports the radon concentrations measured at the nine monitoring locations. The annual average concentrations ranged from 7×10^{-10} to 2.1×10^{-9} $\mu\text{Ci/ml}$ (0.7 to 2.1 pCi/l). Background concentrations ranged from 4×10^{-10} to 5×10^{-10} $\mu\text{Ci/ml}$ (0.4 to 0.5 pCi/l) and have not been subtracted. Based on measured radon concentrations at SLAPS, the on-site radon source has a minimal effect on radon concentrations in the area.

For comparisons of radon concentrations measured from 1984 through 1988, see Subsection 3.6.1.

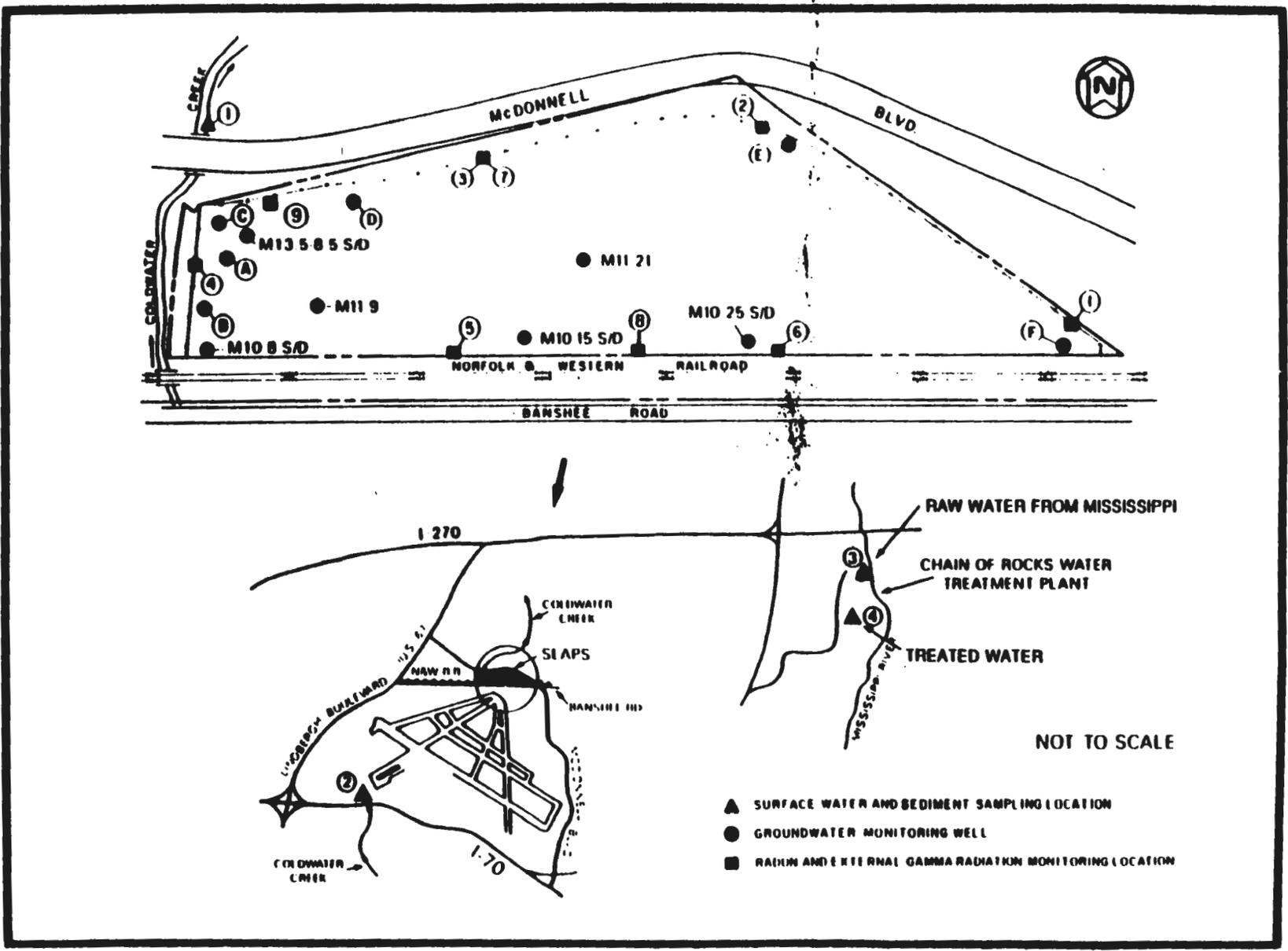


FIGURE 3-1 SLAPS ENVIRONMENTAL MONITORING LOCATIONS

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TABLE 3-1
CONCENTRATIONS OF RADON-222 AT SLAPS, 1988

Sampling Location ^a	Number of Samples	Concentration (10^{-9} $\mu\text{Ci/ml}$) ^{b, c}		
		Minimum	Maximum	Average
1	4	0.3	2.9	1.1
2	4	0.5	1.7	1.2
3	4	0.7	1.5	1.0
4	4	0.6	1.2	1.0
5	4	0.7	4.6	2.1
6	4	0.5	1.0	0.8
7 ^d	4	0.4	1.1	0.7
8	4	0.5	2.9	1.8
9	4	0.4	2.0	1.0
<u>Background</u>				
16 ^e	4	0.3	0.6	0.4
17 ^f	2	0.4	0.4	0.4
18 ^g	2	0.3	0.7	0.5

^aSampling locations are shown in Figure 3-1.

^bBackground has not been subtracted. Note that some locations have radon concentrations below background.

^c 1×10^{-9} $\mu\text{Ci/ml}$ is equivalent to 1 pCi/l.

^dLocation 7 is a quality control for Location 3.

^eLocated in Florissant, MO, 26 km (16 mi) northeast of SLAPS.

^fLocated at McDonnell Blvd., 0.8 km (0.5 mi) east of SLAPS. Established in April 1988.

^gLocated in St. Charles County, MO, approximately 32 km (20 mi) southwest of SLAPS. Established in April 1988.

3.2 EXTERNAL GAMMA RADIATION LEVELS

External gamma radiation levels were measured at the nine monitoring locations that correspond to the radon (Terradex) detector locations shown in Figure 3-1.

External gamma radiation levels are measured using lithium fluoride (LiF) thermoluminescent dosimeters (TLDs). Beginning in 1988, the system of measurement utilizes tissue-equivalent dosimeters to provide values that are more realistic in terms of radiation dose to the tissues of the body at a depth of 1 cm. This dosimetry system offers advantages in accuracy and sensitivity that were not available with the system used previously.

Each dosimetry station contains a minimum of four dosimeters, which are exchanged after one year of accumulated exposure. For example, a dosimeter placed in the station in October 1987 would be removed in October 1988. Each dosimeter contains five individual LiF chips (each group of which was preselected on the basis of having a reproducibility of ± 3 percent across a series of laboratory exposures), the responses of which are averaged. Analysis is performed by Thermo Analytical/Eberline (TMA/E). The average value is then corrected for the shielding effect of the shelter housing (approximately 8 percent) and for the effect of fade.

Fade is the loss of dose information brought about by environmental effects, primarily high summer temperatures. Fade is determined by collocating dosimeters that have been exposed to a known level of radiation (called a spike) before they are placed at a minimum of two stations, generally on the eastern and western boundaries of a site. The fade factor can be determined by subtracting the station radiation value from the fade control dosimeter radiation value followed by dividing by the known spike level. The corrected value is then converted to milliroentgens per year by dividing by the number of days of exposure and subsequently multiplying by 365 days.

Some differences in external gamma radiation values may be noted in the 1988 data in comparison with the 1987 values. The current measurement system is more sensitive to low radiation levels and more accurate in its resolution than the system used previously. Therefore, some stations that previously demonstrated no measurable external gamma radiation value in excess of background now exhibit a small measurable value. Similarly, at some other stations values are higher or lower because of the improved method of measurement, not because of deterioration of site conditions or remedial action.

The results of the measurements for external gamma radiation are presented in Table 3-2. Annual radiation levels ranged from 38 to 2,128 mR/yr above background at the monitoring locations. The highest radiation level occurred at Location 2, which is in an area known to be contaminated. The elevated level is due to this station's proximity to a ditch that is located between the site fence and McDonnell Boulevard (Ref. 7). The radioactive contamination in the ditches will be cleaned up as part of the remedial action to be conducted at the site, and these areas will be monitored along with the site itself until remedial action is complete.

The next highest annual average gamma radiation level measured at the SLAPS in 1988 was 129 mR/yr above background. The annual average background radiation level was 73 mR/yr. For comparisons of external radiation levels measured from 1984 through 1988, see Subsection 3.6.2.

The background external gamma radiation value for a given location is not a static constant. Because the background radiation value is a combination of both natural terrestrial sources and cosmic radiation sources, factors such as the location of the detector in relation to surface rock outcrops, stone or concrete structures, or highly mineralized soil can affect the value measured. Independent of the placement of the detector at the Earth's surface are the factors of site altitude, annual barometric pressure cycles, and the occurrence and frequency of solar flare activity (Ref. 17).

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TABLE 3-2
EXTERNAL GAMMA RADIATION LEVELS AT SLAPS, 1988

Sampling Location ^a	Number of Measurements	Radiation Level (mR/yr) ^b		
		Minimum	Maximum	Average
1	4	30	56	47
2	4	1898	2229	2128
3 ^c	4	81	122	101
4	4	16	48	38
5	4	17	70	45
6	4	24	53	43
7 ^c	4	77	167	129
8 ^d	4	21	49	38
9	4	88	183	129
<u>Background^e</u>				
16 ^f	4	63	86	73

^aSampling locations are shown in Figure 3-1.

^bMeasured background has been subtracted from the readings taken at the nine sampling locations shown in Figure 3-1.

^cLocations 3 and 7 are quality control locations.

^dLocation 8 was moved in April 1987.

^eIn April 1988, background detectors were installed at McDonnell Blvd., 0.8 km (0.5 mi) east of SLAPS, and in St. Charles County, approximately 32 km (20 mi) southwest of SLAPS. Because the instruments have been in place for less than 1 year, data will not be reported until 1989.

^fLocated in Florissant, MO, 26 km (16 mi) northeast of SLAPS.

Because of these factors, the background radiation level is not constant from one location to another even over a short time. Thus it is not abnormal for some stations at the boundary of a site to have an external gamma radiation value less than the background level measured some distance from the site.

In April 1988, additional background monitoring locations were established at the Federal Aviation Administration Building, located 0.5 mi east of SLAPS at McDonnell Blvd., and at St. Charles County Airport, located approximately 32 km (20 mi) southwest of SLAPS in St. Charles County. Because the 6 months of exposure time is not representative of the yearly fluctuations in background that occur because of seasonal weather variations, data from these locations will not be reported until 1989.

3.3 WATER SAMPLING

During 1988, sampling was performed to determine the concentrations of uranium, radium, and thorium in surface water and groundwater at both off-site and on-site locations (Figure 3-1).

3.3.1 Surface Water

Surface water samples were collected quarterly from four off-site locations. Water samples were taken from Coldwater Creek approximately 15 m (50 ft) downstream of the ditch that runs along McDonnell Boulevard (Location 1) and at the intersection of the creek and Interstate 70 (Location 2). Location 2 is upstream of SLAPS and provides an indication of background concentrations. Locations 3 and 4 are at the Chain of Rocks Water Treatment Plant downstream of the point at which Coldwater Creek discharges into the Missouri River, which then discharges into the Mississippi River.

Samples were collected using nominal 1-liter (0.26-gal) grab samples to fill a 4-liter (1-gal) container and were analyzed by TMA/E. Total uranium was determined by a fluorimetric method. Radium-226 concentrations in water were determined by radon emanation. (This

method consists of precipitating radium as sulfate and transferring the treated sulfate to a radon bubbler, where radon-222 is allowed to come to equilibrium with its radium-226 parent. The radon-222 is then withdrawn into a scintillation cell and counted by the gross alpha technique. The quantity of radon-222 detected in this manner is directly proportional to the quantity of radium-226 originally present in the sample.) Thorium-230 was eluted in solution, electrodeposited on stainless steel discs, and counted by alpha spectrometry.

The results of analyses for uranium, radium-226, and thorium-230 at all sampling locations are presented in Table 3-3. The average concentrations of each of these radionuclides at the three sampling locations downstream of SLAPS were nearly equal to the background concentrations measured upstream of the site. These values may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D of this report.

For comparisons of radionuclide concentrations measured in surface water from 1984 through 1988, see Subsection 3.6.3.

3.3.2 Groundwater

During 1988, groundwater samples were collected quarterly from 16 on-site wells. Samples were collected by a hand bailer after the wells had been pumped dry or three well casing volumes had been removed and ample time had been allowed for well recharge. Nominal 1-liter (0.26-gal) grab samples were collected to fill a 4-liter (1-gal) container. Samples were analyzed by TMA/E for total uranium, dissolved radium-226, and thorium-230 using the methods applied to surface water analyses (see Subsection 3.3.1).

Results of analyses for concentrations of total uranium, radium, and thorium in groundwater are presented in Table 3-4. Averages for radium-226 ranged from 3×10^{-10} to 9×10^{-10} $\mu\text{Ci/ml}$ (0.3 to 0.9 pCi/l). For thorium-230, averages ranged from

TABLE 3-3
 CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230
 IN SURFACE WATER IN THE VICINITY OF SLAPS, 1988

Sampling Location ^a	Number of Samples	Concentration (10^{-9} $\mu\text{Ci/ml}$) ^{b, c}		
		Minimum	Maximum	Average
<u>Total Uranium</u>				
1	4	<3	5	4
2 ^d	4	<3	5	4
3	3 ^e	3	5	4
4	3 ^e	3	3	3
<u>Radium-226</u>				
1	4	0.2	0.4	0.3
2 ^d	4	0.2	1.3	0.5
3	3 ^e	0.1	0.4	0.3
4	3 ^e	0.1	0.3	0.2
<u>Thorium-230</u>				
1	4	0.1	0.5	0.3
2 ^d	4	<0.1	0.2	0.1
3	3 ^e	0.3	0.4	0.3
4	3 ^e	<0.1	0.1	<0.1

^aSampling locations are shown in Figure 3-1.

^b 1×10^{-9} $\mu\text{Ci/ml}$ is equivalent to 1 pCi/l.

^cWhere no more than one value is less than the limit of sensitivity of the analytical method, values are considered equal to the limit of sensitivity, and the average value is reported without the notation "less than."

^dLocation is upstream of the site and acts as background. Background values have not been subtracted.

^eSamples lost in transit to the laboratory in the fourth quarter.

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TABLE 3-4
(continued)

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Sampling Location ^a	Number of Samples	Concentration (10^{-9} $\mu\text{Ci}/\text{ml}$) ^{b,c}		
		Minimum	Maximum	Average

Radium-226 (continued)

Background

Well B53W01S	2 ^d	0.3	0.8	0.6
Well B53W01D	2 ^d	1.0	1.1	1.1

Thorium-230

Well A	4	1.1	4.9	2.8
Well B	4	1.3	3.2	2.0
Well C	4	<0.1	0.4	0.3
Well D	4	0.4	1.3	0.9
Well E	4	0.2	14.0	4.8
Well F	4	1.1	3.0	2.0
Well M10-25S	4	0.2	0.6	0.4
Well M10-25D	4	0.2	0.9	0.5
Well M11-21	4	8.0	130.0	52.0-
Well M10-15S	4	1.3	17.0	5.3
Well M10-15D	4	0.1	4.5	1.3
Well M10-8S	4	0.2	1.1	0.5
Well M10-8D	4	0.1	0.6	0.3
Well M11-9	4	0.3	2.6	1.0
Well M13.5-8.5S	4	0.2	1.1	0.7
Well M13.5-8.5D	4	0.2	0.9	0.7

Background

Well B53W01S	2 ^d	0.1	0.2	0.2
Well B53W01D	2 ^d	0.2	0.2	0.2

^aSampling locations are shown in Figure 3-1. Background locations are shown in Figure 1-5 as W01D and W01S.

^b 1×10^{-9} $\mu\text{Ci}/\text{ml}$ is equivalent to 1 pCi/l.

^cWhere no more than one value is less than the limit of sensitivity of the analytical method, values are considered equal to the limit of sensitivity, and the average value is reported without the notation "less than."

^dNew wells; first sampled in July 1988. Located at Byassee Drive, approximately 0.8 km (0.5 mi) northwest of SLAPS.

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3×10^{-10} to 5.2×10^{-8} $\mu\text{Ci/ml}$ (0.3 to 52 pCi/l). Averages for total uranium in groundwater ranged from $<3.0 \times 10^{-9}$ to 5.59×10^{-6} $\mu\text{Ci/ml}$ (<3 to 5,590 pCi/l).

Concentrations of total uranium in several of the shallow wells at SLAPS are high because the wells are located in areas of known subsurface contamination. However, because SLAPS is fenced, the public does not have access to these wells; furthermore, there is no known consumption of groundwater in the vicinity of the site. Groundwater that might discharge to Coldwater Creek is monitored as part of the surface water monitoring program. Current indications are that this potential transport pathway has not resulted in degradation of surface water quality. As a result, there is no evidence that anyone is being exposed to levels of radiation that approach the DOE radiation protection standard of 100 mrem/yr.

For a discussion of the comparisons of radionuclide concentrations in groundwater measured from 1984 through 1988, see Subsection 3.6.4.

3.4 SEDIMENT SAMPLING

During 1988, samples consisting of approximately 500 g of sediment (1.1 lb) were collected off-site at surface water sampling Locations 1 and 2 (Figure 3-1). TMA/E analyzed the samples for total uranium, radium-226, and thorium-230. Total uranium concentrations were obtained by summing the results from isotopic uranium analyses. Isotopic uranium and thorium-230 were determined by alpha spectrometry, wherein the uranium and thorium-230 are leached, extracted, and electroplated on metal substrates. Radium-226 concentrations were determined by radon emanation.

Analytical results for uranium, radium-226, and thorium-230 (based on dry weight) are presented in Table 3-5. The annual average concentration of total uranium, radium-226, and thorium-230 at the downstream sampling location was 2.6, 1.0, and 5.4 pCi/g, respectively. These concentrations of radium-226 are lower than background concentrations measured at upstream Location 2. Total

TABLE 3-5
 CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230
 IN SEDIMENT IN THE VICINITY OF SLAPS, 1988

Sampling Location ^a	Number of Samples	Concentration [pCi/g (dry)]		
		Minimum	Maximum	Average
<u>Radium-226</u>				
1	4	0.9	1.1	1.0
2	4	1.0	1.9	1.5
<u>Thorium-230</u>				
1	4	2.7	8.0	5.4
2	4	0.4	3.3	1.3
<u>Uranium-234</u>				
1	4	1.1	1.3	1.2
2	4	0.8	1.0	0.9
<u>Uranium-235</u>				
1	4	<0.1	0.1	<0.1
2	4	<0.1	<0.1	<0.1
<u>Uranium-238</u>				
1	4	1.2	1.3	1.3
2	4	0.6	0.8	0.7
<u>Total Uranium^b</u>				
1	4	2.4	2.7	2.6
2	4	1.5	1.9	1.7

^aSampling locations are shown in Figure 3-1. Location 1 is downstream and Location 2 is upstream of the site.

^bTotal uranium concentration for each location is determined by summing the measured concentrations of each isotope for the respective location.

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Subsection 3.5.1. Measured radon concentrations are discussed fully in Subsection 3.1.

3.5.1 Dose to the Maximally Exposed Individual

To identify the individual in the vicinity of SLAPS who would receive the highest dose from on-site radioactive materials, the dose from exposure to external gamma radiation was calculated at various monitoring locations that could be accessible to the public. From these calculations, it was determined that the highest overall dose would be received by an individual who walked daily along the northern site boundary. Because the area adjacent to SLAPS is normally unoccupied, exposure was calculated assuming that the maximally exposed individual walked along the fence line twice a day, 5 days per week. It was also assumed that the individual walked at a rate of 4.8 km/h (3 mph) along the 0.8-km (0.5-mi) northern site boundary and during this period was exposed to an average of the annual exposure rates observed at Locations 1, 2, and 3.

The external exposure to this individual would be 7.5 mR/yr above background. Because 1 mR is approximately equivalent to 1 mrem, this exposure is approximately equivalent to 7.5 percent of the DOE radiation protection standard of 100 mrem/yr and is approximately equal to the exposure a person would receive during two round-trip flights from Los Angeles to New York as a result of the greater amounts of cosmic radiation at higher altitudes (see Appendix D). This scenario is highly conservative in that it is unlikely that any individual would spend so much time at this location. A more realistic assessment of the use of the site would demonstrate that the incremental dose is less than 1 mrem/yr.

3.5.2 Dose to the Population in the Vicinity of SLAPS

The dose to the population represents the conceptual cumulative radiation dose to all residents within an 80-km (50-mi) radius of a given site. This calculated dose includes contributions from all

potential pathways. For SLAPS, these pathways are direct exposure to gamma radiation, inhalation of radon, and ingestion of water containing radioactivity.

The contribution to the population dose made by gamma radiation from on-site radioactive materials is too small to be measured because gamma radiation levels decrease rapidly as distance from the source of contamination increases. For example, if the gamma exposure rate at a distance of 1 m (3 ft) from a small-area radioactive source were 100 mR/yr, the exposure rate at a distance of 6.3 m (21 ft) would be indistinguishable from naturally occurring background radiation. Similarly, radon is known to dissipate rapidly as distance from the radon source increases (Ref. 18). Therefore, radon exposure does not contribute significantly to population dose.

On the basis of radionuclide concentrations measured in water leaving the site, it also appears that there is no plausible pathway by which ingestion of water could result in a significant dose to the population. As water migrates farther from the source, radionuclide concentrations are further reduced, lowering potential doses to even less significant levels.

Because the contributions to population dose via all potential exposure pathways are inconsequential, calculation of dose to the population is not warranted. The cumulative dose to the population within an 80-km (50-mi) radius of SLAPS that results from radioactive materials present at the site is indistinguishable from the dose the same population receives from naturally occurring radioactive sources.

3.6 TRENDS

The environmental monitoring program at SLAPS was established to allow an annual assessment of the environmental conditions at the site, to provide a historical record for year-to-year comparisons, and to permit detection of trends. In the following subsections, 1988 annual averages for each monitoring location for radon,

external gamma radiation, surface water, and groundwater are compared with results for 1984 through 1987 (Refs. 12-15). As the environmental monitoring program at SLAPS continues and more data are collected, comparisons and analyses of trends will become more meaningful.

3.6.1 Radon

As shown in Table 3-6, overall radon levels remained relatively constant as compared with 1987 levels. Radon concentrations along the northern boundary of the site are heavily influenced by soil moisture and the presence or absence of standing water in the ditch that abuts the fence line. In 1988, dry weather conditions moderated slightly, and the ditch contained some standing water throughout the year. This may account for the slight decrease in radon levels.

3.6.2 External Gamma Radiation Levels

As shown in Table 3-7, external gamma radiation levels at the site boundary have not demonstrated a significant change since monitoring began in 1984. Overall, the 1988 external gamma radiation levels remained stable as compared with the 1987 values.

3.6.3 Surface Water

Measured concentrations of radionuclides in surface water at SLAPS have remained relatively stable since 1984 and remain about equal to the upstream values. Surface water data for the 1984-1988 period are given in Table 3-8.

3.6.4 Groundwater

Ten new wells installed in 1986 were added to the groundwater monitoring program in April 1987. Uranium, radium-226, and thorium-230 values for 1987 and 1988 in these new wells are presented in Table 3-9. Statistical comparisons are made only on

TABLE 3-6
ANNUAL AVERAGE CONCENTRATIONS OF RADON-222
AT SLAPS, 1984-1988^a

Sampling Location ^b	Concentration (10 ⁻⁹ μ Ci/ml) ^{c,d}				
	1984	1985	1986	1987	1988
1	0.1	0.5	0.4	1.6	1.1
2	0.5	1.2	3.5	3.6	1.2
3	0.3	0.8	0.8	0.7	1.0
4	0.6	0.4	0.9	0.8	1.0
5	- ^e	0.8	0.6	2.1	2.1
6	0.4	0.5	0.6	0.5	0.8
7	- ^e	0.5	0.7	0.8	0.7
8	- ^e	1.0	0.7	1.3	1.8
9	- ^f	- ^f	- ^f	3.1	1.0
<u>Background</u>					
16 ^g	- ^g	0.5	0.3	0.4	0.4
17 ^h	- ^h	- ^h	- ^h	- ^h	0.4
18 ⁱ	- ⁱ	- ⁱ	- ⁱ	- ⁱ	0.5

^aData sources for 1984-1987 are the annual site environmental reports for those years (Refs. 12-15).

^bSampling locations are shown in Figure 3-1.

^cBackground has not been subtracted.

^d1 x 10⁻⁹ μ Ci/ml is equivalent to 1 pCi/l.

^eDetector installed in 1985.

^fDetector installed in April 1987.

^gBackground detector installed in 1985 in Florissant, MO, approximately 24 km (15 mi) northeast of SLAPS.

^hBackground detector installed in April 1988 at McDonnell Blvd., approximately 0.8 km (0.5 mi) east of SLAPS.

ⁱBackground detector installed in April 1988 in St. Charles County, approximately 32 km (20 mi) southwest of SLAPS.

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TABLE 3-7
ANNUAL AVERAGE EXTERNAL GAMMA RADIATION LEVELS AT
SLAPS, 1984-1988^a

Page 1 of 2

Sampling Location ^b	Radiation Level (mR/yr) ^c				
	1984	1985	1986	1987	1988
1	59 ^d	46	14	34	47
2	2157 ^d	2087	1363	1557	2128
3	115 ^d	116	67	87	101
4	51 ^d	57	21	38	38
5	- ^e	3	81	67	45
6	28 ^d	41	10	35	43
7 ^f	- ^e	93	43	58	129
8	- ^e	12	17	25	38
9	- ^g	- ^g	- ^g	110	129
<u>Background^h</u>					
16 ¹	- ⁱ	99	97	77	73

^aData sources for prior years are the annual site environmental reports for those years (Refs. 12-15).

^bSampling locations are shown in Figure 3-1.

^cMeasured background has been subtracted from the readings taken at the nine sampling locations shown in Figure 3-1.

^dSampling location installed in late 1984; data are for fourth quarter only.

^eSampling location established in early 1985.

^fLocation 7 is a quality control for Location 3.

^gLocation 9 was established in April 1987.

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TABLE 3-7
(continued)

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^hBackground detector installed at McDonnell Blvd., approximately 0.8 km (0.5 mi) east of SLAPS, and in St. Charles County, approximately 32 km (20 mi) southwest of SLAPS. Because the instruments have been in place for less than 1 year, data will not be reported until 1989.

ⁱBackground detectors installed in April 1985. Located in Florissant, MO, approximately 24 km (16 mi) northeast of SLAPS.

TABLE 3-8
 ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM,
 RADIUM-226, AND THORIUM-230 IN SURFACE WATER
 IN THE VICINITY OF SLAPS, 1984-1988^a

Sampling Location ^b	Concentration (10 ⁻⁹ μ Ci/ml) ^c				
	1984	1985	1986	1987	1988
<u>Total Uranium</u>					
1	14.0	3.4	4.3	4.2	4.0
2 ^d	4.0	<3.0	<3.0	<3.0	4.0
3	- ^e	<3.0	<3.0	<4.0	4.0
4	- ^e	<3.0	3.5	<4.0	3.0
<u>Radium-226</u>					
1	0.2	0.2	0.2	0.4	0.3
2 ^d	0.1	0.1	0.3	0.3	0.5
3	- ^e	0.2	0.2	0.3	0.3
4	- ^e	0.1	0.2	0.3	0.2
<u>Thorium-230</u>					
1	0.1	0.4	<0.2	0.4	0.3
2 ^d	0.36	<0.4	<0.2	0.2	0.1
3	- ^e	<0.5	0.3	0.3	0.3
4	- ^e	<0.4	<0.2	<0.2	<0.1

^aData sources for 1984-1987 are the annual site environmental reports for those years (Refs. 12-15).

^bSampling locations are shown in Figure 3-1.

^c1 x 10⁻⁹ μ Ci/ml is equivalent to 1 pCi/l.

^dLocation 1 is upstream of the site and acts as background. Background values have not been subtracted.

^eSampling Locations 3 and 4 were added in 1985.

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TABLE 3-9
ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM,
RADIUM-226, AND THORIUM-230 IN GROUNDWATER AT
SLAPS, 1984-1988^a

Page 1 of 2

Sampling Location ^{b,c}	Concentration (10 ⁻⁹ µCi/ml) ^d				
	1984	1985	1986	1987	1988
<u>Total Uranium</u>					
Well A	1287	2375	1184	1139	1700
Well B	5700	4735	6570	5829	5590
Well C	40	36	16	13	18
Well D	233	474	802	637	475
Well E	129	114	540	576	197
Well Fe	141	177	146	106	265
Well M10-25S	--	--	--	25	39
Well M10-25D	--	--	--	4	4
Well M11-21	--	--	--	45	73
Well M10-15S	--	--	--	11	9
Well M10-15D	--	--	--	9	5
Well M10-8S	--	--	--	32	19
Well M10-8D	--	--	--	5	4
Well M11-9	--	--	--	4578	4620
Well M13.5-8.5S	--	--	--	4	4
Well M13.5-8.5D	--	--	--	<3	<3
<u>Background^f</u>					
Well B53W01S	--	--	--	--	3
Well B53W01D	--	--	--	--	4
<u>Radium-226</u>					
Well A	0.3	0.2	0.3	0.3	0.4
Well B	0.3	0.2	0.3	0.3	0.5
Well C	0.3	0.2	0.3	0.4	0.5
Well D	0.2	0.1	0.3	0.1	0.3
Well E	0.6	0.2	0.5	0.3	0.6
Well Fe	0.2	0.1	0.2	0.3	0.6
Well M10-25S	--	--	--	0.2	0.6
Well M10-25D	--	--	--	0.2	0.4
Well M11-21	--	--	--	0.5	0.7
Well M10-15S	--	--	--	0.3	0.8
Well M10-15D	--	--	--	0.4	0.9
Well M10-8S	--	--	--	0.4	0.5
Well M10-8D	--	--	--	0.3	0.6
Well M11-9	--	--	--	0.5	0.8
Well M13.5-8.5S	--	--	--	0.5	0.8
Well M13.5-8.5D	--	--	--	0.5	0.6

TABLE 3-9
(continued)

Page 2 of 2

Sampling Location ^{b,c}	Concentration (10 ⁻⁹ µCi/ml) ^d				
	1984	1985	1986	1987	1988
Radium-226 (continued)					
Background^f					
Well B53W01S	--	--	--	--	0.6
Well B53W01D	--	--	--	--	1.1
Thorium-230					
Well A	9.5	2.3	<0.4	0.8	2.8
Well B	0.3	0.3	1.2	1.4	2.0
Well C	0.2	0.2	0.2	0.9	0.3
Well D	0.9	1.3	0.3	0.9	0.9
Well E	0.3	1.0	0.4	0.9	4.8
Well Fe	0.4	1.1	0.2	1.7	2.0
Well M10-25S	--	--	--	0.2	0.4
Well M10-25D	--	--	--	<0.8	0.5
Well M11-21	--	--	--	15.2	52.0
Well M10-15S	--	--	--	1.8	5.3
Well M10-15D	--	--	--	0.4	1.3
Well M10-8S	--	--	--	0.2	0.5
Well M10-8D	--	--	--	<0.1	0.3
Well M11-9	--	--	--	0.3	1.0
Well M13.5-8.5S	--	--	--	0.4	0.7
Well M13.5-8.5D	--	--	--	<0.1	0.7
Background^f					
Well B53W01S	--	--	--	--	0.2
Well B53W01D	--	--	--	--	0.2

^aData sources for 1984-1987 are the annual site environmental reports for those years (Refs. 12-15).

^bSampling locations are shown in Figure 3-1, and background locations are shown in Figure 1-5.

^cThe "M" wells were added to the environmental monitoring program in April 1987.

^d1 x 10⁻⁹ µCi/ml is equivalent to 1 pCi/l.

^eUpgradient well.

^fWells established for background in July 1988.

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the A-F wells because there are insufficient data for analyses of the M wells (Figure 3-1). As shown in Table 3-9, concentrations of total uranium in groundwater have remained consistently high in wells A and B; in 11-9, which is located approximately 15.2 m (50 ft) east of well B; and in M13.5-8.5S. Uranium concentrations in well C remained low over the period 1984-1988. These five wells are located on the western end of the site.

Levels of radium-226 and thorium-230 have been generally stable at low levels. An insignificant increase in levels of radium-226 and thorium-230 was observed in 1988.

Uranium concentrations in groundwater are strongly influenced by the rate at which groundwater moves through the site. For years in which there is a significant deficit in rainfall and thus a reduced recharge of the groundwater, uranium levels can be expected to rise. Uranium concentrations observed in certain wells (F and A) increased from those measured in 1987.

Though these increases cannot be definitively explained, it is known that wells D and E are located adjacent to buried radioactive materials. Because SLAPS is fenced, the public does not have access to these wells and there is no known consumption of groundwater in the vicinity of the site. Based on analytical results for surface water and hydrogeological studies concerning discharge of groundwater into Coldwater Creek, there is no evidence that surface water downstream of the site has been degraded. Therefore, there is no reason to suspect that any member of the public receives an internal dose of radiation that would approach the DOE radiation protection standard.

4.0 RELATED ACTIVITIES AND SPECIAL STUDIES

4.1 RELATED ACTIVITIES

In April 1987, monitoring of the groundwater for chemical indicator parameters began at SLAPS. These parameters include pH, specific conductance, total organic carbon (TOC), and total organic halide (TOX). These parameters are indicators of changes in the inorganic and organic composition of the groundwater.

Specific conductance and pH measure changes in the inorganic composition of the groundwater. Acidity and basicity are measured by pH. A change in pH affects the solubility and mobility of chemical contaminants in groundwater. Specific conductance measures the capacity of water to conduct an electrical current. Conductivity generally increases with elevated concentrations of dissolved solids. Waters with high salinities or high total dissolved solids exhibit high conductivities.

Groundwater is analyzed for TOC and TOX to determine the organic content of the water. TOC measures the total organic carbon content of water but is not specific to a given contaminant. TOX measures organic compounds containing halogens, which are organic compounds containing fluorine, chlorine, bromine, and iodine.

Table 4-1 lists the ranges of observed concentrations of the four indicator parameters. Except for specific conductance and the TOX values, all other parameter levels are within the range of the background wells (B53W01S and B53W01D).

The elevated TOX values occurred in wells B, D, and M11-9. No explanation for these elevated levels is currently available. However, investigations will be conducted in 1989 to determine the possible cause.

Reference 6

**Excerpts From National Priorities List Summary Sheet for the
St. Louis Airport/Hazelwood Interim Storage/Futura Coatings Company Site;
EPA; Undated**

National Priorities List

Superfund hazardous waste site listed under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) as amended in 1986

ST. LOUIS AIRPORT/HAZELWOOD INTERIM STORAGE/FUTURA COATINGS CO. St. Louis County, Missouri

The St. Louis Airport/Hazelwood Interim Storage/Futura Coatings Co. Site is in St. Louis County, Missouri. It consists of three areas used for storing radioactive and other wastes resulting from uranium processing operations conducted in St. Louis by the Atomic Energy Commission (AEC) and its successor, the U.S. Department of Energy (USDOE). None of the three areas is now owned by the Federal Government.

The St. Louis Airport area covers 21.7 acres immediately north of Lambert St. Louis International Airport, approximately 15 miles northwest of downtown St. Louis. It is bounded by a railroad track, Coldwater Creek, and McDonnell Boulevard. Radioactive metal scrap and drums of waste were stored in the airport area in uncovered and unstabilized piles from 1947 to the mid-1960s, when they were transferred 0.5 mile northeast to AEC's Hazelwood Interim Storage (HIS) area. Buildings in the airport area were razed, buried, and covered with clean fill after 1967. Contaminated soil was removed to the Weldon Spring Quarry in St. Charles County, Missouri, which was placed on the NPL in July 1987. In 1969, the land was conveyed to the St. Louis-Lambert Airport Authority.

HIS and the Futura Coatings Co. plant cover 11 acres adjacent to Latty Avenue, Coldwater Creek, and Hanley Avenue. In 1966, Continental Mining and Milling Co. acquired the property and recovered uranium from wastes purchased from AEC's St. Louis operations. In 1967, the company sold the property, and by 1973 most processing residues had been removed. Under the direction of the Nuclear Regulatory Commission (NRC), the present owner excavated contaminated soil and is storing it in two large piles in the eastern portion of the 11 acres. Since the 1970s, Futura Coatings, a manufacturer of plastic coatings, has leased the western portion.

High levels of uranium, thorium, and radium are present in surface and subsurface soils and ground water near the airport area, according to tests conducted by NRC (1976), Oak Ridge National Laboratory (1977), and a USDOE contractor (1986). Radon-222 was present in the air near the airport area in the USDOE tests. A McDonnell Douglas Corp. office building with 24,000 employees is within 0.5 mile of the airport area.

USDOE has investigated the site under its Formerly Utilized Sites Remedial Action Program (FUSRAP). In 1982, USDOE conducted preliminary studies of radioactive contamination of the ditches along the sides of the roads leading to and from the areas. In 1986, boreholes were drilled to continue the contamination study and collect geological information. In 1984, USDOE cleared the HIS and Futura Coatings areas, constructed a vehicle decontamination facility, installed a perimeter fence, excavated and backfilled the edges and shoulders of Latty Avenue, and consolidated the resulting contaminated soils into one storage pile. In 1986, during a city road improvement project, contaminated soil from roads leading to and from all three areas was excavated. USDOE plans further studies in all areas, which will lead to additional remedial actions.

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Reference 7

**Excerpts From Site Plan for Latty Avenue Properties, Hazelwood, Missouri;
Prepared for the U.S. Department of Energy by Bechtel National, Incorporated;
November 1989**

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**SITE PLAN FOR LATTY AVENUE PROPERTIES
HAZELWOOD, MISSOURI**

NOVEMBER 1989

Prepared for

**UNITED STATES DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE
Under Contract No. DE-AC05-81OR20722**

By

**Bechtel National, Inc.
Oak Ridge, Tennessee
Bechtel Job No. 14501**

Site: Latty Avenue
Properties
WBS: 140
Date: 10/09/89

II. HISTORY

In early 1966, ore residues and uranium- and radium-bearing process wastes that had been stored at SLAPS were purchased and moved to a storage site on Latty Avenue. These wastes had been generated by a St. Louis plant from 1942 through the late 1950s under contracts with the Atomic Energy Commission and its predecessor, the Manhattan Engineer District. Residues on the site at that time included 74,000 tons of Belgian Congo pitchblende raffinate containing approximately 13 tons of uranium; 32,500 tons of Colorado raffinate containing roughly 48 tons of uranium; and 8,700 tons of leached barium sulfate containing about 7 tons of uranium. The Commercial Discount Corporation of Chicago, Illinois, purchased the residues in January 1967; much of the material was then dried and shipped to the Cotter Corporation facilities in Canon City, Colorado. The material remaining at the Latty Avenue site was sold to the Cotter Corporation in December 1969. From August through November 1970, Cotter Corporation dried some of the remaining residues at the site and shipped them to its mill in Canon City. In December 1970, an estimated 10,000 tons of Colorado raffinate and 8,700 tons of leached barium sulfate remained at the Latty Avenue Site.

In April 1974, the newly established Nuclear Regulatory Commission (NRC) was informed by Cotter Corporation that the remaining Colorado raffinate had been shipped in mid-1973 to Canon City without drying and that the leached barium sulfate had been diluted with site soil and transported to a landfill area in St. Louis County. Reportedly, 12 to 18 in. of topsoil had been removed with the leached barium sulfate.

Before the present owner occupied the site, a radiological characterization was performed by the Oak Ridge National Laboratory (ORNL) (Ref. 2). Thorium and radium contamination in excess of DOE guidelines were found in and around the buildings and in the soil to depths of up to 18 in. Subsequently, in preparing the property for use, the owner demolished one building, excavated portions of the western half of the property, and paved certain areas in addition to erecting several new buildings. The material excavated during these activities (approximately 13,000 yd³) was piled on the eastern portion of the property.

In 1981, Oak Ridge Associated Universities (ORAU) characterized the pile and surveyed the northern and eastern boundaries of the property for radioactivity (Refs. 3 & 4).

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Properties
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Levels of contamination (principally thorium-230) similar to those on site were found in both areas. As a followup to this survey, ORNL conducted a detailed radiological survey of the north and south shoulders of Latty Avenue for DOE in January and February 1984 (Ref. 5). Results indicated that contamination in excess of DOE guidelines was present along the road beyond Hazelwood Avenue. Properties adjacent to HISS were also found to be contaminated, probably as a result of flooding, surface runoff, and road and utility line activities.

The 1984 Energy and Water Appropriations Act directed DOE to conduct a decontamination research and development project at four sites throughout the nation, including 9200 Latty Avenue and properties in its vicinity. Although the contamination in Hazelwood did not result directly from the atomic energy program, the Latty Avenue Properties were added to FUSRAP by Congress to expedite the decontamination process.

Remedial action activities in 1984 consisted of clearing the site and selected adjacent properties, constructing the decontamination facility and installing the perimeter fence, excavating and backfilling the edges and shoulders of Latty Avenue, and consolidating and covering the contaminated soils storage pile. The 1984 remedial action resulted in the addition of 14,000 yd³ of contaminated soil to the HISS storage pile.

In 1986, a municipal drainage improvement project was implemented, which included the installation of a storm sewer along Latty Avenue. As a result of the excavations for sewer pipe placement, 4,600 yd³ of contaminated spoils were placed in HISS in a pile just north of the 27,000 yd³ stockpile. This brought the total amount of contaminated material in above grade storage at HISS to approximately 32,000 yd³.

In 1985, remedial action activities consisted of Latty Avenue cleanup, surveying services, material testing, and monitoring well installation. Work activities started in July 1984 and were completed in June 1985. Approximately 100 yd³ of contaminated soil was excavated at locations along Latty Avenue and placed on the existing pile.

Site: Latty Avenue
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IV. REMEDIAL ACTION

A. Site Characterization and Scoping

Radiological and chemical characterization of LAP was completed in FY 1987. Both HISS and the Futura Coatings, Inc., properties were characterized. This characterization included both surface and subsurface investigations. Monitoring of the environment within the buildings on the Futura Coatings, Inc., property was conducted for four quarters.

Routine surveillance and maintenance of the interim storage area, including environmental monitoring, will be continued. Radiological characterization was completed along the vicinity properties in 1989.

Analyses of soil samples taken during an NRC investigation of HISS in 1976 indicated the presence of uranium- and thorium-bearing residues. Furthermore, at some areas on the site, direct readings of radiation exceeded guidelines established by the DOE for decontamination of land areas prior to release for unrestricted use.

A radiological characterization of the site was done by ORNL in the summer of 1977 prior to occupation of the site by the current owner. At that time, radioactive contamination in excess of the DOE guidelines was found in the buildings and over the site from uranium, thorium, radium, actinium, and their decay products. Sample analyses indicated contamination exceeding the guidelines at various depths down to 45 cm (18 in.).

Characterization of the soil pile on the eastern part of the site was completed in the fall of 1981 by ORAU. In addition, ORAU performed radiological surveys on the northern boundary of the site along Latty Avenue and along the eastern boundary. These surveys showed elevated levels of the same radionuclides that are present on site.

A surface scan along the north and south shoulders of Latty Avenue was completed in the summer of 1983 by ORNL. The results of this surface survey indicated that a formal radiological characterization should be completed to determine surface limits and depths along the roadway. This survey was conducted from January 23 to February 4, 1984. It included the City of Berkeley's proposed road and storm drain construction area, i.e.,

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Date: 10/09/89

the roadway and both shoulders of Latty Avenue. Additional surveys conducted in March and April 1984 included the site boundaries and surrounding areas.

Bechtel National, Inc. (BNI) initiated engineering activities to develop the engineering packages necessary for the radiological/chemical characterization of 9200 Latty Avenue. These characterization activities were completed in 1987. Radiological and chemical characterizations were conducted in accordance with FUSRAP Project Instructions and monitoring plans developed for each characterization. The objective of the characterization was to determine the vertical and horizontal limits of contamination on site. Parameters measured included, but were not limited to, uranium-238, radium-226, thorium-232, thorium-230, and soil and water parameters specified in the Resource Conservation and Recovery Act (RCRA). All composite samples were subject to multielement analysis and a total organic carbon analysis. Results of these analyses were compared with those made on background soil samples.

In 1987 and 1988, BNI performed a radiological characterization of the vicinity properties shown in Figure IV-1. Results from this characterization effort showed radioactive contamination present on all six properties. Thorium-230 was identified as the primary contaminant. Typically, the contamination is confined to the top 3 ft of soil.

The radiological characterization indicated contamination present on HISS to a depth of 6 ft at one location. The average depth of contamination at HISS is 3 ft. Contamination is present on the Futura Coatings site to a depth of 15 ft at one location. Soil sample analyses indicated elevated levels of uranium-238, radium-226, thorium-232, and thorium-230. Figures IV-2 and IV-3 show the areas and depths of radioactive contamination at HISS and Futura, respectively.

Soil samples collected from the six Latty Avenue vicinity properties and the Norfolk and Western Railroad property immediately adjacent to 9200 Latty Avenue were analyzed for uranium-238, radium-226, thorium-232, and thorium-230. At Property 1, results showed that depths of contamination range from the surface to 14 ft. Typically, the contamination is confined to the top 3 ft of soil. In general, the areas of contamination are smaller and fewer relative to greater distances from HISS.

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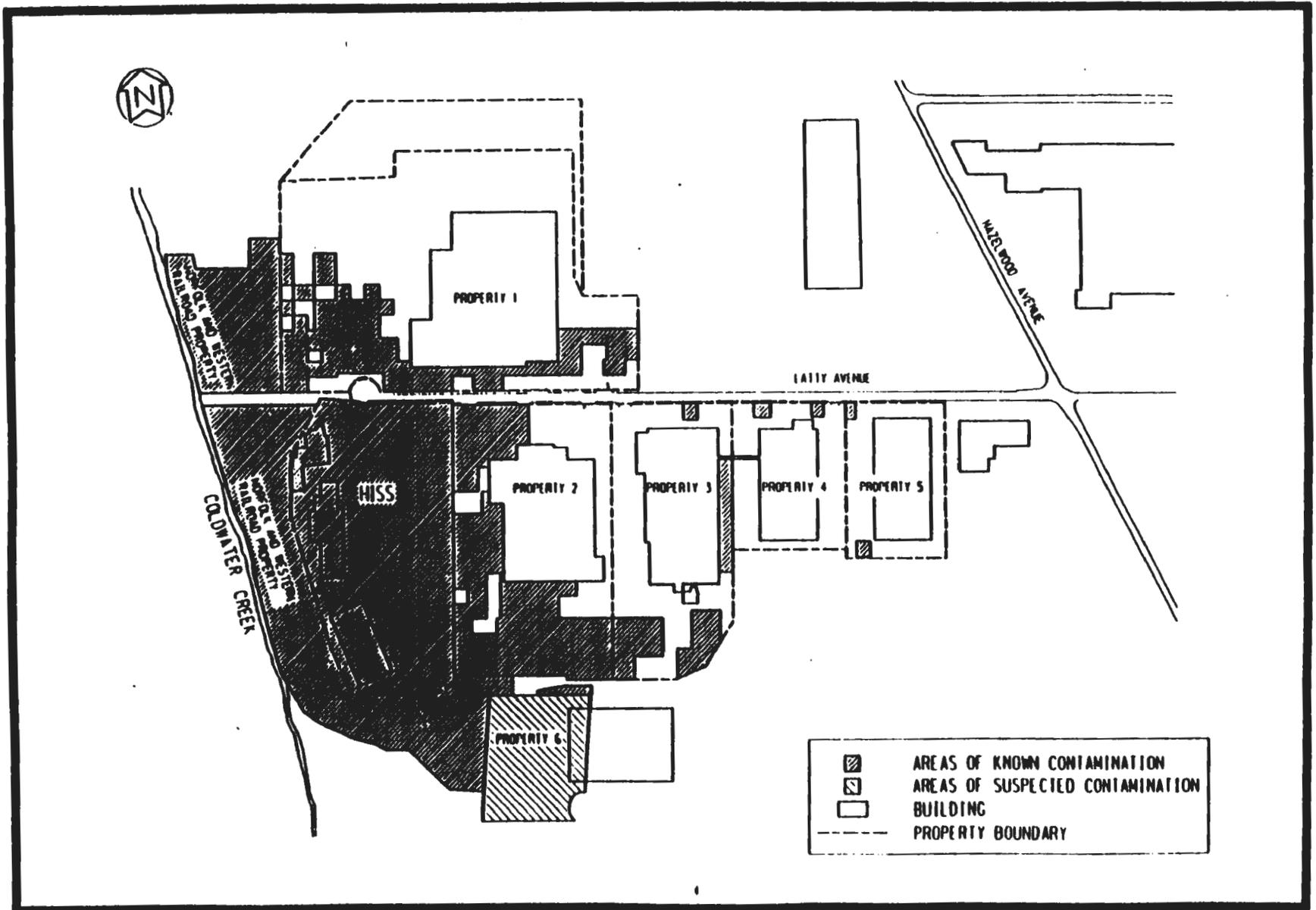


FIGURE IV-1 RADIOLOGICAL CHARACTERIZATION OF THE LATTY AVENUE VICINITY PROPERTIES

Site: Latty Avenue
Properties
WBS: 140
Date: 10/09/89

V. COST AND SCHEDULE

Estimated costs associated with the portion of work specifically addressing the LAP during the time period covered by this plan are listed in Figures V-1 and V-2. The costs shown are in year-of-expenditure dollars. The schedule of work for FY 91 through FY 95 as illustrated in Figure V-3 and the text of this plan are based upon current progress and priorities.

(S000)

ACTIVITY	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95
BNI ASSESSMENT (B&R AH-10-05-01)	-	644	386	216	99	-
CLEANUP (B&R AH-10-05-02)	640	8,600	600	771	1,016	10,878
SUBTOTAL	640	9,244	986	987	1,115	10,878
ANL	5	25	75	125	100	50
HQ	130	690	55	45	40	330
TOTAL	775	9,959	1,116	1,157	1,255	11,258

NOTE: Dollars are BA

FIGURE V-1 LATTY AVENUE PROPERTIES SITE BUDGET

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FY90 DETAIL — LATTY AVENUE PROPERTIES, MO

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
140 LATTY AVE.													
CHARACTERIZATION REPORT							PUBLISH ▽						
LEASE HISS PROPERTY							⊙						
DESIGN & PROCURE SUBCONTRACT FOR HISS EXPANSION					◇								
PREPARE SCOPING/ PLANNING DOCUMENTS									DOE REVIEW DRAFT ▽				
COMMUNITY RELATIONS PLAN									DOE REVIEW DRAFT ▽				
REMEDIAL INVESTIGATION REPORT									DOE REVIEW DRAFT ▽				
ENVIRONMENTAL MONITORING													
FUSRAP	71	49	63	57	66	58	78	40	39	39	40	40	
ANL	—	—	—	—	—	1	1	1	1	1	—	—	
HQ	11	11	11	11	11	11	11	11	11	11	10	10	
TOTAL (\$000-BA)	82	60	74	68	77	70	90	52	51	51	50	50	
FIVE YEAR PLAN FY90 VS FY90 BASELINE RECONCILIATION THE RIFS PROCESS HAS BEEN ACCELERATED AND STARTED IN FY 89 AND WILL CONTINUE IN FY 90 ORIGINALLY FY 90 PLANNED ACTIVITIES FOR THIS SITE WERE INCLUSIVE TO SURVEILLANCE AND MAINTENANCE ACTIVITIES													
PROPOSED MILESTONES CONTROLLED BY ⊙ DOE HQ ▽ ORO TSD ◇ PMC ○ ANL													

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0/89 1141 17

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FIGURE V.2 FY 90 DETAIL

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LATTY AVENUE PROPERTIES — 5-YEAR PLAN																				
	FY 91				FY 92				FY 93				FY 94				FY 95			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
ASSESSMENT RI/FS - EIS																				
CLEANUP ACQUIRE HISS	—		⊙																	
EXPAND HISS (FOR RECEIPT OF WASTE FROM SLAPS V.P.)			—																	
CLEANUP VICINITY PROPERTIES																				
ENVIRONMENTAL MONITORING																				
	ANNUAL REPORTS																			

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FIGURE V-3 FY 91 - 95 SCHEDULE

Mining Waste NPL Site Summary Report

**Sulphur Bank Mercury Mine
Lake County, California**

**U.S. Environmental Protection Agency
Office of Solid Waste**

June 21, 1991

FINAL DRAFT

Prepared by:

**Science Applications International Corporation
Environmental Health Sciences Group
7600-A Leesburg Pike
Falls Church, Virginia 22043**

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DISCLAIMER AND ACKNOWLEDGEMENTS

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract No. 68-W0-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Carolyn d'Almeida of EPA Region IX [(415) 744-2225], the Remedial Project Manager for the site, whose comments have been incorporated into the report.

SULPHUR BANK MERCURY MINE

LAKE COUNTY, CALIFORNIA

INTRODUCTION

This Site Summary Report for Sulphur Bank Mercury Mine was developed as one of several National Priorities List (NPL) Site Summary Reports and will be used to support EPA mining waste program activities. In general, these reports summarize the types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of August 30, 1990 (55 Federal Register 35502). Each summary report is based on pertinent information gathered from EPA files and reports, and on a review of the summary by the EPA Region IX Remedial Project Manager for the site, Carolyn d'Almeida.

SITE OVERVIEW

Sulphur Bank Mercury Mine is located in Lake County, California, on the eastern shore of the Oaks Arm of Clear Lake (see Figure 1). Mining has occurred at the site intermittently since 1865 and has involved sulphur and mercury mining (Reference 1, page 4). The site consists of approximately 120 acres of mine tailings and waste rock, a partially dismantled mill facility, and an open, unlined, and unstabilized mine pit referred to as the Herman Pit, or Herman Impoundment. An earthen dam was constructed at the west end of the pit in 1979, with a design capability to withstand overflow from a 200-year flood. Prior to dam construction, water from the pit would overflow into Clear Lake seasonally and during large magnitude storm events (Reference 2, page 12). The pit, which is located about 700 feet east of Clear Lake (see Figure 2), covers approximately 23 acres and is filled with water to a depth of up to 90 feet (Reference 1, page 4; Reference 2, page 3).

Mercury contamination of biota, surface water, and sediments has been found in the vicinity of the site (i.e., the Oaks Arm of Clear Lake). Although mercury is the main contaminant of concern, significant levels of arsenic are present in surface-water mine discharges and Oaks Arm bottom sediments (Reference 2, page 18; Reference 4, page 2). In May 1986, the State of California issued public health advisories recommending restrictions on consumption of fish from Clear Lake due to the levels of mercury detected (Reference 2, page 4).

Based on the nature and distribution of the contamination, EPA has designated three Operable Units at the site. These include Herman Impoundment; waste piles and contaminated soils; and lake sediments in Oaks Arm of Clear Lake (Reference 2, page 1).

Sulphur Bank Mercury Mine

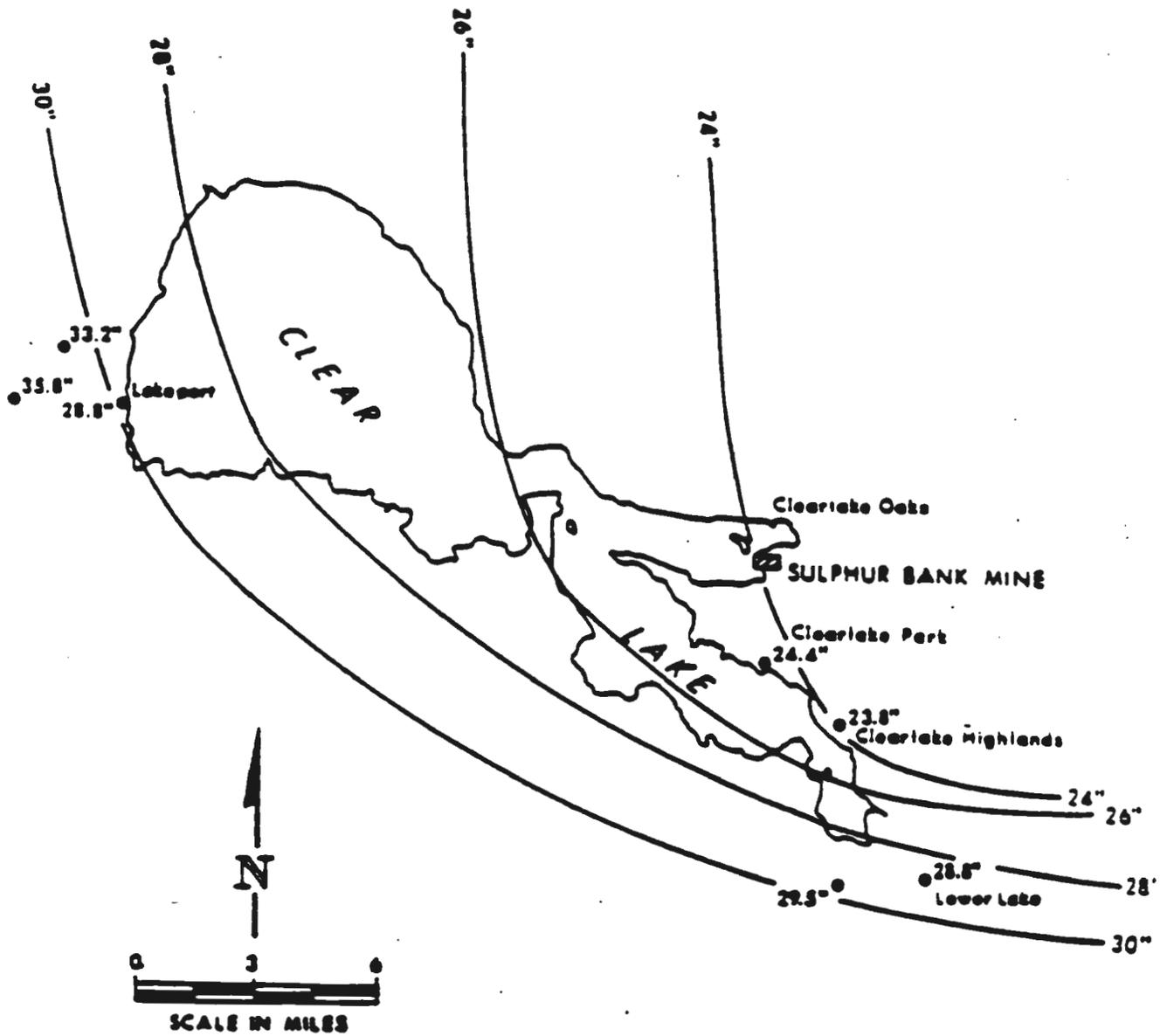


FIGURE 1. SULPHUR BANK MERCURY MINE LOCATION

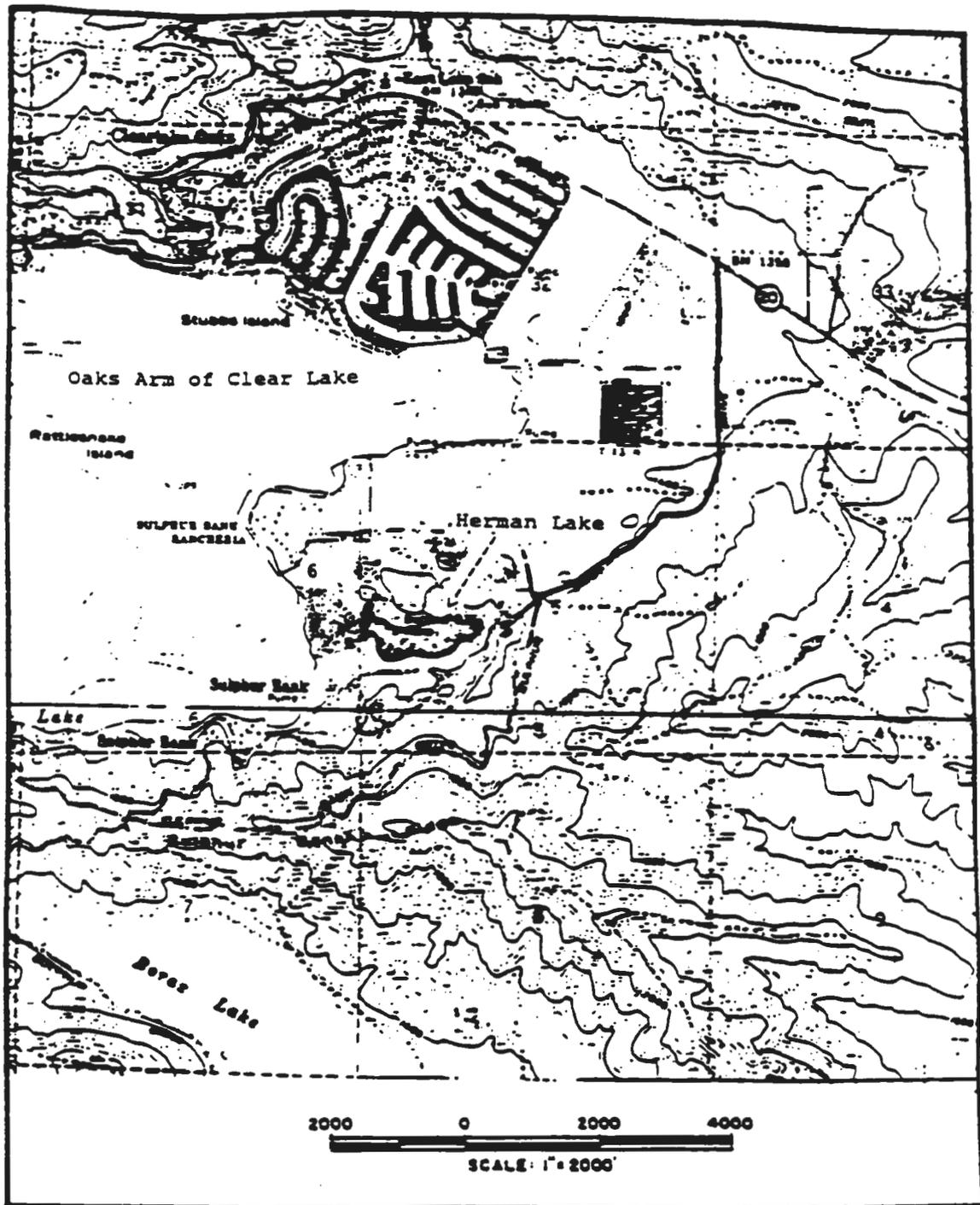


Figure 2. General Site Location Map.

FIGURE 2. GENERAL SITE LOCATION MAP

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Sulphur Bank Mercury Mine

The Sulphur Bank site was proposed for the NPL in June 1988, with a Hazard Ranking System score of 46.59 (53 Federal Register 23988; June 24, 1988). The proposed listing was based mainly on a perceived threat to the City of Clear Lake Oaks' ground-water supply wells (currently serving approximately 4,700 people). The NPL site proposal was also based on the fact that the State of California does not have an approved program under the Surface Mining Control and Reclamation Act (SMCRA) of 1977, making the site ineligible for SMCRA reclamation funds.

On August 22, 1988, the only "surviving" Potentially Responsible Party (PRP) identified to date, Bradley Mining Company (BMC), protested the listing proposal on the grounds that the primary source of mercury, arsenic, and other inorganic substances in both Herman Lake and Clear Lake is from natural geothermal activity and not surface runoff from mining waste. It also argued that the releases, which it claimed were occurring naturally, have not contaminated public drinking-water supplies and did not threaten to do so (Reference 3, pages 1, 3 and 30). Despite this opposition, the site was placed on the NPL on August 30, 1990.

Enforcement actions and investigations at the site have progressed as described here. The Central Valley Regional Water Quality Control Board (RWQCB) has been the lead agency in addressing the site contamination. In 1983, the Clear Lake Mercury Task Force was set up to address public and regulatory concerns that arose from "hundreds" of mercury-contaminated fish samples collected in the late 1970's and early 1980's. It consisted of representatives from the California Departments of Health Services (DHS) and Fish and Game, RWQCB, the Elem Indian Reservation, and several other county and local concerns (Reference 2, page 4). In 1985, a Preliminary Site Assessment was completed by Columbia Geoscience for the BMC. In 1987, as required under the California Toxic Pits Clean-up Act (TPCA), BMC conducted a study addressing contaminants in the Herman Impoundment (Reference 6). In 1989, DHS determined that as long as the sediments remain at the bottom of Herman Impoundment they might not be considered as hazardous waste, but if removed, the sediments would be a State-regulated hazardous waste (Reference 2, pages 4 and 5).

Phase One of the Hydrogeological Assessment Report (which addresses onsite ground-water characterization) was completed by Columbia Geoscience for BMC in 1988. Several monitoring wells were drilled, water samples were collected, and field tests were conducted to determine aquifer characteristics. An ongoing ground-water monitoring program is part of the Hazard Ranking System study. Phase II and Phase III reports were submitted by Columbia Geoscience in 1989 and 1990, respectively (Reference 2, page 5).

In addition, researchers from Humboldt State University completed a study for the RWQCB on the source of mercury and arsenic contaminants in Clear Lake (Sulphur Bank Mine was identified as the primary source) and on methods to control further contamination of the Lake. This study (Abatement

and Control Study: Sulphur Bank Mine and Clear Lake) was completed and submitted to the RWQCB in January 1990 (Reference 1, pages ix and 2; Reference 2, page 5).

In February 1990, the RWQCB issued Waste Discharge Requirements to BMC regarding the Sulphur Bank Mercury Mine site. Under the Water Discharge Requirements, BMC will implement, with EPA oversight, erosion control measures over a 5-year period. The Water Discharge Requirements do not address the contamination present in Clear Lake sediments (Reference 2, page 5).

OPERATING HISTORY

Prior to mining, the Sulphur Bank site consisted of various hot springs surrounded by thick surface deposits of native sulphur. The California Borax Company began removing sulphur from the surface pits in 1865. The sulphur was transported by rail to a refinery where the ore was liquified to drive off impurities, then cooled and shipped. Mine operations ceased in 1871 when market prices decreased and when increasing impurities increased refinery costs. Approximately 1,000 tons of sulphur were produced from 1865 to 1871 (Reference 2, page 3).

In 1872, California Borax Company reopened the mine for mercury ore production. The ore was mined from the Herman shaft at a depth of 450 feet. Approximately 3,200 tons of mercury were produced by the time California Borax ceased operations in 1883. The Sulphur Bank Quicksilver Mining Company began mining in 1887 by sinking two new shafts, the Diamond and Babcock shafts (about 640 and 710 feet deep, respectively). The Sulphur Bank Quicksilver Mining Company removed 400 tons of mercury by the time the operation was closed in 1897. The Empire Consolidated Mining Company assumed ownership in 1899, and operated until 1906. The three previous shafts collapsed and the new owners sank two new shafts, the Empire shaft and the Parrot shaft (about 610 and 730 feet deep, respectively). Underground mining operations ceased in 1905 because of extreme heat and gas. About 20 tons of mercury were produced during these years (Reference 2, page 3).

Mining resumed at the site in 1915, when the Sulphur Bank Association of San Francisco began open-pit mining. Operations ceased in 1918; between 1915 and 1918, 80 tons of mercury were produced. The BMC began open-pit operations at the site in 1927 under a lease from the G. T. Ruddock estate. It also sank two new shafts, which subsequently caved in by 1944. By the time BMC ceased operations in 1945, approximately 1,200 tons of mercury had been produced. At the conclusion of BMC's operations, the pit filled with precipitation and runoff, forming the Herman Impoundment. Ten years later, in 1955, BMC owned the mine. It drained Herman Impoundment and resumed open-pit mining. During this final production phase, BMC removed 120 tons of mercury. Mine

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Sulphur Bank Mercury Mine

operations ceased in 1957, and the pit filled with precipitation and runoff again, forming the existing Herman Impoundment (Reference 2, pages 3 and 4).

Sulphur Bank was one of the largest producers of mercury in California with an estimated total production ranging from 4,400 to 7,000 tons. Between 1865 and 1945, an estimated 1,250,000 tons of material were removed, processed, and disposed at Sulphur Bank (Reference 1, page 4).

Both mining activities and natural sources have caused mercury deposition in Clear Lake. Recent or current sources of mercury contamination include:

- Shoreline erosion of steep slopes made of tailings and waste rock; sheetwash erosion from the banks; and/or slope failures from undercutting of the slope by lake waves. Mercury concentrations measured in the Humboldt study averaged 158 parts per million (ppm); mercury loadings from this source were estimated at greater than 132 kilograms (kg) per year in 1988 and 1989 (which were dry years, so the average may be higher).
- Fluvial transport (as drainage from the rest of the mine site) of mercury-contaminated sediments to the Oaks Arm. The possibility that the Herman Impoundment Dams might fail is of particular concern (and has to be addressed under the RWQCB order). Water in onsite peripheral streams contained mercury at 330 to 490 parts per billion (ppb) in 1989. The Humboldt study estimated the average mercury load in drainage as 1.24 to 18.6 kg of mercury per year.
- Ground-water transport from Herman Impoundment to the Lake.
- Air transport of mercury vapor and/or mercury-contaminated particulates (Reference 2, pages 20 through 22).

Historical sources, in addition to those listed above, included:

- Mercury from mine water and sludge pumped into the Lake during open-pit mining operations
- Airborne mercury from ore smelting
- Disposal of overburden and mercury tailings from ore smelting (Reference 2, page 18).

Natural mercury inputs from active hydrothermal (high-temperature water) sources have also been documented in the Sulphur Bank vicinity (Reference 1, pages 10 and 11). Deeper sediments in Clear Lake also contain high mercury concentrations, the result of natural sources prior to mining (Reference 2, page 18). For example, there is a mercury peak at a depth of about 4 meters. These sediments were deposited about 6,000 years ago.

In the 1990 study done by Humboldt State University for the RWQCB, it was concluded that sheet-wash erosion and slope failures deliver approximately 100 kg of mercury into Oaks Arm annually; fluvial transport contributes about 10 kg; and ground-water sources deposit less than 1 kg per year. Sulphur Bank Mine was found to be the most significant source of mercury entering the Oaks Arm of Clear Lake.

SITE CHARACTERIZATION

Mining Wastes

Waste generated at the site consists of waste-rock piles and tailings piles. The waste-rock piles contain overburden and barren rock that were removed from the mine shafts and open excavations from 1865 to 1957. The excavated, barren, waste-rock piles occupy about 90 acres of land at Sulphur Bank. The tailings piles, derived from milled and roasted ore-bearing rock from which mercury was extracted, cover about 17 acres (Reference 5, page 36). There is a minimum of 193,600 cubic yards of wastes onsite (Reference 2, page 17). The distribution of these wastes at the site is presented in Figure 3. Both mercury and arsenic concentrations in these materials are elevated. RWQCB samples (in 1983 and 1984) showed mercury concentrations from 1 to 624 milligrams per kilograms (mg/kg). Humboldt later found an average mercury concentration of 158 ppm. Although arsenic in wastes has not yet been adequately characterized, RWQCB's data also showed arsenic levels of up to 140 ppm (Reference 2, page 17).

Surface Water

The Clear Lake Watershed is approximately 1,370 square kilometers (km²) and Clear Lake itself is approximately 178 km² (Reference 1, page 5). The Sulphur Bank site is bounded by the Oaks Arm of Clear Lake to the north and west. Most of the year's precipitation occurs between September and April, and ranges from 56 to 165 centimeters per year depending on elevation and location within the basin (Reference 1, page 5). Lake outflow is through the west arm of the Lower Lake forming the headwaters of Cache Creek, which drains into the Sacramento River.

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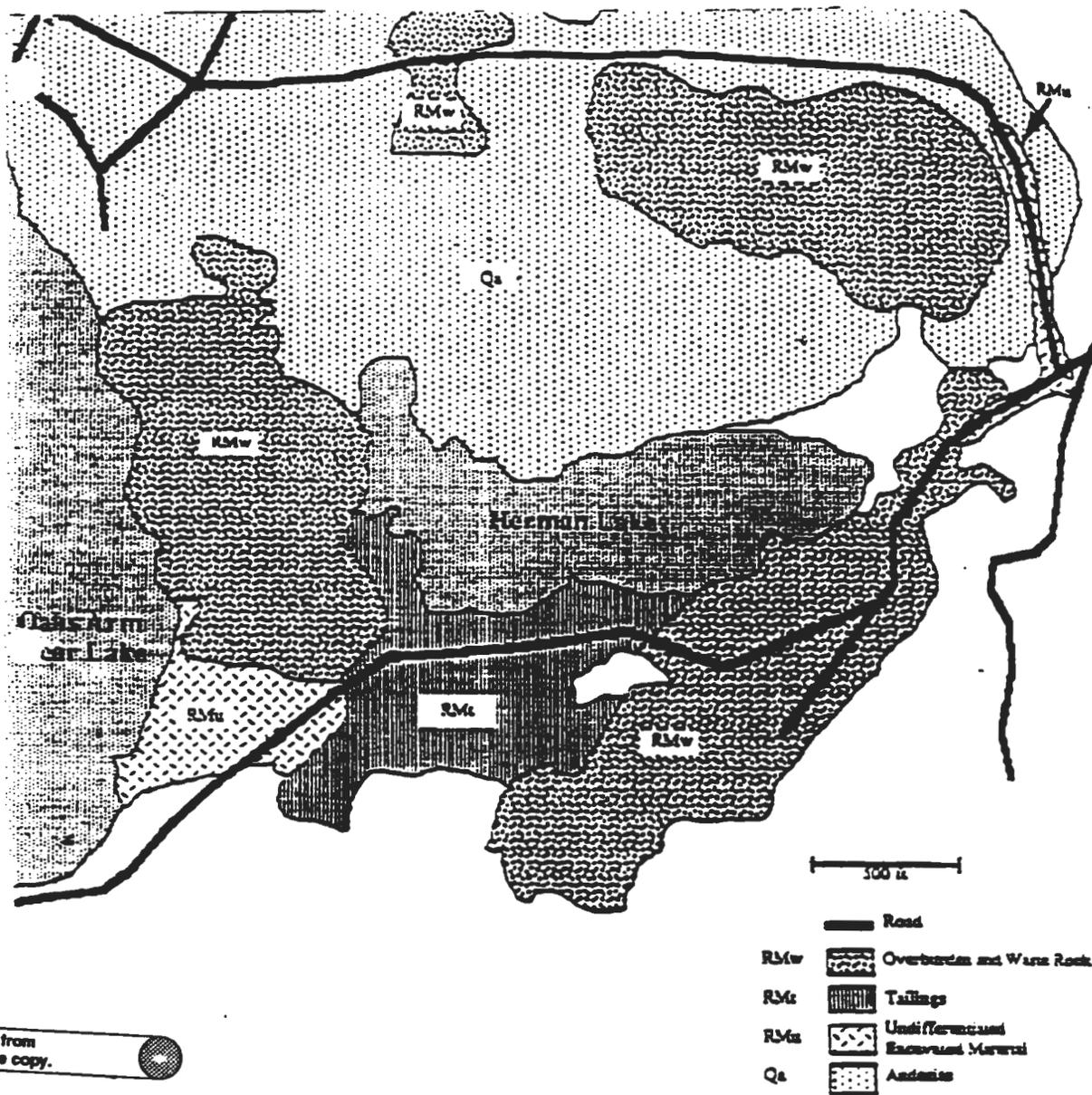


Figure 3

Classification and Spatial
Distribution of Mine Wastes
at Sulphur Bank Mine

USEPA Site Management
Plan January 1990

FIGURE 3. CLASSIFICATION AND SPATIAL DISTRIBUTION OF MINE WASTES AT SULPHUR BANK MINE

Clear Lake is classified as "eutrophic to highly eutrophic" and is thermally stratified for only short periods in the summer (ranging from a few hours to a week). The Lake is ranked as one of the most productive sport fisheries in California, and supports over 300,000 angler days per year (Reference 1, page 5). (Results of sampling conducted on fish in the Lake are discussed below with environmental damages and risks). The pH of the lake is high, ranging from 7.5 to 9.0 (Reference 5, page 23).

Steeply sloped tailings and waste-rock piles extend into the Lake and are in contact with about 2,060 feet of shoreline. Runoff from these piles drains into Clear Lake. In addition, wave activity from storms results in erosion at the base of the piles (Reference 2, page 13).

Researchers from Humboldt State University collected water-column samples from four locations in the Oaks Arm region of Clear Lake from February 1988 to March 1989 (Reference 1, page 193). In the 1990 report to RWQCB, the researchers found no consistent pattern in depth or season for evidence of mercury in the water column. The average mercury concentration based on 40 samples was 1.0 micrograms per liter ($\mu\text{g/l}$) with a standard deviation of 2.1 $\mu\text{g/l}$. However, when two outliers were removed from the sample (both more than 3 standard deviations larger than the mean), the average mercury concentration was 0.5 $\mu\text{g/l}$ with a standard deviation of 0.3 $\mu\text{g/l}$ (Reference 1, page 79). As noted, water in peripheral streams that drain the mine site and discharge to Oaks Arm of Clear Lake contained mercury concentrations of 330 to 490 ppb ($\mu\text{g/l}$) in 1989 (Reference 2, page 21).

Herman Impoundment, formed in the mine pits, has water levels several feet above the surface of nearby Clear Lake. It contains about 700 acre-feet of water and is up to 90 feet deep in some areas. Prior to construction of an earthen dam in 1979, overflow into Clear Lake from the Impoundment occurred seasonally and during large storm events. The source of water is primarily infiltrating ground water and drainage from 88 acres of the mine site (Reference 2, page 12).

Herman Impoundment also contains high concentrations of sulfate, sodium, chloride, boron, and ammonia. Large volumes of geothermal gases (carbon dioxide, methane, nitrogen, and hydrogen sulfide) continuously boil through the oxygen-rich water, creating a highly reactive environment (Reference 5, pages 24 and 25).

The Impoundment is a unique water body, very acidic (with a pH of about 3.0, the result of natural geothermal and chemical activity) and with elevated trace metals. The unusual geochemical nature of Herman Impoundment sediment and waters is the combined result of diverse sources, including:

Sulphur Bank Mercury Mine

- Discharge of natural geothermal fluids and gases
- Erosion of sediment from waste rock and tailings
- Discharges of meteoric water in contact with waste rock and tailings
- Chemical reactions between impoundment water and pit wall-rock (Reference 2, page 12).

"The major source of mercury in the pit sediments was likely associated with detrital accumulation from site surface runoff. Less significant contributions may be attributed to pit-wallrock reactions and precipitation from geothermal fluids entering the bottom of the pit" (Reference 2, page 15).

In 1987, Columbia Geoscience conducted a study for the PRP (BMC), to comply with the requirements for the California TPCA. In this study, water samples from Herman Impoundment were found to be below the toxic limits specified in the TPCA (Reference 6, page 1). According to this study, the average mercury concentration from nine samples taken in Herman Impoundment ranged from 0.0038 to 0.00025 milligrams per liter (mg/l), with an average of 0.00081 mg/l. One sample exceeded the EPA Maximum Contaminant Limit Drinking Water Standard (DWS) of 0.0020 mg/l of mercury (Reference 6, page 22; Reference 5, page 25). However, two filtered water samples from the impoundment contained 1.3 and 0.75 $\mu\text{g/l}$ of mercury, which exceed EPA's No-Adverse-Response Level of 0.144 $\mu\text{g/l}$ and the Ambient Water Quality Standard of 0.012 $\mu\text{g/l}$ for fresh-water aquatic life. Pit water also exceeds DWSs for cadmium and Ambient Water Quality Criteria for fresh-water aquatic life for beryllium, copper, nickel, and zinc (Reference 2, pages 15 and 16).

Sediments

Mercury concentrations from bottom sediments in the Oaks Arm portion of Clear Lake range from 11 to 250 mg/kg, with an average of 80 mg/kg. This compares to the State action level for mercury in sediments of 20 mg/kg. Bottom sediments in the rest of Clear Lake ranged from not detected to 12 mg/kg, with an average of 2 mg/kg. High levels of mercury were found in the upper 50 to 60 centimeters of sediment, which corresponds to the last 100 years of lake deposition (i.e., during the period of mining) (Reference 2, pages 17 and 18).

Much of the mercury in Oaks Arm is in the upper sediments, about 100,000 kg, as compared to about 440 kg in the sediments blanket and 60 kg in the water column. Mining practices "appear to be the most likely source for mercury" (Reference 2, pages 17 and 18).

High arsenic levels have also been detected in the bottom sediments of the Oaks Arm portion of Clear Lake. Concentrations ranged from less than 5 to 95.9 mg/kg, with an average of 27.9 mg/kg (Reference 2, page 18).

Data from the study of Herman Impoundment performed by Columbia Geoscience also showed that the sediments of the Oaks Arm portion of Clear Lake and Herman Impoundment contain elevated levels of mercury. However, the study concluded that high mercury levels have been present in the sediments of Clear Lake for thousands of years. Columbia Geoscience further concluded that the data also showed that mercury is not leaching into Herman Impoundment from the sediments or adjacent rock. Additionally, it contends that mercury-bearing geothermal water and gas continued (through 1987 - the date of the study) to be discharged into Clear Lake and Herman Impoundment. Finally, it provided volume calculations in an attempt to show that erosion from the mine cannot account for the near-surface, mercury-rich sediments in the Oaks Arm portion of Clear Lake (Reference 6, page 40).

A primary concern for the Lake Sediments Operable Unit is the bioaccumulation of mercury in the food chain and, potentially, the human population; this occurs when inorganic mercury in Oaks Arm sediments (and possibly the water column as well) is biologically converted (by microorganisms in water and/or sediments) to its methylated form. Methyl mercury, in turn, is assimilated by fish and bioaccumulated (and concentrated). Many factors influence the methylation process, including speciation of the inorganic mercury (e.g., elemental or ionic); dissolved oxygen content of water; temperature; (a measure of ionization potential); pE; pH; type and concentration of bacteria present; and type and concentration of complexing ligands and chelating agents (Reference 2, pages 22 through 27, 30 and 31). Critical to the process of evaluating and selecting remedies for sediment contamination will be an understanding of the significance of Sulphur Bank as a source of bioavailable mercury in the Lake (Reference 2, page 45), and of the other factors that influence or control methyl mercury production in Clear Lake and its sediments (Reference 2, page 25).

Ground Water

Ground-water contamination has been characterized by data collected from onsite and offsite wells. Three monitoring wells exist at the site. No domestic-water wells are known to have detectable levels of mercury (Reference 2, page 18). Columbia Geoscience reported that the mercury level in an unused onsite BMC well was 0.2 $\mu\text{g/l}$ (Reference 2, page 19). Researchers from Humboldt State University found (unfiltered) mercury concentrations from one sample site to range from 7 to 130 $\mu\text{g/l}$. Analysis of two filtered samples from one monitoring well were 0.4 and 0.6 $\mu\text{g/l}$ of mercury; the other two monitoring wells' samples measured 15 and 60 $\mu\text{g/l}$. The research team considers the sampling results suspect because of improper filtration (Reference 2, pages 18 through 26).

Sulphur Bank Mercury Mine

The Herman Impoundment receives shallow ground-water seepage from the north, east, and south. Seepage from Herman Impoundment migrates westward to Clear Lake (Reference 5, page 43; Reference 2, page 19). The amount of mercury being transported via ground water from Herman Impoundment to Clear Lake is dependent on the elevation difference between the two water bodies, the hydraulic conductivity of the aquifer, and the mercury content in ground water. Compared to erosion of shoreline sediments, Herman Impoundment's contribution of mercury to Clear Lake via ground water is considered very low (Reference 2, page 19).

No domestic, stock, or public water-supply wells are located downgradient of the Sulphur Bank mine site. Nearby wells showed mercury at, or below, detection limits (sampling data were not provided) (Reference 2, page 19).

Air

The air migration pathway has not been evaluated to date. A mercury vapor survey by RWQCB (in 1988) found vapor concentrations well below the 0.05 milligrams per cubic meter exposure limit (10-hour time-weighted average) recommended by the National Institute of Occupational Safety and Health. Indoor mercury concentrations have not been measured in the onsite caretaker's residence or several homes in the Elem community, which are constructed on mine tailings. Nor have onsite or offsite particulate concentrations been measured (Reference 2, page 22).

ENVIRONMENTAL DAMAGES AND RISKS

Elevated levels of mercury were first detected in Clear Lake in 1970 by the California DHS. Since then, samples from fish and water fowl and from sediments and water in the vicinity of Sulphur Bank Mercury Mine and the Oaks Arm of Clear Lake have been analyzed for mercury. Data from these samples indicate that the highest levels of mercury are found in the Oaks Arm portion of Clear Lake in the proximity of the Sulphur Bank Mine (Reference 1, page 11).

In fish and bird populations, mercury concentrations from 0.1 to 10 ppm are common. Mercury rates in fish ranged from 0.07 to 1.5 mg/kg (fresh weight) while mercury rates in Grebe populations ranged from 0.4 to 9.8 mg/kg (fresh weight). Concentrations of mercury in fish sometimes exceed the Food and Drug Administration limit of 1.0 ppm and often exceed the National Academy of Science level of 0.5 ppm established to protect fish and predator species that consume fish (Reference 1, page 11).

In 1983, the Clear Lake Mercury Task Force was formed due to growing public and regulatory concern about the site. Toxicological studies addressing mercury in fish from Clear Lake were conducted by DHS. As a result of these studies, guidelines for human consumption of fish contaminated with methyl mercury in Clear Lake were issued in May 1986 and in April 1987. In May 1986, the State of California issued health advisories recommending restrictions on fish consumption due to the levels of mercury detected in Clear Lake fish (Reference 2, page 4).

REMEDIAL ACTIONS AND COSTS

To date, no remedial actions have been taken under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). However, BMC has been ordered by RWQCB to take several actions to control sources of mercury contamination from the waste piles and Herman Impoundment (Reference 2, page 32). Table 1 presents the primary environmental concerns associated with each of the three Operable Units and possible remedies to address these concerns.

CURRENT STATUS

The site was placed on the NPL on August 30, 1990. EPA Region IX recently completed the interim final work plan for the Remedial Investigation/Feasibility Study (Reference 2). The tentative schedule calls for the work plan to be made final by the summer of 1991; the Records of Decision (ROD) should be finalized for two of the Operable Units (Herman Impoundment and Mine Waste Piles) in the winter of 1993-1994. A ROD for the Lake Sediments Operable Unit should be complete by the winter of 1994-1995 (Reference 2, Appendix I, page 1).

TABLE 1. PRIMARY CONCERNS AND POTENTIAL REMEDIES FOR SULPHUR BANK NPL SITE

Operable Unit	Primary Concerns	Possible Remedies
Herman Impoundment	<ul style="list-style-type: none"> • Human/ecological direct contact with acidic pit water • Potential surface- and ground- water discharge of acid and metals into Clear Lake 	<ul style="list-style-type: none"> • No action • Neutralizing acid waters (by liming) • Draining and plugging the pit • Rerouting ground-water flow with barriers
Mine Waste Piles	<ul style="list-style-type: none"> • Physical hazards • Potential soil ingestion by children playing onsite • Potential ingestion of tules, wild berries, or garden vegetables growing onsite or in adjacent areas with mercury-contaminated soils • Possible air exposure to mercury and arsenic vapor and particulates • Continued erosion of mine waste into Oaks Arm of Clear Lake 	<p>To be accomplished by BMC under RWQCB order:</p> <ul style="list-style-type: none"> • Rip-rapping shoreline • Constructing toe buttress on waste piles to stabilize slope • Minimizing erosion with gully work • Improving dam <p>Potential additional remedies:</p> <ul style="list-style-type: none"> • Cutting back sloped piles along shoreline • Capping (with clean soil) and revegetating piles • Onsite reburial of wastes in the pit • Grouting, covering, solidifying, and/or vitrifying waste piles
Lake Sediments	<ul style="list-style-type: none"> • Methyl mercury production and bioaccumulation 	<ul style="list-style-type: none"> • No action • Dredging some or all sediments • Covering some or all sediments with clean sand or clay

Source: Reference 2, pages 31 through 33 and 40 through 45

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2. **Work Plan for the EPA Region IX In-house Remedial Investigation/Feasibility Study, Sulphur Bank Mercury Mine Site: Interim Final; EPA Region IX; April 1991.**
3. **Comments of Bradley Mining Company in Opposition to the Proposed Listing of the Sulphur Bank Mine on the NPL; Anthony O. Garvin, Landels, Ripley & Diamond; August 22, 1988.**
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Sulphur Bank Mercury Mine

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Reference 1

**Excerpts From Abatement and Control Study: Sulphur Bank Mine and Clear Lake;
Charles Chamberlin et al.; Prepared for the California Regional Water Quality Control Board
by Humboldt State University; January 1990.**

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**Abatement and Control Study:
Sulphur Bank Mine and Clear Lake**

Contract No. 7-703-150-0

**Prepared for
California Regional Water Quality Control Board
Central Valley Region
3443 Routier Road, Suite A
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January 1990

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Executive Summary

This report details the procedures, findings, and recommendations of a source control and pollution abatement study of the mercury contamination problem in Clear Lake, California. The project has sought to identify the critical mercury sources, understand the mercury transport processes that are most important, and design and evaluate control and abatement strategies that are most promising. The major sections of the report deal with: (1) mercury discharges from the Sulphur Bank Mine (SBM); (2) the calculation of a mercury balance for the Oaks Arm of the lake, including the identification of the principal inputs and outputs of mercury and the amounts of mercury contained in the waters, sediments, etc.; (3) an analysis of source control strategies for limiting the rate at which mercury enters the lake; (4) an analysis of pollution abatement strategies for dealing with the quantities of mercury that are presently in the lake; and (5) recommendations.

The principal findings may be summarized as follows:

Mercury Sources and Transport:

1. The most significant source of mercury entering the Oaks Arm of Clear Lake is the Sulphur Bank Mine.
2. Shoreline transport of soil materials through sheet-wash erosion and slope failures represent the largest contribution of mercury to the Oaks Arm. This delivers approximately 100kg of mercury per year, in contrast to fluvial transport and groundwater sources, which contribute approximately 10 and less than 1 kg of mercury per year, respectively, to the Oaks Arm.
3. Of the mercury already in the Oaks Arm, the largest amount (about 100,000kg) is in the upper sediments, while the sediment blanket and the water column account for much smaller quantities of mercury (respectively, 440kg and 60kg).
4. The most significant outputs of mercury from the Oaks Arm are losses into the sediments. This amounts to approximately 100kg of mercury per year. Losses to the atmosphere and flows out of the Oaks Arm each account for approximately 10kg per year.
5. Historically, mining practices that have disposed of waste rock and surface overburden directly into the lake during the periods of 1927-44 and 1955-57 appear to be the most likely source for the mercury stored in the upper sediments of the Oaks Arm.

Source Control Strategies:

6. For greatest effectiveness, source control strategies should focus first on reducing rates of shoreline erosion and then on fluvial transport mechanisms.
7. Twelve source control strategies were targeted for detailed examination, and various combinations of these strategies were evaluated on the basis of

magnitude of mercury transport via groundwater, it would be necessary to develop a groundwater flow model for the aquifer involved. In other cases, applicable control and/or abatement experience from other sites with mercury contamination were used.

3. Data Analysis and Report Preparation

The results of the data collection program and the detailed assessments were analyzed and are presented here in this final report. A range of source control and pollution abatement measures are described that would provide a gradation of control and abatement levels and costs.

Following a brief description of the context and history of the current problem in Section II, the estimated current mercury discharges into Clear Lake from the SBM will be discussed in Section III and a mass balance for mercury in the Oaks Arm and Clear Lake as a whole will be developed in Section IV. This section will also cover estimates of historical loadings from the mine site. Sections V and VI will outline and evaluate source control strategies for the SBM site and pollution control strategies for mercury contamination in the Oaks Arm. Finally, Section VII will present recommendations and conclusions regarding the trade-offs between the costs and effectiveness of the most promising control and abatement strategies.

Disclosure Statement

This work was carried out by the Environmental Resources Engineering Department of Humboldt State University through the Humboldt State University Foundation for the California State Water Resources Control Board under Contract No. 7-703-150-0 beginning 10 December 1987. The total project budget was \$80,000. Dr. Charles E. Chamberlin was the project director and principal investigator. Drs. Ronald Chaney, Brad Finney, Peter Lehman, Mac McKee, and Robert Willis were co-principal investigators.

United States Geological Survey has drilled cores in Clear Lake sediment to depths up to 112 meters (350 feet) entirely within recent sediment. Pollen data and ash bed correlations from Clear Lake cores show a paleoclimatic record of approximately 130,000 years (Sims et al., 1981).

Sulphur Bank Mine

White and Roberson (1962) classify Sulphur Bank as the most productive mineral deposit in the world that is clearly related to hot springs. The ore is late Quaternary in origin and is localized in rocks immediately below the water table as it existed prior to mining. The hydrothermal alteration and mineralogy of the veins have been controlled largely by the water table.

At the time of its discovery by Veatch in 1856, native sulphur, without cinnabar, was abundant near the surface; but, as the water table was approached, sulfur decreased, and cinnabar became abundant. The principal ore bodies were at and below the water table and consisted of cinnabar, marcasite, pyrite, dolomite, calcite, quartz, a zeolite mineral, and all minerals of the original rocks. In the process of removing the ore first by shaft mining and later by open pit mining, overburden and waste rock piles and tailings piles were built up within the mine site. For the purposes of the current work, the overburden and waste rock piles that form the bluffs along the shoreline of the Oaks Arm of Clear Lake are the most significant.

The mineralization produced by the hot springs is quite recent (late Quaternary) and is still continuing (Sims and White, 1981). The springs in the vicinity of the mine yield gases rich in CO₂, CH₄, and H₂S, in contrast to springs at other sites in the lake. At all sites, mercury levels in the water and gases associated with the springs has been approximately 1 to 3 ppb (White et al., 1970). The principal ore bodies at the Sulphur Bank Mine resulted from the reaction of mercury and H₂S to form the insoluble precipitate HgS, or cinnabar at the interface formed by the groundwater table. The spring flowrate has been estimated variously from 0.15 m³/min to 1.1 m³/min. It currently enters the deep pond (Herman Lake) filling the mine pit.

Although these deposits originally attracted commercial attention because of native sulfur deposits (ca. 1865), the Sulphur Bank mercury mine became a very productive mercury mine, active from 1873-97, 1899-1902, 1915-18, 1927-47, and most recently from 1955-57.

White and Roberson (1962) cite unpublished data to estimate that the mine yielded 129,418 flasks of mercury from 1873 through 1957. Each flask contained about 75 lbs of mercury (specifically, 76.5 lbs from 1873 through 1903 and 75 lbs from 1904 onward). Therefore, the total commercial yield of mercury from the Sulphur Bank Mine was 4400 to 4500 MT. Taking into account mining and furnace losses and mercury left in the ground, White and Roberson (1962) estimate that the original mercury content of the site was no more than 7000 MT. Combining these limits, 4400 to 7000 MT of mercury were removed from the site. According to Averill (1947), mining activity at Sulphur Bank Mine between 1865 and 1945 resulted in the removal, processing, and subsequent disposal of over 1,250,000 tons of material.

The mine is currently inactive. The site contains approximately 120 acres of tailings, overburden and dumps and 23 acres covered by a pond (up to 150 feet deep) filling the abandoned mine pit. Neither the tailings nor dumps are vegetated and are therefore subject

to severe erosion. Along 1240 feet of shoreline, mine dumps are in direct contact with the lake and are highly susceptible to shoreline erosion. Along an additional 820 ft, other mine waste is in contact with water but less susceptible to erosion. See Figure II-1.

Several geological maps of the mine site have been prepared: Becker(1888), Ross(1940), Everhardt(1946), and Columbia Geoscience(1988). Figure II-2 is based on the most recent of these maps and distinguishes three categories of mine wastes: RMw - overburden and waste rock, RMt - tailings, and RMu - undifferentiated excavated material.

Water Quality Setting

Clear Lake consists of an approximately circular main basin or upper arm (UA) with two narrow arms, the Lower Arm (LA) and the Oaks Arm (OA). See figures II-3 and II-4. Inflows to the lake come primarily from Rodman Slough (Scotts Creek, Middle Creek), Adobe Creek, and Kelsey Creek all of which enter the Upper Arm. A small (ca. 13 mi² or 34 km² drainage area) seasonal stream, Schindler Creek, feeds into the Oaks Arm. Outflow exits from the Lower Arm via Cache Creek which is a tributary of the Sacramento-San Joachum system. Table II-1 summarizes hydrologic data for these sites (USGS, 1984; USGS, 1971).

Located along the north edge of the Clear Lake volcanic field, the lake is at a current elevation of 400 m in a valley of the Northern Coastal Range, bounded by the Russian River basin on the west. Its drainage area is about 5228 mi² or 1370 km² (Sims et al., 1981). Lake morphological properties are summarized in Table II-2.

The lake phytoplankton and productivity have been studied by Goldman and others (Goldman and Wetzel, 1963; Horne and Goldman, 1972; Horne et al., 1971; Sandusky and Horne, 1978). The lake is classed as eutrophic to highly eutrophic but is thermally stratified for only short periods in the summer ranging from only a few hours to a week. Water temperature ranges from 6 - 27 C. Precipitation is concentrated from September through April (valley - 56 cm to hills - 165 cm). Both during winter storms and during the summer, substantial wave action is observed. The sediment remains anoxic from July to November and the water near the sediments also has very low dissolved oxygen (DO) levels. The water is quite turbid throughout most of the year.

Blooms of both blue-greens and dinoflagellates have been observed in the lake (Sandusky and Horne, 1978; Horne and Goldman, 1971). Other dominant phytoplankton species observed include *Scenedesmus* spp., *Cryptomonas* spp., and *Cyclotella* spp. In some cases, the blooms have been, at least initially, concentrated in the Oaks Arm and/or Lower Arm.

The lake is ranked as one of California's most productive sport fisheries. It supports over 300,000 angler-days per year of effort and yields 34.7 kg/ha. Unfortunately, the composition of the fishery catch has changed dramatically from the 1930's to the present, with marked declines in the largemouth bass populations (Week, 1982). The changes in the composition of the catch and the decline in the largemouth bass fishery are both attributed to loss of littoral (e.g., marshland) habitat.

In addition, Clear Lake has also had the distinction of being the only lake in California to support a commercial fishery. About 250,000 lbs of Carp and 350,000 lbs of Blackfish were commercially removed each year during the early 1970's (DWR, 1975).

**Table II-1
Streamflow Properties**

Name	USGS STN No.	Drainage Area (mi ²)	Ave Flow (CFS)	Min Daily (CFS) (*)	Period of Record
Adobe Cr.	11448500	6.36	11.8	0.00 (120)	1956-68
Highland Cr.	11448900	11.9	18.6	0.00 (30)	1964-68
Highland Cr.	11449000	12.7	20.1	0.00 (60)	1956-62
Scotts Cr.	11449100	52.3	70.5	0.00 (120)	1961-68
Kelsey Cr.	11449500	36.6	71.5	0.7	1947-68
Cache Cr.	11450500	528	500.8	0.0 (0)	1902-15
Cache Cr.	11451000	528	318.2	0.3	1946-68

* Indicates the approximate number of days per year at 0.0 CFS.

**Table II-2
Clear Lake Morphology (after Horne and Goldman, 1972)**

Basin	Surface Area		Mean Depth (m)	Max Depth (m)	Max Fetch (km)	Volume (10 ⁶ m ³)
	(mi ²)	(ha)				
Upper Arm	49.0	12,700	7.1	12.2	16.4	904
Lower Arm	14.4	3,720	10.3	18.4	13.4	384
Oaks Arm	4.8	1,250	11.1	18.4	8.5	138
-----	-----	-----	-----	-----	-----	-----
Total	68.2	17,670	8.1	18.4	--	1426

Chemical analyses (Goldman and Wetzel, 1963; DWR, 1975) show that the waters are "hard" with substantial levels of sulfate (see Table II-3).

The lake lies in a fault-bounded valley and contains a long sediment accumulation history. Analysis of pollen patterns, C14 dating, and ash-bed correlations for long cores removed from the UA indicate that the lake has existed for at least 130,000 years (Sims et al., 1981). Cores taken from the Oaks Arm provide a sediment record covering about 44,000 years. Hot springs, some subaqueous, feed into the lake, carrying high levels of CO₂ and CH₄.

Mercury levels in sediment cores indicate that there have been periodic episodes of high mercury levels in the lake (Sims and White, 1981). Peaks are notable at 6 core depths with ages estimated from C14 dates and ash-bed correlations as summarized in Table II-4.

TABLE II-3
Clear Lake Water Chemistry (Upper Arm)

Anions	Concentration		Cations	Concentration	
	(mg/l)	(meq/l)		(mg/l)	(meq/l)
HCO ₃ -	136	2.2	Mg ++	17	1.4
SO ₄ --	8	0.2	Ca ++	17	0.9
Cl -	7	0.2	Na +	7	0.3
			K +	1	0.03
Total Anions		2.6	Total Cations		2.6

7.5 < pH < 9

Table II-4
Paleo-History of Mercury Contamination in Oaks Arm Sediments
(after Sims and White, 1981)

Peak Age (Years Before Present)	Mercury Content (ppm)
3600	35
7400	65
9500	12
18000	20
23300	5
34000	10
(local background)	0.4

High levels of mercury have been observed in the lake sediments and in fish and bird populations. Typical values observed on the mine site range from 10 to 1000 ppm (dry weight); in the surface sediments of the Oaks Arm mercury levels are generally about 10 to 100 ppm (dry weight). Sediment levels of mercury in the Upper Arm and Lower Arm are much lower, suggesting localization of the mine contributions to the Oaks Arm. The following chapter discusses these levels in greater detail.

In the fish and bird populations, mercury concentrations of 0.1 to 10 ppm (fresh weight) are common. Tables II-5 and II-6 reproduce a summary of mercury levels in fish and birds at Clear Lake prepared by the CVRWQCB (1987). Mercury levels in the fish species examined range 0.07 to 1.5 mg/kg (fresh weight) while mercury levels in the grebe range from 0.4 to 9.8 mg/kg (fresh weight). The fish levels sometimes exceed the FDA established limit of 1.0 ppm and often exceed the NAS level of 0.5 ppm established to protect fish and predator species that consume fish.

- C_t = mercury concentration in tributary streamflow into the Oaks Arm (kg/m³)
- L_{sb} = flux from water column to sediment blanket (kg/yr)
- L_a = flux from water column to air (kg/yr)
- Q_o = flow due to currents from the Oaks Arm into the Narrows (m³/yr)
- C_w = mercury concentration in Oaks Arm water column (kg/m³)
- L_s = flux from sediment blanket into sediments (kg/yr)

Estimates for some of these contributions can be taken directly from the hydrologic balance for the Oaks Arm summarized in Table IV- 12 or from the analysis of mercury discharges from the Sulphur Bank Mine site given in Chapter III. In this section, estimates will be developed for the current mercury mass stored in the water column, the sediment blanket, and the upper sediments and for the remaining contributions to the balance.

Mass Storage Levels

Three storage compartments collectively make up the Oaks Arm and Narrows mercury storage: 1) storage in the water column (S_w), 2) storage in the sediment blanket (S_{sb}), and 3) storage in the upper sediments (S_s). The current mass of mercury stored in each of the first two compartments can be estimated based on the observed mercury concentration (i.e., mass/volume) and the compartment volume. The current mass in the upper sediments can be estimated from observed mercury concentrations (i.e., mass/mass dry weight), water content, bulk density, and compartment volume.

Essentially all of the mercury in the water column is expected to be associated with particulates which is consistent with the results of Gill(1987). In this project, water samples were collected from the water column on four occasions at two locations at five depths each time. Sampling locations were determined by triangulation. Figure IV-14 shows the sampling locations. Sample depths were distributed over the total water column depth but were concentrated near the bottom, e.g., if the water column depth was 40 ft, then samples might be collected at 3, 20, 30, 35, and 37 ft.

Each sample was analyzed for mercury (i.e., total recoverable mercury or TRHg). Details of the collection, sample handling, and analyses are given in Appendix A. In addition, half of the samples were filtered through 0.45 μ m membrane filters to remove particulates and the mercury level in the filtrate was determined. This filtrable fraction was used to approximate the dissolved fraction. None of the filtered samples contained measurable mercury levels but essentially all of the TRHg analyses contained levels above the detectable limit (i.e., approximately 0.2 μ g/l). Figure IV-15 shows the mercury profiles observed in the water column. No consistent pattern with depth or season is evident. The average concentration based on all 40 samples was 1.0 μ g/l with a standard deviation (SD) of 2.1 μ g/l. However, two of the observed concentrations were more than 3 SD's larger than the mean and were suspected of being contaminated with material from the sediment blanket. If these probably spurious data are censored, then the mean of the remaining 38 observations drops to 0.5 μ g/l with a SD of 0.3. The medians of the total and the censored data sets were the same: 0.4 μ g/l.

Based on a water level of 7.5 ft on the Rumsey gage, the water volume of the Oaks Arm is $0.111 \cdot 10^6$ ac-ft or $138 \cdot 10^6$ m³. The sediment blanket is assumed to be approximately 1 m thick. Since the surface area of the Oaks Arm is about 2624 ac or $11 \cdot 10^6$ m², the volume of the sediment blanket is about $11 \cdot 10^6$ m³. Therefore the water column volume

Sampling Methods

The following were the methods used for the collection of soil and water samples for the study period of February 1988 thru March 1989.

Sample Types

Three types of sampling took place; subsurface, surface and shore sampling. Boats and scuba diving teams were used for the subsurface collection of cores and suspended sediment samples from the lake. Surface teams procured water column samples from the lake by boat. Shore teams gathered soil samples and water samples from monitoring wells and from the shores of both the lake and Herman Lake. Site location for the lake stations was done by line of sight triangulation from the boat or marked according land based survey team triangulation. Land stations were located according to surveys or by cartographic marking.

Subsurface Transect Sampling

Using two boats the weighted ends of a twenty five meter transect with markings at ten meter increments and a float attached to the westward end, was released from a taught surface position such that the transect was essentially straight and oriented East/West. Additionally, a single boat method was applied by dropping the eastern end and running the boat westerly releasing the float end while the boat was still moving and keeping the float line taught. In either case, the float line was attached to the boat to act as an anchor line.

The suspended sediment samples were obtained prior to any core on a given transect for the purposes of minimal water column disturbance. All of the suspended sediment samples were obtained utilizing a transect, such that one set was collected at each marking for a total of three sets per transect. The cores were collected on a basis of two per transect at a distance of ten or twenty meters apart.

Subsurface Station Sampling

Using a single boat, an anchor line was lowered and the core taken near the anchor

Suspended Sediment Sampler

Discrete suspended sediment samples were obtained utilizing a polyvinyl chloride (PVC) pipe 110 cm in length and a 6 cm OD with circular openings drilled across the central axis and through both sides at the selected heights of 100, 50, 20, 10 and 5 cm from the support grate bound to the bottom. In each opening a 60 ml all plastic syringe with plunger was affixed in the PVC stand using waterproof tape.

While on the transect site, the leading diver would slowly lower the grate into the sediment-water interface at an arms length in front of them. Ensuring that the sampler was properly aligned vertically, they would then pull from the bottom plunger up filling the syringes while making as little movement as possible. The filled sampler was then returned.

Reference 2

**Excerpts From Work Plan for the EPA Region IX In-house Remedial Investigation/
Feasibility Study, Sulphur Bank Mercury Mine Site: Interim Final;
EPA Region IX; April 1991**

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WORKPLAN FOR THE
EPA REGION 9 IN-HOUSE
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
(RI/FS)

SULPHUR BANK MERCURY MINE
SUPERFUND SITE

Clear Lake, California

INTERIM FINAL

April 1991

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APPENDIX

I. Tentative RI/FS Schedule

II. Compliance With Other Laws: Applicable, or Relevant and Appropriate Requirements (ARARs)

- A. Discussion
- B. Initial Identification and Screening of ARARs

II. Remedial Investigation

- A. Community Relations Plan (CRP)
- B. Quality Assurance Project Plan (QAPjP)
- C. Health and Safety Plan (HSP)
- D. Field Sampling Plan (FSP)

III. Risk Assessment Workplan

- A. Human Health Risk Assessment
- B. Ecological Assessment

SULPHUR BANK MERCURY MINE

RI/FS WORKPLAN

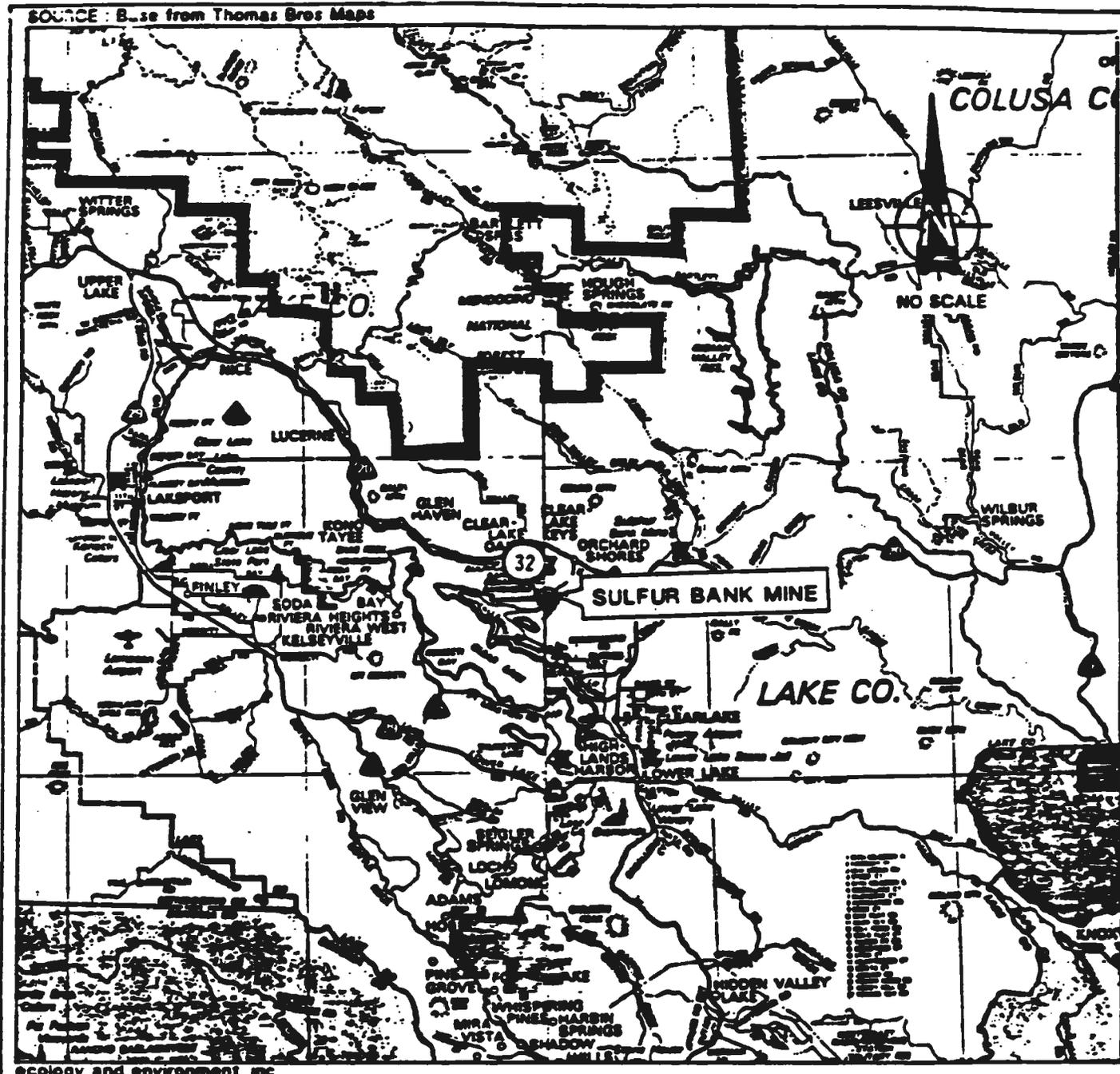
1.0 Executive Summary

This workplan has been prepared for the In-House Remedial Investigation and Feasibility Study (RI/FS) for the Sulphur Bank Mercury Mine Superfund site located near Clear Lake, in Lake County, California. The objectives of the RI/FS will be to characterize the nature and extent of contamination at the site; identify the contaminants of concern, and their potential migration and exposure pathways; evaluate the adverse effects of actual or threatened releases upon human and ecological receptors; and evaluate the feasibility and cost-effectiveness of potential remedial alternatives to aid in selecting a cleanup remedy.

The Sulphur Bank Mine is located on the eastern shore of the Oaks Arm of Clear Lake, within a geothermally precipitated ore body of cinnabar (mercury sulfide) and native sulphur. During past open pit mining activities, waste rock excavated from the mine pit and ore processing wastes were directly disposed in Clear Lake. Erosion from the mine continues to add to the mercury contaminated sediments already present in the lake. Inorganic mercury in the lake sediments is biologically converted to methyl mercury, which bioaccumulates in the food chain. Tissue samples collected from fish and some birds indicates that mercury is concentrating in higher trophic level species. Many samples collected from Clear Lake fish contain mercury levels in excess of the U.S. Food and Drug Administration (FDA) guideline. Although the State has issued a public health advisory limiting the consumption of Clear Lake fish, the lake still supports an economically important sport and commercial fishery.

The RI/FS will be conducted primarily in-house, using EPA personnel and expertise to the maximum extent possible. Work which cannot be readily carried out in-house will be assigned to contractors. RI/FS will be conducted in a phased approach, and will focus on investigating and developing remedial alternatives for three operable units: the mine pit, waste piles and contaminated soils, and contaminated lake sediments.

2.0 Site Background



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FIGURE 1
SITE LOCATION MAP
SULFUR BANK MINE

2.1 Site Location, Description, Potential Contaminants

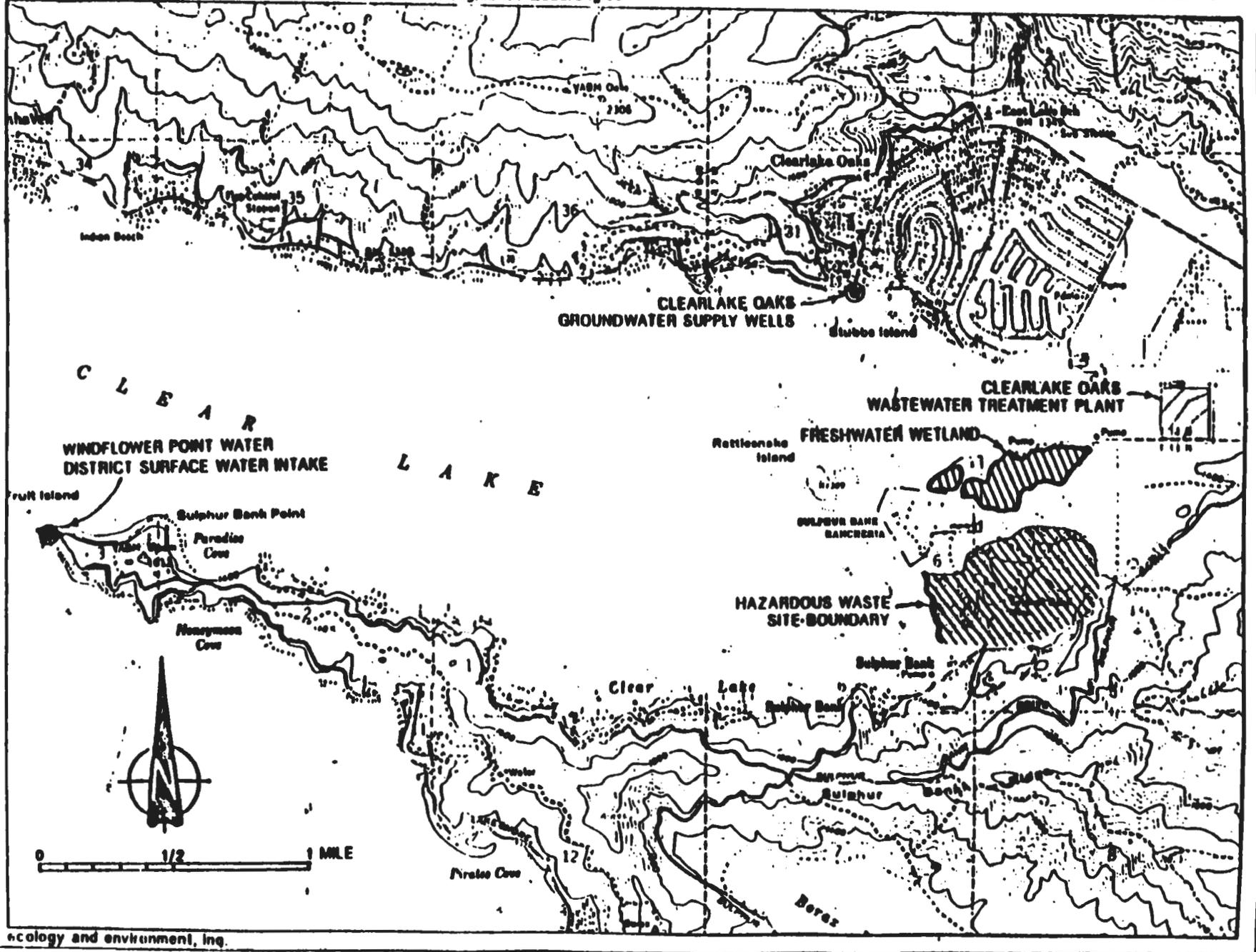
The Sulphur Bank Mercury Mine (SBMM) is located on the eastern shore of the Oaks Arm of Clear Lake, located in Lake County, California (Figures 1 & 2). The surrounding area is largely rural; the community of Clearlake Oaks (population 2,677) lies approximately 1/2 mile across the lake to the north of the mine site; the larger town of Clearlake (population 15,200) lies approximately 5 miles to the south. The Elem colony of Pomo Indians is located immediately to the north of the site, a group of residential homes are located just south of the mine, along Sulphur Bank Point.

Clear Lake is the oldest and largest fresh water body lying entirely within California, and supports a highly productive commercial and sport fishery. Clear Lake is classified as a highly eutrophic lake, which supports large algal blooms during the summer months. Elevated mercury levels in Clear Lake were first detected in 1970 by the California Department of Health Services (DHS). Since that time, hundreds of samples from fish and waterfowl tissues and water and sediment samples have been collected near the SBMM site and elsewhere in Clear Lake. The highest mercury levels found in Clear Lake were in the bottom sediments of the Oaks Arm, near the Sulphur Bank Mine. Mercury levels in Clear Lake fish often exceed the U.S. Food and Drug Administration (FDA) and National Academy of Sciences (NAS) guidelines for human consumption. The highest mercury levels tend to be found in fish caught in the Oaks Arm of the lake. The Sulphur Bank Mine has been identified as the most significant source of mercury contamination entering the Oaks Arm.

The Sulphur Bank Mine, inactive since 1957, was one of the largest mercury producers in California and has been considered one of the world's most productive mineral deposits clearly related to hot springs (White & Roberson, 1962). The Sulphur Bank Mine is situated at the intersection of several regional faults and associated shear zones which serve as avenues for upward flow of hot mineralizing water and gas. Prior to mining, the ore body consisted of cinnabar (mercury sulfide, HgS) geothermally precipitated along fault lines, in rocks immediately below the water table. As the gasses produced by the springs rose above the water table the mercury content of the ore decreased, and elemental sulphur was deposited just below and at the ground surface.

The mine site consists of approximately 120 acres of tailings and waste rock and an unlined pit (Herman Impoundment) which is filled with acidic water (pH 3) to a depth of up to 90 feet. The mine tailings and waste rock were disposed in the Oaks Arm of

SOURCE : Base from USGS Clearlake Oaks and Clearlake Highlands Quadrangles



ecology and environment, inc.

FIGURE 2
TOPOGRAPHICAL MAP

the Lake along 1,320 feet of shoreline. The Herman Impoundment covers approximately 23 acres and is located 750 feet upgradient from the lake. (Figure 3)

2.2 History of Mine Operations

The Sulphur Bank ore deposit was first discovered in 1857 by Dr. John Veatch of the California Borax Company. California Borax Company filed a mining claim on the ore deposit and began removing the sulphur from surface pits in 1865. The sulphur ore was hauled away in rail cars to a refinery where the ore was heated to a liquid state to drive off impurities, then cooled and shipped. Mining operations ceased in 1871 when market prices dropped and increasing cinnabar contamination increased the refining costs. Approximately 1,000 tons of sulphur were produced during this period.

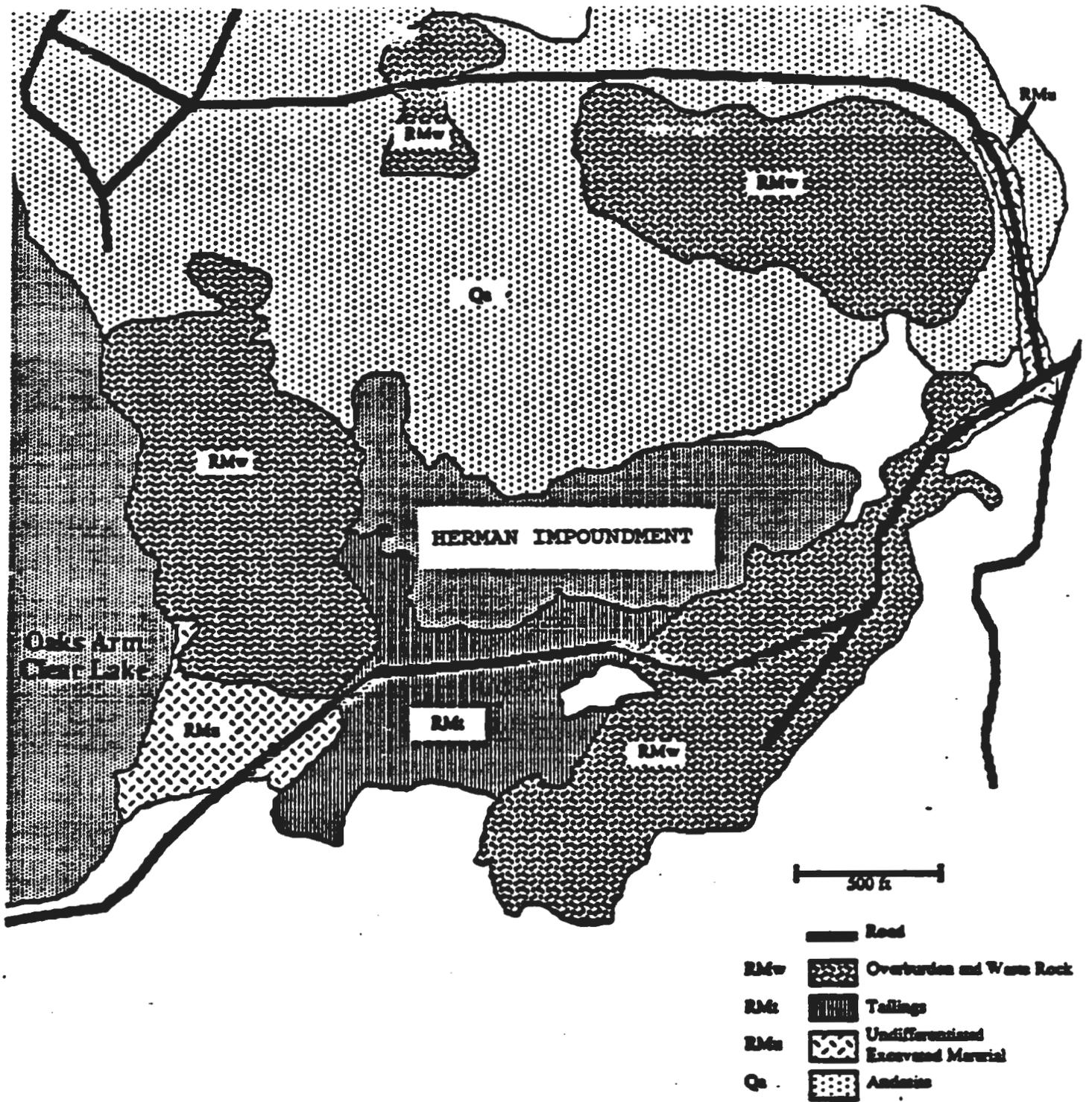
In 1872 California Borax Company reopened the mine for the production of mercury ore. The ore was mined from the Herman Shaft which was sunk to the 950 foot elevation (approximately 450 foot depth). The ore was heated with a fluxing agent in a Knox Osborne/Scott furnace to vaporize the mercury, which was drawn off, collected and cooled to a liquid state. Approximately 3200 tons of mercury were produced by California Borax by the time their operations ceased in 1883.

Sulphur Bank Quicksilver Mining Company resumed mine operations in 1887, sinking two new shafts: the Diamond shaft sunk to elevation 1140 feet, and the Babcock shaft to elevation 1210 feet. Approximately 400 tons of mercury were recovered by the time operations ceased in 1897.

Empire Consolidated Mining Company assumed ownership in 1899 and operated until 1906. The three previous shafts caved in; Empire Consolidated sank the Empire shaft to the 1110 foot level, and the Parrot shaft to the 1230 foot level, producing about 20 tons of mercury. Underground mining operations ceased in 1905 due to extreme heat and gas.

In 1915 to 1918, Sulphur Bank Association of San Francisco resumed mining operations using open pit mining techniques. They replaced the old Knox-Osborne/Scott furnace with a new rotary furnace. 80 tons of mercury were produced during a three year period.

Bradley Mining Company began open pit mining at the site in 1927, under a lease from the G.T. Ruddock Estate. They also sunk two new shafts, which caved by 1944. With the introduction of power shovels and blasting techniques, 1200 tons of mercury were produced.



Source: Humboldt State University - Abatement and Control Study

FIGURE 3

SULPHUR BANK MERCURY MINE
SITE GEOLOGY

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In 1945, following the end of World War II, Bradley Mining Company ceased operations, allowing the mine pit to fill with rainwater and run-off, forming Herman Impoundment. Bradley Mining Company eventually assumed ownership of the mine and ten years later, in 1955, Bradley Mining Company drained the mine pit and resumed open pit operations, producing 120 tons of mercury during the final production period. Mine operations ceased in 1957, and the mine pit again filled with water, forming the existing Herman Impoundment.

An estimated 4400 to 7000 tons of mercury were removed from the site, considering furnace losses and residual left behind in tailings and waste rock. Over 1,250,000 tons of material were estimated to have been removed, processed and disposed during nearly a century of mining activity.

2.3 Regulatory Status: Regulatory Enforcement and Investigations to Date

Until the final NPL listing in August 1990, the Central Valley Regional Water Quality Control Board (RWQCB) was the lead regulatory agency at SBMM. Bradley Mining Company (BMC), the current property owner, which conducted open pit mining activities at the site during the last two productive periods (1922-1944 and 1955-1957) is the only surviving potentially responsible party identified to date.

Hundreds of fish tissue samples were collected by the California Department of Fish and Game (DFG) during the late 70's and early 80's which were found to contain elevated mercury levels in edible tissue. Growing public and regulatory concern led to the formation of the Clear Lake Mercury Task Force in 1983, which consisted of representatives from the California Department of Health Services (DHS), RWQCB, DFG, Elem Indian Reservation and several other county and local concerns. DHS conducted toxicological studies concerning the elevated mercury levels in Clear Lake fish, summarized in two reports: Methyl Mercury in Clear Lake Fish: Guidelines for Fish Consumption (May 1986) and Methyl Mercury in Northern Coastal Mountain Lakes: Guidelines for Sport Fish Consumption for Clear Lake (April 1987). In May 1986, DHS issued public health advisories recommending restrictions on consumption of Clear Lake fish, which have been incorporated in the California Sport Fishery Regulations for each subsequent year.

Under the supervision of the RWQCB, Bradley Mining Company's consultant, Columbia Geoscience, has conducted several studies of the SBMM site. In 1985, they completed a preliminary site assessment. Under the Toxic Pits Cleanup Act (TPCA), BMC was re-

quired to conduct a study of the contaminants in Herman Impoundment, which was completed in 1987. In December 1989, DHS determined that the bottom sediments of the Herman Impoundment might not be considered a hazardous waste under state law, as long as they remain in place. However, if removed, the sediments would be classified as a State-regulated hazardous waste. DHS indicated that the erosional sediments from the mine tailings might also be classified as a hazardous waste under state law, but more information would be required to be certain.

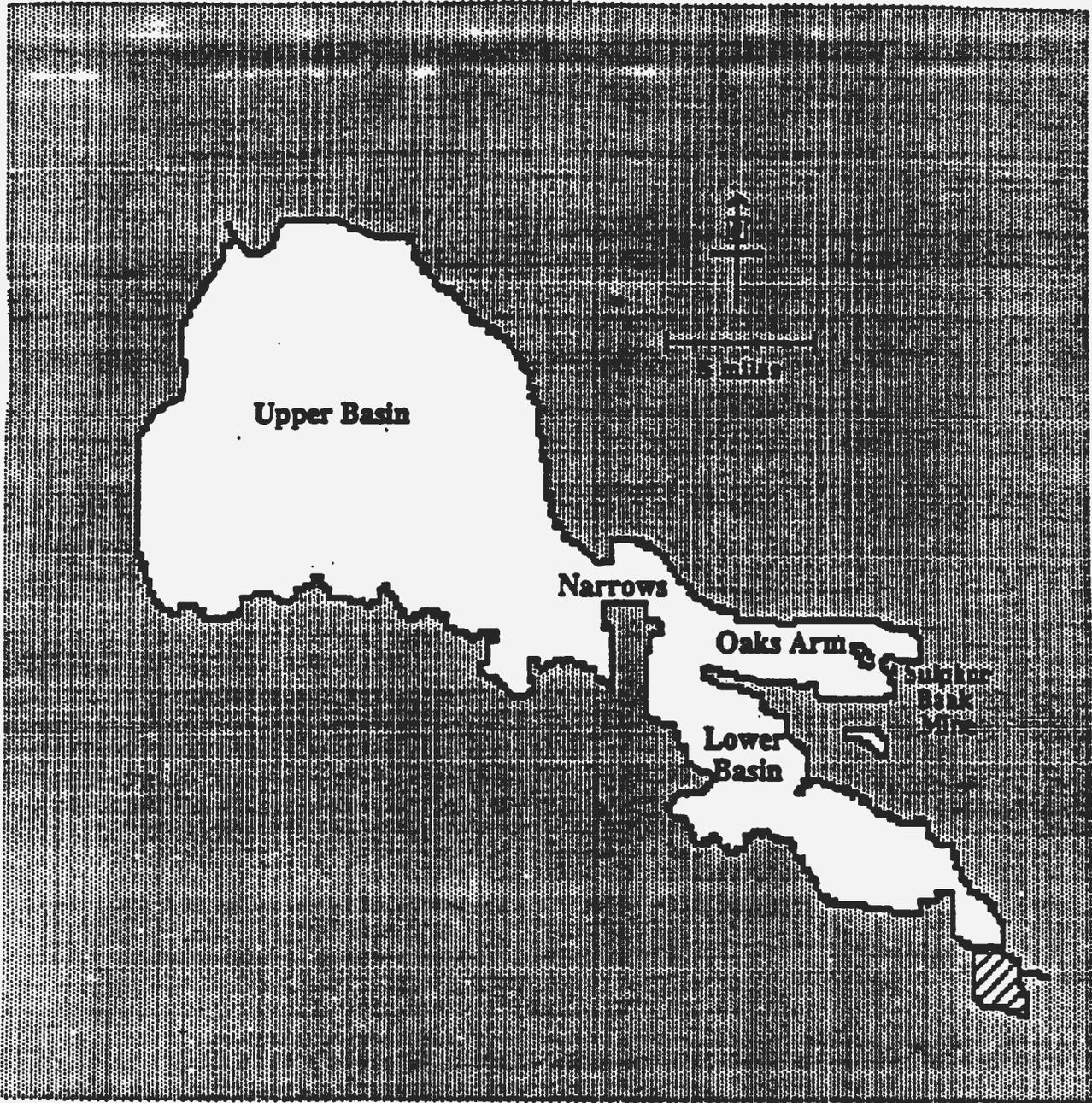
Columbia Geoscience completed Phase I of the Hydrogeological Assessment Report (HAR) in late 1988, addressing the on-site ground water contamination. As a part of this study, several on-site groundwater wells were installed, water samples were collected, and field tests were conducted to determine aquifer characteristics. The HAR study includes an on-going groundwater monitoring program; Columbia Geoscience submitted the Phase II and Phase III reports in 1989 and 1990.

Additionally, under a contract with the RWQCB, Humboldt State University completed the Abatement and Control Study: Sulphur Bank Mine and Clear Lake in January 1990. The study identified the SBMM as the primary source of mercury contamination of Clear Lake and proposed methods to control further mercury inputs into the lake. Several abatement strategies were proposed to control both the erosion of waste piles and to address the contaminated mine sediments already present in Clear Lake.

Following the completion of the Abatement and Control Study, the RWQCB issued Waste Discharge Requirements (WDRs) to Bradley Mining Company in February 1990 to address the erosion from the mine site. The WDRs do not address the problem of the contaminated lake sediments. Under the WDRs, Bradley Mining Company will be implementing erosion control measures over a 5 year period. EPA will review and comment on Bradley Mining Company's submittals to the RWQCB, and oversee the work to be performed under the WDRs. EPA's Remedial Investigation and Feasibility Study will be to characterize the potential threats posed by the SBMM site upon human health and the environment, and to examine the need for further remedial action.

3.0 Site Physical Setting

The Sulphur Bank Mine is located on the eastern shore of the Oaks Arm of Clear Lake, approximately 1.5 miles south of the community of Clearlake Oaks in Lake County, California. The mine is associated with naturally occurring geothermal hot springs which have deposited various minerals at the site for thousands of



Source: Humboldt State University - Abatement and Control Study

FIGURE 4

MAJOR SECTIONS OF CLEAR LAKE

years. The following sections present a summary of what is known about the site physical setting and the relationships between the lake, the geothermal hot springs, and the mine site.

3.1 Physiography

The Sulphur Bank Mine property occupies approximately 203 acres of land adjacent to the shore Clear Lake. The lake is naturally occurring and lies in a valley formed by a complex structural depression surrounded by mountains. Clear Lake is at a current elevation of about 1320 feet above mean sea level (MSL) and the surrounding mountains vary in elevation from 2000 to 4600 feet above MSL. The lake is 18 miles long, covers an area of about 68 square miles, and is the largest freshwater lake entirely within California. Clear Lake consists of an approximately circular northern main basin called the Upper Arm with two southern narrow arms, the Lower Arm and the Oaks Arm (Figure 4).

Communities surrounding the Sulphur Bank Mine include Clearlake Oaks, residential homes located along Sulphur Bank Point, and the Elem colony of the Pomo Indians adjacent to the Sulphur Bank Mine. Many recreational resorts and communities are located on the shores of Clear Lake. Lake water is used for recreational water sports, fishing, domestic purposes, and agricultural irrigation. Important economic activities in the Clear Lake area include cattle and sheep ranching, fruit orchards, recreational resorts, forestry harvesting, and mining. Clear Lake is ranked as one of California's most productive sports fisheries and is the only lake in California to support a commercial fishery.

3.2 Climate

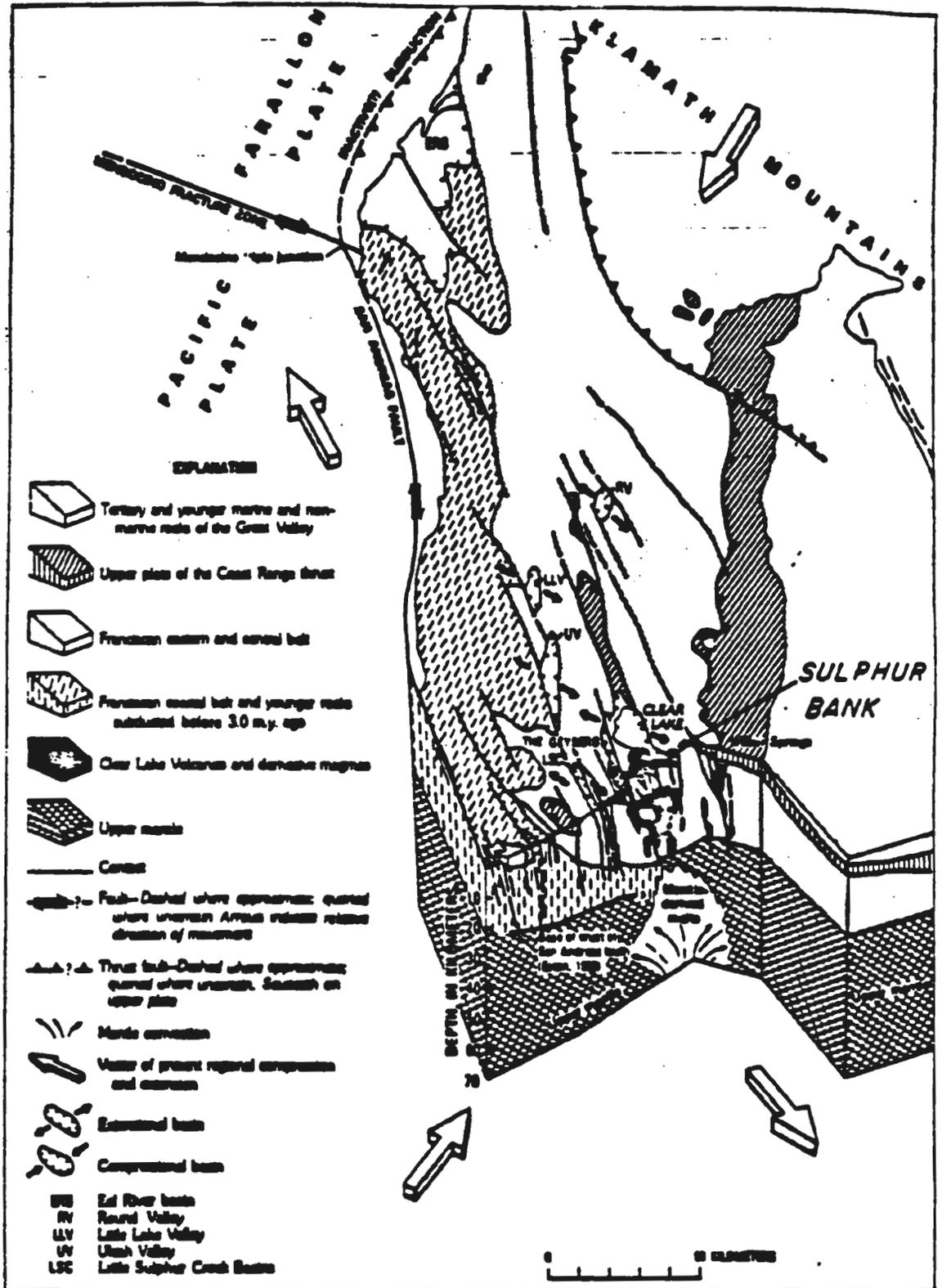
The climate and vegetation of the Clear Lake area is typical of Mediterranean climates. Moderate to heavy annual precipitation can locally exceed 100 inches in the mountains and can be as low as 20 inches in the Clear Lake basin. The mean annual precipitation at the Sulphur Bank Mine is estimated to be 24 inches, with 80% of the rain falling between the months of November and March. Snow is common in the mountains above the 3,000 foot elevation. The mean annual lake evaporation is estimated to be 48 inches. Mean monthly precipitation usually exceeds mean monthly evaporation from November through February. Mean annual temperatures for the Clear Lake area are about 60 degrees Fahrenheit, with summer temperatures ranging above 100 degrees Fahrenheit and winter temperatures below freezing.

Vegetation patterns are affected by climate, elevation, and soil type. Grassland, scrub oak, stands of cypress, manzanita, and other chapparral-type plants are distributed between the lowlands and moderately high ridges. Evergreen conifers and some deciduous plants, such as dogwood, are most common in the higher elevations and often are specific to soils developed on certain rock types, such as serpentine and rhyolite. Prevailing winds are from a northwesterly direction. Air pollution is not a common problem at the site.

3.3 Regional Geology

The Clear Lake Area is located in the northern portion of the Coast Range geomorphic province. Clear Lake is approximately 60 miles east of the San Andreas Fault at the margin of the Pacific and North American Plates. The Coast Range is predominated by north west-trending faults and shear zones related to right-lateral stress of the San Andreas Fault system. Clear Lake is generally fault bounded and situated in a subsiding structurally controlled depression. The structure in the Clear Lake area is interpreted as a local development of the overall structural pattern of the San Andreas Fault system, overprinted by local deformations related to active volcanism. The subsiding Clear Lake basin is thought to be an extension of a graben structure related to movements along the San Andreas Fault system. The late Cenozoic history of Clear Lake is characterized by faulting and volcanic activity.

Bedrock in the Clear Lake basin consists of the structurally broken and complex group of rocks known as the Franciscan Formation. These rocks were formed approximately 65 million years ago during the Cretaceous time period when the sea floor in the Pacific Ocean was subducted beneath the North American continental plate. Sediment and rock scraped from the top of the descending Pacific plate, accumulated along the margin of the upper North American plate, and formed the Franciscan Formation. The Geysers-Clear Lake area has many occurrences of geothermal activity believed to be related to a shallow magma source defined by geophysical evidence. The shallow magma chamber in this area is also thought to be related to the subduction of the Pacific plate beneath the North American Plate. The shallow magma chamber is located within and below the Franciscan Formation which acts as a cap rock to contain the magma. Geothermal activity is evidenced in the surface geology where the Franciscan Formation is thin or fractured and the magma chamber protrudes near the surface. Commercial geothermal power plants are currently operating near Cobb Mountain and the Geysers steam field located about 15 miles southwest of Clear Lake.



Source: McLaughlin, USGS Professional Paper 1141 (1981)

FIGURE 5

MAJOR CRUSTAL FEATURES OF NORTHERN CALIFORNIA AND THEIR RELATION TO EMPLACEMENT OF MAGMA BENEATH THE GYESERS-CLEAR LAKE AREA

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surface. Commercial geothermal power plants are currently operating near Cobb Mountain and the Geysers steam field located about 15 miles southwest of Clear Lake.

3.4 Regional Hydrogeology

There is relatively little background information available on the regional hydrogeology of the Clear Lake area and the site hydrogeology has not been fully characterized. The regional ground water flow system primarily consists of relatively shallow ground water aquifers which flow down from the surrounding mountains into Clear Lake. It is believed that there is little ground water seepage lost from Clear Lake because the entire lake area is underlain by the impermeable, non-water bearing, Franciscan Formation. The regional ground water flow direction in the vicinity of the site is believed to be towards the North from the steep mountains towards Clear Lake.

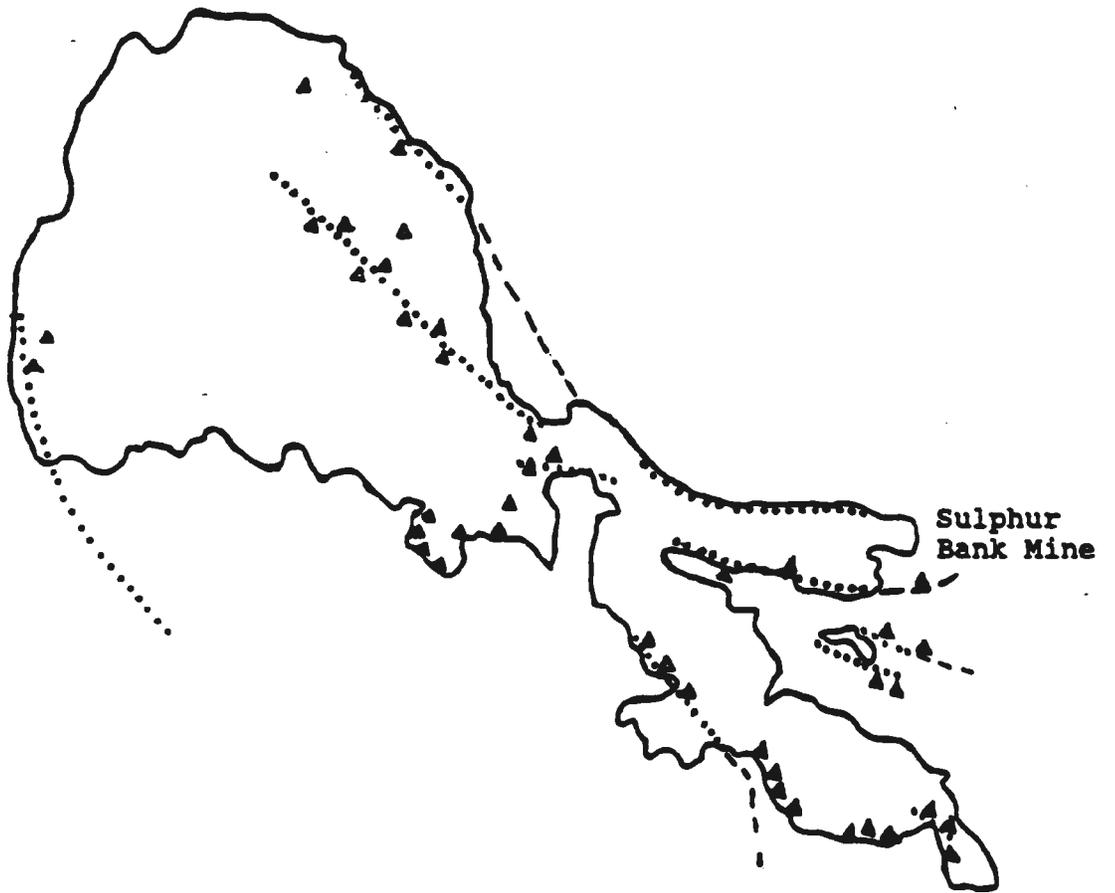
The U.S. Geological Survey has mapped numerous hot springs throughout the Clear Lake area; many of them discharge directly into the lake. (See Figure 6)

3.5 Site Geology

The geology of the Sulphur Bank Mine has been well documented in published literature. In general, the Herman Impoundment area is the center of a pipeline zone of hydrothermal alteration where three faults and shear zones intersect. Geothermal fluids moving upward along the faults altered the existing rock units and deposited various minerals. The original appearance of the deposit was described by Veatch who discovered it in 1856. The "hill of white powder" consisted of altered lava impregnated with abundant native sulphur. Hot vapors and sulphurous fumes escaped from cracks and fissures, and small springs rich in boric acid emerged from the south base of the hill.

Prior to the first mining activity in 1856, the Sulphur Bank area consisted of hot springs and gas vents surrounded by thick deposits of native sulphur in a nearly pure form. As mining activities proceeded deeper and the water table was approached, the sulphur decreased and cinnabar became abundant. The principal ore bodies were at or below the water table and consisted of cinnabar, marcasite, pyrite, dolomite, calcite, quartz, metacinnabar, and stibnite.

There are four major rock types present at the site. The oldest rocks are metamorphic sandstones and shales of the Franciscan Formation of late Mesozoic age. These are overlain unconformably by lake sediments and landslide debris of late Pleis-



Adapted from USGS Map MF-271, Sims & Rymer 1976

FIGURE 6

APPROXIMATE LOCATIONS OF GASEOUS SPRINGS
AND ASSOCIATED FAULTS IN CLEAR LAKE

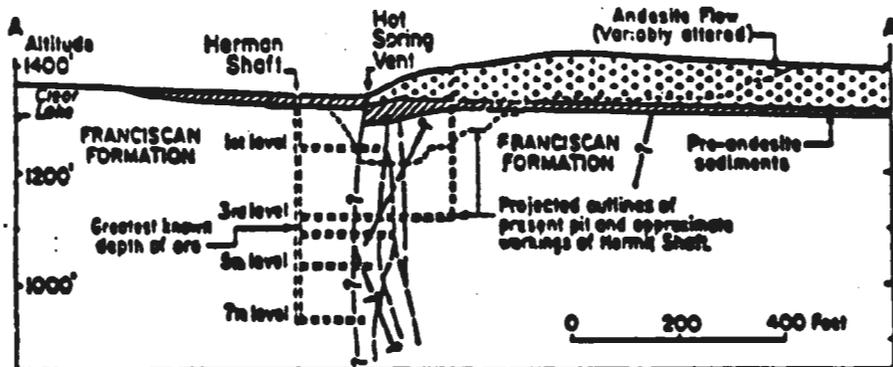
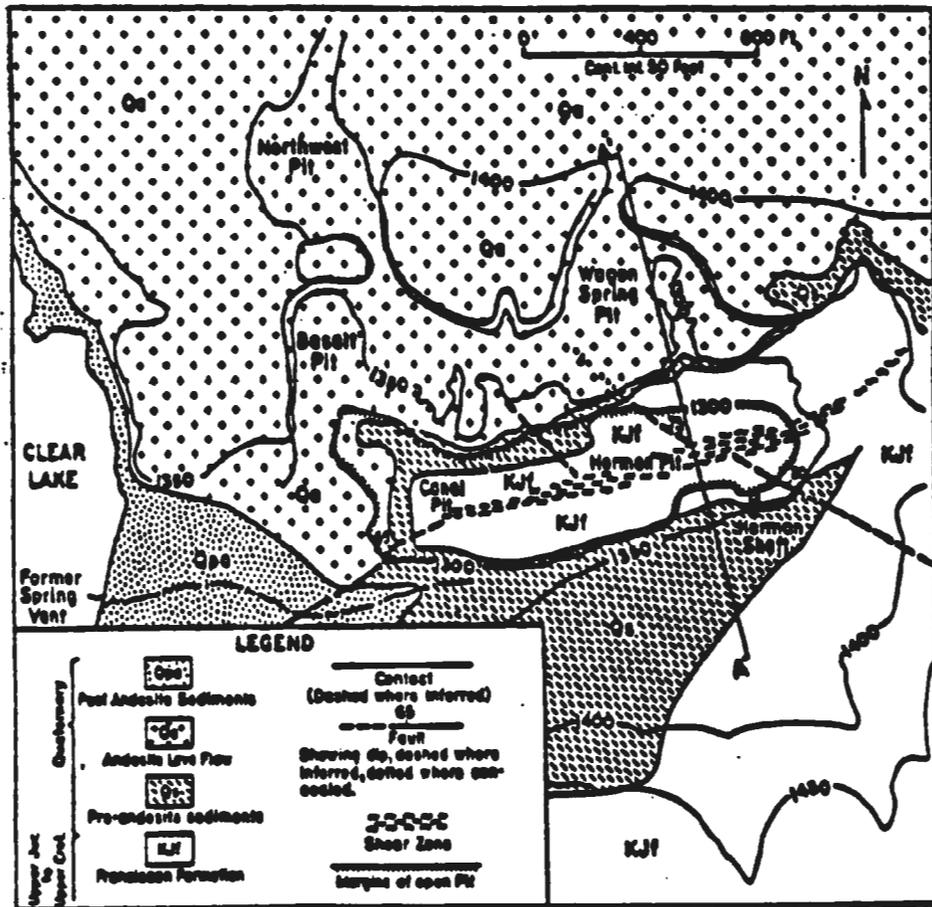
site are thin, usually less than 30 centimeters, acidic, and generally derived by residual weathering of natural rock and mine waste rock. The four major rock types are described below:

Franciscan Formation - In the Sulphur Bank area the Franciscan Formation is composed of contorted beds of graywacke and black shale with local chert-bearing zones. Evidence of low-grade metamorphism is present throughout the formation. In the eastern portion of the mine area and where the formation crops out at the surface in the western part of the mine, kaolinite/halloysite and hydrous sulfate alteration of the Franciscan rocks is observed. These white zones of alteration are often associated with the smell of sulphur-bearing gas and no vegetation is growing on these rocks.

Lake Sediments and Landslide Debris - This grouping of sediments generally consists of two major units. The uppermost unit is a poorly bedded conglomerate and breccia, with many lenses of cross-bedded sandstone and other beds that are dominated by silt and sand. The conglomerates and breccias consist of blocks of sandstone and shale derived from the Franciscan Formation, in a shaly or sandy matrix. The angularity of these fragments suggests a landslide origin for these sediments. Underlying the coarser sediments is a thick section of blue-gray lake sediments consisting mainly of clay with minor silt and sand. Drilling near the site encountered about 60 feet of blue-gray clay. The entire grouping of lake sediments and landslide debris is as much as 200 feet thick in the south-central portion of the mine area.

Augite Andesite Lava Flow - An augite andesite lava flow overlies the lake sediments. It mantles the area of about one square mile above lake level and averages close to 100 feet in thickness. The fresh lava is dark gray with irregular vesicles that are commonly more abundant in the upper part. The upper bleached zone is generally glaringly white without prominent megascopic structure. In places it is in sharp contact with the underlying boulder zone, but elsewhere the contact is gradational through a few feet. The bleached zone consists predominantly of opalized andesite, best explained as a product of attack by sulfuric acid, and corresponding to the near surface zone of bleaching in the older rocks.

Post Andesite Sediments - The Andesite flow is overlain by sands and gravels of possible lacustrine origin as much as 50 feet above the lake level. Two small patches of coarse clastic sediments as much as 75 feet above lake level were also described as lacustrine deposits. The origin and age of these rocks is uncertain and has been debated.



Source: White & Roberson, 1962

FIGURE 7

GEOLOGIC MAP AND SECTION A - A'
SULPHUR BANK MERCURY MINE

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The mineral deposit at the the Sulphur Bank Mine is situated at the intersection of three sets of regional faults and shear zones which serve as conduits for upward flow from depth of hot mineralized water and gas. Three sets of faults intersect at the mine: 1) The northwest trending fault associated with the ore body and soil mercury anomalies; 2) A set of two steeply dipping, northwest trending faults exposed in the mine workings; and 3) the fault or shear zone delineated by as east-west line of gas leakage. The faulting and the associated discharge of mineral bearing geothermal fluids which formed the ore deposit postdates the augite andesite lava flow.

The hydrothermal alteration and mineralogy of the ore and gangue are controlled to a major extent by the water table. The upper part of the augite andesite flow probably has always been above the water table and is extensively leached by sulfuric acid formed by oxidation of hydrogen sulfide in the hydrothermal fluid. Waters deep in the system appear to be neutral, but near the water table they become acidic because of mixing with supergene nonmeteoric waters containing sulfuric acid. Native sulphur was deposited at the surface down to the water table. The main ore deposit was restricted to depths near or below the inferred position of the water table prior to mining. Rich ore bodies were found as veins and disseminated masses in the lower part of the andesite and in the lake and landslide deposits immediately below the contact. Some commercial grade ore was deposited in the Franciscan Formation but in decreasing concentrations with depth.

The original location of geothermal springs and gas vents on the site have been altered or covered up by mining activities. It is likely that mining operations have altered the hydrothermal system which previously existed at the site.

3.6 Site Hydrogeology

The major aquifer at the site is located within the lake sediments and landslide debris deposit of late Pleistocene age. The occurrence of ground water at the site generally corresponds with the contact between the lake sediments and landslide debris deposit and the overlying augite andesite flow. The occurrence of ground water in the augite andesite flow and the interconnection between the aquifer and Clear Lake is unknown. The shallow aquifer is unconfined to semiconfined and is first encountered at depths of less than 1 foot near the shore of Clear Lake to 80 feet below the ground surface further away from the lake. The shallow aquifer includes fractured rock of low permeability and lake sediments of moderate permeability consisting of silt, sand, a gravel alluvial deposits with thin clay layers. Wells screened in the aquifer generally have a low yield which may be attributed

to a low hydraulic conductivity and because the aquifer averages only 75 to 100 feet in thickness. The permeability of specific layers in the alluvial deposits is highly variable and the extent to which individual layers are interconnected is unknown. It is also likely that ground water exists within the waste rock stock piles. The unsaturated zone at the site has not been characterized. Also, the elevation of the ground water at the site has been altered by mining activity and the existence of Herman Impoundment.

The presence of Herman Impoundment clearly alters the direction of regional ground water flow and most likely creates a ground water mound anomaly. Previous investigations have shown that ground water flows from the higher elevation Herman Impoundment to the lower elevation Clear Lake. This flow direction is confirmed by ground water surface elevations and pH gradients, measured in three monitoring wells between Herman Impoundment and Clear Lake. Other monitoring wells have been drilled at the site but their present condition and locations are unknown. The ground water flow characteristics on the north, south, and east sides of Herman Impoundment are unknown.

Local geothermal waters flow upward from depth along fault zones and are responsible for the formation of the Sulphur Bank Mine deposit. The hot geothermal waters have a unique metamorphic origin and generally follow a fault zone located at the bottom of Herman Impoundment, where previous mining activities and mineral deposits were concentrated. The shallow water table caused problems during early mining operations and has been altered by the formation of Herman Impoundment. The temperature and water chemistry of the shallow aquifer varies considerably over the site. Water temperatures as high as 400 degrees Fahrenheit have been measured at the site during previous geothermal investigations.

3.7 Surface Water

The two major surface water features related to the site are Herman Impoundment and the Oaks Arm of Clear Lake. Some small seasonal ponds and springs are located in and around the mine site. Surface water drainage from the site is to the Herman Impoundment and the Oaks Arm of Clear Lake. The majority of surface drainage at the mine site drains into Herman Impoundment. The water level in Herman Impoundment is several feet higher than the level in Clear Lake. Potential overflow from Herman Impoundment would drain to Clear Lake. An earthen dam was constructed on the west end of Herman Impoundment to control drainage into Clear Lake. Three small drainage areas and the surfaces of

steeply sloped tailings piles at the lake shore drain directly into Clear Lake. Parts of these tailings piles extend into the lake and are exposed to erosion from wave action.

3.7.1 Herman Impoundment

Herman Impoundment is an unlined man-made excavation which cuts through all four geologic rock units at the site including the Franciscan Formation. Herman Impoundment is a highly unique acidic water body containing elevated trace metals and standard mineral constituents. The unique geochemical character of the sediment and waters of Herman Impoundment is the result of a combination of diverse sources. These sources include discharge of natural geothermal fluids and gases, erosion of sediment from waste rock and tailings, discharge of meteoric waters in contact with waste rock and tailings, and chemical reactions with the impoundment water and the pit wall-rock. An analysis of the gasses issuing from a vent near the north shore of the pit reported 93.33% carbon dioxide, 46% methane and 0.13% (1300 ppm) hydrogen sulfide. The water in the pit contains dilute sulfuric acid and has a pH of approximately 3.0. The acid is derived from oxidation of of geothermal hydrogen sulfide gas venting into the bottom of the pit and mixing with impounded water.

The pit is approximately 90 feet deep and has a surface area of about 23 acres. The pit volume is approximately 700 acre feet. Herman Impoundment is located 750 feet east of Clear Lake. The earthen dam was constructed in 1979 at the west end of the pit to provide sufficient freeboard to withstand overflow from a 200 year flood event. Prior to construction of the dam, water from Herman Impoundment would overflow into Clear Lake seasonally and during large magnitude storm events.

Even though no perennial streams exist near Herman Impoundment, there is an area immediately surrounding the pit that contributes surface water run-off during storm events. This area is estimated to have a drainage area of approximately 88 acres, not including the surface water area of the pit, which varies from 21 to 23 acres.

Herman Impoundment is regulated under the Toxic Pits Cleanup Act (TPCA) due to hazardous levels of mercury found in the sediments. The Central Valley RWQCB maintains that the hazardous materials found in Herman Impoundment, derived principally from mining activities, represent culturally disturbed or altered substances, and are therefore subject to state hazardous waste management laws.

3.7.2 Clear Lake

Clear Lake is 18 miles long, and covers an area of about 68 square miles. Clear Lake consists of an approximately circular northern main basin called the Upper Arm with two southern narrow arms, the Lower Arm and the Oaks Arm (Figure 4). The average depth of the Upper Arm is 7.1 meters, the Lower Arm is 10.3 meters, and the deepest part of the lake is the Oaks Arm with an average depth of 11.1 meters. Previous exploration drilling investigations performed by the USGS have recorded over 350 feet of accumulated sediments in the bottom of Clear Lake.

The Clear Lake drainage basin covers an approximate area of 528 square miles (Figure 8). The main tributaries into the lake consist of seven creeks, all of which enter the northern Upper Arm. The lake drains from the south at Cache Creek on the Lower Arm. The level of lake water is controlled by a dam at Cache Creek; the lake is at a current elevation of about 1320 above MSL.

Clear Lake is classified as a highly eutrophic lake and supports seasonal algae blooms of both blue-greens and dinoflagellates. Considerable nutrient concentrations, related principally to run-off from the drainage basin, sustain high levels of algae growth. Studies have also been performed which indicate that waste water treatment facilities at Clearlake Oaks and other communities are adversely impacting lake water quality. The algae blooms often appear to be concentrated in the Lower Arm and the Oaks Arm of the lake which may be attributed to prevailing northwesterly winds that blow the algae blooms to the south and east ends of the lake. Seasonal water temperatures range between 6 and 27 degrees Celsius. The pH of the lake water is basic and ranges from 7.5 to 9.0. Thermal stratification exists only weakly and intermittently for periods of up to a week during the summer. Bottom sediments remain anoxic during the summer and the fall. The shallow lake is generally turbid because surface and bottom waters are rapidly mixed by wind induced circulation.

Three separate sub-basin drainage areas with a total surface area of 14 acres drain from the mine site directly into Clear Lake. Steeply sloped tailing stockpiles from mining operations are located adjacent to the lake shoreline and extend into the lake. The tailing piles are in contact with about 2060 feet of shoreline, and run-off from these piles also drains into Clear Lake. Large storms are capable of producing strong wave activity on the lake which results in erosion at the base of the waste piles.

3.7.3 Springs and Ponds

Submerged springs have been mapped throughout the entire Clear Lake region (Figure 6). Several small seasonal springs and ponds are located in and around the mine site. The exact number and location of all the springs and ponds is unknown but several have been identified. (Hydrogeological Assessment Report (HAR), Columbia Geoscience). The Green Pond is located within the tailings piles and is extremely acidic with a pH of 2.27. This pond acts as a retention basin for run-off from a portion of the surrounding steeply sloped drainage area.

The temperature of naturally occurring springs in the vicinity of the site is variable, and associated with gas venting. The original mineral deposit at the mine was formed by thermal springs flowing upward along faults. These springs are reported to still be actively discharging into the bottom of Herman Impoundment. Thermal springs have previously been reported at the mine site and near the lake shore but they have apparently been disrupted by mining operations or covered by tailings. It is likely that mining operations have altered the hydrothermal system that previously existed at the site.

4.0 Site Contamination Characteristics

This initial evaluation of contamination at the site is based on a preliminary review of existing data concerning the site. Data limitations of the existing data will be identified and further investigated in order to completely characterize site contamination. This evaluation includes a description of the study area and contaminants at the mine site and in Clear Lake.

4.1 Study Area

The SBMM site and surrounding areas which may be affected by site contamination are the primary focus of RI/FS activities discussed in this work plan. The SBMM property occupies approximately 203 acres of land. The study area consists of Herman Impoundment and the SBMM property, and surrounding areas which include but are not limited to, drainage areas contributing surface water run-off to the site, surface soils down-wind from mine smelting operations, the Oaks Arm of Clear Lake, the Elem Indian Colony located adjacent to the site, the community of Clearlake Oaks and other nearby residential areas. During the course of the investigation other areas may be discovered which need to be included in the study.

4.2 Herman Impoundment Water and Sediments

The major surface water feature located on the mine site is Herman Impoundment. The contamination in the Herman Impoundment has been characterized in the Herman Lake TPCA Assessment report, completed by Columbia Geoscience in 1987, under contract with the Bradley Mining Company in compliance with the requirements of the California Toxic Pits Classification Act (TPCA). The purpose of the study was to characterize the chemistry of the water and bottom sediments of the mine pit to determine if it fell within the State definition of a toxic site.

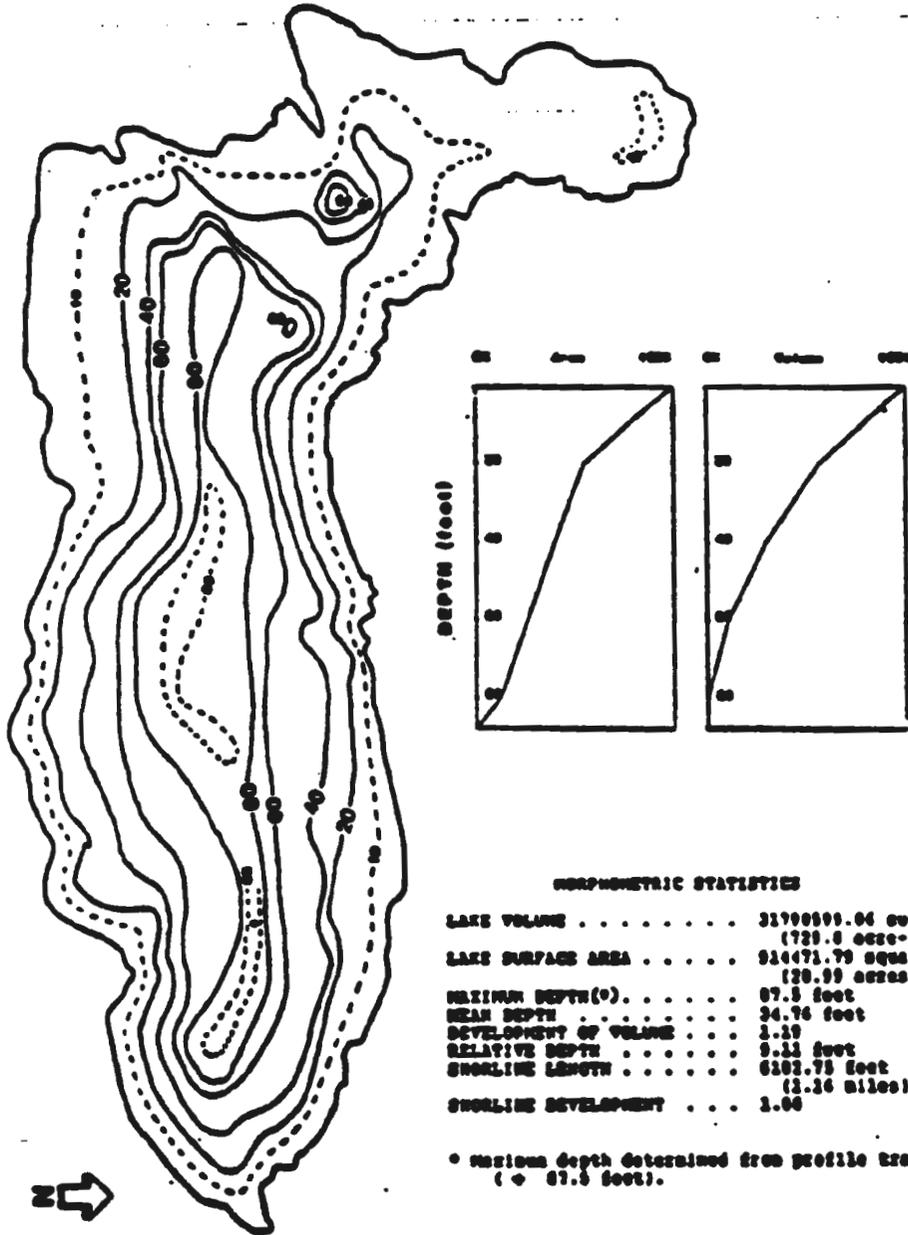
The field investigation was conducted in early November, 1987. Prior to sampling, a bathymetric survey of the mine pit was conducted using a recording fathometer along several straight-line transects. The bathymetric survey revealed a maximum bottom depth of 90 feet. Gas discharges were observed and recorded in several locations within the impoundment. (Figures 9 - 13).

Surface water temperature, pH, specific conductivity, and dissolved oxygen readings were taken from several near-shore locations. Pit sediments, thermal springs and ground water samples were collected within and adjacent to the Herman Impoundment and analyzed for metals and selected anions. The results are tabulated in Tables 1 & 2.

The TPCA report concluded that the water and bottom sediments of Herman Impoundment were below the toxic limits for all title 22 categories of the Toxic Pits Cleanup Act, except for mercury, which ranged from 9 - 46 ppm and averaged 26.33 mg/kg. (TPCA limit - 20 ppm). Bottom sediments were found to be up to 27 feet thick in some areas, have an estimated volume of 5,990,000 cubic feet, and contain an estimated 7.74 tons of mercury. Columbia Geoscience noted that the mercury concentrations observed in the pit sediments were much lower than the mercury levels observed in sediment cores taken from the Oaks Arm of Clear Lake, and elevated mercury levels occur naturally throughout the region. The major source of mercury in the pit sediments is likely associated with detrital accumulation from site surface water run-off. Less significant contributions may be attributed to pit wallrock-water reactions and precipitation from geothermal fluids entering the bottom of the pit.

The water in Herman Impoundment is very acidic with a pH of about 3.0. The source of impoundment water is mostly from infiltrating ground water and surface run-off. Pit water also contains high concentrations of sulfate, sodium, chloride, boron, and ammonia. Two filtered samples of pit water had 1.3 and 0.75 ug/l of mercury which exceed the EPA No-Adverse-Response Level (SNARL) of 0.144 ug/l and the EPA ambient Water Quality Standard to freshwater aquatic life of 0.012 ug/l. The pit water also exceeds drinking water standards for cadmium and ambient water

BATHYMETRY OF HERMAN LAKE, CALIFORNIA



MORPHOMETRIC STATISTICS

LAKE VOLUME	3190099.06 cubic feet (729.8 acre-feet)
LAKE SURFACE AREA	91471.79 square feet (20.99 acres)
MAXIMUM DEPTH(*)	87.5 feet
MEAN DEPTH	34.76 feet
DEVELOPMENT OF VOLUME	1.19
RELATIVE DEPTH	9.11 feet
SHORELINE LENGTH	6102.75 feet (1.14 miles)
SHORELINE DEVELOPMENT	1.00

* various depth determined from profile transects
(= 87.5 feet).



Depth Contour Interval 20 Feet

BRADLEY MINING COMPANY
prepared by Columbia Geoscience

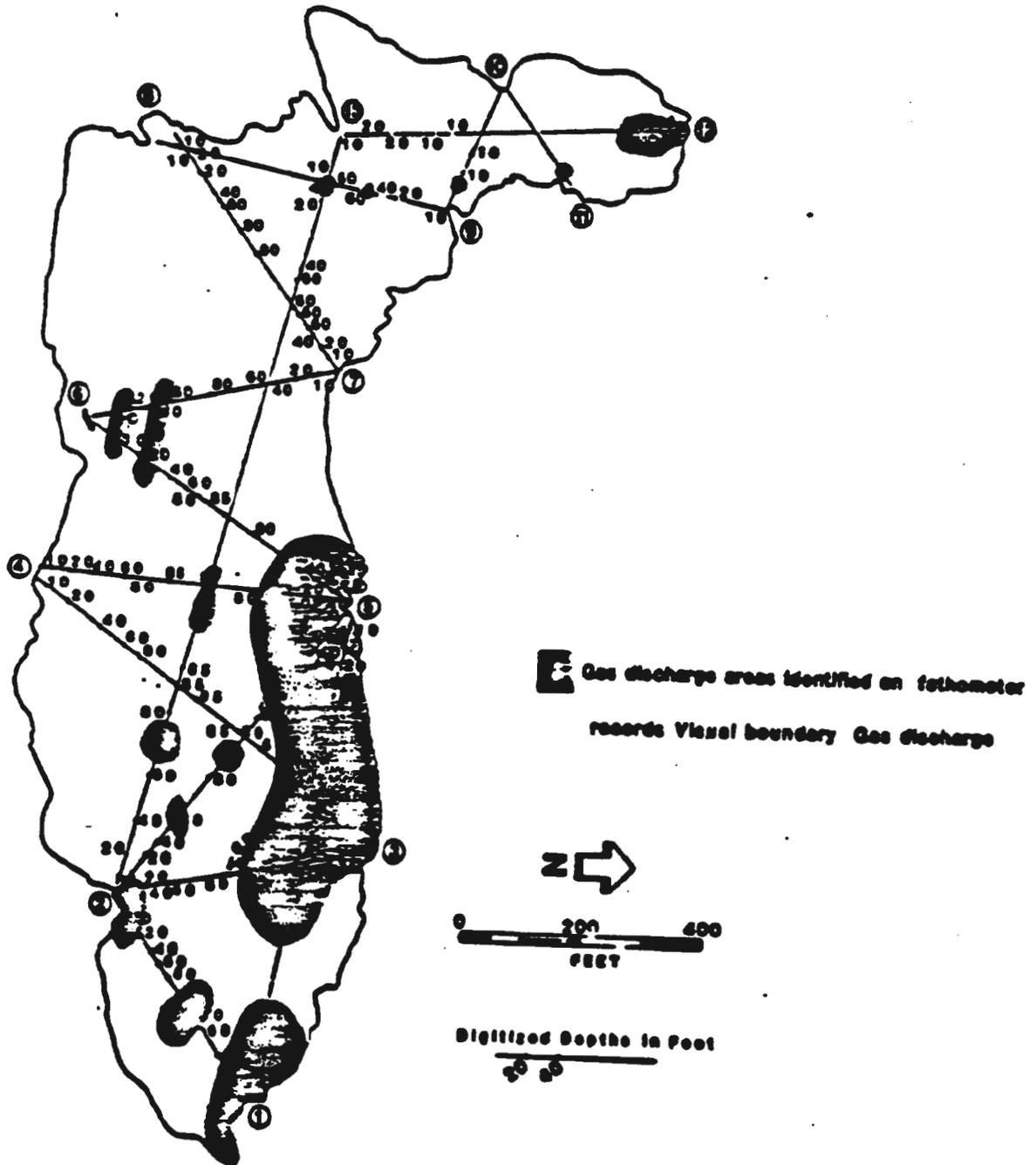
10-01-87

Source: Herman Lake TPCA Assessment, Columbia Geoscience, 1987

FIGURE 9

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GAS DISCHARGE AREAS

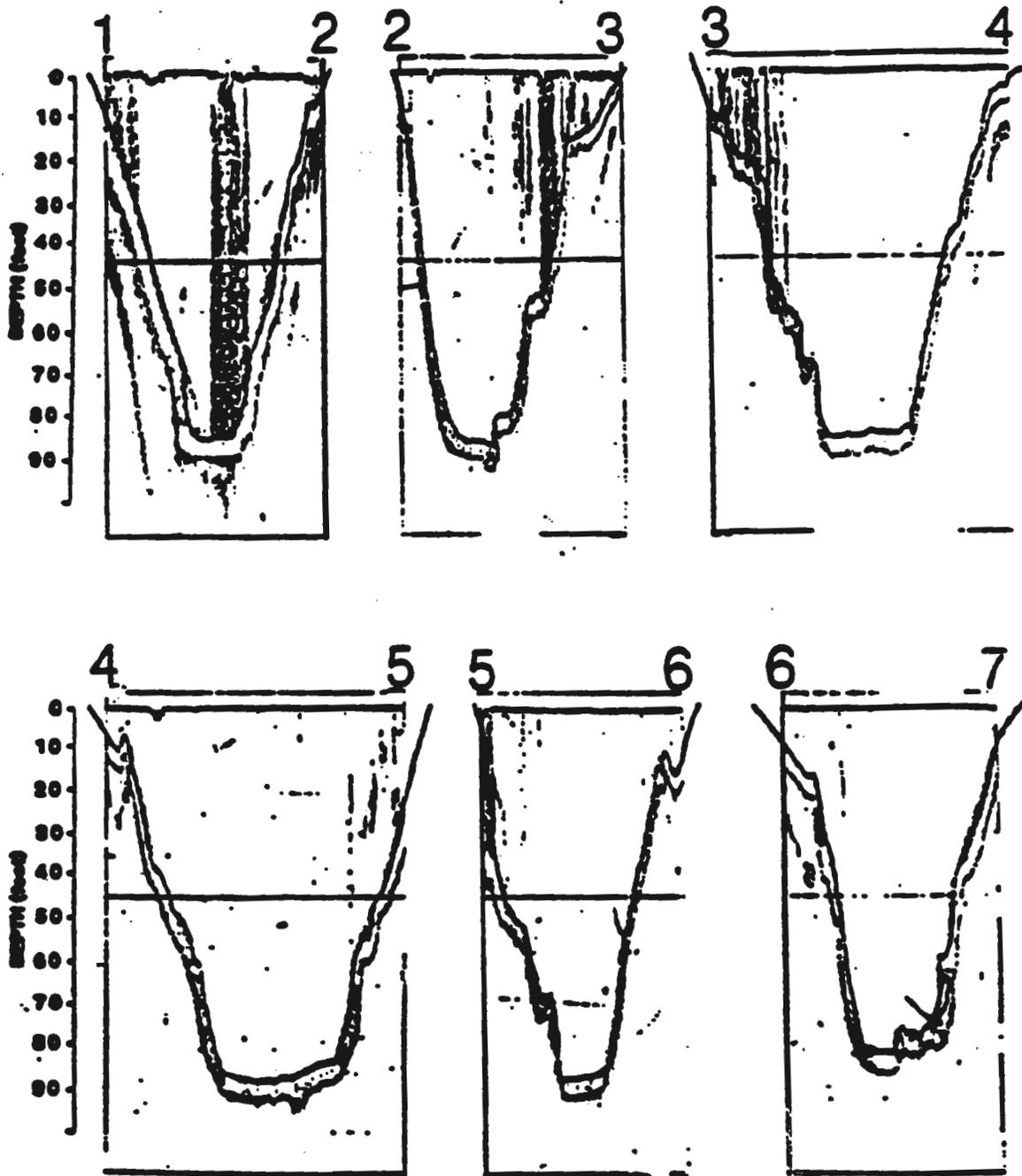


Source: Herman Lake TPCA Assessment, Columbia Geoscience, 1987

FIGURE 10

7/10

FATHOMETER RECORDS USED IN PREPARING HERMAN LAKE BATHYMETRY

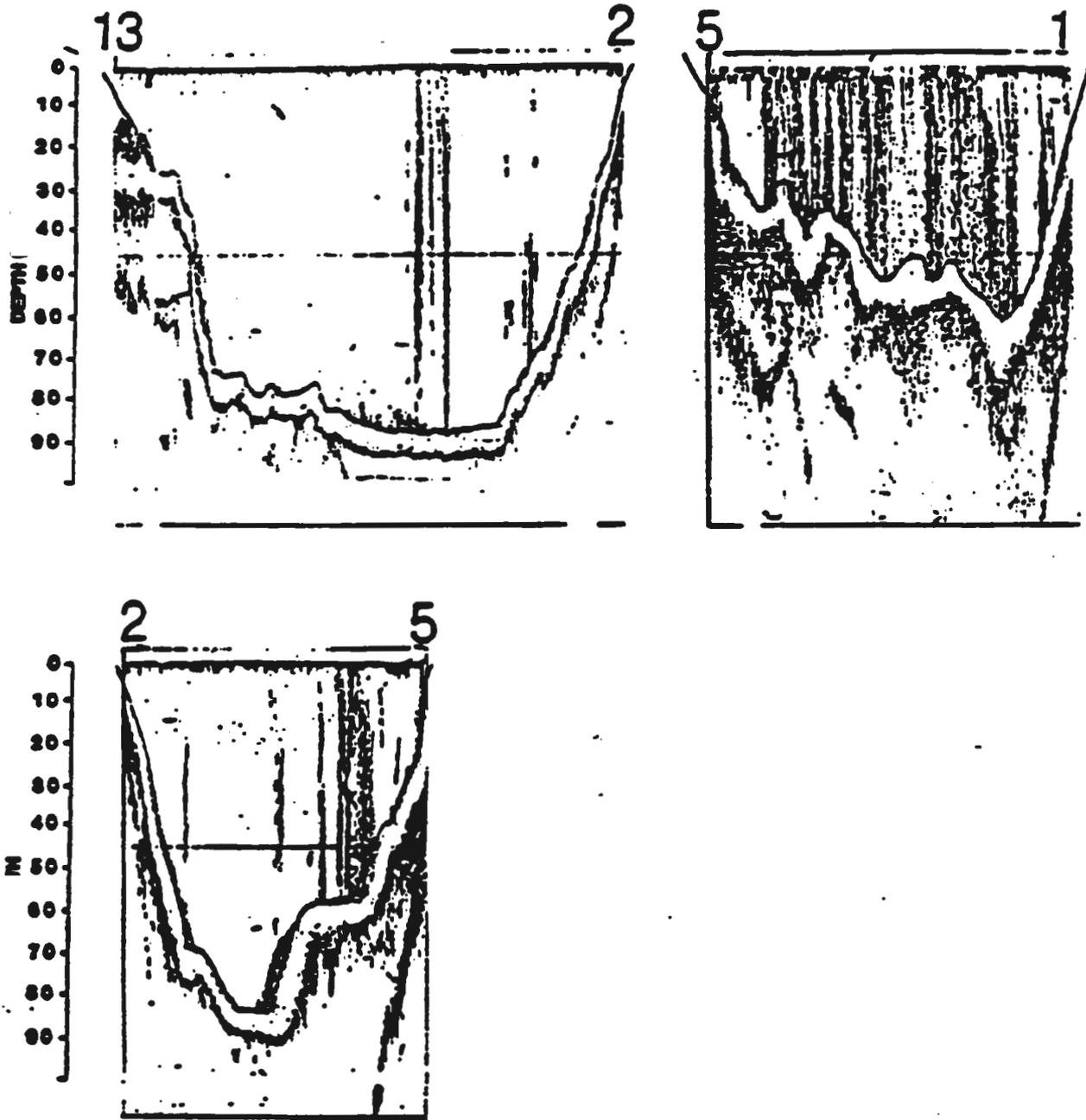


Source: Herman Lake TPCA Assessment, Columbia Geoscience, 1987

FIGURE 11

747

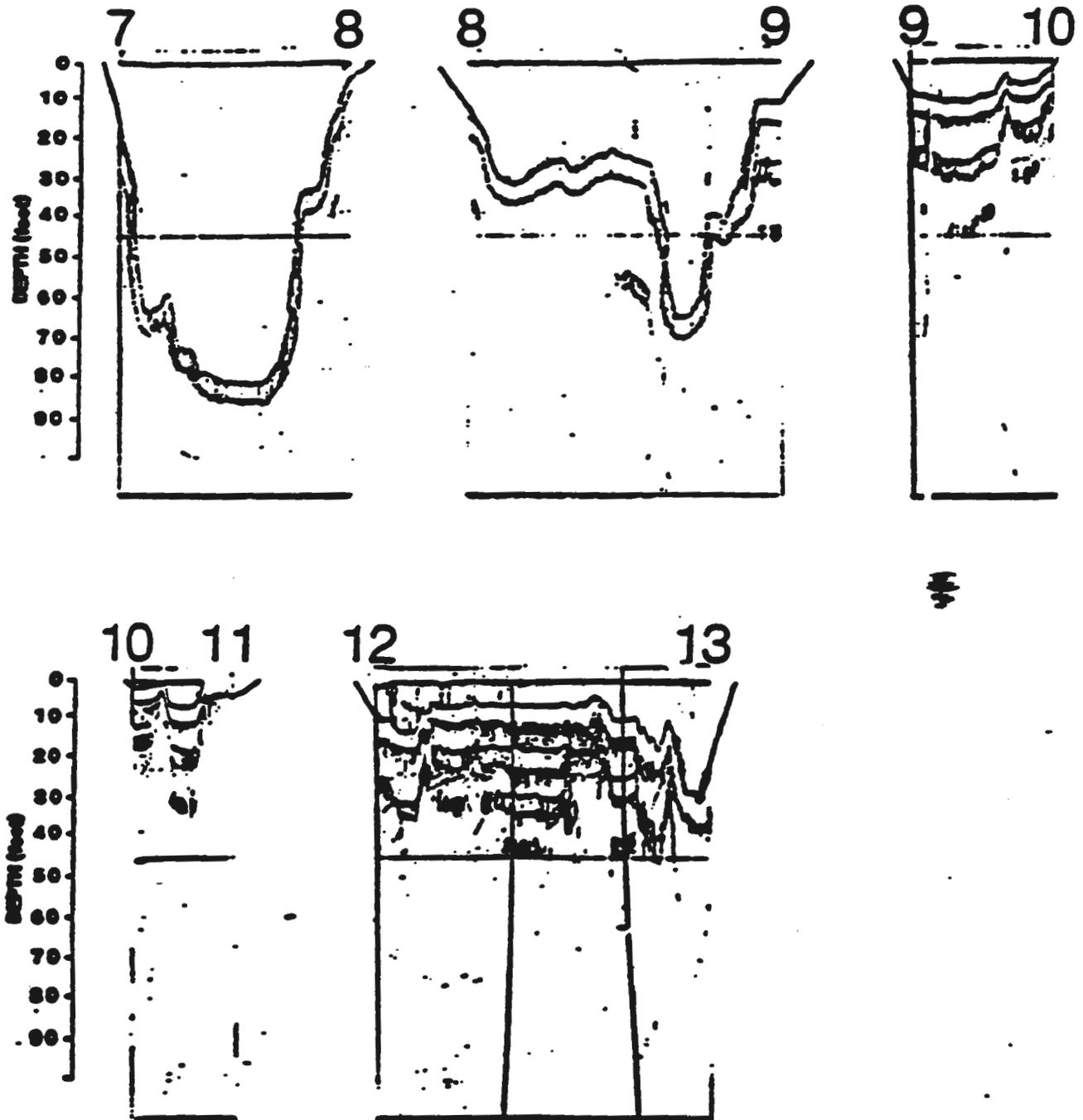
IN PREPARING HERMAN LAKE BATHYMETRY



Source: Herman Lake TPCA Assessment, Columbia Geoscience, 1987

FIGURE 12

FATHOMETER RECORDS USED IN PREPARING HERMAN LAKE BATHYMETRY



Source: Herman Lake TPCA Assessment, Columbia Geoscience, 1987

FIGURE 13

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Table -1 Chemistry of water, sediment, thermal springs and ground-water within and adjacent to Herman Lake, Sulphur Bank Mercury Mine, Clear Lake, California—1938 to 1987.
(Republished from TPCA Assessment Report, Columbia Geoscience, 1987)

REF. NO	Sample Description	Sample Date	Lab #	Depth (m)	Temp. (C)	Sp. Cond.		Field pH	Lab pH	Water in milligrams/liter; cores in milligrams/kg wet wt basis																ANIONS BY DT							
						Field (umho/cm)	Lab			CO	Al	SiO2	B	Ca	Fe	Fe2+	Li	Mg	Mn	K	NH4	SO4	SO2-	Cl	Br	NO3-N	HCO3	BR/Cl	B/Cl	K/Mg	Li/Mg	Li/Cl	
1	P2 Profile (Water)	Nov. 1, 87	2	9	19.7	6620	5600	3.02	2.6	4.8	110	33	270	180	4	47	2.2	140	13	14	520	2800	0.13	320	1.7	180	0	0.005	0.063	0.026	0.004	0.005	
2	P2 Profile (Water)	Nov. 1, 87	1	23	20.3	6540	5600	3.03	2.6	5.2	110	32	280	180	4	48	2.2	140	12	15	530	2700	0.12	270	1.7	180	0	0.006	1.037	0.028	0.004	0.008	
3	P3 Profile (Water)	Nov. 1, 87	3	13	20.0	6600	5600	-	2.6	4.7	110	31	270	180	4	47	2.2	140	12	14	510	2900	0.12	310	1.7	180	0	0.005	0.870	0.027	0.004	0.007	
4	P3 Profile (Water)	Nov. 1, 87	4	26	20.0	6600	5600	-	2.6	5.0	110	31	280	180	4	46	2.2	140	12	14	520	2900	0.13	310	1.7	180	0	0.005	0.903	0.026	0.004	0.007	
5	P4 Profile (Water)	Nov. 1, 87	5	4	20.0	6600	5600	-	2.6	5.7	110	32	260	170	44	47	2.2	140	12	14	490	2800	0.12	380	1.8	180	0	0.004	0.684	0.028	0.004	0.005	
6	P4 Profile (Water)	Nov. 1, 87	6	24	20.0	6600	5600	-	2.6	5.2	93	32	250	150	34	46	1.9	120	11	12	480	2900	0.12	290	1.6	180	0	0.005	0.862	0.025	0.003	0.006	
7	P5 Profile (Water)	Nov. 1, 87	7	5	20.0	6660	5600	-	2.5	4.9	110	31	270	170	4	46	2.2	140	12	14	500	2800	0.12	290	1.6	180	0	0.005	0.931	0.028	0.004	0.007	
8	V-HP (Water)	Aug. 19, 87	C1	6	-	-	-	-	-	-	110	-	270	180	-	47	2.1	150	12	15	490	-	-	-	-	-	-	0.835	0.030	0.004	0.006		
9	V-HP (Water)	Aug. 19, 87	M1	6	-	-	5940	-	2.8	-	-	49.9	253	159	31.2	-	-	139	-	-	408	3374	-	323	-	-	0	0.783	-	-	-		
10	NE-HP (Water)	Aug. 19, 87	C2	6	-	-	-	-	-	-	110	-	270	180	-	46	2.1	140	12	15	490	-	-	-	-	-	-	-	0.000	0.004	0.052	-	
11	NE-HP (Water)	Aug. 19, 87	M2	6	-	-	7570	-	2.4	-	-	52.0	44.2	373	333.6	-	-	186	-	-	172	7880	-	39.7	-	-	0	0.215	-	-	-		
12	Herman Pit (#71)	June 27, 76	#71	6	21.0	-	-	3.5	2.39	-	-	-	395	210	-	86	3.7	195	19	21.6	880	4430	-	205	ND	-	-	1.926	0.024	0.004	0.018		
13	P2 Profile (Core)	Nov. 1, 87	11	23	<top 30 cm	-	-	-	-	-	10000	2700	930	480	35000	46	11.0	330	18	ND	640	3100	1.00	330	ND	190	-	2.818	-	0.017	0.033		
14	P2 Profile (Core)	Nov. 1, 87	12	23	<btm 30 cm	-	-	-	-	-	7700	2100	760	570	26000	31	12.0	600	44	ND	660	3100	1.0	340	ND	210	-	2.235	-	0.017	0.035		
15	P3 Profile (Core)	Nov. 1, 87	14	27	<top 30 cm	-	-	-	-	-	3100	910	460	370	48000	230	4.8	310	67	ND	530	5700	0.69	240	ND	200	-	1.916	-	0.009	0.02		
16	P3 Profile (Core)	Nov. 1, 87	13	27	<btm 30 cm	-	-	-	-	-	7200	1400	630	290	68000	240	8.8	450	39	ND	550	6700	0.67	270	ND	230	-	2.333	-	0.016	0.032		
17	P4 Profile (Core)	Nov. 1, 87	15	25	<top 20 cm	-	-	-	-	-	3100	1400	230	190	44000	210	4.6	570	39	1200	380	4800	0.71	140	ND	140	-	1.642	1.157	0.012	0.032		
18	P4 Profile (Core)	Nov. 1, 87	16	25	<mid 20 cm	-	-	-	-	-	3400	1900	200	180	44000	140	4.7	740	48	750	300	3500	0.91	110	ND	150	-	1.818	2.633	0.015	0.042		
19	P4 Profile (Core)	Nov. 1, 87	17	25	<btm 20 cm	-	-	-	-	-	2600	1000	170	160	27000	180	4.3	660	47	700	290	4400	0.81	120	ND	170	-	1.416	2.413	0.014	0.035		
20	P5 Profile (Core 1)	Nov. 1, 87	18	5	<top 20 cm	-	-	-	-	-	3600	1500	180	270	50000	0.61	4.8	730	53	3600	590	1800	1.2	110	ND	110	-	1.636	6.101	0.008	0.043		
21	P5 Profile (Core 2)	Nov. 1, 87	19	5	<top 40 cm	-	-	-	-	-	4100	1400	190	230	25000	9.2	6.1	1200	72	1500	490	1700	1.1	120	ND	110	-	1.583	3.061	0.012	0.050		
22	SP-D (Sediment)	Aug. 19, 87	C4	6	-	-	-	-	-	-	19000	-	110	860	76000	-	16	1600	120	4000	1200	-	-	-	-	-	-	3.333	0.013	-	-		
23	SBM Well BM1 (Water)	Nov. 2, 87	P	15	-	-	8100	-	6.4	-	ND	33	15	490	1.4	0.87	0.18	210	1.2	24	1100	1.3	0.13	2100	1.5	1.1	1800	7E-04	0.007	0.021	7E-04	9E-05	
24	SBM Well BM1 (Water)	June, 1964	-	497	160	-	-	-	6.06	-	-	-	500	2	-	-	-	<1	-	-	70	770	10	-	990	ND	-	0.505	0.090	-	-		
25	SBM Well BM2 (Water)	June, 1964	-	1214	-	-	-	-	7.85	-	-	-	1300	5	-	-	-	4	-	-	25	2580	70	-	195	ND	-	6.666	0.009	-	-		
26	Bethse Well (Water)	Oct., 1938	-	-	57	-	-	-	-	-	-	-	720	11	-	-	-	0	-	-	50	1560	119	-	741	TR	507	-	0.97	0.032	-	-	
27	S-P (Water)	Aug. 19, 87	C3	6	-	-	-	-	-	-	660	-	47	560	-	570	0.47	200	13	ND	170	-	-	-	-	-	0	-	-	0.002	-		
28	S-P (Water)	Aug. 19, 87	M0	6	-	-	5930	-	2.8	-	-	49	234	160	14.0	-	-	139	-	-	401	2960	-	285	-	-	0	0.821	-	-	-		
29	Thermal Spring	Mar. 26, 57	-	6	77	-	7060	-	7.5	-	-	72	660	7	-	-	4.8	22	-	33	1100	454	-	690	1.4	476	2960	0.002	0.956	0.03	0.004	0.006	
30	Thermal Spring—See footnote g	-	-	6	69.5	-	-	-	6.8	-	-	0.1	42	620	20	-	0.1	-	55	0.2	23	1190	598	-	644	-	464	3290	0.962	0.019	-	-	
DETECTION LIMITS: WATER >>>>										1	NA	0.05	0.05	0.1	0.1	0.02	0.05	0.02	0.1	0.025	5	0.25	0.3	0.05	30	1	ND	1					
(1987 Analyses) SEDIMENTS >>>>												5	5.00	2	10	5	0.05	2	10	0.5	500	5	30	0.5	30	20	100	-					

Footnotes:

- a- See table 2 for additional trace metals, and appendix for STC leachable metals and 1987 lab reports (CALIFORNIA ANALYTICAL LABORATORY)
- b- Analysis ref. no's 8 to 11, 22, 27, and 28, supplied by California Reg. Water Quality Control Board; note apparent lab error in #7 (B & C1).
- c- Analysis ref. no 12 by U.S. Geological Survey and reported by Thompson, Gull, and Donnelly-Hulan (1981).
- d- Analysis ref. no. 23 represents ground-water retrieved from water column in wellbore using vacuum tube at depth of 15 meters.
- e- Analysis ref. no's 24 and 25 from Beale (1985); analysis no. 26 from diamond drill hole water supply (exact location unknown) reported by White (1957).
- f- Analysis ref. no. 28 by U.S. Geological Survey (Ham 1986, Table 19), exact location not provided.
- g- Analysis ref. no 30 by U.S. Geological Survey (White, 1957), exact location and date not provided.

Table 2 Chemistry of water, sediment, thermal springs and ground-water within and adjacent to Herman Lake, Sulphur Bank Mercury Mine, Clear Lake, California—1938 to 1987.
(Republished from TPCA Assessment Report, Columbia Geoscience, 1987)

REF. NO	Sample Description	Sample Date	Depth (m)	Lab #	Water in milligrams/liter; cores in milligrams/kg wet wt basis																		
					As	Sb	Ba	Bc	Cd	Cr	Cr+6	Co	Cu	Pb	Hg	Mn	Ni	Se	Ag	Th	Va	Zn	
1	P2 Profile (Water)	Nov. 1, 87	9	2	ND	ND	0.0100	0.0058	0.0053	0.036	NA	0.27	0.030	ND	0.0025	ND	0.60	ND	ND	ND	ND	0.83	
2	P2 Profile (Water)	Nov. 1, 87	23	1	ND	ND	0.0160	0.0058	ND	0.034	NA	0.27	0.034	ND	0.0010	ND	0.58	ND	ND	ND	ND	0.90	
3	P3 Profile (Water)	Nov. 1, 87	13	3	ND	ND	0.0092	0.0057	0.0082	0.035	NA	0.27	0.029	ND	0.0025	ND	0.60	ND	ND	ND	ND	0.81	
4	P3 Profile (Water)	Nov. 1, 87	26	4	ND	ND	0.0095	0.0056	ND	0.035	NA	0.27	0.030	ND	0.0016	ND	0.58	ND	ND	ND	ND	0.82	
5	P4 Profile (Water)	Nov. 1, 87	4	5	ND	ND	0.0130	0.0056	ND	0.033	NA	0.26	0.028	ND	0.0028	ND	0.59	ND	ND	ND	ND	0.80	
6	P4 Profile (Water)	Nov. 1, 87	24	6	ND	ND	0.0091	0.0048	ND	0.030	NA	0.23	0.028	ND	0.00162	ND	0.50	ND	ND	ND	ND	0.71	
7	P5 Profile (Water)	Nov. 1, 87	5	7	ND	ND	0.0084	0.0056	ND	0.035	NA	0.27	0.028	ND	0.0012	ND	0.58	ND	ND	ND	ND	0.81	
8	V-IP (Water)	Aug. 19, 87	6	C1	ND	ND	0.0068	0.0058	ND	0.036	-	0.28	0.029	ND	0.0013	ND	0.66	ND	ND	ND	ND	0.87	
9	V-IP (Water)	Aug. 19, 87	6	M1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
10	NE-IP (Water)	Aug. 19, 87	6	C2	ND	ND	0.0065	0.0058	ND	0.036	-	0.30	0.028	ND	0.00075	ND	0.69	ND	ND	ND	ND	0.87	
11	NE-IP (Water)	Aug. 19, 87	6	M2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
12	Herman Pit (#71)	June 27, 76	6	71	-	-	-	-	0.015	-	-	-	0.8	-	-	-	-	-	-	-	-	1.20	
13	P2 Profile (Cores)	Nov. 1, 87	23	11	ND	ND	120	ND	ND	17	NA	3.1	19	ND	21	ND	6.3	ND	ND	ND	21	24	
14	P2 Profile (Cores)	Nov. 1, 87	23	12	49	ND	130	ND	ND	15	NA	5.6	16	ND	9.0	ND	18	ND	ND	ND	16	34	
15	P3 Profile (Cores)	Nov. 1, 87	27	14	ND	ND	120	ND	ND	10	NA	4.0	9.0	ND	18	ND	12	ND	ND	ND	16	20	
16	P3 Profile (Cores)	Nov. 1, 87	27	13	ND	ND	250	ND	ND	26	NA	ND	16	ND	23	ND	6.3	ND	ND	ND	29	12	
17	P4 Profile (Cores)	Nov. 1, 87	25	15	ND	ND	100	ND	ND	14	NA	ND	11	ND	19	ND	5.3	ND	ND	ND	17	14	
18	P4 Profile (Cores)	Nov. 1, 87	25	16	ND	ND	110	ND	ND	16	NA	3.9	12	5.4	44	ND	11	ND	ND	ND	21	14	
19	P4 Profile (Cores)	Nov. 1, 87	25	17	ND	ND	85	ND	ND	13	NA	ND	11	6.2	46	ND	6.9	ND	ND	ND	21	15	
20	P5 Profile (Cores)	Nov. 1, 87	5	18	ND	ND	1600	ND	ND	26	NA	4.8	27	5.2	38	ND	13	ND	ND	ND	14	16	
21	P5 Profile (Cores)	Nov. 1, 87	5	19	ND	ND	980	ND	ND	16	NA	5.0	22	5.9	19	ND	13	ND	ND	ND	9.3	24	
22	IP-B (Soil)	Aug. 19, 87	6	C4	48	21	280	0.48	ND	63	-	4.7	41	30	11.4	ND	17	ND	ND	ND	62	27	
23	SBM Well (Water)	Nov. 2, 87	-	8	ND	ND	2.8	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND	0.0060	ND	0.018	ND	ND	
24	SBM Well B#1 (Water)	June, 1964	-	-	-	-	-	-	0.015	-	-	-	0.080	-	-	-	-	-	-	-	-	1.20	
25	SBM Well B#2 (Water)	June, 1964	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
26	Bathhouse Well (Water)	Oct. 27, 38	-	-	0(?)	0(?)	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	
27	S-P (Water)	Aug. 19, 87	6	C3	ND	ND	ND	0.0010	ND	0.17	-	1.0	0.0081	ND	0.0013	ND	0.65	ND	ND	ND	ND	1.6	
28	S-P (Water)	Aug. 19, 87	6	M3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
29	Thermal Spring	March, 57	G	-	0.02	-	1.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
30	Thermal Spring—see footnote g		G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
DETECTION LIMITS: WATER >>>>					0.10	0.050	0.005	0.0010	0.0050	0.010	0.010	0.010	0.015	0.050	0.0020	0.020	0.040	0.20	0.0050	0.40	0.010	0.010	0.010
(1987 Analyses) SEDIMENTS >>>>					40	40	10	0.50	0.50	1.0	1.0	3.0	3.0	5.0	0.10	10	5.0	5.0	2.0	50	5.0	2.0	2.0
TITLE 22 VIOLATIONS AND LIMITS >>>>					20 (CORES ONLY)																		

footnotes:

a—Refer to Table 1 for additional data, references, and coring depth intervals.

Avg Hg 0.00181 <<1987 WATER
Avg Hg 26.33 <<1987 CORES

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quality goals to protect freshwater aquatic life for beryllium, copper, nickel, and zinc. Boron and ammonium concentrations exceed EPA estimated permissible ambient goals.

Columbia Geoscience concluded that the acidic conditions of the Herman Impoundment were due to the large volume of hydrogen sulfide (H_2S) in naturally discharging geothermal fluids reacting with oxygen, rather than due to oxidation of pyrite-bearing rock (FeS_2), to form sulfuric acid (H_2SO_4), as is typical of acid mine drainage. The report also concluded that mercury ore continues to form in the mine pit and is not leaching from the sediments into the water. Columbia Geoscience sensed that the physical and chemical conditions in Herman Impoundment act as a natural treatment process, trapping the discharging geothermal fluids, and restricting solubility and confining the mercury to the bottom of the pit.

Columbia Geoscience estimated that up to 8 tons of mercury may be present in bottom sediments of the Herman Impoundment, and more than 2,600 tons of mercury may exist within the ore bodies below the mine pit.

4.3 Site Soils

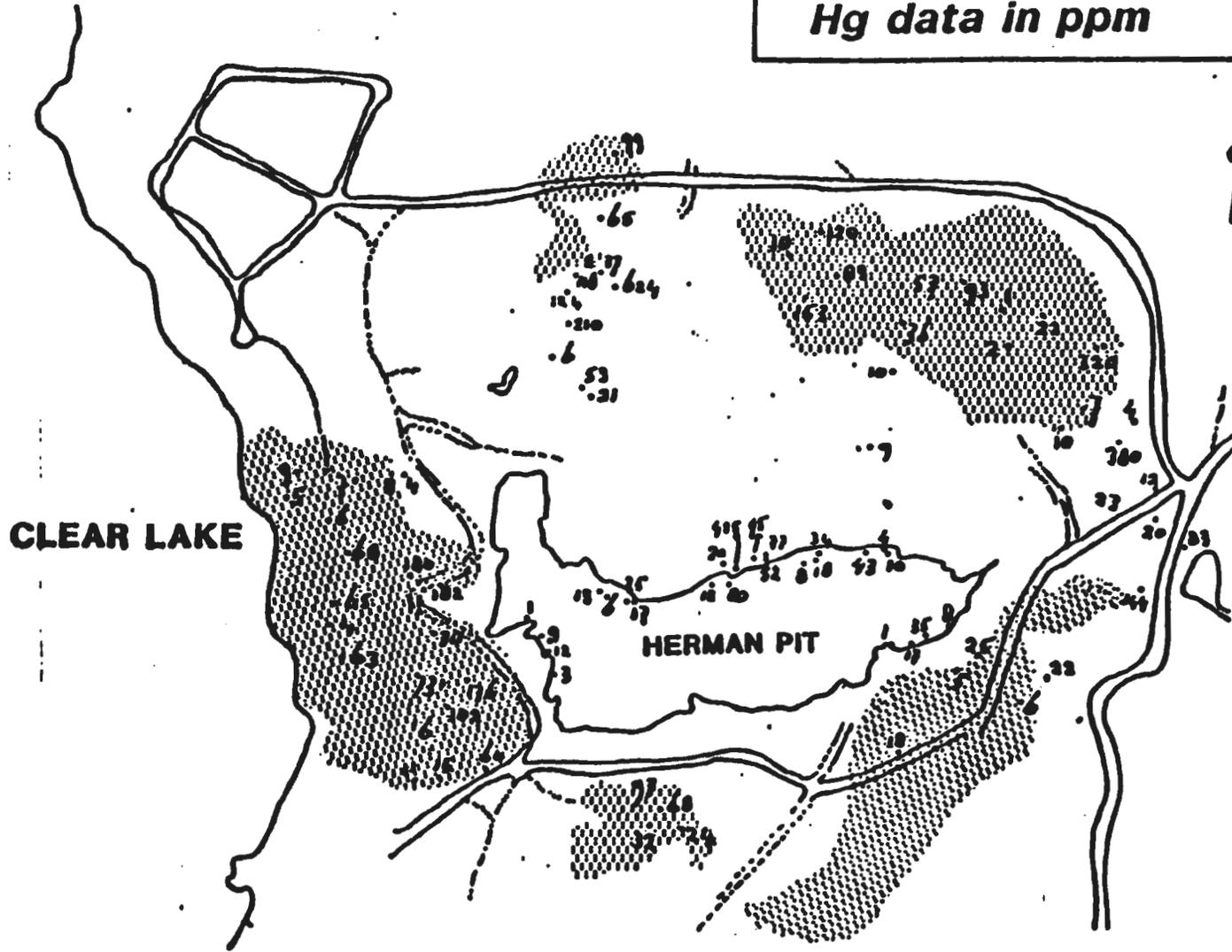
The majority of contaminated soils at the site are associated with surface weathering of the mine waste piles. Contamination of the tailing piles and associated soils are discussed in the following section. Other soils at the site which could be contaminated are surface soils downwind from the mine smelting operations which were adversely impacted by airborne contaminants. The actual location and extent of these contaminated soils is unknown and will be further investigated during the RI.

A soil mercury survey was previously conducted at the site during geothermal exploration activities. Soil mercury anomalies are often associated with geothermal resources and can be used as an indicator during reconnaissance exploration. The mercury survey at the site imply that the mercury bearing shear zone extends both northeast and southwest of the mine and is at least two miles long. A study of wind currents at the site demonstrated that the soil mercury anomaly is not the result of downwind fall out from processing the mercury ore. Soil sampling at the site will be performed in order to determine the extent of naturally occurring mercury anomalies and establish background levels for the site.

4.4 Mine Waste Rock and Tailing Piles

TAILINGS AND MINE DUMPS

SULPHUR BANK MINE
Hg data in ppm



Source: Regional Water Quality Control Board

FIGURE 14

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Two different types of mine wastes are found at the SBMM site, including the reddish tailings (wastes from ore processing) and waste rock, or unprocessed overburden excavated during mining operations, which are white in color. Based on volume estimates of existing tailings and waste rock piles on site, there is a minimum of 193,600 cubic yards of wastes on site. The mine tailings and waste rock extend 1,320 feet in the north-south direction, in contact with 2,060 feet of shoreline, and extend some 3,000 feet eastward from from the lake.

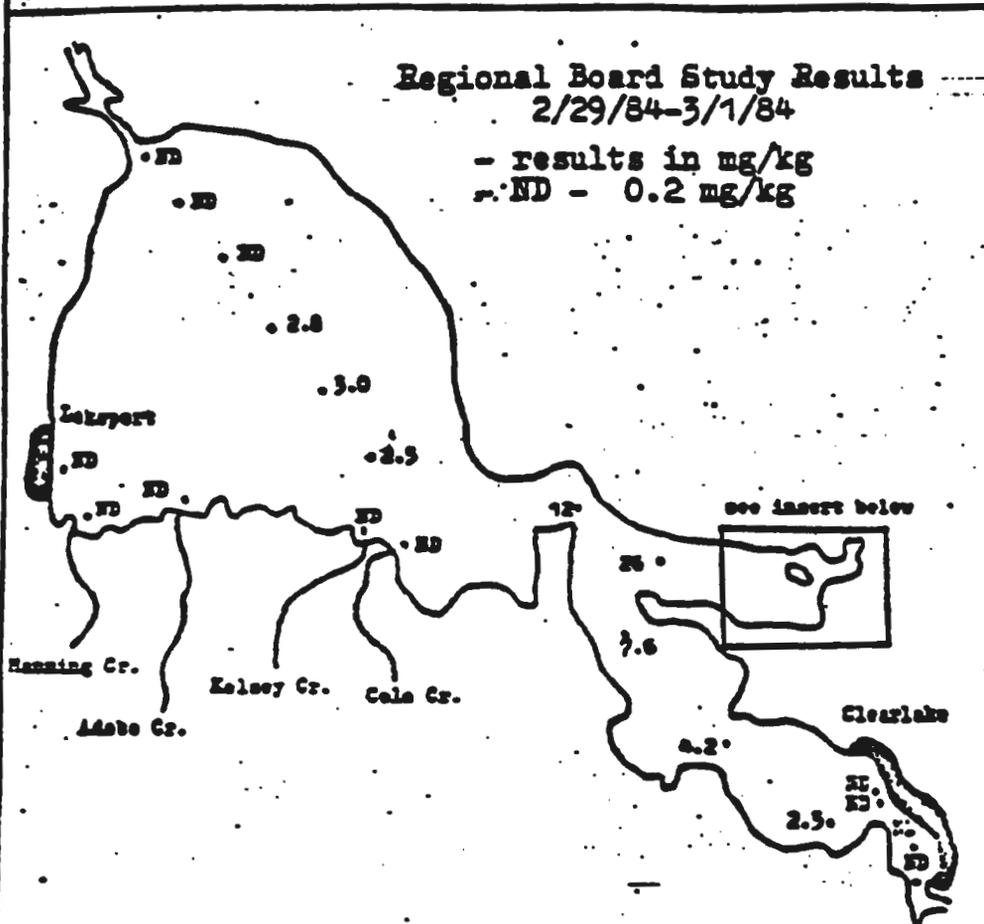
Sampling conducted on-site indicate the mine waste piles contain elevated levels of mercury and arsenic. Samples collected by the RWQCB from all over the mine site during 1983-1984 contained concentrations of mercury ranging from 1 - 624 mg/kg, with a mean concentration of about 60 mg/kg (Figure 14). Arsenic concentrations in the waste rock and tailings have been reported as high as 140 ppm, but have not been sufficiently characterized. However, surface water drainage from the mine site has been found to contain arsenic concentrations as high as six times the Maximum Contaminant Level (MCL) of 0.05 mg/l (RWQCB, 1984).

Subsequent sampling of mine tailings by HSU at various locations indicate the waste piles are uniform with respect to the distribution of mercury levels. Samples that contained fine grained material (clay and silt) had higher mercury contents than samples without fines, but using conventional statistical methods it is not possible to distinguish one sample type from another based on mercury levels. In other words, what "hot spots" do exist are as likely to occur in one area of the mine waste piles as another.

4.5 Clear Lake Surface Water and Sediments

Elevated levels of mercury were first detected in Clear Lake in 1970 by the California Department of Health Services. Since that time hundreds of samples from fish and waterfowl tissue and from sediment and water in the vicinity of SBMM and in Clear Lake have been analyzed for mercury. These data indicate that the highest concentrations of mercury are found in the Oaks Arm of Clear Lake in the proximity of SBMM. Of the mercury already in the Oaks Arm, the largest amount (about 100,000 kg) is in the upper sediments, while the sediment blanket and the water column account for much smaller quantities of mercury (respectively 440 kg and 60 kg). The most significant outputs of mercury from the Oaks Arm are losses into the sediments; this amounts to approximately 100 kg of mercury per year. Losses to the atmosphere and flows out of the Oaks Arm each account for approximately 10 kg per year.

MERCURY IN CLEAR LAKE SURFACE SEDIMENT

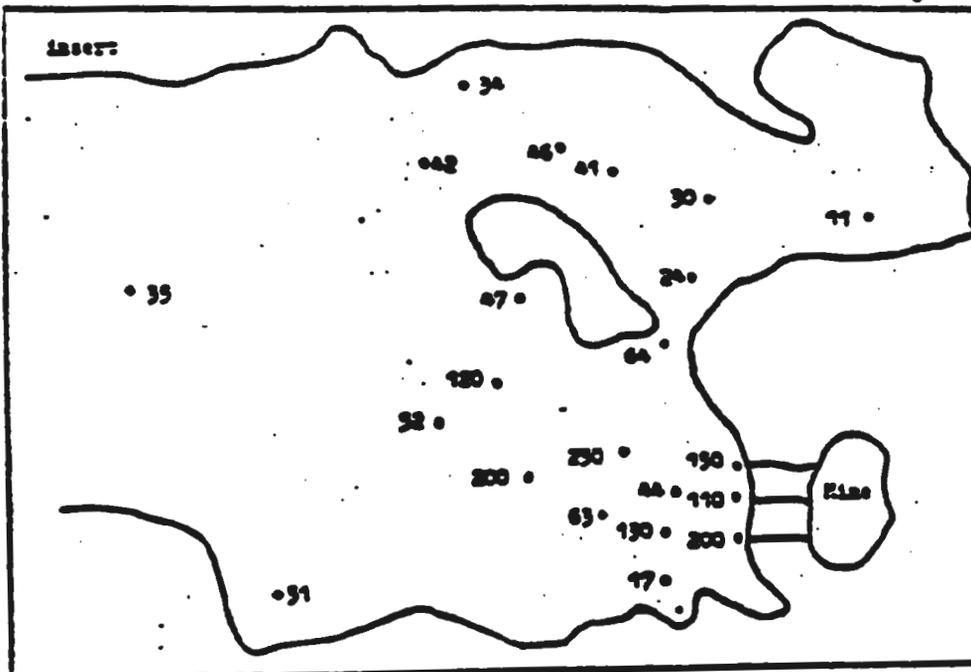


S&G Study Results
8/83

Location	mg/kg
Rodman Sl.	0.
Lower Lake	0.
Rattlesnake Is.	44.
Sulfur Bank	430.
Mine Tail.	

DHS Study Results
7/70

Location	mg/kg
Upper Arm	3.
Lower Arm	4.
Oaks Arm	33.



Source: Regional Water Quality Control Board

FIGURE 15

Historically, mining practices have contributed mercury into the lake during the periods of 1927-44 and 1955-57 and appear to be the most likely source for the mercury stored in the upper sediments of the Oaks Arm. Mercury inputs from mining sources can be further subdivided into five major categories: 1) From mine water and sludge pumped into the lake during open pit mining operations; 2) Airborne inputs during ore smelting operations at the mine; 3) Disposal of wastes during smelting operations; 4) Erosion of detrital material from unstabilized waste piles and local drainages; and 5) Ground water discharge from Herman Impoundment into Clear Lake. Natural inputs from active geothermal systems have been documented in the vicinity of SBMM and throughout the Clear Lake area. The mercury in the deeper portions of lake sediments are associated with natural deposition prior to mining operations at the site.

Mercury levels in the lake water are generally very low and near or well below the analytical detection limit of 5 ug/l. Mercury concentrations from lake bottom sediments in the Oaks Arm range between 11 mg/kg and 250 mg/kg (dry weight) with an average of 80 mg/kg. This is well above the state action level for mercury in sediments of 20 mg/kg. Bottom sediment samples in the rest of Clear Lake range from non-detect to 12 mg/kg with an average of 2 mg/kg (Figure 15). Short cores collected from lake bottom sediments in the Oaks Arm in the vicinity of SBMM contain high levels of mercury in the upper 50 to 60 cm of sediment, which corresponds with the last 100 years of lake deposition, during the period mining activity. Substantially lower amounts of organic matter and soil moisture coincide with this mercury peak, suggesting a changing lacustrine depositional environment with higher shore-derived detrital influx. The presence of pesticides from aerial spraying during the 1950s and 1960s in these upper sediments provide further evidence of recent deposition. Sediments below this mercury peak contain substantially lower concentrations of mercury, until a depth of about 4 meters is reached where a natural mercury peak occurs (depositional age estimated to be about 6000 years before present).

High arsenic levels have also been detected in the bottom sediments of the Oaks Arm of Clear Lake. Concentrations from twenty samples ranged from less than the detection limit at 5 mg/kg to 95.9 mg/kg arsenic with an average of 27.9 mg/kg.

4.6 Ground Water

Ground water contamination has been characterized by data collected from wells on site and nearby. Three monitoring wells are known to currently exist at the site. No domestic water wells in the vicinity of the site are known to have detectable levels of mercury. Mercury levels in water, and specifi-

cally ground water, is dependent upon pH, Eh, chloride and sulfide levels, and temperature. Observed levels in filtered and unfiltered samples from springs and wells near mercury deposits in north-central California are reported to range from non-detectable to 0.7 ug/l. The "Sulphur Bank" well is reported to have levels of 0.5 ug/l in a 1973 survey. The HAR reports mercury levels at 0.2 ug/l in the unused Bradley Mining Company well BM3 located on site.

Humboldt State University (HSU) sampled three on site ground water monitoring wells for the Abatement and Control Study completed under contract to the RWQCB. Mercury analysis of unfiltered samples from the monitoring wells ranged from about 7 to 130 ug/l of total recoverable mercury. Analysis of two filtered samples from one single monitoring well were 0.4 and 0.6 ug/l of mercury and 60 and 15 ug/l for the other two wells. However, HSU considered the latter two results suspect due to improper filtration.

The magnitude of ground water transport of mercury from Herman Pit to Clear Lake is dependent on the elevation difference between Herman Pit and Clear Lake, the hydraulic conductivity of the aquifer, the thickness and areal extent of the aquifer, and the mercury level in the ground water transport. Since the water level of Herman Lake is approximately 3 to 10 feet higher than the level of Clear Lake it is likely that ground water flows from Herman Pit to Clear Lake. The flow of ground water from Herman Pit to Clear Lake is further supported by the hydraulic head and pH gradient measured in the three on site monitoring wells. The pH gradient went from 2.8 at Herman Lake to 4.1 in the well near Clear Lake. Using computer modeling and assuming a flow rate of 20 gpm and 0.5 ug/l as the mercury level, the annual ground water input of mercury is estimated to be 0.02 kg/yr. By this estimation, the contribution of mercury in the ground water from Herman Pit into Clear Lake is very low in comparison to other transport mechanisms such as shoreline erosion.

No domestic, stock or public water supply wells are located downgradient of the Sulphur Bank Mine. Mercury concentrations in water from nearby wells were at or below detection limits at the date and time of measurement.

5.0 Conceptual Model of Site Contamination

5.1 Potential Contamination Sources and Extent of Contamination

Mercury inputs into Clear Lake can be subdivided into two sources: mining activities and natural sources. The Sulphur Bank Mine is not the only mercury mine in the Clear Lake area. The abandoned Bell Mine, and the nearby S-Bar-S quarry are both located in the vicinity of Mount Konocti. Other mercury mines in Clear Lake region include the Mirabel, Helen and Abbott Mines.

At the SBMM site, contaminant sources directly resulting from mining activity include the mine tailings and waste rock piles, which continue to erode into the lake, and the mercury contaminated sediments resulting from direct disposal into the lake. Acid water from the Herman Impoundment from groundwater or surface water discharges may also leach metals into Clear Lake and impact water quality. High concentrations of mercury have been reported in the mine tailings and waste rock piles, ranging from 1 to over 600 ppm mercury. Lake sediment samples collected just off shore from the mine site have been found to contain as high as 250 ppm mercury. Elsewhere in the lake, outside the Oaks Arm, bottom sediments have thus far been found to contain mercury levels ranging from non-detect to only as high as 12 ppm. (Figures 14 & 15) The state action level for mercury in sediments is 20 ppm.

Natural mercury inputs from active hydrothermal sources have also been documented within the immediate vicinity of SBMM. Hot springs have been observed discharging into the Herman Impoundment and elsewhere on the mine site. Historical accounts indicate that several large springs existed along the Clear Lake shoreline, before the hydrothermal system was disrupted by mining activity. The U.S. Geological Survey has mapped numerous springs throughout the Clear Lake Area (Sims & Rymer, 1976). The contribution of these natural springs to the methylation and bioaccumulation of mercury in Clear Lake fish must be investigated prior to selecting a cleanup remedy for the contaminated lake sediments.

5.2 Contaminants of Concern

To date, mercury, in both its inorganic and methylated forms, and arsenic have been identified as the primary contaminants of concern. Previous investigations have not sufficiently characterized the extent and significance of arsenic contamination. Other metals may also be present in the sediments, tailings and waste rock, in concentrations which may effect water quality, but data collections to date have not been sufficient to identify other metals as contaminants of concern.

5.3 Contaminant Migration Pathways

a) Shoreline Erosion:

Approximately 2060 feet of Oaks Arm shoreline is in direct contact with mine wastes; of this, about 1240 feet of shoreline is in contact with very steep (up to 60 degrees), barren slopes made up of tailings and waste rock. Samples collected by Humboldt State University contained an average mercury level of 158 ppm. Two possible erosional processes for mercury transport from the shoreline deposits into Clear Lake include sheetwash erosion from the steep banks and slope failures due to undercutting of the slope by wave action. The shoreline slopes have well developed gully systems and talus cones, indicating sheetwash erosion and mass wasting processes are in progress. Humboldt State University (HSU) estimated the annual contribution of mercury due to mass wasting processes at ≥ 132 kg/yr, based on field measurements made using an array of erosion pins and measurements of precipitation and soil properties. These measurements were taken during dry years (1988-1989); consequently, the normal erosion rates may be higher.

b) Fluvial Transport

In addition to shoreline erosion, drainage from the rest of the mine site is likely to carry additional mercury laden sediment into the lake. The possibility of failure of the dams containing the Herman Impoundment during heavy rains is of particular concern, and is being addressed under the RWQCB order. Water samples collected from on-site ephemeral streams by RWQCB in 1989, contained mercury levels between 330 and 490 ppb. Based on estimated annual discharge rates, Humboldt State University estimated the average annual mercury discharge from fluvial transport ranges from 1.24 to 18.6 kg Hg/yr.

c) Ground Water Transport

As the water level in Herman Impoundment is approximately 10 feet higher than in Clear Lake, ground water flows is likely to be from the mine pit into the lake. The depth to the water table is approximately 10 feet. Two wells were installed by Humboldt State University between the Herman Impoundment and Clear Lake, and head and pH gradients were measured confirming this assumption. The pH gradient went from a pH of approximately 2.8 at Herman Impoundment to 3.9 in the well closest to the mine pit, to 4.1 in the well nearest the shoreline, to 6.9 in the lake.

The aquifer between the Herman Impoundment and Clear Lake consists of 3 layers. The upper layer consists of the waste rock layer, which is underlain by a unit of quaternary sediments up to 35 feet thick, including silty lake sediments, landslide debris and beach sediments. Quaternary andesite volcanics, of unknown thickness, make up the bottom-most layer of the aquifer.

Columbia Geoscience estimated hydraulic conductivities for these units through pump tests and lithologic interpretations. The hydraulic conductivity of the waste rock unit was estimated to range from 1.8×10^{-3} to 8.4×10^{-4} cm/sec. For the quaternary sediment layer, hydraulic conductivities were estimated to range from 1×10^{-7} to 4.3×10^{-8} cm/sec, and for the andesite volcanics, $3.4 - 3.6 \times 10^{-6}$ cm/sec.

Mercury levels in groundwater are dependent upon pH, PE, temperature and levels of chloride and sulfide. Samples collected from on-site wells (Columbia Geoscience - 1988) had reported mercury levels ranging from non-detectable (< 0.2 ug/l) to 0.2 ug/l. Unfiltered samples collected by HSU ranged from 7 to 130 ug/l recoverable mercury. Filtered samples contained 0.4 and 0.6 ug/l in one well and 60 and 15 ug/l in the other two wells. HSU considered the latter two results suspect due to improper filtration.

Based on modeling, HSU and Columbia Geoscience reported estimated ground water transport rates for mercury to be 0.0001 - 0.02 kg/year.

d) Air Transport

Previous investigations have not evaluated the air migration pathway. However, a mercury vapor survey was conducted on-site by the RWQCB in 1988. The survey was conducted using a Jerome Instruments mercury vapor analyzer. The results indicated that vapor concentrations throughout the site were well below the NIOSH recommended exposure limit (10 hour time weighted average, TWA) of 0.05 mg/cubic meter. The highest levels found, (0.012 mg/cubic meter) were found inside structures in the old mill processing area. Background concentrations were mostly between 0 and 0.002 mg/cubic meter, with occasional readings as high as 0.05 mg/cubic meter. Mercury vapor concentrations near the hot springs were not higher than for other areas.

Prevailing winds blow in an easterly direction across the mine site. The potential also exists for particulates to be blown off-site. On windy days, hydrogen sulfide fumes can be smelled as far away as the mine gate.

Both the on-site caretakers residence and several homes in the adjacent Elem community were constructed on mine waste. To date, indoor mercury concentrations in those homes have not been measured.

5.4 The Methylation Process

The recent discovery of elevated mercury levels in certain aquatic species and subsequent findings that mercury tends to bioaccumulate and concentrate in higher life forms, with potentially serious toxic effects, spawned a surge of research into the behavior of mercury in the environment. Research has shown that while mercury in water is present predominantly in inorganic form, methyl mercury is the form usually identified as being present in contaminated aquatic organisms. Inorganic mercury is biologically converted to its methylated form by microorganisms present in the water and sediments.

Inorganic mercury may enter the natural waters as dissolved mercury bound to suspended solids, as detrital cinnabar, or in solution. Inorganic mercury may be present in elemental form (Hg^0 , metallic vapor) ionic form (Hg^{1+} , formed by photochemical oxidation in air or possibly by methylation, or more commonly, Hg^{2+}) or as a compound (e.g.: HgS). Metallic mercury and mercury compounds have low solubility in water (>1 ppm) and tend to sink below the sediment/water interface and become immobilized. Ionic mercury is more soluble, and may form organic species. In general, the speciation of mercury in natural waters is dependent on pH, redox potential, and availability of ligands or binding groups. Under most conditions, dissolved mercury is mainly bound to solids via surface layer adsorption to clays, hydrous oxides, and organic debris so that at least 50%, and more likely 80-96% of total mercury is transported along with suspended solids. The movement of mercury between the water column and surface sediment is rapid, reaching equilibrium within days, and is responsive to short-term physical and chemical changes.

Inorganic mercury is converted to organic mercury in either the form of monomethylmercury (e.g.: methylmercuric chloride) or dimethylmercury. Dimethylmercury is the ultimate product, which may rapidly volatilize in the water column. Monomethylmercury is more stable and more likely to bioaccumulate. Methylation of mercury appears to occur primarily in the upper 5 to 15 cm of sediments under mildly to strongly reducing conditions. Methylation has been shown to occur in the water column as well as in sediments.

Levels of methyl mercury may fluctuate seasonally as the lake switches from aerobic to anaerobic conditions. In addition to dissolved oxygen content, other factors governing the methylation process include temperature, pE, pH, type and concentration of bacteria present, and type and concentration of complexing organic and inorganic ligands and chelating agents (ie: reduced sulphur, chlorides, hydroxides, and suspended solids).

Mercuric ions also tend to chemically adsorb to humic matter, forming soluble complex ions. While these complex ions may not be readily available for methylation by bacteria, they may be oxidized, or metabolized by benthic organisms, and thereby made available to bioaccumulate.

It has been clearly shown that fish assimilate methyl mercury directly from the water column through their gills, from the upper layer of sediments, and may also produce methyl mercury within their own intestines from mercuric precursors. Once in the food chain, mercury may bioaccumulate at levels exceeding FDA guidelines, particularly in the upper trophic level species.

The following mathematical model has been proposed and verified for describing the methylation phenomenon (Bisogni & Lawrence, 1975):

$$\text{NSMR} = a[b(\text{Hg}_{\text{total}})]^n$$

where:

NSMR = Net specific monomethylmercury production rate
a = microbial growth rate
b = biochemical availability of inorganic mercury for methylation
n = reaction order (For mean aerobic systems, n = 0.28;
for mean anaerobic systems, n = 0.15)

As numerous factors may potentially effect the methylation process, it may be possible to reduce the methylation rate in a given natural system by the manipulation of one or more factors. Several remedial strategies have been proposed to date, including:

- 1) Change the mercury binding characteristics of the sediment by adding a strong complexing agent (such as sulfide ions) in sufficient quantity to reduce the availability of mercuric ion for methylation.
- 2) Eliminate or reduce organic input in the benthic zone to stop or reduce biological activity.
- 3) Reduce the total inorganic mercury concentration by:
 - a) dredging, treatment and off-site disposal of mercury contaminated sediments.
 - b) covering contaminated sediments with a cap of sand, clay or gravel.
 - c) using a getter system (mesh network treated with a

complexing agent, such as sulphur) to adsorb mercuric ions and remove them from the water column.

In order to select the most appropriate remedial strategy for a particular system, it is essential to understand which factors control methylmercury production in the particular system of concern.

5.5 Toxic Effects

A considerable amount of research has been conducted and data published on the toxic effects of mercury poisoning, particularly since the widespread outbreak of mercury poisoning in the fishing village of Minimata, Japan in 1953. For years, a plastics plant had directly discharged methyl mercury into the bay. Strange behavior and high death rates were first noted in cats, then neurological disorders, birth defects, and some deaths were reported in the human population. After intensive investigations, the cause of the epidemic was found to be mercury poisoning from the consumption of local fish and shellfish. The source of the mercury was eventually traced to the plastics plant, where near-shore sediments were found to contain as high as 2010 ppm mercury. (Sediments in the Oaks Arm of Clear Lake range from 11 to 250 ppm mercury, with an average concentration of 80 ppm.)

Another case of mercury poisoning was reported in the early 1970's in Iraq, where homemade bread made from seed wheat that had been treated with a mercurial fungicide poisoned over 6500 children and adults. Over 500 hospital deaths were reported; many other deaths may have gone unreported. Patients experienced numbness in their hands, feet and around the mouth (paresthesia), loss of motor control (ataxia), slurred speech (disarthria), tunnel vision and hearing loss.

Symptoms of mercury poisoning include headaches, weakness, forgetfulness, aggressiveness and personality changes in its mildest form, and tingling skin, muscle numbness and slurred speech, to convulsions, delirium, respiratory failure, kidney failure, and death in its most severe forms. The milder symptoms of mercury poisoning, (headache, fatigue, memory loss, lack of concentration) are reversible; the physical effects, (blurred vision, hearing loss, impaired motor control, numbness) are irreversible.

Mercury has been found to be a teratogen in all animal studies; there have also been reported cases of blindness, hearing loss and mental and physical defects in human babies exposed to mercury in the uterus. In most cases of fetal exposure, infants appear normal until the age of six months, then begin to

show signs of slowed reflexes, poor motor control, delayed speech and cerebral palsy. Mercury kills brain cells and other nerve cells, possibly due to its tendency to form covalent bonds with sulfur, by deactivating sulfhydryl enzymes essential to cellular metabolism. In pregnant women, mercury tends to cross the placenta and concentrate in the fetus; breast milk may also contain concentrated levels of mercury.

Mercury is toxic in both its organic and inorganic forms. Inorganic mercury most frequently effects the kidneys first, and may also damage the central nervous system with chronic exposure. Organic mercury tends to be retained in the body, particularly in the brain and the placenta. It attacks the central nervous system and is the form of mercury most often responsible for birth defects.

Methyl mercury is the organic form of primary concern at SBMM. Inorganic mercury in lake sediments is converted biologically to methyl mercury, which enters the food chain and bioaccumulates and concentrates in higher trophic level species. Studies have shown that 98% of methyl mercury in food is absorbed by the tissues, whereas only 1% of inorganic mercury is absorbed. At Clear Lake, high mercury levels in fish prompted the California Department of Health Services to issue a health advisory in May 1986 against consumption of all Clear Lake fish for pregnant women, nursing mothers, and children under age 6, and limiting fish consumption for all others.

While fish consumption is a primary route of exposure, mercury poisoning can also occur through inhalation of mercury dusts or vapors and skin contact with methyl mercury or organic salts.

Although the U.S. Food and Drug Administration has issued an action level of 1 ppm mercury in food, toxic effects are generally not seen until a level of 10 ppm is reached. The acceptable Daily Intake (ADI) for an average 70 kg adult is 30 ug methyl mercury per day. The World Health Organization (WHO) has established 10 ng Hg/ml (0.010 ppm) as a "safe" blood level, although the lowest blood level associated with adverse health effects found to date is 200 ng Hg/ml (0.2 ppm), taking into account the most sensitive populations. Methyl mercury has a half life of 70 days in most humans, however, in some individuals, it may take up to 120 days to excrete half of the toxin. Mercury levels can be measured in hair, blood and urine samples. While hair and blood data tend to correlate well, urine mercury levels cannot be used to calculate an exposure level, but can only be used to provide evidence of recent mercury exposure.

5.6 Uses of Mercury and Prevalence in the Environment

Mercury has a number of industrial uses, including the manufacture of chlorine and caustic soda (chlor-alkali industry) and plastics manufacturing. It was formerly used as a slimicide in the paper manufacturing industry, and is still used in agriculture as a fungicide treatment for seeds. Mercury has also been used in paint, cosmetics, filters on sewage treatment plants, thermometers and scientific instruments, dental preparations, amalgamation, and various mining extraction processes. Coal burning power plants also produce mercury vapor; mercury also occurs naturally in fossil fuels.

Although there are hundreds of potential uses for mercury, only about 18% is recycled. Most of it eventually ends up in the environment.

5.7 Potential Receptors

5.7.1 Surrounding Populations

The Elem community of Pomo Indians is located on the north side of the SBMM site. The community consists of approximately 21 homes and a community center, half of them constructed on mine tailings and waste rock. While the residents formerly relied heavily on subsistence fishing, most of them no longer eat the fish due to the health advisory. Residents still collect tules along the shoreline and eat the raw bulbs. Children frequently play on the mine site and eat wild blackberries that grow on mine tailings. The community's drinking water wells are abandoned; water is now piped through the lake from Clear Lake Oaks. In addition to the Elem community, the caretaker's residence is located on the mine site and was constructed on mine tailings; eight other homes are located just to the south of the mine. The fish and wild game consumption habits and drinking water source for these inhabitants is presently unknown.

The nearby communities of Clear Lake and Clear Lake Oaks, population 15,000 and 2,700 respectively, may also be affected. Residents may still be eating fish caught in the Oaks Arm of the Lake, also, residents have reportedly used algae from the lake as compost for vegetable gardens. Samples of algae collected by EPA from the canals in Clearlake Oaks contained low levels of mercury, below 0.16 ppm (wet weight). The drinking water supply wells for Clear Lake Oaks are located near the Clear Lake shoreline. The depth and screened intervals of the wells are presently unknown, but these wells could conceivably be pumping lake water.

Many of the nearby residents and tourists who come to the area swim in Clear Lake. As methyl mercury may also be absorbed through the skin, swimming provides another possible exposure route.

Beef cattle and sheep also graze near the mine site. While health advisories have been issued against consumption of Clear Lake fish, there are currently four commercial fishing licenses issued for Clear Lake. Most of the fish are caught in the Upper Arm and only a few species are marketed commercially, including Sacramento Blackfish, Carp, Clearlake Hitch and Goldfish (sold as Silver Carp). These fish are sold to Asian markets in the Bay Area, Sacramento and Los Angeles.

5.7.2 Ecological Concerns

Clear Lake is host to a variety of terrestrial, aquatic and benthic communities. The surrounding area includes freshwater marshes and seasonal wetlands containing sedges, rushes and grasses; riparian-woodlands dominated by hardwoods, pines, willows and vines; and grassy chaparrals of shrubs and brush species. These are home to deer, gray squirrels, raccoon, fox, mink, jackrabbit, and many other small mammals, as well as egrets, great blue heron, the rare yellow-billed cuckoo, owls, and many other waterfowl and birds of prey. The U.S. Fish and Wildlife Service reports that federally endangered species found in Lake County include:

American Peregrine Falcon	(<u>Falco peregrinus anatum</u>)
Bald Eagle	(<u>Haliaeetus leucouphalus</u>)
Northern Spotted Owl	(<u>Strix occidentalis caurina</u>)
Loch Lomond Coyote Thistle	(<u>Eryngium constancei</u>)

Other California rare, protected and endangered species and U.S. Forest Service sensitive species found in Lake County include:

Black-shouldered Kite	(<u>Elanus caeruleus</u>)
Northern Goshawk	(<u>Accipiter gentilis</u>)
Golden Eagle	(<u>Aquila chrysaetos</u>)
Prairie Falcon	(<u>Falco mexicanus</u>)
Blue Grouse	(<u>Dendragapus obscurus</u>)
Ringtail	(<u>Bassariscus astutus</u>)
Badger	(<u>Taxidea taxus</u>)

Although various wildlife species may prefer one particular vegetative habitat type, many are dependent on other habitat for specific time intervals. For example, hawks may nest in the riparian-woodland areas but feed in other vegetative zones. The wetlands are particularly important in providing the nutrients

for the growth of micro-organisms which are the base of both aquatic and terrestrial food chains. The loss of wetlands due to past mining activity and the potential for future losses during remediation is an important ecological concern.

Previous studies at Clear Lake have identified seven species of sport fish which live in Clear Lake. Upper trophic species include largemouth bass, channel catfish, and black and white crappie. Middle trophic fish include white catfish and brown bullhead. Lower trophic fish include Sacramento blackfish and hitch. Hundreds of fish tissue samples have been collected by the California Dept of Fish and Game since the late 70's; many fish, particularly the upper trophic species contain levels of mercury in excess of the FDA guideline.

A naturally occurring annual fish kill happens each year when the oxygen level in the water is too low for the fish to survive. The carcasses of the fish wash up on the lake shores where predatory and domestic animals eat the potentially contaminated fish. Also scavenger birds such as vultures feed on the dead fish. Tissue samples collected from two species of birds at Clear Lake indicate a potentially significant ecological impact of mercury contamination on the wildlife population. Samples collected from the fish-eating grebes contained mercury levels 70 times higher than those found in the strictly plant-eating coots.

The toxic effects of mercury on wildlife has been widely studied. In general, mercury is a known mutagen and teratogen, which adversely affects reproduction, growth and development, behavior, motor coordination and sensory perception in birds, mammals and aquatic organisms. The presence of pesticides in addition to mercury tends to increase the toxic effects, whereas the presence of selenium tends to counteract the toxic effects.

In fish species, signs of acute mercury poisoning include flared gills, increased respiratory movements, and loss of equilibrium. Chronic symptoms include emaciation, brain lesions, abnormal and diminished motor coordination, erratic behavior, and diminished response to changes in light intensity. Mercury tends to be most concentrated in the liver, then the brain, and thirdly, in the carcass. Symptoms of severe poisoning appear at relatively high concentrations (5 - 7 mg/kg in the whole body).

Signs of mercury poisoning in birds include poor muscular coordination, falling, slowness, fluffed feathers, calmness, withdrawal, drooping eyelids and hyporeactivity. Mercury levels in birds tend to be highest in the brain, then the liver, kidney, muscles and carcass, in that order.

In mammals, methyl mercury effects the central nervous system, causing sensory disturbances and diminished motor coordination in acute exposures, to brain damage, mental derangement, coma and death following extreme exposures. Additional symptoms of acute exposure may include loss of appetite, belching, bloody diarrhea, and piloerection (hair more erect than usual). In general, larger mammals tend to be more resistant than smaller mammals. Mercury tends to be most concentrated in the fur, followed by the liver, kidney, muscle and brain.

5.8 Conceptual Model

The Sulphur Bank Mercury Mine has been identified as the most significant source of mercury entering the Oaks Arm of Clear Lake. The Oaks Arm is the most contaminated segment of the lake; sediments adjacent to the mine site contain mercury levels in excess of 200 ppm, whereas sediment samples in the rest of the lake range from non-detect to only as high as 12 ppm. Fish from the Oaks Arm also tend to have higher mercury levels than fish from other arms of the lake. Mine wastes were directly disposed in the lake, and erosion from the mine continues to contribute mercury through mass wasting and fluvial processes. To a lesser degree, groundwater migration of contaminants from the Herman Impoundment may also impact water quality. There are currently no water supply wells downgradient of Herman Impoundment. The potential also exists for mercury contaminated particulates to be blown off-site. Mercury does not appear to be volatilizing off the mine wastes, however, this pathway has not been thoroughly investigated.

The methylation of mercury from contaminated lake sediments, and the bioaccumulation of mercury in the food chain and ultimately the human population, is a primary concern. Numerous factors influence the methylation process, namely the availability of mercuric ion, and availability of nutrients for bacterial growth. Additionally, the heavy algal blooms may indirectly accelerate the methylation process by adsorbing inorganic mercury to form complex ions, which are metabolized by benthic organisms, become methylated, and enter the food chain that way. The Oaks Arm tends to heavily accumulate algae blown in from other parts of the lake by prevailing winds.

As natural springs may also discharge mercury into the lake, the speciation and bioavailability of mercury contributed by these springs would need to be evaluated in order to determine the significance of their contribution to the overall production of methylmercury and the bioaccumulation of mercury in fish. If discharges from submerged springs are at all similar to the springs currently discharging in the Herman Impoundment, the sulfide ions contributed by discharged hydrogen sulfide gas would

likely bind the mercuric ions, precipitating cinnabar rather than forming methylmercury. In mine tailings, the roasting process to liberate mercury vapor may have also been instrumental in liberating mercuric ion.

6.0 Preliminary Identification of Remedial Alternatives

Remedial Alternatives for this site will be developed and evaluated during the Feasibility Study, as described in Chapter 10. Remediation of site contamination will be dependent on establishing clean-up goals and standards, and results of the ecological and human health risk assessments. The relationship between remedial alternatives at the site and the actual reduction of exposure to the contaminants will be investigated during the RI/FS. Bench and/or pilot scale treatability studies may be needed to determine the effectiveness of proposed remedial alternatives.

Considerable work has already been done in identifying and screening potential alternatives. The Abatement and Control Study prepared by Humboldt State University (HSU) focused on two primary objectives concerning remedial alternatives for the site: 1) Develop and evaluate source control alternatives to reduce or eliminate future mercury contributions from SBMM to Clear Lake; and 2) Develop and evaluate pollution abatement alternatives to reduce or eliminate human and wildlife exposure to mercury already existing in the water and bottom sediments of Clear Lake.

The Abatement and Control Study did not consider or propose remedial alternatives to address the impact of ground water contamination from the Herman Impoundment. In order to ensure that all potential contamination problems are addressed, EPA has divided the investigation of the site into three parts, or operable units (OUs). The Herman Impoundment, soils and mine waste piles, and contaminated lake sediments will be investigated separately, and remedial alternatives will be developed and screened for each operable unit.

The source control and pollution abatement alternatives that have been identified to date are summarized below.

6.1 Source Control Alternatives

Effective source control alternatives will have to consider the Herman Impoundment and the mine waste piles, and should focus on reducing rates of shoreline erosion. A total of 12 alternatives were evaluated during the detailed analysis in the Abatement and Control Study and are listed below:

- 1) Cut back the shoreline slope of tailing piles to reduce erosion and prevent slope failures
- 2) Revegetate all or part of the mine waste piles to reduce erosion
- 3) Riprap the Clear Lake shoreline to protect the base of the shoreline waste piles slope from wave action undercutting
- 4) Grout the waste piles
- 5) Cap the waste piles with soil-cement
- 6) Cover the waste piles with a flexible geotextile
- 7) Cover the waste piles with a concrete blanket
- 8) Cover the waste piles with a webbed geotextile
- 9) Solidify the waste piles
- 10) Vitrify the waste piles
- 11) Excavate and dispose of the mine waste piles
- 12) Raise the dam and/or construct a spillway on the Herman Impoundment to prevent overflow and dam failure

The Abatement and Control study estimated the costs for these source control alternatives to range from approximately \$200,000 for slope cutback and revegetation to \$250,000,000 for vitrification.

Alternatives to address the groundwater pathway and the physical hazards of acid in the Herman Impoundment were not specifically addressed in the Abatement and Control Study, but could include: no action, draining and plugging the pit, deep underground injection of impoundment water, acid neutralization, or installing barriers to restrict groundwater. Any alternatives considered for the Herman Impoundment will have to account for the presence of natural springs.

The Abatement and Control Study concluded that source control alternatives should focus on reducing shoreline erosion and on fluvial transport mechanisms for mercury contributions from SBMM to Clear Lake. The study recommended a combination alternative of riprapping the lake shoreline, reducing the shoreline slope to 20 degrees and revegetating to minimize erosion, and raising the Herman Impoundment dam and adding a spillway and channel, was recommended as the most cost-effective alternative. The RWQCB has ordered the potentially responsible party (PRP) to implement the erosion controls consistent with these recommendations. EPA will evaluate the effectiveness of measures being implemented by Bradley Mining Company under the RWQCB Order and will determine whether further measures are needed.

6.2 Pollution Abatement Alternatives

The pollution abatement alternatives for mercury in Clear Lake water and bottom sediments evaluated in the Abatement and Control Study are:

- 1) Do Nothing
- 2) Implement a source control program on the mine site but do nothing in the lake
- 3) Dredge the entire Oaks Arm or only the most contaminated lake sediments
- 4) Cover all, or only the most contaminated sediments with clean sand or clay
- 5) Establish a bounty system to remove contaminated fish
- 6) Periodically remove and restock fish

Costs for these alternatives ranged from \$3,000,000 for dredging or covering the area of greatest contamination to \$129,000,000 for periodic removal and restocking of fish.

The most cost-effective pollution abatement alternatives will probably involve either dredging or covering the lake bottom sediments in the Oaks Arm with clay or sand. These approaches have proven to be satisfactory for sediment contamination problems in other areas, but will require additional study to verify their appropriateness for application in Clear Lake. Of particular concern is that the ultimate costs and efficacy of the lake pollution abatement alternatives can only be imprecisely quantified at present. Since these abatement alternatives will be very expensive, it is important that their costs and likelihood of success be more accurately assessed during the RI/FS. Understanding the mercury methylation and bioaccumulation process in Clear Lake will be key in the development of a conceptual model for establishing sediment clean-up criteria that equate to acceptable mercury exposure levels. The technical implementability of these remedial alternatives will be studied during the Feasibility Study, and may require bench and/or pilot scale treatability studies to determine the potential effectiveness of these remedies.

7.0 Data Management Requirements

The RI/FS objectives will be accomplished by collecting environmental data from soils, mine tailings, groundwater, lake water and sediments, lake biota, and air. The quantity and quality of data required will be determined by the establishment of Data Quality Objectives; the data requirements for the RI/FS and are identified and summarized below.

7.1 Identification of Data Needs and Uses

Reference 3

**Excerpts From Comments of Bradley Mining Company in Opposition
to the Proposed Listing of the Sulphur Bank Mine
on the NPL; Anthony O. Garvin, Landels, Ripley & Diamond;
August 22, 1988**

**COMMENTS OF BRADLEY MINING COMPANY
IN OPPOSITION TO THE
PROPOSED LISTING OF
THE SULPHUR BANK MINE
ON THE NATIONAL PRIORITIES LIST**

August 22, 1988
Anthony O. Garvin
Landels, Ripley & Diamond
450 Pacific Avenue
San Francisco, CA 94133
Counsel For The Bradley
Mining Company

PRELIMINARY STATEMENT

The Bradley Mining Company ("Bradley Mining") objects to the U.S. Environmental Protection Agency's ("EPA") proposed designation of the Sulphur Bank Mine on the National Priorities List ("NPL") under the Comprehensive Environmental Compensation, and Liability Act ("CERCLA"), 49 U.S.C. § 1101 et seq.; 53 Fed.Reg. 23988 (June 24, 1988).

EPA's proposed designation and ranking of SBM on the NPL is not warranted and is a EPA's fault

Bradley Mining believes that EPA's proposed ranking of the Sulphur Bank Mine on the NPL is not warranted under CERCLA and EPA's own regulations since the presence of mercury and other inorganic chemicals are the result of natural geothermal processes and not the result of the mine. Bradley Mining also believes that EPA has misapplied the Hazard Ranking System ("HRS") by failing to consider all relevant data, making numerous inaccurate statements, and using erroneous, unsupported assumptions that skewed the results.

For these reasons, the Bradley Mining respectfully requests EPA to withdraw its proposed designation of the Sulphur Bank Mine for inclusion on the National Priority List.

II. DESCRIPTION OF THE PROPOSED ACTION

On June 24, 1988, EPA proposed to add 229 new sites to the NPL. 53 Fed.Reg. 23988 (June 24, 1988). The proposed list includes the Sulphur Bank Mine. Id., at 23995. EPA ranked the Sulphur Bank Mine under group 5 on the proposed list based

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discharged some water to nearby Clear Lake during periods of heavy rainfall, such discharges ceased in 1979 as a result of the construction of an earthen dam by Bradley Mining at the request of the California Regional Water Quality Control Board.

X Recent hydrogeologic studies conducted by Columbia Geoscience on behalf of Bradley Mining indicate that the primary source of mercury, arsenic and other inorganic substances in both Herman Lake and Clear Lake is natural geothermal activity and not surface runoff from mining waste. The studies conducted by Columbia Geoscience were performed at the request of the California Regional Water Quality Control Board pursuant to Section 25208 of the California Health and Safety Code. These studies are entitled "Herman Lake TPCA Assessment, Sulphur Bank Mine, Lake County, California" (1987) and "Hydrogeologic Assessment Report, Sulphur Bank Mercury Mine" (July 1988) ("HAR Reports"). The HAR Reports contain site specific data regarding conditions at Sulphur Bank Mine which should be taken into consideration by EPA in performing any assessment of the mine for purposes of determining whether the mine should be ranked for listing on the National Priority List. In order to facilitate EPA's reevaluation of the proposed listing of the Sulphur Bank Mine, Bradley Mining hereby submits a copy of the HAR Reports and Appendices and incorporates the data contained in these reports as part of its comments.

As mentioned above, the data developed by Columbia Geoscience establishes that the primary source of mercury,

1960's have disturbed the surface of the area, these mining activities have not significantly altered the nature or degree of these releases. The data also demonstrates that these naturally occurring releases have not contaminated public drinking water supplies and do not threaten to do so. For these reasons, Bradley Mining submits that it is inappropriate to include the Sulphur Bank Mine on the National Priority List. Accordingly, Bradley Mining respectfully requests EPA to withdraw its proposal to add the Sulphur Bank Mine to that list.

Reference 4

**Memorandum Concerning Special Study Waste Support Documentation;
From Scott Parish, EPA, Office of Solid Waste and Emergency Response;
Hazard Ranking and Listing Branch; May 17, 1988**

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAY 17 1988

OFFICE OF
SOLID WASTE AND EMERGENCY RESPONSE

MEMORANDUM

SUBJECT: Special Study Waste Support Documentation

FROM: Scott Parrish, Chief
Hazard Ranking and Listing Branch

TO: The Record

Until the Agency's Hazard Ranking System (HRS) is revised, Sections 105(g) and 125 of the Comprehensive Environmental Response, Compensation and Liability Act, as amended by the Superfund Amendments and Reauthorization Act (SARA), require EPA to consider certain additional information before sites involving special study wastes may be proposed for inclusion on the National Priorities List (NPL). Special study wastes are defined under Sections 3001(b)(2) and 3001(b)(3)(A) of the Resource Conservation and Recovery Act and include the following categories of wastes: drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of crude oil or natural gas; fly ash, slag, and flue gas emission control waste generated primarily from fossil fuel combustion; cement kiln dust waste; and solid waste from the extraction, beneficiation, and processing of ores and minerals. EPA has determined that the final category listed above includes coal tars from coal gasification plants and spent pot liners from aluminum production.

Before sites containing any special study wastes except fly ash, slag, and flue gas control wastes can be proposed in Update #7 to the NPL, Section 105(g) requires that the following information be considered:

- The extent to which the HRS score for the facility is affected by the presence of the special study waste at or released from the facility.
- Available information as to the quantity, toxicity, and concentration of hazardous substances at, or released from, the facility; the extent of or potential for release of such hazardous constituents; the exposure or potential exposure to human popula-

tion and the environment, and the degree of hazard to human health or the environment posed by the release of such hazardous constituents at the facility.

Section 125 presents the requirements for listing fly ash, slag, and flue gas emission control wastes. No sites in Update #7 were scored based on this type of waste.

To comply with Section 105(g) of SARA, the Agency has prepared addenda that evaluate the information required for each proposed site having or potentially having special study wastes.

The special study waste addendum for this site is attached. It indicates the special study wastes present a threat to human health and the environment, and fulfills the requirements of Section 105(g).

Attachment

SAMPLE ANALYSIS FOR
SULPHUR BANK MERCURY MINE
CLEARLAKE OAKS, LAKE COUNTY, CALIFORNIA

1. Introduction

The Sulphur Bank Mercury Mine (SBM) is located on the east shore of the Oaks Arm of Clear Lake, Lake County, California. Mining of mercury at the SBM began in the late 1800's and continued on and off until 1957 using underground and open pit methods.

The mine site contains approximately 120 acres of mine tailings and an open, unlined mine pit (called the Herman Pit), which is water filled up to 150 feet deep. Mine tailings extend into the Oaks Arm of Clear Lake along 1320 feet of shoreline. The Herman Pit is approximately 23 acres in size and located 750 feet upgradient from the lake. A drainage channel with a flow of approximately 20 gallons per minute (GPM) leads from the western edge of the Herman Pit to Clear Lake (Ref. 5).

2. Information on Constituents of Wastes

Quantity. Evidence from site inspections conducted by the California Central Valley Regional Water Quality and Control Board (RWQCB) and interviews with state agency representatives indicates the primary wastes disposed of at the site are mercury bearing mine tailings (Ref. 8, 9). These mining wastes are classified as special study wastes under RCRA Section 3001 (b) (3) (A) (ii). Therefore, all wastes at the site are special study wastes and all threats from the site are due to special study wastes.

Sampling conducted on-site indicates that the tailing piles contain elevated levels of mercury and arsenic. Water contained in the Herman Pit also contains low levels of mercury and arsenic. However, because the pit receives water naturally containing low levels of mercury and arsenic through a geothermal vent located at the base of the pit, it is impossible to distinguish contamination emanating from the geothermal vent from leachate derived from the surrounding mine tailings. Therefore, the water-filled Herman Pit is not included in the total quantity of on-site waste. Based on the existing on-site mine tailings at the site a minimum of 193,600 cubic yards of waste are estimated to be on-site.

Sediment grab and core samples taken from the lake bottom indicate that the lake bottom area within a one-half-mile radius of the mine site including most of the Oaks Arm of Clear Lake contain elevated levels of mercury in comparison to other areas of the lake (Ref. 10).

Concentration. Eighty-nine tailings samples, eight sludge samples, and 23 mine pit and drainage surface water samples were collected at the site and analyzed for mercury and arsenic. All of the samples were analyzed for mercury content, while the only samples

analyzed for arsenic content were the surface water samples. Currently, analytical data are not available for arsenic concentrations in soils at the mine site or in lake bottom sediments (Ref. 10, Attachment 1).

Mine tailings at the site contain mercury with concentrations that range from 1-624 mg/kg and have a mean concentration of 60 mg/kg. Sludge samples from the Herman Pit and drainage area range from 45-260 mg/kg mercury and average 143 mg/kg mercury. Surface water that drains from the mine pit downhill from the facility and enters the lake contains mercury at 0.203 mg/l and arsenic at 0.303 mg/l (Ref. 10, p. 1 and Attachment 1).

RWQCB analyzed lake bottom sediments within a 1/2 mile radius of the mine site and detected mercury levels with an average concentration of 102 mg/kg in the surface sediment samples. Levels of mercury in the sediments from other arms of the lake ranged from undetectable to 3.0 mg/kg mercury in the Upper Arm and 7.6 mg/kg mercury in the Lower Arm.

Department of Health Services (DOHS), Department of Fish and Game (DFG), and RWQCB analyses indicate that levels of mercury are present above background in the biota and lake bottom sediments in the Oaks Arm of Clear Lake. In addition, the levels of mercury in fish from Clear Lake are such that the DOHS issued an advisory against the consumption of fish from the lake on May 14, 1986 (Ref. 5).

Thorough sampling of soil, sediment, and water in mine tailing piles and surface water around the site, in addition to samples of lake bottom sediments and lake biota in Clear Lake have been carried out for this site in the course of site investigations and routine sampling since 1970. Results of these samplings serve as the basis for the concentration data used in this analysis.

Toxicity. Toxic compounds of the mine tailings and pit water found at the site include mercury and arsenic. Both of these contaminants were determined to have the same combined toxicity and persistence score on the Hazard Ranking System (HRS). Mercury and arsenic are listed as highly toxic in Dangerous Properties of Industrial Materials (Ref. 11), the standard reference for toxicity classification in HRS scoring. These contaminants are also persistent, which would give them the highest HRS toxicity score of 18 (Ref. 11).

The maximum concentration levels (MCL) for mercury in drinking water is 0.002 mg/l (Ref. 15). Mercury is found in the surface waters of the Herman Pit and associated surface drainages at concentrations 100 times higher than the MCL (Ref. 10, 15). The concentrations of mercury found in the surface water at the site is over four orders of magnitude higher than the EPA chronic fresh water aquatic toxicity criterion for mercury of 0.012 ug/l, and almost two orders of magnitude higher than the acute fresh water toxicity criterion for mercury of 2.4 ug/l (Ref. A).

The MCL for arsenic in drinking water is 0.05 mg/l (Ref. 15). Arsenic is found in the surface waters at the site in concentrations six

Reference 5

**Hydrogeological Assessment Report, Sulphur Bank Mercury Mine,
Clear Lake, California; Prepared for Bradley Mining Company
by Columbia Geoscience; July, 1988**

HYDROGEOLOGICAL ASSESSMENT REPORT

SULPHUR BANK MERCURY MINE

CLEAR LAKE, CALIFORNIA

JULY 1988

**For: BRADLEY MINING COMPANY
SAN FRANCISCO, CALIFORNIA**

**By: COLUMBIA GEOSCIENCE
HILLSBORO, OREGON**

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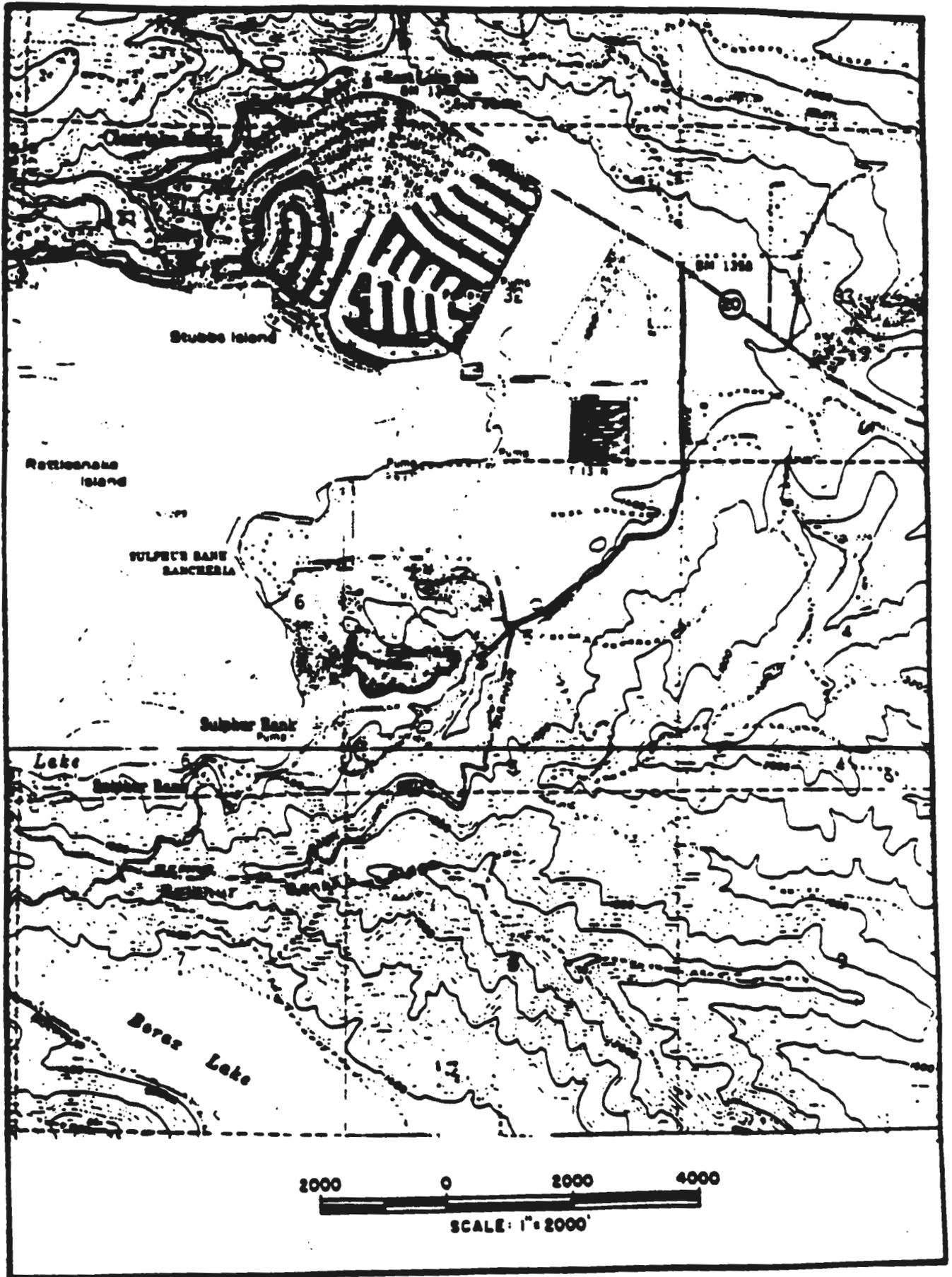


Figure 2.1-1 General Site Location Map.

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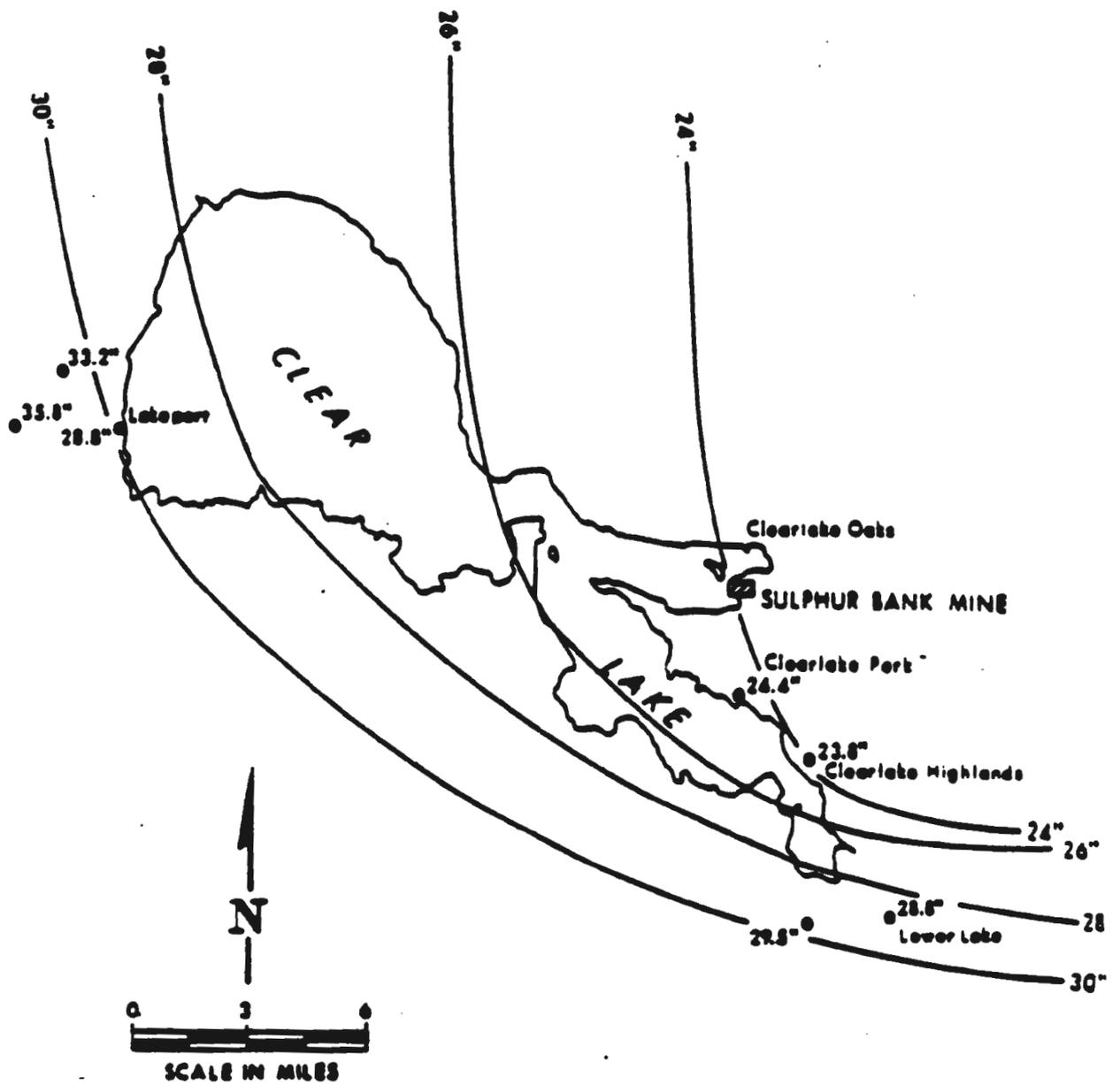


Figure S.1-1 Mean annual precipitation in the Clear Lake region, 1962-69.

6. SURFACE WATER--Continued

6.1 Clear Lake

6.1.2 Chemical Characterization

CLEAR LAKE IS A WARM, EUTROPHIC FRESHWATER LAKE WITH HEAVY NUTRIENT LEVELS AND SEVERE ALGAE GROWTH. RELATIVELY HIGH BORON AND LITHIUM LEVELS SUGGEST INPUT FROM HOT SPRINGS, SIMILAR PERHAPS TO THOSE THAT FORMED THE MERCURY ORE DEPOSIT AT SULPHUR BANK. RECENT MERCURY PROFILES IN CLEAR LAKE AVERAGED ABOUT .0005 MG/L.

The water in Clear Lake can be described as relatively warm with substantial concentrations of magnesium and calcium carbonates (Table 6.1.2-1). The pH is typically in the range from 7.5 to 9.0. The Lake is quite turbid during the fall, winter and early spring as a result of seasonal runoff and wind-induced mixing, while in the late spring and summer clarity improves considerably. Stratification occurs during short periods in the summer with a well-mixed layer near the surface where oxygen levels are reasonably high and an unmixed layer below causing anaerobic bottom conditions. Considerable nutrient concentrations, related principally to runoff from the drainage basin, sustain high levels of algae growth which is a primary water quality concern in Clear Lake.

Boron and lithium concentrations, probably related to thermal springs, have been noted to be relatively high, with Boron occasionally exceeding standards for irrigation of sensitive crops (). Mercury is generally non-detectable or at trace levels, but relatively high concentrations have been detected in certain species of fish from the Lake, and in bottom sediments. According to Charles Chamberlain of Humboldt State University (personal communication to the Board 20 July 1988, Fig. 11), profiled mercury concentrations at 2 sites in nearby Oaks Arm of Clear Lake on 17 June 88 ranged from about .00025 to .00125 mg/l. The apparent average concentration is about .0005 mg/l. The presence in Clear Lake waters of boron and lithium, and lithium/chloride ratios nearly identical to those of Herman Lake and the thermal springs that feed it (bottom of Table 6.1.2-1), suggest a common origin of regional scale for both the boron, lithium, and the mercury.

According to McLaughlin (1981), a large magma chamber directly underlies the Clear Lake basin (Fig. 6.1.2-1) at a depth of about 25 miles. This is the basic driving force for upwelling mineralized fluids and gas in the region, and is responsible for the continuing influx of mercury into Clear Lake basin and into Sulphur Bank.

Table 0.1.2 Physical and major element chemistry of ground water, surface water (1988), and thermal spring summary 1865 to 1957, Sulphur Bank Mine Region

No.	Sample Description	Sample Date	Lab #	TDB Temp. (°C)	Sp. Cond.		Water in milligram/liter; carbon in milligram/kg unit wt basis														Dilution of W					Mercury (pp)				
					Field Lab	Field Lab	Al	SiO2	B	Ca	Fe	Na2	Li	Mg	Mn	K	Na	NO3	NO2	N	Cl	Br	SO4	CO3	CO2		SiO2	SiO2	SiO2	SiO2
1	Well 003 (96-100')	Apr 25, 88	104	14000	10.5	12000	12000	4.26	5.02	nd	4.5	45	472	0.59	455	50	927	10100	nd	31	427	nd	1.451	0.004	0.004	0.009	0.0005			
2	Well 006 (50-60')	Apr 22, 88	704	14000	23.0	6611	1700	5.01	5.71	nd	10.0	1.0	87	0.03	66	nd	16	700	nd	4	2.0	172	0.250	0.004	0.007	nd				
3	Well 007 (20-30')	Apr 18, 88	104	2340	20.6	3400	-	4.87	-	nd	22	4.9	472	0.11	75	0	nd	1730	nd	23	1.1	04	0.215	0.004	0.004	0.004				
4	Well 008 (5-15')	Apr 20, 88	494	4040	10.4	6100	8240	4.09	4.31	nd	30	24.1	254	1.00	141	11	491	9150	nd	140	140	nd	0.777	0.022	0.004	0.004	0.0010			
5	Well 009 (41-67')	June 9, 88	304	5200	20.1	1020	7570	5.19	5.26	nd	29	26.0	177	1.00	150	19	541	9540	nd	297	230	52	0.902	0.013	0.003	0.004	0.0027			
6	Well 009 (41-67')	June 10, 88	704	5360	11.7	6860	-	5.05	-	nd	21	275	302	1.00	166	19	509	3520	nd	302	217	30	0.950	0.022	0.003	0.004	0.0032			
7	Well 009 (5-15')	Apr 24, 88	504A	2620	17.0	3420	-	6.90	-	nd	37.0	7.7	425	0.57	149	nd	70	2200	1.0	10	2.0	44	0.427	0.007	0.003	0.001	0.0005			
8	Well 0010 (77-86')	Apr 24, 88	464	1620	22.7	2300	-	5.95	-	nd	51.0	0.05	429	0.17	53	6	135	5	nd	16	0.2	1000	0.051	0.044	0.001	0.011	0.0004			
9	Well 0010 (2-7')	June 10, 88	304	4560	11.0	5900	-	5.62	-	nd	43	234	197	2.00	121	nd	444	3170	nd	297	154	nd	0.707	0.004	0.004	0.004	0.0140			
10	Well 0012 (2.0-5')	Apr 20, 88	604	2000	11.2	3470	-	5.25	-	nd	46	203	217	2.00	143	nd	195	3000	nd	242	nd	nd	0.620	0.005	0.005	0.0010				
11	Well P01 (Plumb 60')	Apr 20, 88	13	312	10.2	523	-	5.11	-	nd	44	0.0	32	0.43	23	nd	52	2	nd	16	0.3	244	0.620	0.001	0.004	nd				
12	Well P02 (" 105')	Apr 20, 88	12	310	-	-	-	-	-	nd	12	0.0	37	0.36	36	nd	37	16	nd	37	nd	250	0.621	0.105	-	-	nd			
13	Well P03 (Plumb 60')	Apr 25, 88	2	775	13.7	1160	-	5.00	-	nd	45	0.0	17	0.05	35	nd	40	1	nd	42	0.1	610	0.004	0.001	0.001	nd				
14	Well 0014 (Bradley 60')	Apr 20, 88	11	640	-	1570	-	6.26	-	nd	52	0.0	16	0.04	105	nd	37	nd	nd	20	0.46	930	0.009	0.001	0.002	0.0002				
15	Well 0014 (Bradley 62')	Apr 20, 88	14	620	10.6	664	-	6.13	-	nd	32	0.0	16	0.03	35	nd	26	125	nd	34	nd	106	0.004	-	-	-	nd			
16	001 Clear 10 March	Apr 25, 88	0	2010	24.0	2750	-	5.72	-	nd	5.5	26	251	0.55	937	-	14	112	1770	6.7	36	1.0	4	0.722	0.125	0.004	0.015	0.0002		
17	002 Green Pond	Apr 24, 88	5	1610	19.2	1925	-	2.17	-	nd	11	0.45	30	0.16	52	nd	3.5	1120	nd	1	nd	nd	0.006	0.015	0.002	0.0010				
18	003 Black Pond	Apr 24, 88	6	147	16.5	375	-	4.13	-	nd	5.5	0.06	14	nd	0	nd	0.20	65	nd	5	nd	nd	0.017	-	-	-	nd			
19	004 Black Swamp	Apr 25, 88	804	-	-	1304	-	3.06	1.6	-	-	2.5	-	5.00	-	nd	0.99	22200	-	50	-	-	0.036	1.950	0.110	0.0013				
20	005 Granite Pond	Apr 25, 88	-	-	19.5	3150	-	2.63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
21	006 Granite Pit	Apr 25, 88	7	4310	20.7	4570	-	3.00	-	nd	40	19	320	0.22	105	0	nd	5040	nd	22	50	nd	0.643	0.100	0.002	0.010	0.003			
22	007 Upton Pond	Apr 24, 88	-	-	24.4	5100	-	2.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
23	008 One Yard	Apr 24, 88	-	-	16.0	1620	-	2.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
24	009 Norman Pit	Apr 24, 88	-	-	16.0	3510	-	2.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
25	0010 Norman Pit	Apr 25, 88	-	-	19.7	3260	-	2.93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
26	0011 Clear Lake	Apr 25, 88	-	-	17.2	323	-	7.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
27	0012 Bradley Spring	Apr 25, 88	9	400	14.9	604	-	6.00	-	nd	0.9	11	62	nd	35	nd	20	95	0.06	11	nd	300	0.010	-	-	-	nd			
28	0013 Sharp Spring	Apr 25, 88	3	640	11.2	1660	-	6.66	-	nd	43	0.17	210	0.04	60	nd	66	2	nd	21	nd	646	0.000	-	0.001	0.0002				
29	Sulphur Bank Spring Sept, 1865	90	3957	"hot"	-	-	-	-	-	-	11.4	1007	301	tr.	-	tr.	-	tr.	1130	tr.	070	tr.	420	2300	0.473	-	-			
30	Delicate Spring	Oct, 1970	20	7047	60.5	-	-	-	-	0	67	527	56	tr.	-	37	60	1300	1000	480	-	543	1000	1.077	-	-	-			
31	"hot" Spring	July 6, 55	20	57.0	-	-	-	6.6	-	-	-	-	-	"normal"	4.5	-	91	1200	-	740	-	-	-	-	-	0.003	0.004	0.0000		
32	Spring W. Slide Pit	Oct 4, 56	40	7050	47.0	-	7070	-	-	0.0	0.00	0.4	20	600	110	0.04	3.1	110	0.95	23	1240	1430	605	3	2700	2500	0.970	0.019	0.003	0.004
33	"Dayton" Spring	Mar 20, 57	50	6040	69.5	-	7430	-	-	0.0	0.00	0.6	42	620	70	0.0	4.4	95	0.1	23	1000	900	644	1.6	664	3700	0.962	0.319	0.004	0.004
34	Spring W. Slide	Mar 20, 57	60	6400	77.0	-	7060	-	-	7.5	0.02	72	660	7	4.0	22	33	1000	454	600	1.4	470	2060	0.954	0.030	0.004	0.004			
35	Spring W. Slide	Oct 17, 57	70	2320	44.0	-	2360	-	-	6.6	-	130	16	200	0.0	41	5.3	104	142	16	500	1460	1.000	0.029	-	-	-			
36	Pit Filling 1947-54	Jan 17, 54	80	"cold"	-	-	-	-	-	2.7	-	107	249	1.7	-	0.5	100	6040	176	-	-	-	-	-	-	0.002	0.001	0.003	0.004	
37	Pond During Mining	Mar 20, 57	90	4556	23.0	-	5040	-	-	0.0	-	16	200	172	10	1.0	151	-	19	616	2000	270	310	-	-	1.074	0.031	0.003	0.007	
38	Clear 10, lower 10	June 24, 70	11050	24	-	-	-	5.7	7.0	-	6	1.6	24	0.02	16	0.02	3	22	11	3	-	252	0.513	0.136	0.001	0.000				
39	Clear 10, lower	Sept 7, 70	117016	21	-	-	-	5.0	7.91	-	22	0.65	30	1.7	0.03	19	0.05	2	17	11	4	1.1	160	0.162	0.130	0.002	0.007			
40	Clear 10, between 10	Sept 6, 70	117016	22	-	-	-	5.0	7.09	-	21	0.75	26	1.1	0.03	17	0.05	1	11	11	4	1.1	162	0.167	0.001	0.003	0.007			

Footnotes.

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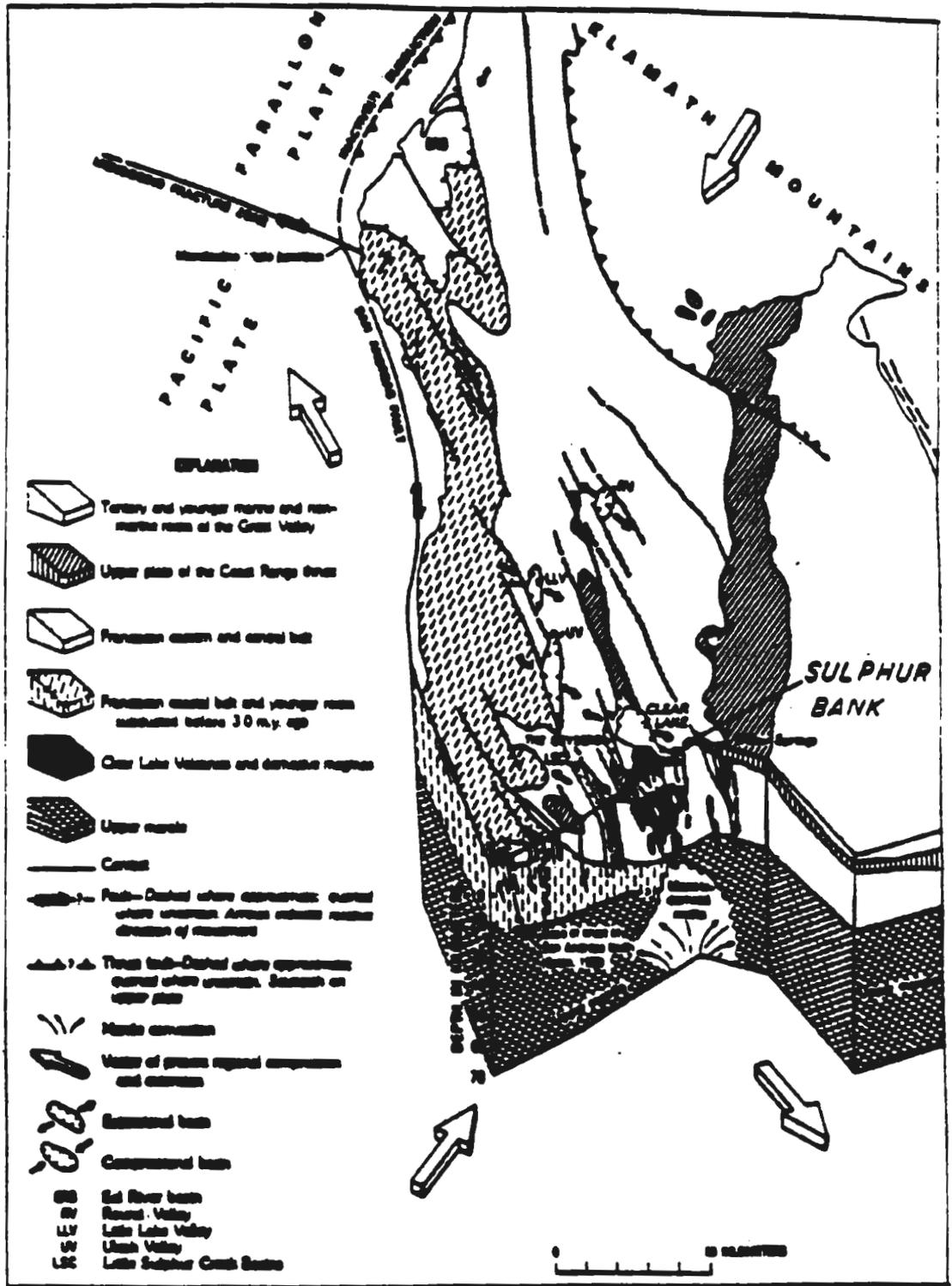


Figure 6.1.2-1 —Major crustal features of northern California and their relation to emplacement of magma beneath the Coeyers-Clear Lake area. (from McLoughlin, 1981, Fig.4)

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6. SURFACE WATER--Continued

6.2 Herman Lake and Thermal Springs

6.2.1 Description and Chemical Character

HERMAN LAKE IS A WELL MIXED GEOTHERMAL LAKE CONTAINING ACID WATER WITH HIGH CONCENTRATIONS OF SULFATE, SODIUM, CHLORIDE, BORDON, AMMONIA, AND TRACE MERCURY CONCENTRATIONS OF .00081 MG/L. LARGE VOLUMES OF GAS CONTINUOUSLY BOIL THROUGH THE OXYGEN-RICH WATER, CREATING A HIGHLY REACTIVE ENVIRONMENT FOR PRECIPITATION OF DISSOLVED METALS INCLUDING MERCURY.

The chemistry of Herman Lake, its bottom sediment and the submerged thermal springs, were fully characterized in the 1987 TPCA assessment report by Columbia Geoscience. However, in order to provide continuity, we have included in this report the two TPCA analytic chemistry tables (Tables 3.1-1 and 3.1-2), and a new analytic chemistry table summarizing the 1988 HAR data (Table 6.1.2-1). This table also contains a summary near the bottom, of all published analytic data on the submerged thermal springs, and several analyses of Clear Lake water. Thermal water analyses #26, #29 and #30 of the TPCA report were not previously known as to sampling location; however, the old bathhouse hot water well (#26) has been identified from old maps and plotted as Well 80H (Plate 3, north side of Herman Lake, site now submerged).

Analysis #30 (TPCA report) has now been identified as "Geyser Spring", north side of Herman Pit, elev. 1230 in 1957 (White, 1962, Table 1), and is included in the 1988 summary. Analysis #29 (TPCA report), similarly is identified as being in Herman Pit southwest of a spring (W4) on the north side at elev. 1225. Although specific field locations are not provided, it is obvious from the elevations in White's Table 1, of 1220 to 1250, that his analyses were all within the deepest excavations of the impoundment. His field descriptions and temperature data clearly demonstrate the mineralized character of these hot springs. The springs were of great variety, with temperatures up to 77°C, and frequently gas-charged. Despite the number of hot springs, White estimated total thermal spring flow of about 50 gal/min during pit dewatering. The highest mercury concentration detected was 0.20 ppm in "Ink Spring" on November 9, 1955, or about 10 times higher than an earlier measurement of .02 ppm (Table 6.1.2-1) (White, 1962, p. 415). White speculated that a pH difference (6.6 vs 4.1) caused the variation or that mercury was more extensively precipitated by sulfide dissolving in the relatively cool spring pool from rising gases (July 6, 1955).

6. SURFACE WATER--Continued

6.2 Herman Lake and Thermal Springs

6.2.1 Description and Chemical Character--Continued

During the TPCA fieldwork, 9 samples of Herman Lake water collected from various depths (Tables 3.1-1,2) had average mercury concentrations of .00081 mg/l with a range of .0038 to .00025 mg/l. At the time of sampling, the lake was well mixed and moderately oxygenated due to wind and large volumes of gas discharge through the bottom sediments. Analyses in Tables 3.1-1,2 show that Herman Lake waters are rather exotic with unusually high boron/chloride ratios and various other ion ratios such as lithium/chloride that are essentially identical to those of the hot springs (see also summary on thermal springs in Table 6.1.2-1).

In general, Herman Lake is typically a well mixed acid water body (D.O. 5 mg/l, pH 3.1), with high concentrations of sulfate, sodium, chloride, boron, ammonia, calcium and magnesium. Large volumes of gas (CO₂, methane, nitrogen and H₂S) constantly boil the water surface in many areas of the lake (see TPCA report).

Such conditions in the presence of well-oxygenated, highly mineralized acid water, helps maintain a highly reactive environment in which precipitation and dissolution reactions probably occur with hours or minutes.

On the basis of water geochemistry, Herman Lake is a geothermal lake fed by subsurface hot springs, with dilution by runoff and rainfall. The same processes that produced the mercury ore deposit during the past 40,000 years or so is still active and largely responsible for deposition of mercury in bottom sediments and the maintenance of trace levels of mercury in the lake waters.

7. WELLS WITHIN 1-MILE RADIUS

7.1 Nearby Water Wells

NO OFFSITE DOMESTIC, STOCK, OR PUBLIC SUPPLY WELLS ARE LOCATED DOWNGRADIENT OF THE SULPHUR BANK MINE IMPOUNDMENT.

Sulphur Bank Mine is bounded on the north and west by Clear Lake, and on the south by a steep mountain ridge without any known inhabitants. To the northeast, Clearlake Oaks Water District supplies water to most of the nearby communities, including the Elem Indian Colony northwest of the mine. Only two domestic wells (FW3, FW4) and three irrigation wells (FW1, FW2, and BM4), are known to be in use within a 1-mile radius of the impoundment (Fig. 7.1-1). Numerous monitoring wells have also been drilled in the vicinity of the Clearlake Oaks waste water ponds to monitor leakage northeast of Sulphur Bank Mine. Many of these have been located and measured, and used to assist in mapping the regional ground-water flow system (Fig. 7.1-1).

In general, well logs in the area offsite show that the Clearlake Oaks waste water ponds are excavated into a moderately permeable shallow water-table aquifer consisting of alluvium (map unit Qs in this report) about 15 feet thick, resting on fractured, scoriaceous basalt (Qa) at least 80 feet deep (well log FW2, Appendix i Section 13.5). Groundwater from irrigation well FW2 is used partly to supply a stock pond on the mine property just northwest of monitoring well SB10. Most of the monitoring wells near the waste water ponds are shallow and do not penetrate the underlying basalt flow.

The ground-water surface and flow directions mapped in April 1988 demonstrate that existing water supply wells in the region cannot be affected by ground-water transport of contaminants from the Sulphur Bank Mine property. Two public supply wells operated by Clearlake Oaks Water District are located on the shore of Clear Lake northwest of Stubbs Island, more than one mile from Sulphur Bank Impoundment. The wells are reported to be less than 70 feet deep, and because of the nature of ground-water flow at the site, they cannot be impacted by the impoundment.

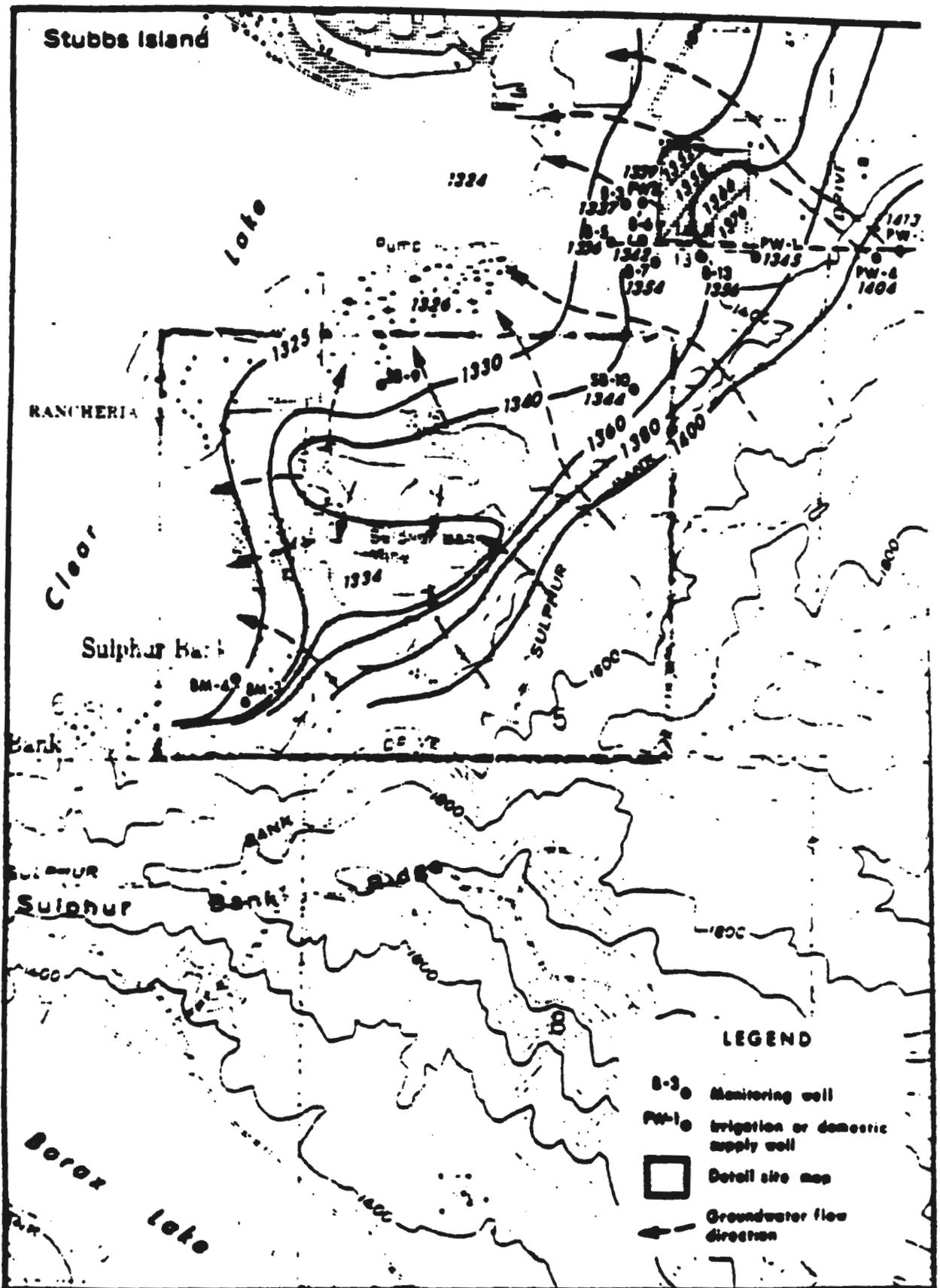


Figure 7.1-1 Distant Wells and Regional Groundwater Flow System, Sulphur Bank Mine Area, April 1988

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7. WELLS WITHIN 1-MILE RADIUS--Continued

7.2 Chemical Character Of Water in Nearby Wells

MERCURY CONCENTRATIONS IN WATER FROM NEARBY WELLS WERE AT OR BELOW THE DETECTION LIMIT. WATER CHEMISTRY DATA INDICATES THAT NEARBY WELLS TAP GROUNDWATER OF NON-THERMAL ORIGIN.

Comprehensive ground-water chemistry has been determined for five water wells in the area (Fig. 7.1-1, wells FW1, FW2, FW3, BM3, BM4). Field chemistry measurements (pH, temperature, and electrical conductivity) were also made and are included in Table 6.1.2-1.

As the contaminant of primary interest, mercury concentrations in all wells were below the detection limit of .0002 mg/l, except in water from the unused Bradley Mining Company well BM3 which was at the detection limit. In general, the inorganic quality of water from these wells is suitable for most purposes and may be characterized as slightly acidic (pH 5.11 to 6.26), calcium-bicarbonate groundwater with total dissolved solids (TDS) concentrations ranging from 312 to 840 mg/l. Three wells (FW3, BM3, BM4) slightly exceed secondary water quality standards for TDS of 500 mg/l. All nearby wells draw groundwater from various rock types in the depth range of 60 to 105 feet. The trace levels of boron, lithium, sodium, chloride and ammonia, coupled with ion ratios show that water from these wells is not of deep-seated thermal origin.

8. GROUND-WATER HYDROLOGY

8.1 Sulphur Bank Geology

SULPHUR BANK MINE IS SITUATED AT THE INTERSECTION OF SEVERAL REGIONAL FAULTS AND ASSOCIATED SHEAR ZONES WHICH SERVE AS AVENUES FOR UPWARD FLOW OF HOT MINERALIZING WATER AND GAS. FRANCISCAN BEDROCK, QUATERNARY SEDIMENTS, AND A YOUNG ANDESITE LAVA FLOW WERE MINED FOR MERCURY ORE ENPLACED DURING THE PAST 34,000 YEARS.

Clear Lake basin lies in an active hinge graben structure. The basement rock in the area is Mesozoic Franciscan Formation, composed of accreted sediments. In the Sulphur Bank area late Pleistocene lacustrine and terrestrial sediments unconformably overlay the Franciscan Formation, thickening to the west toward Clear Lake and pinching out to the east. Late Pleistocene andesitic lava has flowed over the sediments and is currently the uppermost rock unit in most of the central and northern portion of the mine property (Fig. 8.1). Locally in low areas northeast of the mine, soil development and minor sedimentation obscures the andesite flow. Hot geothermal fluids ascending along vertical faults and fractures have caused alteration within each of the rock types present in the mine area and to the east in an area upgradient from the mining property. The ascending geothermal fluids are the carrying mechanism by which mercury is being brought into the area, forming ore deposits where the degree of mineralization is most concentrated, as in the shear zones. Details of these structural features and geology of Sulphur Bank Mine are included on Plate 1 (pocket). Geologic cross sections and thermal gradients contours in the mine area are included within the following foldouts as Figures 8.1-1 through 8.1-5.

8.1.1 Franciscan Formation (Kif)

In the Sulphur Bank area the Franciscan Formation is composed of contorted beds of graywacke and black shale with local chert-bearing zones. Evidence of low-grade metamorphism is present throughout. In the eastern portion of the mine property and upslope east of the mine property, kaolinite/halloysite and hydrous sulfate alteration of Franciscan rocks is observed. These white zones of intense alteration (Fig. 8.1.1-1) are often associated with the smell of sulfur-bearing gasses, no vegetation, and are the result of on-going alteration caused by discharging high-temperature geothermal fluid and gas along deep-seated fault zones.

SULPHUR BANK MINE HAR

8. GROUND-WATER HYDROLOGY--Continued

8.1 Sulphur Bank Geology

EXCAVATED BARREN WASTE ROCK PILES OCCUPY ABOUT 90 ACRES OF LAND AT SULPHUR BANK. TAILINGS DERIVED FROM MILLED AND ROASTED ORE-BEARING ROCK FROM WHICH MERCURY WAS EXTRACTED, COVER ABOUT 17 ACRES.

8.1.4 Waste Rock Piles (RMV)

The material making up the mine piles consists predominantly of overburden and barren rock removed from the mine shafts and open excavations from 1865 to 1957. The term Waste Rock is formally defined within the mining engineering profession as "Valueless rock that must be fractured and removed in order to gain access to or upgrade ore." (McGraw-Hill Dictionary of Earth Sciences, 1984, p.816).

That usage is followed here and such usage should not be construed in any way to represent industrial waste products and contaminants. The material ranges in size from clay, silt and sand of pre-andesite sediments to andesite boulders up to about 3 feet in diameter. The specific size range, origin, and extent of decomposition is extremely variable both vertically and horizontally throughout the waste piles. The greatest percentage of the rock making up the piles is andesite. The degree of alteration observed within the andesite in the waste reflects the same wide range of alteration observed in unexcavated outcrops of andesite. Clay alteration within the top 10 cm. of the piles' surface is common, resulting in reduced infiltration capacity and added runoff during heavy rains. Waste rock piles cover about 90 acres of the mine property (Plate 1) and extend beyond the 1911 and 1927 shoreline of Clear Lake (Plate 3).

8.1.5 Mine Tailings (RMT)

The tailings piles consist of crushed and roasted ore-grade rock from which mercury was extracted. The tailings consist of milled rock ranging in size from silt to rock fragments less than 1 cm. across. Often the piles exhibit bedded structure, reflecting mechanical stacking and grading. Tailings from the earliest mining activities are often mixed with charcoal, reflecting the time when the furnaces were operated with wood rather than oil. Permeability and infiltration capacity within the tailings piles appears to be much higher than in the waste rock piles. Tailings cover about 17 acres of the mine property (Plate 1), and probably were excavated during later mining along the south side of Herman Lake.

8. GROUND-WATER HYDROLOGY--Continued

8.2 Regional Ground-water Flow System

SULPHUR BANK MINE IS SITUATED WITHIN A BROAD REGION OF SHALLOW GROUND-WATER FLOW THAT MIGRATES NORTHWARD FROM STEEP MOUNTAIN FRONTS TO CLEAR LAKE. LOCALLY AT SULPHUR BANK MINE, SHALLOW AND DEEP-SEATED GROUNDWATER SEEPAGE MOVES DIRECTLY INTO HERMAN LAKE AND WESTWARD TOWARD CLEAR LAKE.

The regional ground-water flow system in the Sulphur Bank Mine area consists of a relatively shallow flow system driven by rainfall and gravity, as exemplified in Fig. 7.1-1, and a deep-seated, pressure-driven geothermal system at Sulphur Bank Mine that cannot be shown easily in plan view. The ground-water surface on is based on shallow wells which generally penetrate less than 100 feet of moderately permeable alluvium and lake sediments about 15 feet thick, overlying a fractured andesitic basalt flow, perhaps 100 feet thick. The Clearlake Oaks waste water ponds northeast of Sulphur Bank Mine appear to have formed a slight mound in the regional flow system and some divergence in directions of ground-water flow. However, the predominant directions of ground-water flow are directed towards Clear Lake from the surrounding steep mountain fronts.

Locally at Sulphur Bank Mine, excavations beneath Herman Lake have accentuated the westward flow of groundwater as shown by the 1340 foot contour which now encompasses and surrounds Herman Lake. Under native ground-water flow conditions prior to the start of mining in 1863 the 1340 elevation contour would have closely followed the 1330 contour west of Sulphur Bank Mine. In place of Herman Lake, deep-seated upwelling geothermal fluids and gas, still in obvious abundance in Herman Lake, would have been forced to rise to higher levels in the rock mass to find exit points and migration paths to Clear Lake. Field evidence on the importance of the water table in controlling mercury ore deposition at Sulphur Bank (White, 1962) suggests that at some point the water-table was within 15 feet of the original land surface. The present surface of the andesite flow at Sulphur Bank Mine is more than 1,400 feet in elevation, suggesting that the native ground-water surface once contained a mound approximately located at the north side of Herman Lake, at about 1,400 feet in elevation. The deep-seated vertical pressure gradient still exists, but an infinite east-west permeability zone now exists (Herman Lake). This has allowed the mounded ground-water surface to dissipate and decay to the level of Herman Lake.

SULPHUR BANK MINE HAR

8. GROUND-WATER HYDROLOGY--Continued

8.3 Sulphur Bank Ground-Water Flow System

AT SOME TIME IN THE PAST, NATIVE GROUND-WATER FLOW AT SULPHUR BANK MINE WAS DOMINATED BY A THERMALLY-FED GROUND-WATER MOUND REACHING ELEVATIONS CLOSE TO 1400 FEET. HERMAN LAKE, AT ELEVATION 1334, HAS SUBMERGED THE THERMAL SPRING VENTS AND ACTS AS A MAJOR DEPRESSION IN THE LOCAL GROUND-WATER SURFACE.

The ground-water potentiometric surface at Sulphur Bank Mine and directions of movement are shown in Plate 2 (pocket) and in a series of cross-sections (Fig. 8.3-1,2,3,4) on the following pages. Other relevant figures include the spillway axis section (Fig. 4.2-1), and a map showing the regional flow system (Fig. 7.1-1). The ground-water surface contours of Plate 2 are based on well measurements in late April and early May, 1988. Herman Lake and Clear Lake water surface elevations were 1334 and 1324 feet respectively on April 4, 1988 (the date of aerial photography used in constructing the basemap). These elevations were used in mapping the ground-water surface and may be expected to vary seasonally in elevation with a typical head difference ranging from about 7 to 10 feet based on 1987-88 data. During severe winter storms that affect both lakes, the head difference during short periods may be as low as 3 feet (1335-1331). Because these two lakes are the major ground-water sinks in the area, the adjacent ground-water surface will tend to fluctuate roughly in proportion to changes in the levels of Herman Lake and Clear Lake.

The ground-water surface contours of Plate 2 represent a period of near maximum head difference (10 feet) and therefore maximum rates of ground-water movement from Herman Lake impoundment to Clear Lake. Configuration of the water-level contours show that Herman Lake impoundment receives (in addition to deep-seated flow from submerged thermal springs, shallow ground-water seepage from the north, east, and south. Seepage escaping from the impoundment migrates westward to Clear Lake, however, as shown by the downward slope of the ground-water surface from the west wall of Herman Lake to Clear Lake (Figs. 4.2-1 and 8.3-3). The spillway axis section represents the shortest and steepest ground-water flow path from the impoundment to Clear Lake. For the conditions shown (10 foot head difference), the ground-water gradient works out to about 73 feet per mile over a distance of 720 feet. Gradients along the longest flowpaths to Clear Lake of about 1,000 feet, are about 54 feet per mile. As will be shown in section 8.5, the average rate of ground-water movement is extremely slow and the seepage quantity is relatively small.

Reference 6

**Herman Lake TPCA Assessment, Sulphur Bank Mercury Mine,
Lake County, California; Prepared for Bradley Mining Company
by Columbia Geoscience; 1987**

**HERMAN LAKE TPCA ASSESSMENT,
SULPHUR BANK MINE,
LAKE COUNTY, CALIFORNIA**

for the

BRADLEY MINING COMPANY

by

Columbia Geoscience

1987

HERMAN LAKE TPCA ASSESSMENT,
SULPHUR BANK MINE,
LAKE COUNTY, CALIFORNIA

CONCLUSIONS

- 1) The Herman lake water is found to be below toxic limits for all Title 22 categories of the Toxic Pits Cleanup Act. The sediments at the bottom of the Herman lake is found to be below toxic limits for all categories other than mercury.
- 2) The values for mercury observed in the sediment cores from the Herman lake are among the lowest mercury concentrations observed for sediments in the Oak Arm area of Clear Lake.
- 3) Five of the nine sediment core taken from the Herman lake show mercury in excess of the 20 ppm limit for toxic pits. The Mercury concentrations range from 9 to 46 ppm and average 26.3 ppm for the nine sediment samples.
- 4) Analyses of water fractions from the sediment cores show the pore water to be well below the toxic limits.
- 5) Mercury is not found to be leaching from the Herman lake sediments into the water.
- 6) Herman lake is currently acting as a natural treatment process to impound mercury which may enter it.

The water chemistry profiles (temperature, conductivity, and dissolved oxygen), confirmed that the entire water column was extremely well mixed throughout with a temperature about 20° C, dissolved oxygen about 5 mg/l, pH about 3.02, and specific conductivity about 6,600 micromhos/cm.. Eh measurements at profile site P2 were 791 mv at 1m, 763 mv at 9m, and 762 mv at 23m. Measurements of the 9m and 23m depth water samples were made by inserting the Eh probe into the rubber drain tube at the base of 2.5 liter Mar. Dorn sampler, immediately after bringing the sampler to the surface. A slow flow of water was allowed to drain across the probe during each measurement. Stable readings were obtained within about 2 minutes.

TPCA CHEMISTRY

Waters of Herman Lake

The field investigation of the waters of Herman lake, has failed to detect any violations of the California Toxic Pits Cleanup Act. Persistent and bioaccumulative toxic substances under paragraph 66699 (Title 22), including organic and inorganic substances were undetectable or at concentrations far below those required to trigger action under the current hazardous waste criteria (Tables 1 and 2). Notably, the average concentration of mercury was only 0.00081 mg/l in 9 samples of Herman lake collected in August and November, 1987 (Table 2, samples 1 through 9). The range in mercury concentrations was 0.00380 to 0.00025 mg/l (i.e., deep water at 23 meters versus shallow water at 9 meters, profile P2). The deep water sample at P2 is the only sample in Herman lake that exceeds the EPA drinking water standard of 0.0020 mg/l mercury, and it is about 53 times lower than the STLC trigger level for hazardous waste (0.2 mg/l).

The November samples as shown elsewhere in this report, represent well-mixed, moderately oxygenated lake water recovered from various regions and depths in Herman lake. It is possible that Herman lake becomes anoxic at certain times of the year, thus increasing the solubility of mercury. The 1976 June sample (#12), suggests some increased levels of other metals and anions, but mercury levels and the exact location of the sampling site are not provided. The 1987 August samples by the Board on the other hand, show that the water chemistry at Herman lake remained nearly identical into the November sampling run, despite crossing a typical time of the year when most lakes turn over, causing a mixing of cold, anoxic bottom waters with warm, oxygenated shallow water. Because of the prevailing west wind and the large volume of gas discharge from bottom vents, Herman Lake probably remains well-mixed and moderately oxygenated except on rare occasions. Therefore, the 1987 chemical characterization of Herman lake by the Board and by Columbia Geoscience, probably is representative of the overall long term physical and chemical conditions at Herman lake.

Bottom Sediments of Herman Lake

The field investigation of the bottom sediments of Herman lake, has shown that 5 out of the 9 core samples contain elevated TlC mercury concentrations ranging from 21 to 46 mg/kg (Table 2), which is sufficient to classify parts of the lake bottom sediments as hazardous waste (20 mg/kg). Four core samples contain mercury concentrations ranging from 9 to 19 mg/kg. The average concentration of mercury in all core samples is 26.33 mg/kg, or slightly in excess of current hazardous waste criteria. Leachable STlC mercury concentrations in all cores were at trace levels or below the detection limit (see original lab sheets, appendix B). All other inorganic constituents classified under the TPCA were also at trace levels or below the detection limit.

All coring sites showed evidence of anoxic conditions within the sediment (black to dark green colors, Figure). Cores at sites P4 and P5 were also obtained that showed substantial orange-yellowish coloring, particularly at P5, sample #20 (Tables 1 and 2). The lighter coloring seems to be associated with the gas vents and some type of apparent oxidizing process that penetrates the sediment. The presence of both anoxic and oxidized sediments is not inconsistent with the character of the lake water and the presence of the gas vents. At least some of the mercury contained within the sediment may be originating from the gas phase as suggested by the elevated mercury level (38 mg/kg) in sample 20, site P5.

Three duplicate 60-cm cores have been retained by Columbia Geoscience, as originally retrieved at sites P2, P3, and P4, as well as submerged gas samples from a major gas vent (Figure 18). These may be available for detailed study and analysis at a later date, such work is outside the scope of the present investigation.

DISCUSSION

Herman Lake Water

Chemistry data on Herman lake, the geothermal springs and wells, and lake bottom sediments, have been tabulated in Tables 1 and 2, along with several calculated ion ratios. Both Tables include all analyses of which the writers are aware for the period 1937 to 1987, and many of the referenced analyses may contain supplementary data not reported here. The logic of each Table layout is as follows: samples 1-12 (Herman lake water); samples 13-22 (cores and a surface sediment sample near the lake); samples 23-26 (ground-water samples from wells); samples 27-28 (ponded spring water in a vent area); and samples 29-30 (geothermal springs now submerged by Herman lake).

One of the accepted methods of examining a contaminated site is to

Herman lake is less than one million cubic meters. The proposal requires a total of from 495,000 to 540,000 cubic meters of mercury-rich sedimentation in the bottom of Clear Lake since 1957 and a total of from 1,335,000 to 1,440,000 cubic meters since 1947. These figures represents volumes of 3,280 ft. by 73 ft. by 73 ft. for a minimum of mercury-rich sedimentation since 1957 and 3,280 ft. by 120 ft. by 120 ft. for a minimum since 1947. Extending the area out to include both U.S.G.S. cores; as the Board's above-mentioned 1986 document proposes, covering a minimum area of 1.5 km by 3.5 km lake-bottom area, the required volume of mercury-rich sedimentation from the Sulphur Bank area would be equal to 4,200,000 cubic meters, or 3,280 ft. by 385 ft. by 385 ft.

Based on the bathymetric lake volume of about 900,000 cubic meters (figure 4), and adding a rough estimate of an additional 50% to represent excavated area above the current Herman lake water level, the total excavation volume is unlikely to exceed 1,400,000 cubic meters for the 125 years of the mine's history. If one were to assume that the sedimentary cores from Clear Lake were 50% water, the solid portion would still equal 2,100,000 cubic meters of mercury-rich sediments to be derived from the Sulphur Bank area to satisfy the above 1986 document. All of this is further compounded by the fact that the bulk of the tailings piles are still present to the south, west, and north of the mine excavations. The above volume calculations suggest that it would be physically impossible to attribute the mercury-rich sedimentary mass in the upper 90 cm of even a small portion of the Oak Arm to erosion from mining activities.

Summary

Many scientific investigations have been undertaken in the north-eastern portion of Clear Lake, including the Sulphur Bank area. Most have been undertaken by the U.S. Geological Survey or the California Bureau of Mines. More recently the California Regional Water Quality Control Board has also contributed to the body of data available for the area. Currently the Bradley Mining Co. is funding this study of Herman Lake in compliance with the California Toxic Pit Classification Act. The data from these studies show that sediments in the Oak Arm of Clear Lake and in Herman lake contain mercury. The data show that the sediments in Clear Lake contain much more mercury than the sediments in Herman Lake. High mercury values have been present in the sediments of Clear Lake for thousands of years. The data show that mercury is not leaching into the water of Herman lake from the sediments or adjacent rock. The data show that mercury-bearing geothermal water and gas has been and is currently discharging into Clear Lake and Herman lake. Volume calculations show that erosion from the Sulphur Bank Mine cannot account for the near-surface mercury-rich sediments in the Oak Arm of Clear Lake.

The water in Herman lake is acting to impound mercury which is entering it either through discharging geothermal fluid or through

erosion. The physical and chemical conditions of the lake act as a natural treatment process which appears to efficiently restrict the solubility of mercury. This process acts to confine mercury to the floor of the lake. As long as the current physical and chemical conditions of the Herman lake are preserved, this natural treatment process will likely continue to impound the mercury.

CLOSURE OPTIONS

The options available for changing the toxic mercury deposition from the geothermal discharge in both Clear Lake and the Herman lake are limited, at best. Unfortunately man cannot always control many ongoing geologic forces of nature. Long-lived high temperature geothermal systems, like earthquakes, fall into this category. Technology does not exist today to stop an active geothermal system. The deposition point for much of the mercury entering the mine, however, has likely been lowered due to past mining activities. Prior to mining, the bulk of both sulfur and mercury were being deposited at and very near the topographic surface. Mining has lowered the abrupt thermal and chemical gradients from the topographic surface to in and probably somewhat below the bottom of the excavated area. Except for the small area of intense discharging on the northern edge of the excavation where White observed cinnabar, pyrite and sulfur being deposited (Sims and White, 1981) the bulk of mercury deposition in the mine area is probably now occurring at and below these abrupt thermal and chemical boundaries.

The current physical conditions of the mine excavations stimulate the precipitation of mercury introduced from the upwelling geothermal fluids. An attempt to neutralize the water would be an aggressive and never-ending process as long as the geothermal system continues to discharge sulfur gasses. The common closure action for acid water in actual acid mine drainage problems, neutralizing the water and/or filling in the body of water, would have an undesirable effect on the mercury distribution at Sulphur Bank. Filling the mine excavation would remove the mercury-impounding effects. The abrupt thermal and chemical boundaries would again be at the topographic surface. Mercury and sulfur would likely again be deposited on the surface of the Clear Lake shore line.

The most effective strategy for the toxic mercury conditions in the Sulphur Bank area would appear to be one of preserving the current conditions, allowing the Herman lake to continue to act as a natural treatment process for that portion of the geothermal fluids discharging to the east of the Clear Lake shore line.

APPENDIX B:
(Analytic Laboratory Data Sheets)

**HERMAN LAKE TPCA ASSESSMENT,
SULPHUR BANK MINE,
LAKE COUNTY, CALIFORNIA**

**for the
BRADLEY MINING COMPANY**

**by
Columbia Geoscience**

**James E. Luzier
Albert F. Maibel**

1987

103-

Enseco

December 3, 1987
Lab ID: 32139

James Luzier
Columbia Geoscience
2 Gershwin Ct.
Lake Oswego, OR 97034

Dear Mr. Luzier:

Enclosed is the report for the nineteen samples for your Sulfur Bank Mine Project, Number TPCA-5BM which were received at Enseco-Cal Lab on 3 November 1987.

The report consists of the following sections:

- I Sample Description
- II Analysis Request
- III Quality Control Report
- IV Analysis Results

No problems were encountered with the analysis of your samples.

If you have any questions, please feel free to call.

Sincerely,


John R. Barnett
Inorganic Lab Manager

dmc

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C.A.M. METALS
California Title 22 (Title 26) Protocol
TTL (Total) Data Sheet

Client Name: Columbia Geoscience
Client ID: P2-25M 2.3 M
Lab ID: 32139-012 **Enseco ID:** NA
Matrix: Soil **Sampled:** 01-Nov-87 **Received:** 03-Nov-87
Authorized: 03-Nov-87 **Prepared:** 10-Nov-87 **Analyzed:** 11-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u> (Wet wt.)	<u>Reporting</u> <u>Limit</u>	<u>Regulated Limits</u>		<u>Analytical</u> <u>Method</u>
				<u>TTL</u>	<u>STLC</u>	
Arsenic	49	mg/kg	40	500	5.0	6010
Antimony	ND	mg/kg	40	500	15	6010
Barium	1300	mg/kg	10	10000	100	6010
Beryllium	ND	mg/kg	0.50	75	0.75	6010
Cadmium	ND	mg/kg	0.50	100	1.0	6010
Chromium	15	mg/kg	1.0	2500	560	6010
Chromium-VI	NA	mg/kg	1.0	500	5.0	7196
Cobalt	5.6	mg/kg	3.0	8000	80	6010
Copper	16	mg/kg	3.0	2500	25	6010
Lead	ND	mg/kg	5.0	1000	5.0	6010
Mercury	9.0	mg/kg	0.10	20	0.2	7471
Molybdenum	ND	mg/kg	10	3500	350	6010
Nickel	18	mg/kg	5.0	2000	20	6010
Selenium	ND	mg/kg	5.0	100	1.0	7740
Silver	ND	mg/kg	2.0	500	5.0	6010
Thallium	ND	mg/kg	50	700	7.0	6010
Vanadium	16	mg/kg	5.0	2400	24	6010
Zinc	34	mg/kg	2.0	5000	250	6010

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB 

The cover letter is an integral part of this report.
 Rev 230787

507

E

C.A.M. METALS
California Title 22 (Title 26) Protocol
TTLC (Total) Data Sheet

Client Name: Columbia Geoscience
Client ID: P2-23MT2
Lab ID: 32139-011 Enseco ID: NA
Matrix: Soil Sampled: 01-Nov-87 Received: 03-Nov-87
Authorized: 03-Nov-87 Prepared: 10-Nov-87 Analyzed: 11-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u> (<u>Net wt.</u>)	<u>Reporting</u> <u>Limit</u>	<u>Regulated Limits</u>		<u>Analytical</u> <u>Method</u>
				<u>TTLC</u>	<u>STLC</u>	
Arsenic	ND	mg/kg	40	500	5.0	6010
Antimony	ND	mg/kg	40	500	15	6010
Barium	120	mg/kg	10	10000	100	6010
Beryllium	ND	mg/kg	0.50	75	0.75	6010
Cadmium	ND	mg/kg	0.50	100	1.0	6010
Chromium	17	mg/kg	1.0	2500	560	6010
Chromium-VI	NA	mg/kg	1.0	500	5.0	7196
Cobalt	3.1	mg/kg	3.0	8000	80	6010
Copper	19	mg/kg	3.0	2500	25	6010
Lead	ND	mg/kg	5.0	1000	5.0	6010
Mercury	21	mg/kg	0.10	20	0.2	7471
Molybdenum	ND	mg/kg	10	3500	350	6010
Nickel	6.3	mg/kg	5.0	2000	20	6010
Selenium	ND	mg/kg	5.0	100	1.0	7740
Silver	ND	mg/kg	2.0	500	5.0	6010
Thallium	NC	mg/kg	50	700	7.0	6010
Vanadium	21	mg/kg	5.0	2400	24	6010
Zinc	24	mg/kg	2.0	5000	250	6010

ND=Not Detected
NA=Not Applicable

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Reported by: BEV Approved by: JRB *(Signature)*

The cover letter is an integral part of this report.
Rev 230787

C.A.M. METALS
California Title 22 (Title 26) Protocol
TTL (Total) Data Sheet

Client Name: Columbia Geoscience
Client ID: P3-27MT1 (Top 1/2 Core)
Lab ID: 32139-014 Enseco ID: NA
Matrix: Soil Sampled: 01-Nov-87 Received: 03-Nov-87
Authorized: 03-Nov-87 Prepared: 10-Nov-87 Analyzed: 11-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u> (Wet wt.)	<u>Reporting</u> <u>Limit</u>	<u>Regulated Limits</u>		<u>Analytical</u> <u>Method</u>
				<u>TTL</u>	<u>STL</u>	
Arsenic	ND	mg/kg	40	500	5.0	6010
Antimony	ND	mg/kg	40	500	15	6010
Barium	120	mg/kg	10	10000	100	6010
Beryllium	ND	mg/kg	0.50	75	0.75	6010
Cadmium	ND	mg/kg	0.50	100	1.0	6010
Chromium	10	mg/kg	1.0	2500	560	6010
Chromium-VI	NA	mg/kg	1.0	500	5.0	7196
Cobalt	4.0	mg/kg	3.0	8000	80	6010
Copper	9.0	mg/kg	3.0	2500	25	6010
Lead	ND	mg/kg	5.0	1000	5.0	6010
Mercury	18	mg/kg	0.10	20	0.2	7471
Molybdenum	ND	mg/kg	10	3500	350	6010
Nickel	12	mg/kg	5.0	2000	20	6010
Selenium	ND	mg/kg	5.0	100	1.0	7740
Silver	ND	mg/kg	2.0	500	5.0	6010
Thallium	ND	mg/kg	50	700	7.0	6010
Vanadium	16	mg/kg	5.0	2400	24	6010
Zinc	20	mg/kg	2.0	5000	250	6010

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB *(Signature)*

The cover letter is an integral part of this report.
 Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
TTL (Total) Data Sheet

Client Name: Columbia Geoscience
Client ID: P3-27MB1 (Bottom 1/2 Core)
Lab ID: 32139-013 Enseco ID: NA
Matrix: Soil Sampled: 01-Nov-87 Received: 03-Nov-87
Authorized: 03-Nov-87 Prepared: 10-Nov-87 Analyzed: 11-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u> (Wet wt.)	<u>Reporting</u> <u>Limit</u>	<u>Regulated Limits</u>		<u>Analytical</u> <u>Method</u>
				<u>TTL</u>	<u>STLC</u>	
Arsenic	ND	mg/kg	40	500	5.0	6010
Antimony	ND	mg/kg	40	500	15	6010
Barium	250	mg/kg	10	10000	100	6010
Beryllium	ND	mg/kg	0.50	75	0.75	6010
Cadmium	ND	mg/kg	0.50	100	1.0	6010
Chromium	26	mg/kg	1.0	2500	560	6010
Chromium-VI	NA	mg/kg	1.0	500	5.0	7196
Cobalt	ND	mg/kg	3.0	8000	80	6010
Copper	16	mg/kg	3.0	2500	25	6010
Lead	ND	mg/kg	5.0	1000	5.0	6010
Mercury	23	mg/kg	0.10	20	0.2	7471
Molybdenum	ND	mg/kg	10	3500	350	6010
Nickel	6.3	mg/kg	5.0	2000	20	6010
Selenium	ND	mg/kg	5.0	100	1.0	7740
Silver	ND	mg/kg	2.0	500	5.0	6010
Thallium	ND	mg/kg	50	700	7.0	6010
Vanadium	29	mg/kg	5.0	2400	24	6010
Zinc	12	mg/kg	2.0	5000	250	6010

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB

The cover letter is an integral part of this report.
 Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
TTLG (Total) Data Sheet

Client Name: Columbia Geoscience
Client ID: P4-25MTC (Top 1/2 core)
Lab ID: 32139-015 **Enseco ID:** NA
Matrix: Soil **Sampled:** 01-Nov-87 **Received:** 03-Nov-87
Authorized: 03-Nov-87 **Prepared:** 10-Nov-87 **Analyzed:** 11-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u> (Wet wt.)	<u>Reporting</u> <u>Limit</u>	<u>Regulated Limits</u>		<u>Analytical</u> <u>Method</u>
				<u>TTLG</u>	<u>STLC</u>	
Arsenic	ND	mg/kg	40	500	5.0	6010
Antimony	ND	mg/kg	40	500	15	6010
Barium	100	mg/kg	10	10000	100	6010
Beryllium	ND	mg/kg	0.50	75	0.75	6010
Cadmium	ND	mg/kg	0.50	100	1.0	6010
Chromium	14	mg/kg	1.0	2500	560	6010
Chromium-VI	NA	mg/kg	1.0	500	5.0	7196
Cobalt	ND	mg/kg	3.0	8000	80	6010
Copper	11	mg/kg	3.0	2500	25	6010
Lead	ND	mg/kg	5.0	1000	5.0	6010
Mercury	19	mg/kg	0.10	20	0.2	7471
Molybdenum	ND	mg/kg	10	3500	350	6010
Nickel	5.3	mg/kg	5.0	2000	20	6010
Selenium	ND	mg/kg	5.0	100	1.0	7760
Silver	ND	mg/kg	2.0	500	5.0	6010
Thallium	ND	mg/kg	50	700	7.0	6010
Vanadium	17	mg/kg	5.0	2400	24	6010
Zinc	14	mg/kg	2.0	5000	250	6010

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB *(Signature)*

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 Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
TTLC (Total) Data Sheet

Client Name: Columbia Geoscience
Client ID: P4-25MMC (Middle 1/2 core)
Lab ID: 32139-016 Enseco ID: NA
Matrix: Soil Sampled: 01-Nov-87 Received: 03-Nov-87
Authorized: 03-Nov-87 Prepared: 10-Nov-87 Analyzed: 11-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units (Net wt.)</u>	<u>Reporting Limit</u>	<u>Regulated Limits</u>		<u>Analytical Method</u>
				<u>TTLC</u>	<u>STLC</u>	
Arsenic	ND	mg/kg	40	500	5.0	6010
Antimony	ND	mg/kg	40	500	15	6010
Barium	110	mg/kg	10	10000	100	6010
Beryllium	ND	mg/kg	0.50	75	0.75	6010
Cadmium	ND	mg/kg	0.50	100	1.0	6010
Chromium	16	mg/kg	1.0	2500	560	6010
Chromium-VI	NA	mg/kg	1.0	500	5.0	7196
Cobalt	3.9	mg/kg	3.0	8000	80	6010
Copper	12	mg/kg	3.0	2500	25	6010
Lead	5.4	mg/kg	5.0	1000	5.0	6010
Mercury	44	mg/kg	0.10	20	0.2	7471
Molybdenum	ND	mg/kg	10	3500	350	6010
Nickel	11	mg/kg	5.0	2000	20	6010
Selenium	ND	mg/kg	5.0	100	1.0	7740
Silver	ND	mg/kg	2.0	500	5.0	6010
Thallium	ND	mg/kg	50	700	7.0	6010
Vanadium	21	mg/kg	5.0	2400	24	6010
Zinc	14	mg/kg	2.0	5000	250	6010

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB *(Signature)*

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 Rev 230787

C.A.M. METALS
California Title 22 (Title 26) Protocol
TTL (Total) Data Sheet

Client Name: Columbia Geoscience
Client ID: P4-25MBC (Bottom 1/3 Core)
Lab ID: 32139-017 **Enseco ID:** NA
Matrix: Soil **Sampled:** 01-Nov-87 **Received:** 03-Nov-87
Authorized: 03-Nov-87 **Prepared:** 10-Nov-87 **Analyzed:** 11-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u> (Wet wt.)	<u>Reporting</u> <u>Limit</u>	<u>Regulated Limits</u>		<u>Analytical</u> <u>Method</u>
				<u>TTL</u>	<u>STL</u>	
Arsenic	ND	mg/kg	40	500	5.0	6010
Antimony	ND	mg/kg	40	500	15	6010
Barium	86	mg/kg	10	10000	100	6010
Beryllium	ND	mg/kg	0.50	75	0.75	6010
Cadmium	ND	mg/kg	0.50	100	1.0	6010
Chromium	13	mg/kg	1.0	2500	560	6010
Chromium-VI	NA	mg/kg	1.0	500	5.0	7196
Cobalt	ND	mg/kg	3.0	8000	80	6010
Copper	11	mg/kg	3.0	2500	25	6010
Lead	6.2	mg/kg	5.0	1000	5.0	6010
Mercury	46	mg/kg	0.10	20	0.2	7471
Molybdenum	ND	mg/kg	10	3500	350	6010
Nickel	6.9	mg/kg	5.0	2000	20	6010
Selenium	ND	mg/kg	5.0	100	1.0	7740
Silver	ND	mg/kg	2.0	500	5.0	6010
Thallium	ND	mg/kg	50	700	7.0	6010
Vanadium	21	mg/kg	5.0	2400	24	6010
Zinc	15	mg/kg	2.0	5000	250	6010

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB 

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 Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
TTLG (Total) Data Sheet

Client Name: Columbia Geoscience
Client ID: PS-5MT1 (Core 1) upper 2/3, 2/3 missing on recovery - JGL
Lab ID: 32139-018 Enseco ID: NA
Matrix: Soil Sampled: 01-Nov-87 Received: 03-Nov-87
Authorized: 03-Nov-87 Prepared: 10-Nov-87 Analyzed: 11-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units (Wet wt.)</u>	<u>Reporting Limit</u>	<u>Regulated Limits</u>		<u>Analytical Method</u>
				<u>TTLG</u>	<u>STLG</u>	
Arsenic	ND	mg/kg	40	500	5.0	6010
Antimony	ND	mg/kg	40	500	15	6010
Barium	1600	mg/kg	10	10000	100	6010
Beryllium	ND	mg/kg	0.50	75	0.75	6010
Cadmium	ND	mg/kg	0.50	100	1.0	6010
Chromium	26	mg/kg	1.0	2500	560	6010
Chromium-VI	NA	mg/kg	1.0	500	5.0	7196
Cobalt	4.8	mg/kg	3.0	8000	80	6010
Copper	27	mg/kg	3.0	2500	25	6010
Lead	5.2	mg/kg	5.0	1000	5.0	6010
Mercury	38	mg/kg	0.10	20	0.2	7471
Molybdenum	ND	mg/kg	10	3500	350	6010
Nickel	13	mg/kg	5.0	2000	20	6010
Selenium	ND	mg/kg	5.0	100	1.0	7740
Silver	ND	mg/kg	2.0	500	5.0	6010
Thallium	ND	mg/kg	50	700	7.0	6010
Vanadium	14	mg/kg	5.0	2400	24	6010
Zinc	16	mg/kg	2.0	5000	250	6010

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB

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 Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
TTLIC (Total) Data Sheet

Client Name: Columbia Geoscience
Client ID: P5-5MT2 (Core 2) upper 2/3; 1/3 missing on recovery - 3
Lab ID: 32139-019 **Enseco ID:** NA
Matrix: Soil **Sampled:** 01-Nov-87 **Received:** 03-Nov-87
Authorized: 03-Nov-87 **Prepared:** 10-Nov-87 **Analyzed:** 11-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u> (Wet wt.)	<u>Reporting</u> <u>Limit</u>	<u>Regulated Limits</u>		<u>Analytical</u> <u>Method</u>
				<u>TTLIC</u>	<u>STLC</u>	
Arsenic	ND	mg/kg	40	500	5.0	6010
Antimony	ND	mg/kg	40	500	15	6010
Barium	980	mg/kg	10	10000	100	6010
Beryllium	ND	mg/kg	0.50	75	0.75	6010
Cadmium	ND	mg/kg	0.50	100	1.0	6010
Chromium	16	mg/kg	1.0	2500	560	6010
Chromium-VI	NA	mg/kg	1.0	500	5.0	7196
Cobalt	5.0	mg/kg	3.0	8000	80	6010
Copper	22	mg/kg	3.0	2500	25	6010
Lead	5.9	mg/kg	5.0	1000	5.0	6010
Mercury	19	mg/kg	0.10	20	0.2	7471
Molybdenum	ND	mg/kg	10	3500	350	6010
Nickel	13	mg/kg	5.0	2000	20	6010
Selenium	ND	mg/kg	5.0	100	1.0	7740
Silver	ND	mg/kg	2.0	500	5.0	6010
Thallium	ND	mg/kg	50	700	7.0	6010
Vanadium	9.3	mg/kg	5.0	2400	24	6010
Zinc	24	mg/kg	2.0	5000	250	6010

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB

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 Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
STLC (Leachable) Data Sheet
Citrate Buffer Leachate

Client Name: Columbia Geoscience
Client ID: P2-26M-23M
Lab ID: 32139-012 **Enseco ID:** NA
Matrix: Leachate **Sampled:** 01-Nov-87 **Received:** 03-Nov-87
Authorized: 03-Nov-87 **Prepared:** 18-Nov-87 **Analyzed:** 20-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u>	<u>Reporting Limit</u>	<u>Regulated Limits</u>		<u>Analytical Method</u>
				<u>TILC</u>	<u>STLC</u>	
Arsenic	ND	mg/L	1.0	500	5.0	200.7
Antimony	ND	mg/L	1.0	500	15	200.7
Barium	0.61	mg/L	0.50	10000	100	200.7
Beryllium	ND	mg/L	0.050	75	0.75	200.7
Cadmium	ND	mg/L	0.10	100	1.0	200.7
Chromium	0.26	mg/L	0.10	2500	560	200.7
Chromium-VI	NA	mg/L	0.10	500	5.0	7196
Cobalt	0.19	mg/L	0.10	8000	80	200.7
Copper	0.40	mg/L	0.10	2500	25	200.7
Lead	ND	mg/L	1.0	1000	5.0	200.7
Mercury	ND	mg/L	0.010	20	0.2	245.2
Molybdenum	ND	mg/L	1.0	3500	350	200.7
Nickel	0.78	mg/L	1.0	2000	20	200.7
Selenium	ND	mg/L	0.50	100	1.0	200.7
Silver	ND	mg/L	0.50	500	5.0	200.7
Thallium	ND	mg/L	1.0	700	7.0	200.7
Vanadium	ND	mg/L	0.50	2400	24	200.7
Zinc	1.4	mg/L	0.10	5000	250	200.7

ND=Not Detected
NA=Not Applicable

Reported by: BEV

Approved by: JRB 

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Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
STLC (Leachable) Data Sheet
Citrate Buffer Leachate

Client Name: Columbia Geoscience
Client ID: P2-23MT2
Lab ID: 32139-011 **Enseco ID:** NA
Matrix: Leachate **Sampled:** 01-Nov-87 **Received:** 03-Nov-87
Authorized: 03-Nov-87 **Prepared:** 18-Nov-87 **Analyzed:** 20-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u>	<u>Reporting Limit</u>	<u>Regulated Limits</u>		<u>Analytical Method</u>
				<u>TTC</u>	<u>STLC</u>	
Arsenic	NA	mg/L	1.0	500	5.0	200.7
Antimony	NA	mg/L	1.0	500	15	200.7
Barium	NA	mg/L	0.50	10000	100	200.7
Beryllium	NA	mg/L	0.050	75	0.75	200.7
Cadmium	NA	mg/L	0.10	100	1.0	200.7
Chromium	NA	mg/L	0.10	2500	560	200.7
Chromium-VI	NA	mg/L	0.10	500	5.0	7196
Cobalt	NA	mg/L	0.10	8000	80	200.7
Copper	NA	mg/L	0.10	2500	25	200.7
Lead	NA	mg/L	1.0	1000	5.0	200.7
Mercury	0.049	mg/L	0.010	20	0.2	245.2
Molybdenum	NA	mg/L	1.0	3500	350	200.7
Nickel	NA	mg/L	1.0	2000	20	200.7
Selenium	NA	mg/L	0.50	100	1.0	200.7
Silver	NA	mg/L	0.50	500	5.0	200.7
Thallium	NA	mg/L	1.0	700	7.0	200.7
Vanadium	NA	mg/L	0.50	2400	24	200.7
Zinc	NA	mg/L	0.10	5000	250	200.7

ND=Not Detected
NA=Not Applicable

Reported by: BEV

Approved by: JRB

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Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
STLC (Leachable) Data Sheet
Citrate Buffer Leachate

Client Name: Columbia Geoscience
Client ID: P3-27MT1 (Top 1/2 Core)
Lab ID: 32139-014 Enseco ID: NA
Matrix: Leachate Sampled: 01-Nov-87 Received: 03-Nov-87
Authorized: 03-Nov-87 Prepared: 18-Nov-87 Analyzed: 20-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u>	<u>Reporting Limit</u>	<u>Regulated Limits</u>		<u>Analytical Method</u>
				<u>TTL</u>	<u>STLC</u>	
Arsenic	NA	mg/L	1.0	500	5.0	200.7
Antimony	NA	mg/L	1.0	500	15	200.7
Barium	NA	mg/L	0.50	10000	100	200.7
Beryllium	NA	mg/L	0.050	75	0.75	200.7
Cadmium	NA	mg/L	0.10	100	1.0	200.7
Chromium	NA	mg/L	0.10	2500	560	200.7
Chromium-VI	NA	mg/L	0.10	500	5.0	7196
Cobalt	NA	mg/L	0.10	8000	80	200.7
Copper	NA	mg/L	0.10	2500	25	200.7
Lead	NA	mg/L	1.0	1000	5.0	200.7
Mercury	0.019	mg/L	0.010	20	0.2	245.2
Molybdenum	NA	mg/L	1.0	3500	350	200.7
Nickel	NA	mg/L	1.0	2000	20	200.7
Selenium	NA	mg/L	0.50	100	1.0	200.7
Silver	NA	mg/L	0.50	500	5.0	200.7
Thallium	NA	mg/L	1.0	700	7.0	200.7
Vanadium	NA	mg/L	0.50	2400	24	200.7
Zinc	NA	mg/L	0.10	5000	250	200.7

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB 

The cover letter is an integral part of this report.
 Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
STLC (Leachable) Data Sheet
Citrate Buffer Leachate

Client Name: Columbia Geoscience
Client ID: P3-27MB1 (Bottom 1/2 Core)
Lab ID: 32139-013 **Enseco ID:** NA
Matrix: Leachate **Sampled:** 01-Nov-87 **Received:** 03-Nov-87
Authorized: 03-Nov-87 **Prepared:** 18-Nov-87 **Analyzed:** 20-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u>	<u>Reporting Limit</u>	<u>Regulated Limits</u>		<u>Analytical Method</u>
				<u>TLC</u>	<u>STLC</u>	
Arsenic	NA	mg/L	1.0	500	5.0	200.7
Antimony	NA	mg/L	1.0	500	15	200.7
Barium	NA	mg/L	0.50	10000	100	200.7
Beryllium	NA	mg/L	0.050	75	0.75	200.7
Cadmium	NA	mg/L	0.10	100	1.0	200.7
Chromium	NA	mg/L	0.10	2500	560	200.7
Chromium-VI	NA	mg/L	0.10	500	5.0	7196
Cobalt	NA	mg/L	0.10	8000	80	200.7
Copper	NA	mg/L	0.10	2500	25	200.7
Lead	NA	mg/L	1.0	1000	5.0	200.7
Mercury	0.035	mg/L	0.010	20	0.2	245.2
Molybdenum	NA	mg/L	1.0	3500	350	200.7
Nickel	NA	mg/L	1.0	2000	20	200.7
Selenium	NA	mg/L	0.50	100	1.0	200.7
Silver	NA	mg/L	0.50	500	5.0	200.7
Thallium	NA	mg/L	1.0	700	7.0	200.7
Vanadium	NA	mg/L	0.50	2400	24	200.7
Zinc	NA	mg/L	0.10	5000	250	200.7

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB *(Signature)*

The cover letter is an integral part of this report.
 Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
STLC (Leachable) Data Sheet
Citrate Buffer Leachate

Client Name: Columbia Geoscience
Client ID: P4-25MTC (Top 13)
Lab ID: 32139-015 **Enseco ID:** NA
Matrix: Leachate **Sampled:** 01-Nov-87 **Received:** 03-Nov-87
Authorized: 03-Nov-87 **Prepared:** 18-Nov-87 **Analyzed:** 20-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u>	<u>Reporting Limit</u>	<u>Regulated Limits</u>		<u>Analytical Method</u>
				<u>TLC</u>	<u>STLC</u>	
Arsenic	NA	mg/L	1.0	500	5.0	200.7
Antimony	NA	mg/L	1.0	500	15	200.7
Barium	NA	mg/L	0.50	10000	100	200.7
Beryllium	NA	mg/L	0.050	75	0.75	200.7
Cadmium	NA	mg/L	0.10	100	1.0	200.7
Chromium	NA	mg/L	0.10	2500	560	200.7
Chromium-VI	NA	mg/L	0.10	500	5.0	7196
Cobalt	NA	mg/L	0.10	8000	80	200.7
Copper	NA	mg/L	0.10	2500	25	200.7
Lead	NA	mg/L	1.0	1000	5.0	200.7
Mercury	ND	mg/L	0.010	20	0.2	245.2
Molybdenum	NA	mg/L	1.0	3500	350	200.7
Nickel	NA	mg/L	1.0	2000	20	200.7
Selenium	NA	mg/L	0.50	100	1.0	200.7
Silver	NA	mg/L	0.50	500	5.0	200.7
Thallium	NA	mg/L	1.0	700	7.0	200.7
Vanadium	NA	mg/L	0.50	2400	24	200.7
Zinc	NA	mg/L	0.10	5000	250	200.7

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB

The cover letter is an integral part of this report.
 Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
STLC (Leachable) Data Sheet
Citrate Buffer Leachate

Client Name: Columbia Geoscience
Client ID: P4-25MMC (M: 22/c 13)
Lab ID: 32139-016 **Enseco ID:** NA
Matrix: Leachate **Sampled:** 01-Nov-87 **Received:** 03-Nov-87
Authorized: 03-Nov-87 **Prepared:** 18-Nov-87 **Analyzed:** 20-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u>	<u>Reporting</u>	<u>Regulated Limits</u>		<u>Analytical</u>
			<u>Limit</u>	<u>TTL</u>	<u>STLC</u>	
Arsenic	NA	mg/L	1.0	500	5.0	200.7
Antimony	NA	mg/L	1.0	500	15	200.7
Barium	NA	mg/L	0.50	10000	100	200.7
Beryllium	NA	mg/L	0.050	75	0.75	200.7
Cadmium	NA	mg/L	0.10	100	1.0	200.7
Chromium	NA	mg/L	0.10	2500	560	200.7
Chromium-VI	NA	mg/L	0.10	500	5.0	7196
Cobalt	NA	mg/L	0.10	8000	80	200.7
Copper	NA	mg/L	0.10	2500	25	200.7
Lead	NA	mg/L	1.0	1000	5.0	200.7
Mercury	ND	mg/L	0.010	20	0.2	245.2
Molybdenum	NA	mg/L	1.0	3500	350	200.7
Nickel	NA	mg/L	1.0	2000	20	200.7
Selenium	NA	mg/L	0.50	100	1.0	200.7
Silver	NA	mg/L	0.50	500	5.0	200.7
Thallium	NA	mg/L	1.0	700	7.0	200.7
Vanadium	NA	mg/L	0.50	2400	24	200.7
Zinc	NA	mg/L	0.10	5000	250	200.7

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB (initials)

The cover letter is an integral part of this report.
 Rev 230787

C.A.M. METALS
California Title 22 (Title 26) Protocol
STLC (Leachable) Data Sheet
Citrate Buffer Leachate

Client Name: Columbia Geoscience
Client ID: P4-25MBC (Bottom 13)
Lab ID: 32139-017 **Enseco ID:** NA
Matrix: Leachate **Sampled:** 01-Nov-87 **Received:** 03-Nov-87
Authorized: 03-Nov-87 **Prepared:** 18-Nov-87 **Analyzed:** 20-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u>	<u>Reporting Limit</u>	<u>Regulated Limits</u>		<u>Analytical Method</u>
				<u>ITLC</u>	<u>STLC</u>	
Arsenic	NA	mg/L	1.0	500	5.0	200.7
Antimony	NA	mg/L	1.0	500	15	200.7
Barium	NA	mg/L	0.50	10000	100	200.7
Beryllium	NA	mg/L	0.050	75	0.75	200.7
Cadmium	NA	mg/L	0.10	100	1.0	200.7
Chromium	NA	mg/L	0.10	2500	560	200.7
Chromium-VI	NA	mg/L	0.10	500	5.0	7196
Cobalt	NA	mg/L	0.10	8000	80	200.7
Copper	NA	mg/L	0.10	2500	25	200.7
Lead	NA	mg/L	1.0	1000	5.0	200.7
Mercury	ND	mg/L	0.010	20	0.2	245.2
Molybdenum	NA	mg/L	1.0	3500	350	200.7
Nickel	NA	mg/L	1.0	2000	20	200.7
Selenium	NA	mg/L	0.50	100	1.0	200.7
Silver	NA	mg/L	0.50	500	5.0	200.7
Thallium	NA	mg/L	1.0	700	7.0	200.7
Vanadium	NA	mg/L	0.50	2400	24	200.7
Zinc	NA	mg/L	0.10	5000	250	200.7

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB (Signature)

The cover letter is an integral part of this report.
 Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
STLC (Leachable) Data Sheet
Citrate Buffer Leachate

Client Name: Columbia Geoscience

Client ID: PS-SMT1

Lab ID: 32139-018

Matrix: Leachate

Authorized: 03-Nov-87

Case 1

Enseco ID: NA

Sampled: 01-Nov-87

Prepared: 18-Nov-87

Received: 03-Nov-87

Analyzed: 20-Nov-87

<u>Parameter</u>	<u>Result</u>	<u>Units</u>	<u>Reporting Limit</u>	<u>Regulated Limits</u>		<u>Analytical Method</u>
				<u>TTLG</u>	<u>STLC</u>	
Arsenic	ND	mg/L	1.0	500	5.0	200.7
Antimony	ND	mg/L	1.0	500	15	200.7
Barium	1.2	mg/L	0.50	10000	100	200.7
Beryllium	ND	mg/L	0.050	75	0.75	200.7
Cadmium	ND	mg/L	0.10	100	1.0	200.7
Chromium	0.45	mg/L	0.10	2500	560	200.7
Chromium-VI	NA	mg/L	0.10	500	5.0	7196
Cobalt	0.16	mg/L	0.10	8000	80	200.7
Copper	0.93	mg/L	0.10	2500	25	200.7
Lead	ND	mg/L	1.0	1000	5.0	200.7
Mercury	ND	mg/L	0.010	20	0.2	245.2
Molybdenum	0.26	mg/L	1.0	3500	350	200.7
Nickel	ND	mg/L	1.0	2000	20	200.7
Selenium	ND	mg/L	0.50	100	1.0	200.7
Silver	ND	mg/L	0.50	500	5.0	200.7
Thallium	ND	mg/L	1.0	700	7.0	200.7
Vanadium	ND	mg/L	0.50	2400	24	200.7
Zinc	0.11	mg/L	0.10	5000	250	200.7

ND=Not Detected
 NA=Not Applicable

Reported by: BEV

Approved by: JRB 

The cover letter is an integral part of this report.
 Rev 230787

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C.A.M. METALS
California Title 22 (Title 26) Protocol
STLC (Leachable) Data Sheet
Citrate Buffer Leachate

Client Name: Columbia Geoscience
Client ID: P5-5MT2 Core: 2
Lab ID: 32139-019 Enseco ID: NA
Matrix: Leachate Sampled: 01-Nov-87 Received: 03-Nov-87
Authorized: 03-Nov-87 Prepared: 18-Nov-87 Analyzed: 20-Nov-87

Parameter	Result	Units	Reporting	Regulated Limits		Analytical Method
			Limit	TTL	STLC	
Arsenic	NA	mg/L	1.0	500	5.0	200.7
Antimony	NA	mg/L	1.0	500	15	200.7
Barium	NA	mg/L	0.50	10000	100	200.7
Beryllium	NA	mg/L	0.050	75	0.75	200.7
Cadmium	NA	mg/L	0.10	100	1.0	200.7
Chromium	NA	mg/L	0.10	2500	560	200.7
Chromium-VI	NA	mg/L	0.10	500	5.0	7196
Cobalt	NA	mg/L	0.10	8000	80	200.7
Copper	NA	mg/L	0.10	2500	25	200.7
Lead	NA	mg/L	1.0	1000	5.0	200.7
Mercury	ND	mg/L	0.010	20	0.2	245.2
Molybdenum	NA	mg/L	1.0	3500	350	200.7
Nickel	NA	mg/L	1.0	2000	20	200.7
Selenium	NA	mg/L	0.50	100	1.0	200.7
Silver	NA	mg/L	0.50	500	5.0	200.7
Thallium	NA	mg/L	1.0	700	7.0	200.7
Vanadium	NA	mg/L	0.50	2400	24	200.7
Zinc	NA	mg/L	0.10	5000	250	200.7

ND=Not Detected
NA=Not Applicable

Reported by: BEV

Approved by: JRB 

The cover letter is an integral part of this report.
Rev 230787

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Mining Waste NPL Site Summary Report
Tar Creek
Ottawa County, Oklahoma and Cherokee County, Kansas

U.S. Environmental Protection Agency
Office of Solid Waste

June 21, 1991

FINAL DRAFT

Prepared by:

Science Applications International Corporation
Environmental and Health Sciences Group
7600-A Leesburg Pike
Falls Church, Virginia 22043

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DISCLAIMER AND ACKNOWLEDGEMENTS

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract Number 68-W0-0025, Work Assignment No. 20. A previous draft of this report was reviewed by Noel Bennett of EPA Region VI [(214) 655-6715], the Remedial Project Manager for the site, whose comments have been incorporated into the report.

TAR CREEK

OTTAWA COUNTY, OKLAHOMA AND CHEROKEE COUNTY, KANSAS

INTRODUCTION

The Site Summary Report for the Tar Creek site is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of the summary by the EPA Region VI Remedial Project Manager for the site, Noel Bennett.

SITE OVERVIEW

The Tar Creek site, a lead/zinc mining site, covers approximately 40 square miles across the border of Ottawa County, Oklahoma, and Cherokee County, Kansas, in an area known as the Picher Mine Field (see Figures 1 and 2). Lead and zinc were mined at the site from 1904 to the mid 1960's. After lead-zinc mining operation ceased in the 1960's, the mines were flooded by inflows of surface and ground water. The Boone limestone formation, where the mines are located, is rich in pyrite. Excavation and subsequent flooding of the mine has resulted in the generation of acid mine water, which has, in turn, mobilized the metals in the rock surrounding the mine workings. The acidic nature of the mine water as well as the constituents of concern (zinc, lead, cadmium, and iron) present problems at the site.

Approximately 21,000 people in five communities obtain their drinking water from the underlying Roubidoux aquifer, which is approximately 1,100 feet from the surface. (Reference 1, pages 1 and 5.) According to the Remedial Project Manager, several municipalities in the mining region that use the Roubidoux aquifer for drinking water have experienced water quality problems related to the mines. For the most part, the water quality problems have been attributed to inadequate casings that have allowed mine water to migrate into the Roubidoux wells. Acute surface-water problems in the area exist. Although the surface water is not a source of drinking water, it is used for recreational purposes, thus increasing the likelihood of dermal exposure to mine water through direct contact (Reference 1, pages 4 and 5).

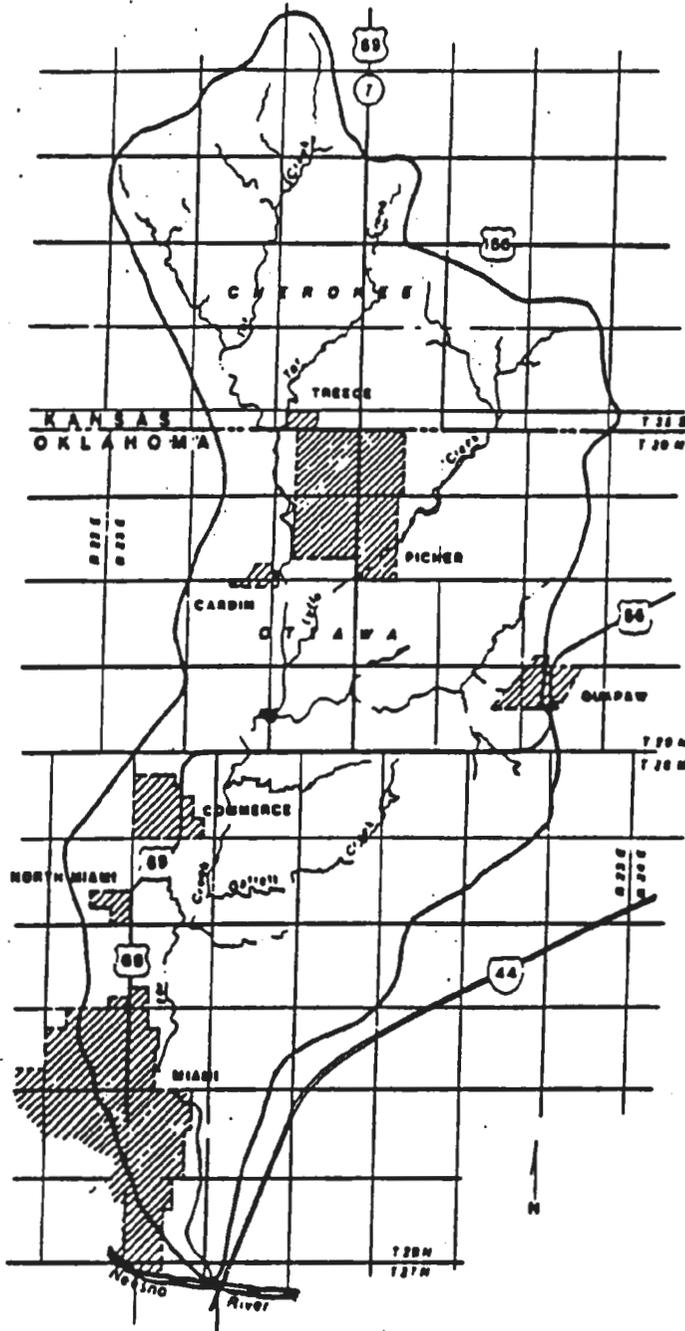


FIGURE 1. TAR CREEK DRAINAGE BASIN

Reproduced from best available copy.

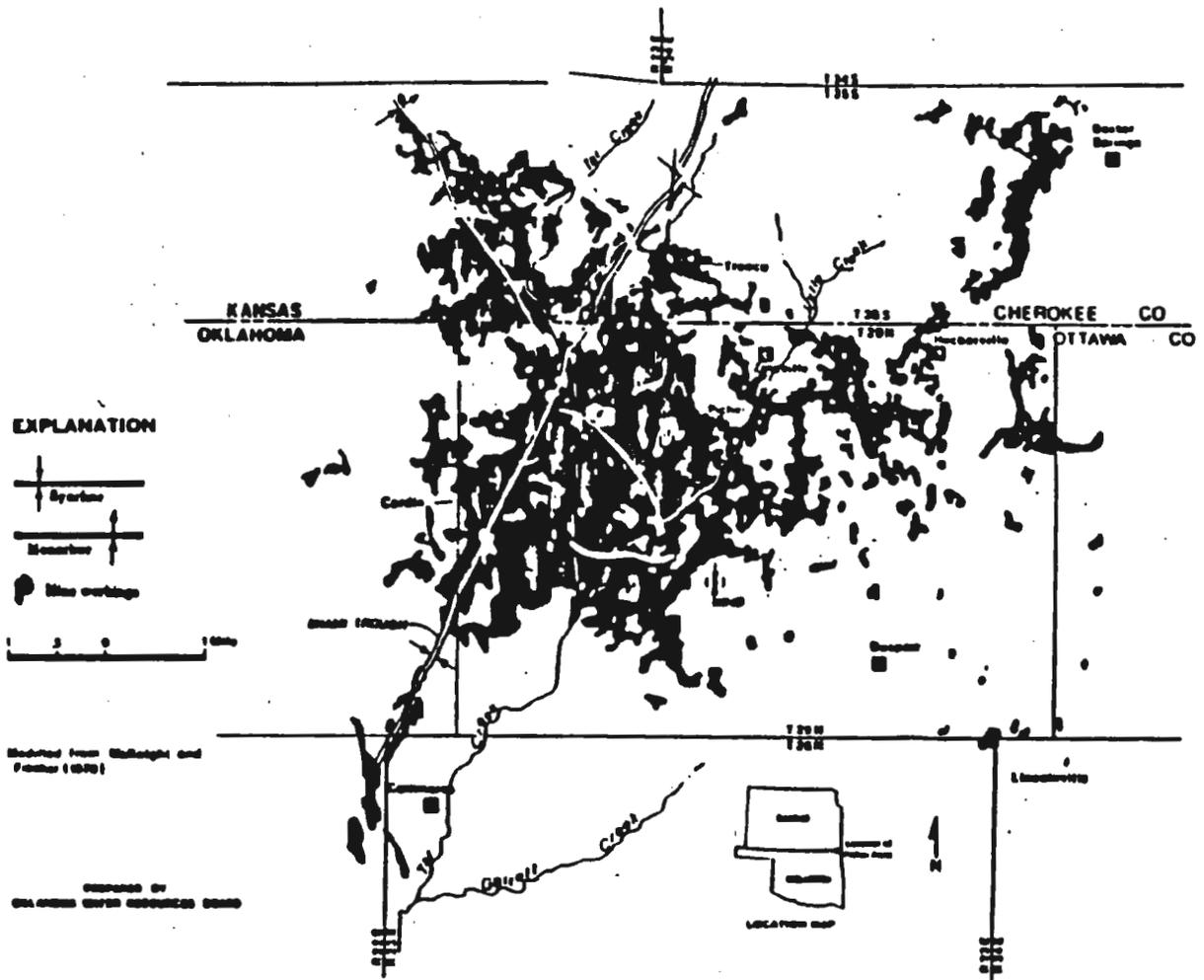


FIGURE 2. GENERALIZED LOCATION OF UNDERGROUND MINE WORKINGS IN THE PICHER FIELD, OKLAHOMA AND KANSAS

Tar Creek

In 1979, the Oklahoma Water Resources Board (OWRB) and the U.S. Geological Survey (USGS) first investigated the site. Soon after the mine drainage began in late 1979, most of the biota in the creek were killed, the banks and bottom of the creek turned red due to ferric hydroxide deposition, and red stains appeared on bridge abutments and cliffs in the Grand River, downstream from its confluence with Tar Creek (Reference 3, page 14). In October 1981, Tar Creek was added to the NPL list (Reference 4, page 1).

A Record of Decision (ROD) describing the remedy at the site was signed in June 1984 by the EPA Assistant Administrator for the Office of Solid Waste and Emergency Response. The States of Oklahoma and Kansas agreed with the remedy, which included diversion of surface flows at three sites and plugging of 66 Roubidoux wells followed by a ground-water monitoring plan to assess the effectiveness of the surface diversion and well plugging. During the remedial action, an additional 17 wells were plugged. The ROD estimated the cost of future remedial actions, assuming a 30-year period for site activities, to be \$4 million in capital outlays and \$5,000 per year in Operation and Maintenance (O&M). Additional expenses were to be taken on by the State of Oklahoma, which would conduct long-term ground-water monitoring (Reference 3, page 13). According to EPA, remediation of the site was completed in 1986 and EPA is currently conducting monitoring.

OPERATING HISTORY

Lead-zinc ores were first discovered at the site in 1901, and the first mining output began in 1904. In 1914, the main body of ore was discovered, and mining activities increased substantially. From 1904 to the early 1930's, mining was conducted by small operators on separate 40-acre tracts. In the 1930's, centralized milling began, which led to the consolidation of mining operations. Large capacity pumps were used during active mining to control ground-water inflow and flooding. However, when large-scale mining activities ceased in the mid-1960's, the pumps were removed from the mines. By 1979, the majority of the underground mines were completely flooded. Acid mine water began to discharge via abandoned or partially plugged mine shaft openings and boreholes (Reference 1, pages 1 and 2).

SITE CHARACTERIZATION

The Tar Creek site encompasses several mines that open into the Boone formation, cherty limestone averaging about 370 feet in thickness. Below the Boone formation are the Cotter dolomite and the Jefferson City dolomite, each approximately 200 feet thick. Directly below the dolomite layers is the Roubidoux formation, a 160-foot thick sequence of cherty dolomite with several sandy sequences (see Figure 3). Surface features are characterized by numerous large tailing piles consisting primarily of

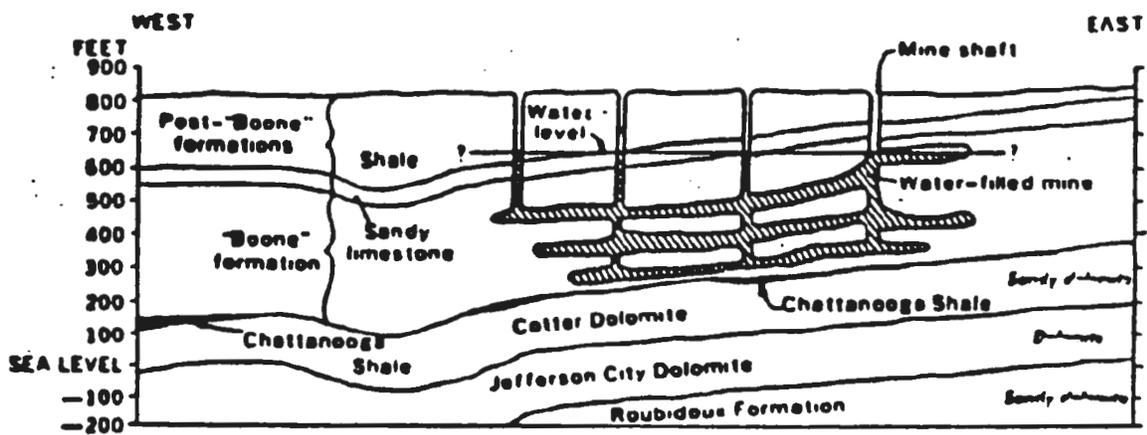


FIGURE 3. GENERALIZED GEOLOGIC SECTION SHOWING THE LOCATION OF THE WATER-FILLED MINES

Tar Creek

limestone and chert (Reference 1, page 1 and Figure 3; Reference 1, Addendum 4, pages 1 and 2) with collapsed structures such as mines and subsidence areas (Reference 1, page 1). An investigation of the site identified two potential exposure pathways (surface water and ground water).

Surface Water

Tar Creek is the principal drainage system in the site. Tar Creek discharges to the Neosho and Spring Rivers, and Grand Lake. Two springs were identified as the primary discharge sites for acid mine water into the Tar Creek watershed. The first site is intermittent and discharges at an average flow of 1.04 cubic feet per second (cfs) when flowing. The average pH at the point of discharge is 5.7, but can reach a minimum of 3.9. The concentration of the constituents of concern can vary at the point of discharge, as shown in Table 1 (Reference 1, Table 2).

TABLE 1. SURFACE-WATER CONSTITUENT CONCENTRATIONS ($\mu\text{g/l}$)

Constituent	Site One		Site Two	
	Mean	Maximum	Mean	Maximum
Iron	53,751	290,000	53,450	129,000
Zinc	38,644	141,000	87,250	137,000
Cadmium	56	260	43	69
Lead	171	1,920	27	47

The second site discharges year round at an average flow of 0.31 cfs. The average pH at the point of discharge is 4.1, but can reach a minimum of 3.6. The variance in the concentration of the constituents of concern is shown in Table 1.

Tar Creek can be best characterized as having high heavy metals concentrations, high hardness, and low pH, as a result of low flow velocities and a low buffering capacity. Thus, the impact from acid mine water is severe (Reference 1, page 3).

The Neosho and Spring Rivers, and Grand Lake, which receive water from Tar Creek, can be safely used as a raw water source for public water supplies, and fish samples indicate that the fish are safe for human consumption (Reference 1, page 5). Most of the heavy metals present in the acid mine water precipitate out of the water and into the Tar Creek and Neosho River stream sediments. This occurs primarily at the Tar Creek and Neosho River confluence, because the Neosho River has a flow capacity approximately 500 times greater than Tar Creek and a much greater buffering capacity (Reference 1, page 4). The Neosho River has received little impact from acid mine drainage into Tar

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Creek other than aesthetic alteration at the Tar Creek confluence (Reference 1, page 6). Air impacts were not evaluated.

Ground Water

There are two possible pathways for the migration of acid mine water from the Boone formation into the Roubidoux formation according to the Remedial Project Manager. natural flow through the pores and fractures of the intervening strata and flow through abandoned Roubidoux wells. Due to the low permeabilities of the intervening strata (Cotter and Jefferson City dolomite formations), it is unlikely that flow through the pores of intact material would occur. The hydraulic conductivities of the Cotter and Jefferson City dolomite formations, measured from intact specimens, were 3.1×10^{-7} and 9.6×10^{-9} centimeters per second (cm/sec), respectively. It is also unlikely that fractures in the intervening strata would be sufficiently interconnected to transmit flow from the Boone into the Roubidoux, a distance of 300 to 400 feet. In addition, a self-plugging mechanism caused by chemical precipitation was thought to impede natural flow (Reference 1, page 4).

A more likely mechanism for cross-contamination between the Boone and Roubidoux is abandoned wells, which would provide direct access for mine water migration. To date, according to the Remedial Project Manager, approximately 100 abandoned wells have been identified that extend from the surface into the Roubidoux. USGS studies indicate a downward water flow at two of the abandoned wells (Reference 1, page 5; Reference 5, pages 45 and 46).

ENVIRONMENTAL DAMAGES AND RISKS

Surface Water

At locations both above and below the acid mine water discharge points, chronic water quality criteria for several heavy metals is exceeded. Heavy metal loadings increase downstream, while the pH decreases, resulting in severe stress to the aquatic community of Tar Creek. Studies found no fish and only a few benthic macroinvertebrates surviving in Tar Creek. The greatest threat to human health comes from dermal exposure to mine water from direct contact. Tar Creek is used for recreational purposes, including swimming (Reference 2, page 2; Reference 1, pages 3 and 4).

Ground Water

The Roubidoux aquifer is the primary source of public drinking water in Ottawa County, according to the Remedial Project Manager. It serves a population of 21,000 in five communities (Miami, Picher,

Cardin, Quapaw, and Commerce) and a few rural water districts (Reference 2, page 5). Several communities in Ottawa County have experienced water-quality problems related to the mines. The contamination has been attributed to mine water entering the wells as a result of inadequate casings (Reference 5, pages 45 and 46). Another possible pathway of contamination is migration of mine water from the contaminated Boone formation through wells to the Roubidoux aquifer (Reference 1, page 5).

REMEDIAL ACTIONS AND COSTS

The remedial action presented in the ROD consists of the following (Reference 1, pages 8 and 9).

- **Roubidoux Wells** - Well plugging at the site involves clearing the well holes of obstructions and setting an acid-resistant cement plug from bottom to top. For the 66 abandoned Roubidoux wells in Kansas and Oklahoma, the projected cost of construction varied from \$10,000 to \$25,000 per well, depending upon the difficulty in clearing each well. The total capital costs, including design, contingencies, and administrative costs, were estimated at \$1,951,900 with no associated O&M costs (Reference 1, page 8). According to EPA, the actual cost of well plugging was \$2,698,708. In addition to the 66 Roubidoux wells that were identified for plugging at the time the ROD was prepared, an additional 17 wells were identified for plugging during remedial actions. A total of 83 wells have been plugged to date.
- **Surface Diversion** - Construction of water diversion was proposed to prevent surface runoff inflows into mine shafts, subsidence areas, and open boreholes. The action targeted three major inflow areas (Muncie, Big John, and Admiralty) that combined, allowed approximately 75 percent of the yearly surface flows into the mine workings. Diversion work was directed on two of the sites (Muncie and Big John), but the third site (Admiralty) would be diverted only if changes in ground-water inflow made it necessary. Estimated costs for diversion at the three sites is \$2,000,000 in capital outlay and \$5,000 in O&M per year for 30 years (Reference 1, page 13). According to EPA, the actual cost of the surface diversion program was \$1,570,605, with \$8,000 in yearly O&M costs.
- **Monitoring** - A 2-year ground-water surveillance program was called for to determine if diversion successfully stopped the discharge of mine water. The program was to begin after the completion of the surface diversion efforts at Muncie and Big John to record ground-water level changes. In particular, the surveillance program would monitor the impact of diversion efforts at the Admiralty site to determine if diversion was needed there. In addition, monitoring of the Roubidoux aquifer was directed to detect infiltration from the Boone aquifer (Reference 1, Addendum 4, page 3). According to EPA Region VI, although no cost estimate for the monitoring program was provided in the ROD, the cost of after-action monitoring was \$59,586.

The outlay to date for remediation of the Tar Creek/Picher Mine Field site is \$3,269,313 in capital expenditures and \$59,586 for after-action monitoring, representing a total outlay of over \$4.32 million plus \$8,000 per year for O&M. The estimated cost of remediation was \$3.95 million, with O&M costs of \$5,000 per year. The difference in the figures is attributable to a significantly higher cost for well plugging, offset slightly by a moderately lower cost for the diversion program.

CURRENT STATUS

According to EPA Region VI, the well plugging and surface diversion activities have been completed. Ground-water monitoring efforts will continue for several years. The State of Oklahoma continues to assess the impact of the tailings piles at the site and to assess the impact of water degradation on municipal water system wells

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3. Tar Creek Field Investigation Task I.1: Effects of Acid Mine Discharge on the Surface Water Resources in the Tar Creek Area, Ottawa County, Oklahoma; Oklahoma Water Resources Board, Water Quality Division; March 1983.
4. Hazard Ranking System Package, Tar Creek, Ottawa County, Oklahoma; EPA; August 2, 1983.
5. Geohydrology and Water Quality of the Roubidoux Aquifer, Northeastern Oklahoma, Open-file Report 90-570; Scott C. Christenson, David L. Parehurst, and Roy W. Fairchild, U.S. Geological Survey, Oklahoma City, Oklahoma; 1990.

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Reference 1

**Excerpts From Record of Decision
for the Tar Creek Superfund Site, Oklahoma;
Lee M. Thomas, Assistant Administrator,
EPA Office of Solid Waste and Emergency Response;
June 6, 1984**

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Superfund Record of Decision:

Tar Creek Site, OK



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RECORD OF DECISION

REMEDIAL ALTERNATIVE SELECTION

SITE: Tar Creek/Picher Mine Field, Ottawa County, Oklahoma, and Cherokee County, Kansas

DOCUMENTS REVIEWED

I am approving this action based on the following documents describing the analyses of cost-effectiveness of remedial alternatives for the Tar Creek site:

- Tar Creek Site Investigation Report - Tar Creek Feasibility Report Summary of Remedial Alternative Selection

DESCRIPTION OF SELECTED REMEDY

- Diversion and diking at two major inflow areas in Kansas. A third area will also be diverted and diked if it becomes an inflow site in Oklahoma.
- The plugging of 66 Roubidoux aquifer wells, 26 of which are located in the Picher Mine Field area of Kansas.
- Implementation of a monitoring plan to assess effectiveness of diversion in mitigating discharge of acid mine water to the surface and well plugging in preventing contamination of the Roubidoux aquifer.

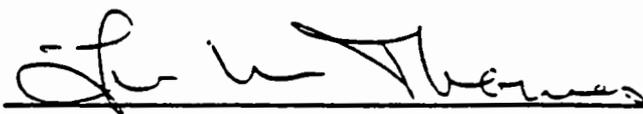
DECLARATIONS

Consistent with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the National Contingency Plan (40 CFR part 300), I have determined that the plugging of abandoned Roubidoux wells and diversion of surface inflow away from the mine workings provides adequate protection of public health, welfare, and the environment. The States of Oklahoma and Kansas have been consulted and agree with the approved remedy.

In addition, I have determined the following conditions apply to the enactment of the selected remedy.

1. The action being taken is appropriate when balanced against the availability of Trust Fund monies for use at other sites.

2. The cost-effective remedy does comply with other environmental regulations.
3. Future remedial actions may be required if selected alternatives do not adequately mitigate the risk to human health.
4. Superfund assistance is necessary for Tar Creek because of the limitations associated with other possible resources for funding (see addendum 5).



Lee M. Thomas
Assistant Administrator
Office of Solid Waste & Emergency Response

June 6, 1984
Date

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SUMMARY OF REMEDIAL ALTERNATIVE SELECTION

TAR CREEK

SITE LOCATION AND DESCRIPTION

The Picher Field, located in Ottawa County, Oklahoma, and Cherokee County, Kansas, is one of the lead-zinc subregions which comprise the tri-state mining region of Oklahoma, Kansas, and Missouri. The field encompasses six square miles, and was one of the most productive lead-zinc mining districts in the United States. Figure 1 shows the mine workings in the main part of the Picher Field.

Surface features are characterized by numerous large tailing piles consisting primarily of limestone and chert. There are also several collapsed structures such as subsidence areas and mine shafts that have caved in.

The Picher Field is situated on the west ridge of the Ozark Plateau province. The Ozark Plateau is a broad, low structured dome laying mainly in southern Missouri and northern Arkansas. However, the main part of the Picher Field is within the Central Lowland province. This province is characterized by a nearly flat, treeless prairie underlain by Pennsylvania shales.

The streams that traverse the mining field flow southward to the Neosho River. Elm Creek, on the western edge of the field, and Tar Creek and its main tributary, Lytle Creek, are the principal streams. A short distance east of the mining field is the Spring River, which is the major south-flowing tributary of the Neosho.

The principal communities within the Picher Field are Miami, Picher, Cardin, Quapaw, and Commerce. All these communities receive their drinking water from the Roubidoux aquifer, which is approximately 1,100 feet from the surface.

SITE HISTORY

Lead-zinc ores were first discovered in the Picher Field in 1901, with output of concentrates beginning in 1904. The main portion of the ore body was discovered in 1914, leading to a vast increase in ore production. Early mining was characterized by a multitude of small operators on 40 acre tracts, with each operator conducting mining, drilling, and milling operations. In the 1930's centralized milling began, leading to the consolidation of mining and milling operations.

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Large scale mining activities ended in the mid 1960's and pumps were removed from the mines. By 1979, the majority of the underground mine workings were completely flooded and acid mine water began to discharge via abandoned or partially plugged mine shaft openings and boreholes.

Land ownership in Oklahoma was originally vested with the Quapaw Indian tribe. The Quapaw Indians were given 150 sections of land in southeastern Kansas and northeastern Oklahoma in 1833. However, an allotment plan approved in 1893-94 divided the reservation into 236 200-acre allotments and 231 40-acre allotments. Today ownership can be classified as private, or Indian restricted. Approximately 9,120 acres of Indian restricted lands are held by Indian allottees and (or) their heirs in the vicinity of the Picher Field.

Since November 1979, the Tar Creek watershed has received highly mineralized acid mine discharges from flooded underground lead-zinc mines of the Picher Field in Ottawa County, Oklahoma. The Oklahoma Water Resources Board (OWRB) in cooperation with the Tar Creek Task Force investigated the problem initially in 1980 and 1981. Additional study of specific areas was deemed necessary in order to fully assess the impact of acid mine water on the area's surface and ground water resources.

In October 1981, Tar Creek was listed among the sites on the National Priorities List under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). A Cooperative Agreement, with a grant award of \$435,368 to conduct Remedial Investigation/Feasibility Studies was signed between EPA and the Oklahoma State Department of Health on June 16, 1982. An Interagency Agreement was finalized with the Oklahoma Water Resources Board for \$173,000 to conduct monitoring and sampling. Investigation work began in July 1982 and was completed in March 1983. The final report was approved the month thereafter. The Feasibility Study was initiated in May 1983 and completed in December 1983. The major findings of the investigation and feasibility reports are discussed in the section titled "Current Site Status."

CURRENT SITE STATUS

As with many underground mines in the area, continual inflow of ground water during mining posed a problem. Inflows were controlled by the installation of large capacity pumps. However, upon cessation of mining activities, drifts and shafts of the abandoned workings began to flood. Pyrite-rich wastes in the Boone formation were being oxidized by exposure to the oxygen-rich atmosphere while mining was occurring. Upon flooding, these oxidized sulfides readily dissolved into the surrounding ground water producing acid mine water. The acid water reacted with

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the surrounding rock causing many of the metals present to dissolve, resulting in a water with high concentrations of zinc, lead and cadmium. These are pollutants and contaminants and are listed hazardous substances under 101(14) of CERCLA. The concentration of these three metals, as well as iron, greatly exceed drinking water standards as shown in Table 1.

Discharge of these acid ground waters at the surface has resulted in degradation of Tar Creek and could eventually affect other major water resources of the area. Of potentially greater importance is the impact of acid mine water on the underlying Roubidoux aquifer. The contamination of the Roubidoux on a large scale would result in the loss of current municipal water supplies for much of the region.

The Tar Creek Investigation was developed to assess the health and environmental impacts of acid mine drainage on potential ground water and surface water receptors. Of foremost concern are the impacts to the area's drinking water sources: Grand Lake and the Roubidoux aquifer.

The following is a separate discussion on each of the critical pathways for migration.

Surface Water Impacts

Tar Creek is the principal drainage system in the Picher Field. With its headwaters in Cherokee County, Kansas, Tar Creek flows southerly through the field between Picher and Cardin, passing Commerce and Miami on the east, to its confluence with the Neosho River, one of two major rivers in northeastern Oklahoma. Tar Creek is a small ephemeral stream characterized by standing pools. Along with its major tributary Lytle Creek, Tar Creek drains approximately 53 square miles of area.

The primary discharge points for acid mine water into the Tar Creek watershed are sites 4s and 14 (Figure 2). Site 4s is intermittent and discharges at an average flow of 1.04 cfs when flowing. Site 14 discharges all year long at an average flow of 0.31 cfs. Typical concentrations of heavy metals discharging from the streams are shown in Table 2. Because of the low flow velocities at most times of the year, and the low buffering capacity of Tar Creek, the impact from acid mine water is severe. Hence Tar Creek is characterized as having high concentrations of heavy metals, high hardness, and low pH. Tar Creek has had a pH of 2.9 as far downstream as Miami.

As exhibited in Table 2, the chronic water quality criteria for several heavy metals is exceeded for all parameters above and below the acid mine water discharge points. There is, however, a significant increase in heavy metal loadings (and a decrease

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Table 2. Statistical summary of water quality data for mine discharge sites (1980-82).

Site * Number	Mean Concentration	Maximum Concentration	Water Quality Criteria	
			<u>Acute</u>	<u>Chronic</u>
<u>pH (SU)</u>				
4a	6.2	5.2	-	-
4	5.7	3.9	-	-
10	5.7	3.3	-	-
14b	4.1	3.6	-	-
20	5.4	2.9	-	-
22	6.5	6.0	-	-
<u>Iron (ug/L)</u>				
4a	12,020	96,000	-	-
4	53,751	290,000	-	-
10	27,137	162,000	-	-
14b	53,450	129,000	-	-
20	8,853	52,000	-	-
22	1,278	2,890	-	-
<u>Zinc (ug/L)</u>				
4a	27,398	80,000	320	47
4	38,644	141,000	-	-
10	37,247	151,000	-	-
15b	87,250	137,000	-	-
20	21,333	104,000	-	-
22	7,582	14,200	-	-

Table 2. (Continuation)

Site * Number	Mean Concentration	Maximum Concentration	Water Quality Criteria	
			<u>Acute</u>	<u>Chronic</u>
<u>Cadmium (ug/L)</u>				
4a	24.0	59	3.0	0.025
4	56.0	260		
10	32.0	82		
14b	43.0	69		
20	18.6	63		
22	4.0	11		
<u>Lead (ug/L)</u>				
4a	2.0	49		
4	171.0	1,920		
10	92.0	1,090		
14b	26.7	47		
20	33.0	196		
22	20.0	20		

* Site 4a is upstream of discharge point; 4 is a mine discharge site; Site 10 is approximately 3 miles downstream from Site 4; Site 14 is 1/2 mile below discharge point 14; Site 20 is 10 miles below discharge point and near Miami; Site 22 is at the Tar Creek-Neosho River confluence.

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in pH) downstream from the acid mine discharge points at site 4s and 14 resulting in severe stress to the aquatic community of Tar Creek. Studies conducted by the Tar Creek Task Force Subcommittee on Environmental Effects found no fish and only a few benthic macroinvertebrates surviving in Tar Creek.

Tar Creek is not used for a drinking water source. The greatest threat to human health along Tar Creek comes from possible dermal exposure to mine water from direct contact. Local residents use Tar Creek for recreational purposes including swimming.

The remedial investigation showed that Tar Creek currently has no significant impact on Grand Lake because when Tar Creek waters flow into Grand Lake, most of the heavy metals precipitate out of the water and into the Tar Creek and Neosho River stream sediments. The primary location where this phenomenon occurs is at the Tar Creek and Neosho River confluence. With the Neosho River having flow capacities approximately 500 times greater than that of Tar Creek plus much greater buffering capacity, the acid mine water dilutes quickly and the heavy metals precipitate out. Inspection of water quality data at site 22b and data from heavy metal loadings in the sediments confirms these predictions.

Ground Water Impacts

There are two possible pathways for migration of acid water from the Boone Formation into the Roubidoux (Figure 3). These pathways are: natural flow through intervening strata and flow through abandoned Roubidoux wells. Therefore, the goal of the ground water portion of the investigation was to assess the potential for migration via these pathways.

To assess the potential for acid mine drainage to flow under natural conditions from the Boone into the Roubidoux, hydraulic conductivity studies were done on cores from the intervening rock formations. The findings revealed very low permeabilities of 3.1×10^{-7} and 9.6×10^{-9} cm/sec, for the Cotter and Jefferson City dolomites, respectively.

In addition to the low permeabilities, a self plugging mechanism caused by chemical precipitation is thought to impede natural flow. On the same cores in which permeability studies were conducted, mine water was introduced at a mixture of 1:2 and 1:20 mine water to Roubidoux water. In the subsequent permeability tests, there was a reduction in core permeabilities of 72% and 67% respectively.

Some potential exists for contamination of the Roubidoux by natural flows if fractures are interconnected from the Boone down through the Cotter and Jefferson City formations and into the Roubidoux. It is unlikely that any interconnections span the entire 300-400 ft. distance between the Boone and the Roubidoux.

Another mechanism for cross-contamination between the Boone and Roubidoux is abandoned wells. These wells provide direct access for mine water to migrate into the Roubidoux. The USGS conducted studies on two of the abandoned wells and showed that water was flowing downward. Sixty-six wells have been identified that extend from the surface into the drinking water aquifer. A possibility exists that more abandoned wells could be discovered in the future. If this occurs, additional funds would have to be requested in order to plug them.

Unlike the acute surface water problem, the Roubidoux aquifer is still a safe drinking water supply. Five communities (Miami, Picher, Cardin, Commerce and Quapaw) and a few rural water districts, with a total population of approximately 21,000, receive their drinking water from the Roubidoux aquifer. Most of the historical data on drinking water quality of the affected community wells indicate no degradation to date. The exception is the city wells serving Quapaw. At this location, two wells were abandoned because of mine water influx. Contamination is attributed to either casing failure or migration of mine water from nearby abandoned wells.

Other Environmental and Public Health Findings:

- Water distributed by the public water supplies and rural water districts of the Tar Creek area is safe to drink.
- The Neosho River, Spring River and Grand Lake can be safely used as a raw water source for public water supplies.
- The fish fillet samples indicate fish from the mouth of Tar Creek, Neosho River, Spring River and Grand Lake are safe for human consumption.
- No significant concentrations of toxic metals or radiation were observed in the particulate air samples collected at Picher.
- Effects on the fish community diminish rapidly, once waters enter the Neosho River.
- Metals found in the fish indicate that biomagnification is not significant in the fish community of Grand Lake.
- Although Tar Creek provides a concentrated source of metals, the head waters of the Neosho and Spring Rivers also contribute large quantities of metals.
- Sediments provide an effective long-term sink for metals and should effectively remove them from most biological processes.

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- The Neosho River has received little impact from acid mine drainage into Tar Creek other than aesthetic alteration at the Tar Creek confluence.
- At current spring flows, all mine water will be displaced in 60 to 100 years.
- There is an estimated 76,000 acre feet of heavy metal laden mine water in the flooded underground mines.
- Mine waters are being introduced into the Roubidoux via abandoned wells.
- Although some contamination of heavy metals are provided by the tailings piles the overall quantity is insignificant compared to loading rates from the springs.

ENFORCEMENT

A meeting was held with the potentially responsible parties on January 16, 1984, to determine willingness to participate in design/construction activities. None of the companies provided assurances that they would participate in funding cleanup at that time. The companies were asked to negotiate among themselves and reply as to their intentions by February 16, 1984, and they did not formally respond. The parties have been informed that the Agency will proceed with the ROD and they will have 30 days following its signature to agree on a cleanup.

ALTERNATIVES EVALUATION

The objectives for cleanup at the Tar Creek site were to mitigate the potential threat to public health and the environment by preventing contamination of the Roubidoux and by minimizing toxic releases damage to Tar Creek. Two of the seven alternatives initially selected for evaluation addressed both cleanup objectives and would accelerate the improvement at ground water quality in the Boone formation. These remedial options were:

- In situ treatment of mine water
- Collection and treatment of mine water

Both alternatives were eliminated from detailed analysis because they were excessively expensive. Long-term pumping and treatment of ground water from the Tar Creek area would be expensive and imprecise. Present value capital and operation and maintenance costs were estimated to approach \$30 million. This option is ineffective because long-term pumping would not assure significantly less contaminated ground water.

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2. Plug 66 Roubidoux Wells

The well plugging program would consist of clearing the well holes of obstructions and setting an acid resistant cement plug from bottom to top (Figure 4) in sixty-six abandoned Roubidoux wells in Kansas and Oklahoma (see Figures 5 and 6 for locations). It is projected that construction costs will vary from \$10,000 to \$25,000 per well depending upon the difficulty in clearing each well. The total capital costs, including design, contingencies, and administrative costs, are \$1,951,900 with no associated O&M costs.

The well plugging program will not completely mitigate all threats to the Roubidoux aquifer. There are several ways that the Boone may contaminate the Roubidoux (as outlined in the Ground Water Impacts Section) including: fractures, unknown abandoned wells and natural flow. There is also a slight potential that some of the identified abandoned Roubidoux wells may be technically difficult or impossible to plug. If additional abandoned Roubidoux wells are located, additional funds would be required in order to plug them. Therefore, implementation of a monitoring program is recommended to detect trends in water quality of the Roubidoux. The detailed plans for the Roubidoux monitoring program are given in Addendum 4.

3. Surface Diversion

There are 600 mine shafts and collapse depressions within the study area each providing avenues for inflow of surface water into the mines. Total inflow is estimated to be 5,000 acre-feet per year. Once water has entered the mines, it acidifies and flows out of springs into Tar Creek further downstream. Surface discharge is estimated to be 1,000 acre-feet per year. The remainder of the inflow is believed to be removed from the system via lateral ground water flow in the Boone. Inflow points were ranked in the feasibility study to determine those providing significant inflow reduction and the cost effectiveness of plugging or diverting water from these areas as shown in Table 3.

The hydraulics of the mine system are such that water entering the mines at sites K-1 and K-2 in Kansas flow out of springs and into Tar Creek downgradient in Oklahoma. Approximately 3,800 acre-feet per year flows into these sites. The main inflow point is K-1 (Muncie) which drains 4.52 sq. mi. and provides 2800 acre-feet of water to the mines in a year. The next priority area is K-2 (Big John) which is responsible for 1,000 acre-feet of the total surface water entering the mines each year.

Diversion work at K-1 and K-2 will significantly reduce the inflow and cause ground water levels to recede. If ground water levels drop below the present static water level at site O-3, then it too will become an inflow point and may require diking and diversion work.

RECOMMENDED ALTERNATIVES

Section 300.68(j) of the National Contingency Plan states that "The appropriate extent of remedy shall be determined by the lead agency's selection of the remedial alternative which the agency determines is cost-effective (i.e. the lowest cost alternative that is technologically feasible and reliable and which effectively mitigates and minimizes damage to and provides adequate protection of public health, welfare or the environment)." Based upon investigation and feasibility studies, EPA Region VI and the States of Oklahoma and Kansas agree that the well plugging, and the diversion and diking programs meet the NCP criteria.

The diversion program will constitute rerouting surface flows away from mine shafts, subsidence areas, and open boreholes. Three major inflow areas allowing approximately 75% of the yearly surface flows into the mine workings are designated for diversion work. The Muncie and Big John diversion work will be implemented at the completion of design. However, the Admiralty diversion work will be delayed twelve to eighteen months to establish new inflow and outflow patterns. The Admiralty will be constructed, if required.

Because the diversion work may not completely stop all surface discharge of acid mine water, a ground water monitoring program of the Boone aquifer will be conducted for two years to allow time for the system to equilibrate and to determine the effectiveness of the diversion work. If there continues to be significant discharge, remedial measures would be evaluated to determine if further action is appropriate.

There are many more inflow areas that were considered, but each taken on a individual basis is insignificant compared to the top three priority sites. Therefore, to do diversion work at these sites would result in decreasing environmental protection that cannot be justified by the increased costs. The capital cost for diversion at the three sites is \$2,000,000 with O&M costs of \$5,000 per year for 30 years.

The diversion work may not completely stop the surface discharge of mine water. A surveillance program will be initiated after construction to record ground water level changes. The plan for this monitoring program along with the water quality monitoring program for the Roubidoux is given in Addendum 4.

Well plugging is the cost-effective remedy to protect the Roubidoux. This portion of the remedy is expected to cost \$2,000,000 and should assure that contaminated mine waters from the Boone do not affect the Roubidoux. Provision of an alternative source of water to the Town of Commerce is not required because the Roubidoux is a safe source of drinking water. The State will undertake a long-term ground water monitoring program of the Roubidoux to assure the safety of the Roubidoux.

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ADDENDUM 4

Tar Creek Site
Ottawa County, Oklahoma

Remedial Alternatives Analysis

TAR CREEK GROUND WATER MONITORING PROGRAM

I. PURPOSE

The purpose of this addendum is to:

1. Review the Tar Creek Site Remedial Alternatives Analysis in areas discussing a post closure ground water level monitoring plan.
2. Describe in more detail a post closure ground water level monitoring plan.

II. INTRODUCTION

The Site Investigation report presented a description of the Tar Creek site hydrogeology. The following discussion only refers to the Boone and Roubidoux hydrogeology.

The Boone Formation is a Mississippian age cherty limestone averaging about 370 feet in thickness. Lead and zinc deposits of the Picher Mining District are found in various members of the Boone. Prior to initiation of large scale mine dewatering, the Boone was probably the major source of water for the local residents.

To maintain unsaturated conditions in the mine workings, large capacity sump pumps were used. Pumpage from the Boone varied with time and depth of mining. During World War II an estimated 14 mgd were discharged by the various mining operations. As the demand for lead and zinc declined after the war, pumpage declined to about 9 mgd as the lower grade ore present in deeper workings were abandoned (Reed, 1955). Pumping from the Boone continued until the mid-1960's when major mining ceased.

Water levels of the Boone recovered to their approximate pre-mining level by 1980 and began discharging at the surface in 1979. Recharge to the Boone system comes not only from natural infiltration, but also from direct surface water inflow to shafts, bore holes and collapsed structures.

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The Boone contains solution openings which enhance the movement of ground water and produce large water yields from wells intersecting these passageways. A well not encountering any solution cavities or fractured zones might yield only moderate amounts of water. Transmissivity values as calculated by Hittman Associates, ranges between 45,000 to 75,000 gpd/ft for confined and unconfined conditions respectively.

III. ROUBIDOUX FORMATION

The Roubidoux Formation is a 160 foot thick sequence of Ordovician age cherty dolomite with several sandy sequences. This aquifer is the major water producer for Ottawa County. Depth to this aquifer is generally between 900 to 1000 feet in the mining area. Reed (1955) reported that wells completed in the Roubidoux flowed at the surface prior to 1918. The increased water withdrawals by the numerous mining and milling operations caused a lowering of the potentiometric surface of the Roubidoux, with pumping lifts reaching more than 500 feet by 1947. Water level decline within the Roubidoux apparently has stabilized, at least since 1975, based upon water level data obtained from the city of Miami, Oklahoma. Seasonal water level fluctuations can be observed; however, the potentiometric surface of the Roubidoux appears to have remained about 320 feet above msl around Miami, Oklahoma, since 1975.

Away from the major pumping areas, the potentiometric surface of the Roubidoux is higher. A well completed in the Roubidoux at the Eagle Picher Boron Plant had a reported water elevation of approximately 490 feet above msl.

Direction of ground water movement in the Roubidoux is not well defined; however, it is inferred to be in a generally westerly direction.

1. Aquifer Parameters

Data concerning aquifer testing in the Roubidoux are limited. Reed (1955) analyzed three pumping tests of Roubidoux wells at the B.F. Goodrich plant near Miami, Oklahoma, and determined an average transmissivity value of approximately 39,000 gpd/ft and a storage coefficient of 8×10^{-5} .

2. Water Quality

Ground water derived from Roubidoux wells generally has a total dissolved solids (TDS) concentration of less than 500 milligrams per liter (mg/l). Water from the Roubidoux is typically classified as a calcium-bicarbonate or a sodiumchloride type, based upon the milliequivalent concentration per liter of

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the major anions and cations. Dissolved metals are usually present only in trace amounts; however, a well at the Eagle Picher Boron Plant has reported high concentrations of dissolved metals, especially iron.

IV. Proposed Post Closure Ground Water Monitoring Plan

There are two separate monitoring programs recommended for implementation. These are the Roubidoux water quality monitoring program and the mine ground water level surveillance plan. The following is an outline of each program.

A. Roubidoux Aquifer Monitoring Plan

The following Roubidoux Aquifer Monitoring Plan is suggested as a possible measure to detect infiltration from the Boone Aquifer.

The municipal wells listed below are suggested as possible indicator locations for monitoring of the Roubidoux Aquifer:

Each well will be collected and analyzed twice each year, once in October and once in April for the following parameters:

- | | |
|--------------|-------------------------|
| a) pH | e) Total hardness |
| b) Iron | f) Lead |
| c) Manganese | g) Cadmium |
| d) Sulfate | h) Specific Conductance |

B. Mine Ground Water Level Monitoring Plan

A ground water level surveillance program is suggested to determine success of diking and diversion work in preventing surface flow of mine discharges. The plan will entail monitoring the rates of spring discharge and ground water levels in selected nearby mines for two years after closure. Actual measurements of these parameters should be done at least four times a year with the greatest number of observations being collected during high ground water levels and/or after high precipitation events.

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Reference 2

**Excerpts From Summary of Data Collected by
Governor's Tar Creek Task Force Regarding
Ground-Water Discharge From Abandoned Lead and Zinc Mines
of Ottawa County, Oklahoma; Oklahoma Water Resources Board;
December 1979 to March 1981**

INTRODUCTION

In response to a complaint regarding historically poor water quality and recent mine discharges into Tar Creek, Oklahoma Water Resources Board personnel reconnoitered the Tar Creek basin in Ottawa County on February 5, 1980.¹ Conclusions of this reconnaissance led to the following recommendations:

Further investigation is necessary to determine:

- (1) Movement of water in the Boone Formation through the mined area, and directions of flow and possible consequences to Roubidoux Formation, and the impact of these formations on rural domestic and stock wells, stream contamination, and springs.
- (2) Variations and trends of water quality in groundwater in abandoned mines and groundwater levels.
- (3) Future impact of mine discharge of the artesian spring on Tar Creek.

On June 2, 1980, Governor George Nigh formed the Tar Creek Task Force which is composed of 23 state and federal agencies, and local interest groups (Appendix A). The interdisciplinary nature of the Tar Creek Task Force provided needed expertise in each of the problem areas identified by OWRB reconnaissance, i.e., streamwater, groundwater, and mine water quantity and quality, and biological reconnaissance and sampling and allowed development of a work plan which established a monitoring system to satisfy the recommendations cited in the OWRB Tar Creek reconnaissance report (Appendix B). This report will summarize the data gathered on all elements of the work plan.

¹ Adams, James C. 1980. Tar Creek Quality Reconnaissance Regarding Groundwater Discharge From Abandoned Lead and Zinc Mines of Picher Field, Ottawa County, Oklahoma. Oklahoma Water Resources Board, Publication No. 100.

MATERIALS AND METHODS

Stream sample sites, frequency, and analyses parameters are in accordance with Phase I of the Task Force work plan. Sample sites were located as shown in Figure 1. Narrative descriptions of each sample site are given in Table 1.

Water samples were taken from each site sample and consisted of one-half liter for chemical quality, iced to 4°C; one-half liter for filtered metals using a 0.45 micron Millipore filter system; and one-half liter for total metals preserved both with nitric acid and iced to 4°C. Field parameters were recorded at each site using a Model 4041 digital Hydrolab. Sample analyses were performed by the Oklahoma State Department of Health, Water Quality Laboratory (see Tables 2 and 3). Bottom material sampling was discontinued because of substrate type. The U.S. Geological Survey collected 24-hour monitoring data at Sites 10 and 20 for pH, D.O., specific conductance, and temperature, using a mounted Hydrolab unit. Site 20 also contained a USGS manometer to record fluctuations in stream stage. Flow measurements at Sites 10 and 20 were performed by USGS personnel for development of a flow/stage curve. Flows were measured with a pygmy flow meter using a beaded transect line and stopwatch.

Table 2 is a compilation of all data collected at stream sites from December 27, 1979, to March 6, 1981. It is presented by site and by dates for each parameter analyzed. Table 3 is a historical presentation of the same data organized in a format to compare various sites by date.

Groundwater sampling consisted of two types; mine water and well or drill hole water. Mine water samples were taken from the three previously sampled mine shafts reported in USGS Open File Report 78-294 (Figure 2). Mine shaft samples were collected using a USGS aluminum boom and a two liter PVC Kemmerer sampler. A Model 4041 digital Hydrolab was used for measuring field parameters at 20 foot increments in each shaft from surface to bottom. The water level was recorded and samples were taken at the surface of each shaft. When stratified levels

Reference 3

**Excerpts From Tar Creek Field Investigation Task I.1:
Effects of Acid Mine Discharge on the Surface Water Resources
in the Tar Creek Area, Ottawa County, Oklahoma;
Oklahoma Water Resources Board, Water Quality Division;
March 1983**

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obtained. Loading rates for site 4S were computed using the overall average pollutant concentrations and average flow data collected at the weir between December 11, 1982, and February 16, 1983. For site 14, loading rates were computed using the overall average pollutant concentrations and average flow data measured at the weir between September 9, 1982, through February 14, 1983. The calculated loading rates for various pollutants are listed in Table 5.

It should be noted that the mean flow computed at site 4S is only valid for those months during which the spring is flowing. During these months the loading from site 4S is generally greater than the loading from site 14.

EFFECTS OF ACID MINE DRAINAGE FROM THE PICHER FIELD ON STREAMWATER

Mine drainage has had a severe impact on Tar Creek since late 1979. Soon after discharge commenced, most of the biota in the creek were killed. The banks and bottom of the stream turned red due to ferric hydroxide precipitates. Red stains have been observed on bridge abutments and cliffs in Grand River downstream from its confluence with Tar Creek.

Discharge of acid mine water with a high concentration of ferrous iron (Fe^{+2} ions) to a body of surface water can result in substantial changes in surface water quality, especially if the surface waters have a low buffering capacity. The absence of significant amounts of bicarbonate in Tar Creek results in an extremely low buffering capacity. Consequently, the water course is very sensitive to any external sources of H^+ ions and OH^- ions. A rapid change in pH can be expected under such conditions. When groundwater with high Fe^{+2} ion concentrations reaches the surface, the Fe^{+2} ions in solution are oxidized to form ferric iron (Fe^{+3} ions). These ions, in turn, form an insoluble hydroxide and produce hydrogen ions according to the reaction:



The release of hydrogen ions could substantially decrease the pH of the surface water body, and in the process, the surface water can become oxygen depleted as the Fe^{+2} ions are oxidized.

The pH has usually remained moderate near the discharge points, sites 4S and 14, because there is not sufficient oxygen present to rapidly oxidize the Fe^{+2} ions and because sewage treatment effluent, with a higher pH, is discharged to the drainage. However, a pH of 2.9 was recorded in Tar Creek at site 20 in Miami, Oklahoma, which is a violation of the Oklahoma Water Quality Standards of 6.5 su. It is thought that eventually the waters of Tar Creek can recover to the previous quality, once the discharge of acid mine water ceases.

In Figures 6 and 7 the pH was much lower at site 20 than at upstream sites, indicating the above reactions take place relatively slowly. In Figure 8, when flow velocities are much reduced, low pH's occur much further upstream. A statistical summary for the pH data, as well as for

Reference 4

**Excerpts From Hazard Ranking System Package,
Tar Creek, Ottawa County, Oklahoma; EPA;
August 2, 1983**

TAR CREEK

Ottawa County, Oklahoma

The Tar Creek Site, located near Picher, Oklahoma, in Ottawa County, covers 40 square miles. Tar Creek is a segment of the Eagle Picher Mining District, which covers 100 square miles and extends into Missouri and Kansas. The primary concern raised over this site is its potential for contamination of both surface and groundwater.

The area produced significant quantities of iron and zinc in the 1920s and 1930s. Major mining operations ceased in the 1970s. Water from an underlying aquifer began to discharge to the surface through the abandoned mine shafts in 1979. At this point, the U.S. Geological Survey and the Oklahoma Water Resources Board (OWRB) became involved in the site investigation. OWRB contracted to conduct additional water monitoring and sampling.

In 1981, the State of Oklahoma declared the site its number one pollution problem. Negotiations began between the U.S. Environmental Protection Agency, OWRB, and the Oklahoma State Department of Health (OSDH), which resulted in the award of \$435,368, on 1 July 1982. This amount was set aside for two phases of remedial activities at the Tar Creek Site. OSDH, the primary Superfund State agency, has signed an interagency agreement for \$173,000 with OWRB to continue surface and mine water monitoring and sampling.

This site was on the Interim Priority List of 160 sites.

Reference 5

**Excerpts From Geohydrology and Water Quality of the Roubidoux Aquifer,
Northeastern Oklahoma, Open-file Report 90-570;
Scott C. Christenson, David L. Parehurst, and Roy W. Fairchild,
U.S. Geological Survey, Oklahoma City, Oklahoma; 1990**

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**GEOHYDROLOGY AND WATER QUALITY OF THE ROUBIDOUX AQUIFER,
NORTHEASTERN OKLAHOMA**

By Scott C. Christenson, David L. Parkhurst, and Roy W. Fairchild

U.S. GEOLOGICAL SURVEY

Open-File Report 90-570

Prepared in cooperation with the
OKLAHOMA GEOLOGICAL SURVEY



Oklahoma City, Oklahoma

1990

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U.S. DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

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gross-alpha radioactivity, it is possible that the water from these nine wells exceeded the gross-alpha radioactivity MCL. If uranium radioactivity contributes a large part of gross-alpha radioactivity, ground water that exceeds the gross-alpha radioactivity MCL would be rare.

The MCL for radium is 5 pCi/L for the sum of radium-226 and radium-228 radioactivity. Seven wells that had large gross-alpha radioactivity and two wells that had large censored values for gross-alpha radioactivity were resampled and analyzed for radium-226 (an alpha emitter) and radium-228 (a beta emitter). Concentrations of radium-228 were reported as censored values in all nine samples. However, concentrations of radium-226 exceeded the 5-pCi/L MCL in samples from all seven of the wells that had samples with large uncensored gross-alpha radioactivity.

Water-Quality Problems

Three water-quality problems are apparent in the Roubidoux aquifer in northeast Oklahoma: (1) Contamination by mine water, (2) large concentrations of sodium and chloride, and (3) large concentrations of radium-226. In this section, the spatial occurrence of these problems is discussed.

Mine-Water Contamination

Lead and zinc sulfides were mined from the Boone Formation in the northeast part of the study unit from about 1900 until about 1970. The mines were dewatered during mining operations by extensive pumping, but later filled with water when pumping ceased. The compositions of the mine waters in the Boone Formation are detailed in Playton, Davis, and McClafflin (1980) and in Parkhurst (1987). Sulfate is the dominant anion in the mine waters, and calcium, magnesium, iron, and zinc are the dominant cations. Large concentrations of cadmium, copper, fluoride, lead, manganese, and nickel have been analyzed in some mine water.

Because the hydraulic head in the Boone Formation is higher than the head in the Roubidoux aquifer, water will tend to move from the mine workings in the Boone Formation downward through pores and fractures in the rock units, toward the Roubidoux aquifer. The Chattanooga Shale and the Northview Shale are stratigraphically below the Boone Formation, and have very small vertical hydraulic conductivity. Although they are not impervious, they could slow the downward movement of water. However, the two shale formations are absent in a large part of the the mining area.

Besides flow through the pores and fractures of the rock units, mine water could reach the Roubidoux aquifer through leaky well casings. According to Reed, Schoff, and Branson (1955), about 100 wells were drilled into the Roubidoux aquifer in the mining area to supply water for milling operations. Leaks in the casings at the level of the mine workings would allow movement of mine water down into the Roubidoux aquifer. Movement of this type was demonstrated in two abandoned wells in the mining area, 29N-23E-16 DDD 1 and 29N-23E-32 AAC 1. These wells were logged with a down-hole flowmeter and the data show downward water flow in both wells.

The flow rate in each well was estimated to be less than 2 gallons per minute. The U.S. Environmental Protection Agency has funded work to locate and plug any abandoned wells in the mining area that penetrate the Roubidoux aquifer. Both wells described here were plugged in 1984.

Several municipalities in the mining area have experienced water-quality problems related to the mines. In two of the public-supply wells for the City of Commerce, concentrations of sulfate, iron, zinc, and dissolved solids increased between July 1981 and October 1982. Repairs were made in the casings of these wells and the water quality returned to acceptable limits for public supply. The problems were apparently due to mine water entering the wells through leaks in the casings or through the grout seals of the wells.

Another municipality that has experienced water-quality problems related to the mines is Juapaw. When a water-supply well, 29N-23E-25 BDB 1, was completed in November 1977, the iron concentration in water from the well was about 100 ug/L (micrograms per liter) and the pH was 7.8. By July 1981, the pH was 7.0 and the iron concentration was 20,000 ug/L. The well was abandoned and plugged. The large iron concentrations and lowered pH indicate mine-water contamination.

The background concentrations of sulfate in the Roubidoux aquifer are relatively low. Three samples from the Picher water-supply wells, which were taken between 1942 and 1951, had sulfate concentrations ranging from 11 to 15 mg/L. These concentrations are similar to the median concentration of 16 mg/L for all of the available data (table 7). Mine-water concentrations of sulfate are large, approximately 3,000 mg/L (Playton, Davis and McClafflin, 1980). If sulfate migrates into the Roubidoux aquifer, it is expected to be conservative (unreactive). Therefore, increasing sulfate concentration is an indicator of mine-water contamination. Samples taken during this study (1981 and 1982) from the Picher water-supply wells had sulfate concentrations ranging from 47 to 92 mg/L. The increase in sulfate concentrations between the early samples and the samples of this study indicate mine-water contamination. Iron concentrations in the samples of this study were slightly greater than the median, but no other trace elements showed increased concentrations. In 1985, one of Picher's three water-supply wells began producing water with large concentrations of sulfate, iron, and dissolved solids. This well was subsequently abandoned and a new well was drilled in a new location.

At present (1990), all instances of ground-water contamination by mine water can be explained by faulty seals or leaky casings in wells that pass through the zone of mine workings and down to the Roubidoux aquifer. All of the wells that have had problems with mine-water contamination are within the perimeter of the mining area. None of the data available to date indicate that mine water has migrated from the Boone Formation through the pores and fractures of the intervening geologic units to the Roubidoux aquifer.

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