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RESPONSE ACTION CONTRACT FOR REMEDIAL, ENFORCEMENT OVERSIGHT, AND NON-TIME CRITICAL REMOVAL ACTIVITIES AT SITES OF RELEASE OR THREATENED RELEASE OF HAZARDOUS SUBSTANCES IN EPA REGION VIII

ADMINISTRATIVE RECORD

FILE PLAN
2.08

ENGINEERING EVALUATION/COST ANALYSIS FOR STRAY HORSE GULCH OPERABLE UNIT 6 CALIFORNIA GULCH NPL SITE LEADVILLE, COLORADO

JUNE 1997

CONTRACT NO. 68-W5-0022

CDM Federal Programs Corporation
A Subsidiary of Camp Dresser & McKee Inc.

RESPONSE ACTION CONTRACT FOR REMEDIAL ENFORCEMENT OVERSIGHT AND NON-TIME CRITICAL REMOVAL ACTIVITIES AT SITES OF RELEASE OR THREATENED RELEASE OF HAZARDOUS SUBSTANCES IN EPA REGION VIII

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ENGINEERING EVALUATION/COST ANALYSIS FOR STRAY HORSE GULCH OPERABLE UNIT 6

CALIFORNIA GULCH NPL SITE
LEADVILLE, COLORADO

Work Assignment Number: 016-NS-BN-0829
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Prepared for:

U.S. Environmental Protection Agency
Region VIII
999 18th Street
Denver, Colorado

Prepared by:

CDM Federal Programs Corporation
and
Pacific Western Technologies, Ltd.

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LIST OF ACRONYMS

AC	Acre
ARARs	Applicable or Relevant and Appropriate Requirements
ARD	Acid Rock Drainage
AVIRIS	Airborne Visible and Infra-Red Imaging Spectroscopy
BCY	Bank Cubic Yard
California Gulch Site	California Gulch Superfund Site
CD	Consent Decree
CDM Federal	CDM Federal Programs Corporation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFS	cubic feet per second
CMP	Corrugated Metal Pipe
COC	contaminant of concern
CY	Cubic Yard
EA	Each
EE/CA	Engineering Evaluation/Cost Analysis
Fe	Iron
GAL	Gallon
HDPE	High Density Polyethylene
HI	hazard index
HQ	Hazardous Quotient
HR	Hour
KWH	Kilowatt Hour
LB	Pound
LF	Linear Foot
LMDT	Leadville Mine Drainage Tunnel
LMDTTP	Leadville Mine Drainage Tunnel Treatment Plant
LS	Lump Sum
mg/kg	milligram per kilogram
MI	Miles
MSL	Mean Sea Level
NCP	National Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
NRHP	National Register of Historic Places
O&M	Operations and Maintenance
OU	Operable Unit
RA	Risk Assessment
RAC	Response Action Contract
RAO	Removal Action Objectives
RCP	Reinforced Concrete Pipe
Reclamation	United States Department of the Interior, Bureau of Reclamation
RI	Remedial Investigation
ROD	Record of Decision

LIST OF ACRONYMS (Continued)

SARA	Superfund Amendments and Reauthorization Act
SF	Square Feet
SFS	Screening Feasibility Study
SHG	Stray Horse Gulch
sq. mi.	Square Mile
TBC	to be considered
TBV	Toxicity Benchmark Value
TCLP	Toxic Characteristic Leaching Procedure
TMW	Tailings Monitoring Well
TSS	total suspended solids
U.S.	United States
USC	United States Code
USEPA	United States Environmental Protection Agency
WAMP	Work Area Management Plan
WMW	Waste Pile Monitoring Well
YR	Year
°F	degrees Fahrenheit
μg/L	micrograms per liter
μhmos/cm	micro hmos per centimeter
%	Percent

EXECUTIVE SUMMARY

This Engineering Evaluation/Cost Analysis (EE/CA) has been prepared for the United States Environmental Protection Agency (USEPA) Region VIII by CDM Federal Programs Corporation (CDM Federal) under the Response Action Contract (RAC), USEPA contract number 68-W5-0022. This EE/CA presents an evaluation of technological alternatives for the non-time-critical removal action at the Stray Horse Gulch (SHG) watershed basin within Operable Unit (OU) 6 located at the California Gulch Superfund Site (California Gulch Site). This EE/CA has been prepared under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and in accordance with the National Contingency Plan (NCP).

SITE BACKGROUND

The OU6 site comprises approximately 3.4 (2,200 acres) of the 16.5 square miles of the California Gulch Site. OU6 includes nearly all of the SHG drainage, the upper portion and headwater of Evans Gulch, and the lower portion of Evans Creek. On the western boundary, OU6 includes the eastern edge and portions of the City of Leadville, but does not include the heavily populated areas of Leadville. The OU6 site also includes a drainage corridor along 5th Street and Starr Ditch downstream of the confluence with the SHG drainage.

The California Gulch Site was added to the National Priorities List in 1983. USEPA began an investigation of mine wastes in California Gulch in 1987. In 1993, USEPA conducted a Screening Feasibility Study (SFS) to develop and evaluate possible response alternatives for addressing control of and/or remediation of the various sources at the California Gulch Site. ASARCO Incorporated conducted several remedial investigations (RIs) in 1994, including the Mine Waste Pile RI, the Tailings Disposal RI, and the Hydrogeological RI. The United States, the State of Colorado, and the Potentially Responsible Parties (PRPs) entered into a Consent Decree (CD) in 1994. The CD divided the California Gulch Site into 12 OUs for the cleanup of geographically-based areas within the Site. OU6 is one of these OUs. The United States Department of the Interior, Bureau of Reclamation (Reclamation) conducted investigations within OU6 in 1995 and 1996 to characterize and assess the contribution of contaminant metals from various sources to the surface water drainages during seasonal snowmelt runoff in OU6 and to assess the water and sediment chemistry, and characterize mine waste rock and mill tailings material. Reclamation initially developed the *Value Analysis, Draft-Presentation Report, Project: California Gulch OU6 Removal Action Evaluation and Decision Phase* (Value Analysis Report) (Reclamation, 1996b) to evaluate alternatives for OU6. USEPA modified and clarified the original Value Analysis Report and presented the findings in the *Revised Plan for Removal Action, Stray Horse Gulch Drainage, Operable Unit 6, California Gulch Superfund Site* (USEPA, 1996). The purpose of the revised plan was to address concerns, issues, and considerations raised by Lake County. This EE/CA summarizes information from the previous investigations as they pertain to the SHG watershed and builds upon the findings of the aforementioned evaluation reports to present information for choosing an appropriate removal action for SHG.

Several removal/response actions have already taken place within OU6. Most of these actions have centered around the Hamm's Tailing Impoundment, the channels in its vicinity, and Starr Ditch. Most recently in 1996, the USEPA conducted a removal action that involved removing the Penrose Mine Waste Pile and depositing the mine waste in the Hamm's tailings impoundment. The waste material in the impoundment was consolidated, reshaped, and graded to a stable configuration. The removal action includes future capping of the Hamm's tailings pile.

Current site uses for OU6 include limited mining activities, recreation, commercial activities, mine tourism, and residential. The Leadville area has been classified as a National Historic Landmark. Little Stray Horse Gulch contains several famous historic mines, including the Matchless Mine of Baby Doe and Horace Tabor. Tours are held at the Matchless Mine throughout the summer months and Little Stray Horse Gulch and SHG receive numerous recreational/tourist visits. The SHG watershed basin includes several sites recommended for National Register of Historic Places (NRHP). Many of these sites contribute to the Leadville Mining District heritage.

NATURE OF CONTAMINATION

For a period of over 130 years mine wastes were deposited on the ground surface during mining activities. During snow melt and rainstorm runoff, these mine waste materials are subject to weathering processes which oxidize, break down, and release remaining contaminant metals into the surface water drainages. Several different types of ore bodies were mined, including both sulfide and oxide carbonate ores (Reclamation, 1997). Of particular concern are the wastes from the mines that worked the sulfide ore bodies. When the sulfide ore waste material is exposed to oxidative weathering processes, the breakdown and alteration of the sulfide minerals generates low-pH (acidic) water which leaches heavy metals constituents out of the rock and into the surface water runoff waters. This acidic leachate is termed acid rock drainage (ARD). High levels of heavy metal contaminants have been observed in the surface water flows of SHG which is an secondary tributary to the Arkansas River.

OU6 has been screened by a high altitude spectral geochemical mapping technique called Airborne Visible and Infra-Red Imaging Spectroscopy (AVIRIS). AVIRIS mineral mapping indicates that the mine waste piles along SHG contain ARD-generating minerals. The AVIRIS findings were further verified by surface sampling.

In addition to the potential sources of ARD generation is the concern about the possible extent of surface heavy metal exposure to human health. Principle among these metals are lead. Lead surface contamination has been found at many of the same locations that AVIRIS indicated as potential for ARD generation.

REMOVAL ACTION OBJECTIVES

This removal action will focus on the watershed basin of SHG within the boundaries of OU6. Based on the investigations conducted by Reclamation, SHG is a major contributor of contaminated surface water from OU6 to the Arkansas River via California Gulch.

The Removal Action Objectives (RAOs) developed for this non-time-critical removal action are drawn from the NCP (40 CFR Part 300.430 (a) (1) (I)). The goal of the remedy selection process according to the NCP is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste.

The following are the specific RAOs for this removal action at OU6.

- Control airborne transport of contaminated materials.
- Control erosion of contaminated materials into local water courses.
- Contol leaching and migration of metals from contaminated materials into surface water.
- Control leaching and migration of metals from contaminated materials into groundwater.
- Control direct contact with and ingestion of contaminated materials.
- Maintain/preserve historic and cultural features of the OU consistent with the NRHP and current tourism draw.

These RAOs are consistent with the remedial action objectives defined for the California Gulch Site in the SFS (USEPA, 1993a) as well as historical preservation requirements and concerns specific to OU6.

Specific water quality goals for surface streams and groundwater contamination have not been established at this time. USEPA has agreed to establish specific surface and groundwater requirements at a later date when USEPA, Colorado Department of Public Health and Environment, and the PRPs have reached agreement on the allowable heavy-metals contaminant loadings for each of the contributing source areas (operable units) for the entire California Gulch Site. Although the objectives of controlling leaching and migration of metals from contaminated sources into surface waters and groundwater can not be quantified at this time, to be consistent with long term remedial action for OU6, the EE/CA aims to select a removal action that from the attempts to maximize the reduction in concentration of contaminants in the waters emanating from the SHG watershed by remediating those source areas that are the most likely contributors to the degradation of water quality based on the investigations.

The future land use at OU6 will largely be recreational. In meeting the objective of controlling direct contact with, or ingestion of, contaminated materials, lead is considered the principal risk to the recreational visitor. Baseline risk assessments performed for the site developed an action level of 16,000 milligrams per kilogram (mg/kg) under this exposure pathway (Weston, 1995c). This removal action will remediate contaminated materials with a concentration greater than 16,000 mg/kg. Some of these areas, although immediately outside of the SHG watershed basin, are in close proximity to the City of Leadville.

Groundwater is not directly addressed by this removal action. As stated above, the RAOs for this removal action included controlling leaching and migration of metals into groundwater by remediating source areas sitewide. Groundwater will be addressed by OU12.

EXTENT OF CONTAMINATION

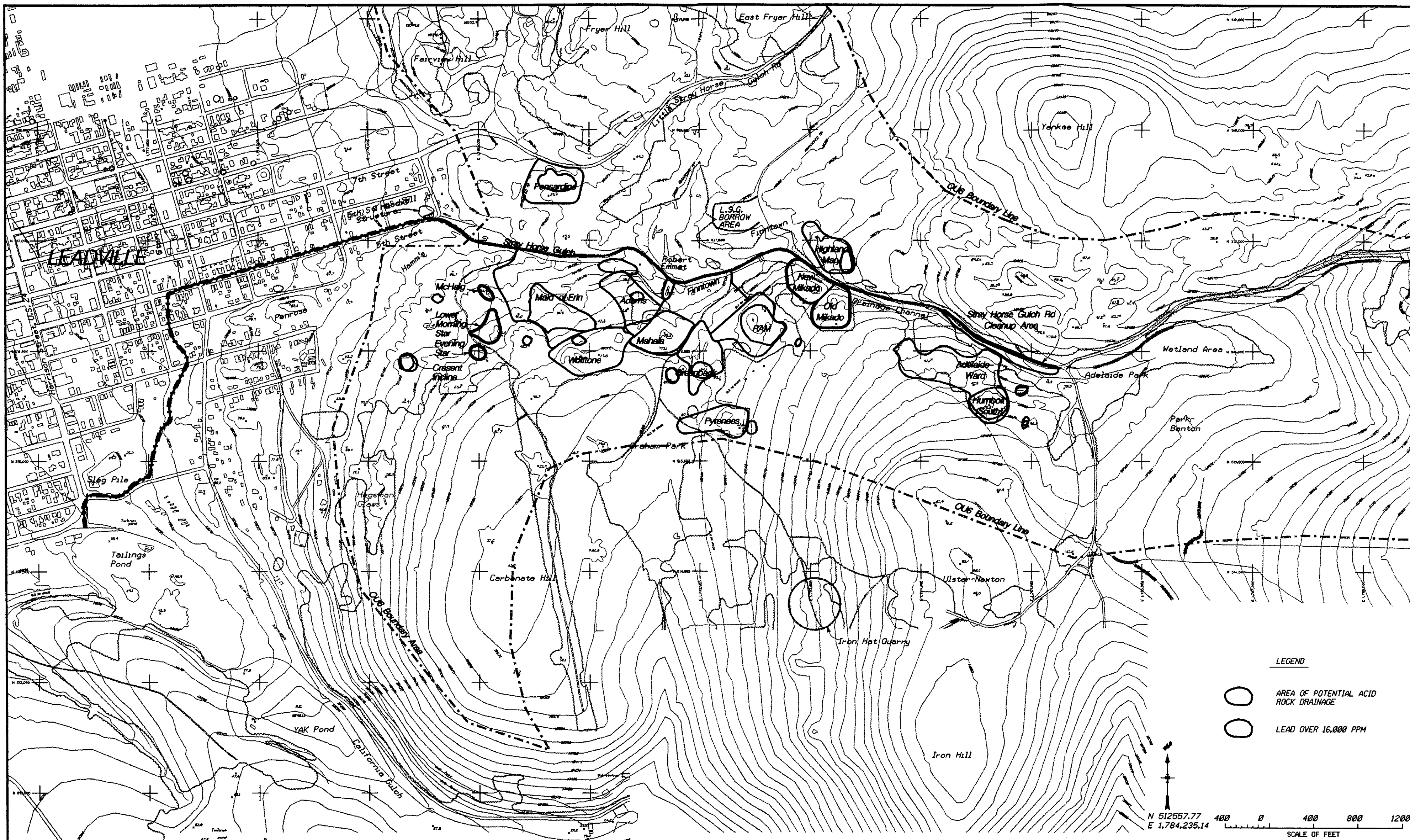
This removal action targets the surface water within SHG watershed basin as well as the sediments and fluvial tailings within SHG and Starr Ditch. The total volume of sediments is estimated at 15,600 cubic yards. The deposition of sediments and fluvial tailings originated in part from the erosion of mine waste piles located within the SHG watershed.

This removal action also targets those mine waste areas identified by AVIRIS as the ARD-generating sources within the SHG watershed basin. Those areas are outlined on Figure ES.1. The volume of this material was estimated by comparing the pre-mining topography of the SHG area with the existing topography. The pre-mining topography (the ground surface located beneath the mine waste rock pile) was estimated by interpretation of existing topography, aerial photographs, historical photographs, and United States Geographic Survey plates. These volumes are given in Table ES.1.

This removal action will also target surficial lead-contaminated mine waste located within SHG watershed basin and in the vicinity of Leadville. Those areas exceeding 16,000 mg/kg lead are also demarcated in Figure ES.1. Much of the lead-contaminated areas overlap the areas described above as being ARD-generating.

Color Map(s)

The following maps contain color that does not appear in the scanned images. To view the actual images please contact the Superfund Record Center at (303) 312-6473.



TARGET AREAS FOR ACID ROCK DRAINAGE AND LEAD

TABLE ES.1
ESTIMATED MINE WASTE VOLUME

WASTE AREA	ESTIMATED VOLUME (CUBIC YARDS)
Maid of Erin	186,000
Lower Morning Star/McHaig	10,000
Adams Mill	7,000
Wolftone	52,000
Mahala	33,000
Greenback	44,000
RAM	24,800
Old Mikado	42,000
New Mikado	44,000
Highland Mary	27,000
Ponsardine	11,000
Adelaide/Ward/Humboldt	54,000
Evening Star	2,000
Pyrenees	60,500
Finntown Area	1,000
Stray Horse Gulch Road near Adelaide	2,250
Additional Miscellaneous Lead Locations	4,000
Total Volume	604,550

Source: U.S. Bureau of Reclamation

REMOVAL ACTION ALTERNATIVES

In the SFS, site-wide remedial technologies and process options for waste rock piles, impounded tailings, fluvial tailings, stream sediments, slag, and non-residential area soils were identified, evaluated, and screened based on information contained in the RIs and in other collected data. Technologies and process options retained after the screening were used to develop specific alternatives for the various source areas.

The development and analysis of alternatives within this EE/CA is purposely divided into two subgroups. One subgroup of alternatives were developed to study the feasibility of controlling the migration of contamination by remediating the areas/materials that are presumed to be the sources of contamination. The second subgroup of alternatives approach various methods of either reducing the migration of contamination by diverting surface water away from the sources of contamination or separating (treating) the contaminants from the surface water after it has come in contact with the sources of contamination. It is anticipated that the removal action selected for meeting the RAOs of this EE/CA will ultimately be comprised of a pairing of one alternative from each subgroup.

The following removal action alternatives have been developed to address the source areas found at OU6:

Alternative S1:	Sediment Removal
Alternative S2:	Consolidation into Single Repository with Capping
Alternative S3:	Consolidation into Multiple Piles with Capping
Alternative S4:	Consolidation into Multiple Piles with Solidification

Separately, the following removal action alternatives have been developed to control the surface water within OU6:

Alternative W1:	Rehabilitation of the SHG Channel
Alternative W2:	Detention of Surface Waters within SHG

Alternative W3:	Diversion of Surface Waters via Graham Park
Alternative W4:	Diversion of Surface Waters to Leadville Mine Drainage Tunnel (LMDT)
Alternative W5:	Treatment of Surface Waters within SHG

A detailed description of the four source control alternatives follows.

Alternative S1 - Sediment Removal

In this alternative contaminated sediment would be removed from SHG and Starr Ditch and placed at a designated disposal site such as the Hecla tailings impoundment at OU2. This alternative would leave mine waste in place and untouched. The removal of sediments and fluvial tailing may precipitate the need to restructure sections of the SHG channel; thus, one of the surface water control alternatives may be required as an adjunct to the selection of this alternative as the Removal Action.

Alternative S2 - Consolidation into Single Repository with Capping

This alternative includes the construction of a single large repository in the SHG area which will contain the entire estimated 604,550 cubic yards of mine waste from the source areas identified in Table ES.1. The repository pile would be capped with an impervious geomembrane liner. To maintain the historic appearance in the region, the surface would be vegetated or covered with dolomite waste rock from the Sherman Mine source.

Contaminated sediments and fluvial tailings from SHG and Starr Ditch would be removed and also placed in the single repository. This removal of sediments and tailings would precipitate the need to restructure sections of the SHG channel; thus, one of the surface water control alternatives may be required as an adjunct to the selection of this alternative as the Removal Action.

Alternative S3 - Consolidation into Multiple Piles with Capping

Similar to Alternative S2, this alternative will mitigate the mine waste from the source areas identified on Figure ES.1; except instead of creating a single repository, Alternative S3, would consolidate and/or isolate the mine waste into several piles. The larger existing mine waste piles within each area would be used as the final waste piles in order to minimize the amount of waste to be moved and the haul distance. Approximately 325,500 cubic yards would be excavated from the areas identified in Table ES.1 and consolidated onto the remaining following seven piles:

Maid of Erin
Wolftone
Adelaide-Ward
Mikados
Mahala
Highland Mary
Ponsardine.

The volume of mine waste already existing within each consolidated pile area has an estimated volume totaling 279,050 cubic yards (including the three piles discussed below). This work will involve partial reconstruction of some piles previously reduced by reprocessing activities; consolidation of waste; capping of the consolidated waste with geomembranes. The geomembrane liner would be covered by a layer of rock, either dolomite from the Sherman Mine or another local rock type, to protect the geomembrane liner. A veneer of white porphyry and white porphyry mixed with dolomite would be placed on the surface to provide a more aesthetic appearance.

The following piles will be treated differently than those described above:

Pyrenees
Greenback
RAM

The treatment of these piles will more carefully address preservation of appearance, configuration, and coloration of the piles; and preservation or restoration of historic structures such as crib walls, buildings, and mine head frames. Innovative technologies and design would be considered for the preservation of the cultural aspects of these three piles.

Preservation may include a chemical stabilization agent to mitigate acid production and metals leaching; containment of surface water runoff on a site-by-site basis with a "moat"; removing the rock faces of the piles with placement of a cover or soil cement and replacement of the face material; consolidation of waste materials behind the piles, with capping of the backside of the piles only; covering of the piles with limerock; or grading of the piles and capping of the entire piles.

As a pilot test, it is proposed that during the summer 1997 work season a surface-water containment moat or ditch would be constructed around the base of the Pyrenees waste pile. This moat would serve to detain and isolate surface waters which contact the Pyrenees pile. It is anticipated that the impounded water will be reduced in volume through evaporation and direct infiltration into the subsurface rock mass. Lime rock lining may be used to buffer low pH runoff captured within the moat. If this method proves effective, it may be used in the following work season for the Greenback and RAM piles.

In addition, treatability studies have been conducted solidifying/stabilizing samples from the RAM and the Pyrenees mine waste piles. Preliminary results of these treatability studies indicate that adding 25% cement by mass of dry waste met the requirements for the Toxic Characteristic Leaching Procedure (TCLP), compressive strength, wetting-drying durability, and freezing-thawing durability. This cement/waste mixture can also be made to resemble the original colors of the piles.

Contaminated sediments and fluvial tailings from SHG and Starr Ditch would be removed and placed in one of the capped piles or at a designated disposal site such as the Hecla tailings impoundment. This removal of sediments and tailings would necessitate restructuring sections of the SHG channel; thus, one of the surface water control alternatives may be required as an adjunct to the selection of this alternative as the Removal Action.

Alternative S4 - Consolidation into Multiple Piles with Solidification

This alternative is essentially identical to Alternative S3 with the difference being the method of capping the mine waste piles. In lieu of the geomembrane cap used in Alternative S3, Alternative 4 would employ the use of a solidification and/or stabilization agent to minimize infiltration and/or runoff contact with the mine waste. Alternative S4, would consolidate and/or isolate the mine waste into several piles. This consolidation would permit the reduction of contamination and facilitate the pugmill mixing of a solidification/stabilization material with the top 3 to 5 feet of the compacted waste piles. Approximately 325,500 cubic yards would be excavated from the areas identified in Table ES.1 and consolidated onto the remaining following piles:

Maid of Erin
Wolftone
Adelaide-Ward
Mikados
Mahala
Highland Mary
Ponsardine.

No excavation or consolidation would occur at the following piles:

Pyrenees
RAM
Greenback.

The volume of mine waste already existing within each consolidated pile area has an estimated volume totaling 279,050 cubic yards.

This alternative would involve solidification/stabilization of the piles and site areas with reduced impact to their appearance and historic features. Treatability studies have been conducted solidifying/stabilizing samples from the RAM and the Pyrenees mine waste piles. Preliminary results of these treatability studies indicate that adding 25% cement by mass of dry waste met the requirements for the TCLP, compressive strength, wetting-drying durability, and freezing-thawing durability. This cement/waste mixture can also be made to resemble the original colors of the piles.

The treatment of the Pyrenees, Greenback, and RAM piles would carefully address preservation of appearance, configuration, and coloration of the piles and preservation or restoration of historic structures such as crib walls, buildings, and mine head frames. This application may use innovative techniques and possibly new technology to preserve the cultural aspects of the sites and piles.

Contaminated sediments and fluvial tailings from SHG and Starr Ditch would be removed and placed in one of the capped piles or at a designated disposal site such as the Hecla tailings impoundment. This removal of sediments and tailings would precipitate the need to restructure sections of the SHG channel; thus, one of the surface water control alternatives may be required as an adjunct to the selection of this alternative as the Removal Action.

A detailed description of the five surface water control alternatives follows.

Alternative W1 - Rehabilitation of the SHG Channel

In this alternative the SHG channel would be rehabilitated, lined, and armored to safely convey the 100-year storm and be stable for storm flows up to the 500-year storm event.

Alternative W1 would be considered as a potential surface water control if either Alternative S2, Alternative S3, or Alternative S4 is selected as the source control alternative. Alternative W1 provides for the rehabilitation of the SHG channel necessitated by the sediment and fluvial tailing removal that occurs as a component of these source control alternatives.

This alternative would not control exceedances of the city drainage system capacity along 5th Street, and continued flooding of streets and residential areas could occur.

Alternative W2 - Detention of Surface Waters within SHG

With Alternative W2, the SHG channel would be rehabilitated, lined, and armored in the same manner as Alternative W1 in order to safely convey the 100-year storm and be stable for storm flows up to the 500-year storm event. In addition, stream flow rates at the lower end of SHG would be controlled through the construction of a detention basin and dam. The basin and dam would be sized to retain up to 100-year, 24-hour storm flows while controlling releases at a flow rate of approximately 30 cubic feet per second (cfs) to match the conveyance capacity of the pipelines along 5th Street. In addition, the dam will be designed to safely withstand a 500-year storm event. To preserve cultural resources, the detention basin will be designed to blend in with the landscape to the maximum extent practicable.

Alternative W3 - Diversion of Surface Waters via Graham Park

Alternative W3 is similar to Alternative W2 but in order to reduce the capacity of the detention basin, the upper reaches of SHG would be diverted to California Gulch via Graham Park. Alternative W3 would construct a pipeline or ditch to convey the water from below the wetlands of Adelaide Park (and upstream of the Mikado Mine waste piles) to the main channel of California Gulch. The proposed construction would be a buried pipeline through a steep drainage ditch between Iron Hill and Carbonate Hill into California Gulch at the point where Starr Ditch discharges into the channel.

As with Alternative W1, the SHG channel would be rehabilitated, lined, and armored in order to safely convey the 100-year storm and be stable for storm flows up to the 500-year storm event. And similar to Alternative W2, the surface-water detention basin would be constructed in the SHG channel. The basin and dam would be sized to retain up to 100-year, 24-hour storm flows while controlling releases at a flow rate of approximately 30 cfs to match the conveyance capacity of the pipelines along 5th Street. In addition, the dam will be designed to safely withstand a 500-year storm event. To preserve cultural resources, the detention basin will be designed to blend in with the landscape to the maximum extent practicable.

Alternative W4 - Diversion of Surface Waters to LMDT

Alternative W4 is similar to Alternative W3 except the poor quality water of the lower SHG (below the Adelaide Park diversion) would be diverted to the LMDT in lieu of the 5th Street headwall. Alternative W4 would construct a pipeline or ditch to convey the water from below the wetlands of Adelaide Park (and upstream of the Mikado Mine waste piles) to the main channel of California Gulch. The proposed construction would be a buried pipeline through a steep drainage ditch between Iron Hill and Carbonate Hill into California Gulch at the point where Starr Ditch discharges into the channel.

As with Alternative W1, the SHG channel would be rehabilitated, lined, and armored in order to safely convey the 100-year storm and be stable for storm flows up to the 500-year storm event. And similar to Alternative W3, the surface-water detention basin would be constructed in the SHG channel. The basin and dam would be sized to retain up to 100-year, 24-hour storm flows while controlling releases at a flow rate of approximately 30 cfs to match the conveyance capacity of the pipelines along 5th Street. In addition, the dam will be designed to safely withstand a 500-year storm event.

An additional smaller catch basin would be located just upstream of the point where the Stray Horse stream flow enters the 5th Street headwall and drainage pipelines. This catch basin would collect any contaminated flows entering the channel from the lower watershed area below the primary detention basin discussed above. To preserve cultural resources, the basins will be designed to blend in with the landscape to the maximum extent practicable.

The two basins would be used to stabilize and regulate the rate of runoff flow being diverted to the Emmet Shaft. The primary detention basin would be used to divert the water through an angle-drill hole lined with casing or conveyance pipe to the rehabilitated Robert Emmet Shaft.

Rehabilitation of the Emmet Shaft would be necessary to convey these flows and allow the construction of a control drop structure. The water would then flow through the LMDT to the Leadville Mine Drainage Tunnel Treatment Plant (LMDTTP) where the remaining sediment and heavy-metals contamination would be removed. The water would then be discharged into the East Fork of the Arkansas River. Upgrades to the LMDTTP would probably be necessary to handle the increased flows. Further, additional annual operations and chemical costs would be required for the increased flows.

Alternative W5 - Treatment of Surface Waters within SHG

Alternative W5 is similar to Alternative W4 except in lieu of diverting the poor quality water of the lower SHG (below the Adelaide Park diversion) to the LMDT, the surface waters would be treated in a newly constructed treatment plant (located on site) and metered at a rate not to exceed the conveyance capacity of the pipelines along 5th Street.

Alternative W5 would construct a pipeline or ditch to convey the water from below the wetlands of Adelaide Park (and upstream of the Mikado Mine waste piles) to the main channel of California Gulch. The proposed construction would be a buried pipeline through a steep drainage ditch between Iron Hill and Carbonate Hill into California Gulch at the point where Starr Ditch discharges into the channel.

As with Alternative W1, the SHG channel would be rehabilitated, lined, and armored in order to safely convey the 100-year storm and be stable for storm flows up to the 500-year storm event. And similar to Alternative W4, the surface-water detention basin would be constructed in the SHG channel. The basin and dam would be sized to retain up to 100-year, 24-hour storm flows while controlling releases at a flow rate of approximately 4 cfs to match the anticipated capacity of the new treatment system. In addition, the dam will be designed to safely withstand a 500-year storm event.

An additional smaller catch basin would be located just upstream of the point where the Stray Horse stream flow enters the 5th Street headwall and drainage pipelines. This catch basin would collect any contaminated flows entering the channel from the lower watershed area below the primary detention basin discussed above. To preserve cultural resources, the basins will be designed to blend in with the landscape to the maximum extent practicable.

The on-site treatment plant would be situated downstream of the main detention basin at a location were the gulch widens and flattens sufficiently to permit construction. The treatment plant would probably be sized to handle normal spring runoff flow rates on the order of 4 cfs. The specific type of treatment will be selected to be compatible with the contaminants of concern, the flow-through volume requirement, the sediment load, and consistency with other treatment technologies in use in the California Gulch Site and vicinity. It is most likely that the treatment will be based on chemical precipitation. The discharge flow would be conveyed through a pipe or ditch to a discharge point just upstream of the concrete headwall at 5th Street. Treated water will be required to meet National Pollutant Discharge Elimination System permit requirements. Operation would include sediment and sludge removal for disposal at the Hecla tailings impoundment.

Innovative techniques will be used to construct the face of the basin embankment to make it resemble a mine pile. The basin bottoms will be "hardened" in a manner that minimizes visual impacts, such as using soil-cement that resembles soil rather than concrete.

COMPARATIVE ANALYSIS OF REMOVAL ACTION ALTERNATIVES

The alternatives developed above were analyzed using two sets of criteria. The first set of criteria, the NCP criteria, are the conventional criteria used in EE/CAs as defined in the EPA guidance document *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (USEPA, 1993b) and as required by the NCP. The second set of criteria, the Work Area Management Plan (WAMP) criteria, are additional site-specific criteria beyond the required NCP criteria. This set of criteria has been developed for evaluating remedial alternatives for the OUs at the California Gulch Site. These criteria are consistent with the PRP WAMP attached to the CD for the California Gulch Site.

The comparative analysis is summarized in Tables ES.2 through ES.5.

RECOMMENDED REMOVAL ACTION

Recommended Source Control Alternative

The recommended alternative is Alternative S3. Alternative S3 meets all of the RAOs developed for OU6. Alternative S3 will control airborne transport of contaminated materials, control erosion of contaminated materials into local water courses, control leaching and migration of metals from contaminated materials into surface water and groundwater, control direct contact with and ingestion of contaminated materials, and maintain/preserve historic and cultural features of the OU. Alternative S1 by itself cannot achieve most of these RAOs. If paired with one of the surface water treatment alternatives (W4 or W5), the combination could reduce the concentration of metals in the surface water but would have no impact on the surface lead contamination. Alternative S2 achieves most of the RAOs but at the expense of not being able to preserve the historic features consistent with the NRHP. Alternatives S4 will achieve all of these RAOs but at a higher cost than Alternative S3.

Alternative S3 will also conform to all the WAMP criteria with the exception of the flow capacity criteria. Alternative S3 will meet surface erosion and slope stability requirements. It will reduce surface water and groundwater loading and reduce exposure of the terrestrial ecosystem. This alternative is anticipated to show a quantifiable improvement in the quality of the SHG surface water. The actual net load reduction will be determined after Alternative S3 is implemented and post-remediation sampling is conducted.

To conform with the flow capacity criteria, Alternative S3 will require the selection of a surface water control alternative.

TABLE ES.2
COMPARISON OF SOURCE CONTROL ALTERNATIVES USING NCP CRITERIA

NCP Criteria	Alternative S1 Sediment Removal	Alternative S2 Consolidation into Single Repository with Capping	Alternative S3 Consolidation into Multiple Piles with Capping
EFFECTIVENESS Protectiveness	Limited short-term effect. Will have no direct impact on the source of contamination, namely the mine waste piles. Will not protect against contact with lead contamination.	This alternative provides for protection of human health and the environment by capping mine wastes and isolating the contaminated materials that come in contact with run-on and precipitation.	This alternative provides for protection of human health and the environment by capping mine wastes and isolating the contaminated materials that come in contact with run-on and precipitation.
Ability to Achieve Removal Objectives	Achieves the RAO for preserving historical features but does not achieve any of the other RAOs.	Achieves all of the RAOs except preserving historical features.	Achieves all of the RAOs.
IMPLEMENTABILITY Technical Feasibility	There are no anticipated technical difficulties with implementing this alternative.	Geomembranes are a reliable technology for covering waste piles.	Geomembranes are a reliable technology for covering waste piles.
Availability	Utilizes readily available materials and labor.	Utilizes readily available materials and labor.	Utilizes readily available materials and labor.
Administrative Feasibility	May not be acceptable to governmental agencies responsible for protection of human health and the environment.	Site access and land acquisition may be difficult and could delay the project. Due to the NRHP eligibility of several of the mining locations, this alternative may not be administratively feasible.	Site access may pose delays to the project.
COST Net Present Worth	$850,000	$8,574,000	$7,786,000

TABLE ES.2 (Continued)
COMPARISON OF SOURCE CONTROL ALTERNATIVES USING NCP CRITERIA

NCP Criteria	Alternative S4 Consolidation into Multiple Piles with Solidification
EFFECTIVENESS Protectiveness	This alternative provides for protection of human health and the environment by encapsulating mine wastes and isolating the contaminated materials that come in contact with run-on and precipitation.
Ability to Achieve Removal Objectives	Achieves all of the RAOs.
IMPLEMENTABILITY Technical Feasibility	Preliminary treatability study results show the use of solidification to be technically viable.
Availability	The materials and equipment used for soil-cement solidification are readily available.
Administrative Feasibility	Site access may pose delays to the project.
COST Net Present Worth	$10,425,000

TABLE ES.3
COMPARISON OF SOURCE CONTROL ALTERNATIVES USING WAMP CRITERIA

WAMP Criteria	Alternative S1 Sediment Removal	Alternative S2 Consolidation into Single Repository with Capping	Alternative S3 Consolidation into Multiple Piles with Capping
Surface Erosion Stability	No measures would be taken to ensure erosional stability of SHG and waste piles.	Surfaces in the remediated areas would be designed for stability during storm events.	Surfaces in the remediated areas would be designed for stability during storm events.
Slope Stability	No improvement to the stability of the mine waste piles.	A slope factor of safety of 1.5 will be achieved by the design of the cap.	A slope factor of safety of 1.5 will be achieved by the design of the cap.
Flow Capacity and Stability	The selection of a surface water control alternative would be required to meet WAMP criteria.	The selection of a surface water control alternative would be required to meet WAMP criteria.	The selection of a surface water control alternative would be required to meet WAMP criteria.
Surface Water and Groundwater Contaminant Load Reduction	Short-term reduction of loading from sediments; however the source of the contaminated sediments (the mine piles) will continue to redeposit in SHG.	Most of the source areas will be isolated from precipitation and run-on, resulting in contaminant loading reductions to surface water and groundwater as measured by comparison of baseline and post-removal monitoring results.	Most of the source areas will be isolated from precipitation and run-on, resulting in contaminant loading reductions to surface water and groundwater as measured by comparison of baseline and post-removal monitoring results.
Terrestrial Ecosystem Exposure	Terrestrial ecosystem would not be restored or improved and risk to all species would remain unchanged.	Sources of contamination would be isolated from the terrestrial ecosystem through capping.	Sources of contamination would be isolated from the terrestrial ecosystem through capping.
Nonresidential Soils	No improvement in non-residential soils .	The risk to recreational users posed by nonresidential soils would be minimized.	The risk to recreational users posed by nonresidential soils would be minimized.

TABLE ES.3 (Continued)
COMPARISON OF SOURCE CONTROL ALTERNATIVES USING WAMP CRITERIA

WAMP Criteria	Alternative S4 Consolidation into Multiple Piles with Solidification
Surface Erosion Stability	Surfaces in the remediated areas would be designed for stability during storm events.
Slope Stability	A slope factor of safety of 1.5 will be achieved by the design of the solidified cap.
Flow Capacity and Stability	The selection of a surface water control alternative would be required to meet WAMP criteria.
Surface Water and Groundwater Contaminant Load Reduction	Most of the source areas will be isolated from precipitation and run-on, resulting in contaminant loading reductions to surface water and groundwater as measured by comparison of baseline and post-removal monitoring results.
Terrestrial Ecosystem Exposure	Sources of contamination would be isolated from the terrestrial ecosystem through encapsulation.
Nonresidential Soils	The risk to recreational users posed by nonresidential soils would be minimized.

TABLE ES.4
COMPARISON OF SURFACE WATER CONTROL ALTERNATIVES USING NCP CRITERIA

NCP Criteria	Alternative W1 Rehabilitation of the SHG Channel	Alternative W2 Detention of Surface Waters within SHG	Alternative W3 Diversion of Surface Waters via Graham Park
EFFECTIVENESS Protectiveness	Alternative W1 alone would be neither protective of public health nor the environment. This alternative is designed chiefly to complement a source control alternative.	Alternative W2 alone would be neither protective of public health nor the environment. This alternative is designed chiefly to complement a source control alternative.	Alternative W3 alone would be neither protective of public health nor the environment. This alternative is designed chiefly to complement a source control alternative.
Ability to Achieve Removal Objectives	By itself, the only RAO Alternative W1 would achieve is preservation of historic features.	By itself, the only RAO Alternative W2 would achieve is preservation of historic features.	By itself, the only RAO Alternative W3 would achieve is preservation of historic features.
IMPLEMENTABILITY Technical Feasibility	There are no anticipated technical difficulties with implementing this alternative.	There are no anticipated technical difficulties with implementing this alternative.	Silt blockages or ice dams may occur regularly in the buried piping requiring costly repairs.
Availability	Utilizes readily available materials and labor.	Utilizes readily available materials and labor.	Utilizes readily available materials and labor.
Administrative Feasibility	There are no administrative issues for Alternative W1. There may however be issues surrounding the source control alternative that is selected to complement it.	The size of the detention basin and its potential impact on the views of the vista present a concern to the Lake County officials.	The diversion pipeline to Graham Park could impact future remedial activities and/or land use in OU4 and OU6. Site access and land acquisition may be difficult and could delay the project.
COST Net Present Worth	$524,000	$1,328,000	$2,681,000

TABLE ES.4 (Continued)
COMPARISON OF SURFACE WATER CONTROL ALTERNATIVES USING NCP CRITERIA

NCP Criteria	Alternative W4 Diversion of Surface Waters to LMDT	Alternative W5 Treatment of Surface Waters within SHG
EFFECTIVENESS Protectiveness	Alternative W4 would reduce heavy metals loading into Starr Ditch and California Gulch. The alternative does not protect against direct contact with lead-contaminated materials.	Alternative W5 would reduce heavy metals loading into Starr Ditch and California Gulch. The alternative does not protect against direct contact with lead-contaminated materials.
Ability to Achieve Removal Objectives	By itself, the only RAO Alternative W4 would achieve is preservation of historic features. Although the alternative will not control migration of metals from contaminated materials into the surface water, it will directly treat the contaminated surface water and groundwater.	By itself, the only RAO Alternative W5 would achieve is preservation of historic features. Although the alternative will not control migration of metals from contaminated materials into the surface water, it will directly treat the contaminated surface water.
IMPLEMENTABILITY Technical Feasibility	The large volume of water diverted during a storm event may be deterimental to the stability of the Emmet Shaft and LMDT. The LMDTTP may have difficulty handling the increase flow and variation in chemistry.	Materials of construction specified in the design of the treatment plant would have to account for the low-pH influent and adverse weather conditions. Treatment system utilizes conventional process units.
Availability	Specialized equipment may be required in refurbishing the Emmet Shaft.	Equipment and materials for treatment plant may not be available locally. Difficult to implement in short construction season.
Administrative Feasibility	The diversion pipeline to Graham Park could impact future remedial activities and/or land use in OU4 and OU6. Site access and land acquisition may be difficult and could delay the project. Further, the second diversion of water to the LMDT may affect water rights along California Gulch.	The diversion pipeline to Graham Park could impact future remedial activities and/or land use in OU4 and OU6. Site access and land acquisition may be difficult and could delay the project.
COST Net Present Worth	$7,429,000	$25,107,000

TABLE ES.5
COMPARISON OF SURFACE WATER CONTROL ALTERNATIVES USING WAMP CRITERIA

WAMP Criteria	Alternative W1 Rehabilitation of the SHG Channel	Alternative W2 Detention of Surface Waters within SHG	Alternative W3 Diversion of Surface Waters via Graham Park
Surface Erosion Stability	Surfaces in remediated areas would be designed for stability during storm events.	Surfaces in remediated areas would be designed for stability during storm events.	Surfaces in remediated areas would be designed for stability during storm events.
Slope Stability	Slopes of embankments would be designed with a factor of safety of 1.5.	Slopes of impoundment embankments would be designed with a factor of safety of 1.5.	Slopes of impoundment embankments would be designed with a factor of safety of 1.5.
Flow Capacity and Stability	The SHG stream channel would carry flows up to a 100-year storm event while stable for a 500-year storm event. No additional measures would be taken to control exceedances of the 5th St headwall.	The SHG stream channel would carry flows up to a 100-year storm event while stable for a 500-year storm event. Measures would be taken to control exceedances of the 5th St headwall.	The SHG stream channel would carry flows up to a 100-year storm event while stable for a 500-year storm event. Measures would be taken to control exceedances of the 5th St headwall.
Surface Water and Groundwater Contaminant Load Reduction	No mass load reduction would be achieved by Alternative W1 alone. Loading reduction would occur when the alternative is paired with a a source control alternative.	No mass load reduction would be achieved by Alternative W2 alone. Loading reduction would occur when the alternative is paired with a a source control alternative.	No mass load reduction would be achieved by Alternative W3 alone. Loading reduction would occur when the alternative is paired with a a source control alternative.
Terrestrial Ecosystem Exposure	Terrestrial ecosystem would not be restored or improved by Alternative W1 alone.	Terrestrial ecosystem would not be restored or improved by Alternative W2 alone.	Terrestrial ecosystem would not be restored or improved by Alternative W3 alone.
Nonresidential Soils	No improvement in non-residential soils.	No improvement in non-residential soils.	No improvement in non-residential soils.

TABLE ES.5 (Continued)
COMPARISON OF SURFACE WATER CONTROL ALTERNATIVES USING WAMP CRITERIA

WAMP Criteria	Alternative W4 Diversion of Surface Waters to LMDT	Alternative W5 Treatment of Surface Waters within SHG
Surface Erosion Stability	Surfaces in remediated areas would be designed for stability during storm events.	Surfaces in remediated areas would be designed for stability during storm events.
Slope Stability	Slopes of impoundment embankments would be designed with a factor of safety of 1.5.	Slopes of impoundment embankments would be designed with a factor of safety of 1.5.
Flow Capacity and Stability	The SHG stream channel would carry flows up to a 100-year storm event while stable for a 500-year storm event. Measures would be taken to control exceedances of the 5th St headwall.	The SHG stream channel would carry flows up to a 100-year storm event while stable for a 500-year storm event. Measures would be taken to control exceedances of the 5th St headwall.
Surface Water and Groundwater Contaminant Load Reduction	By diverting surface waters to LMDTTP, contaminant loading is reduced through treatment. Groundwater is also treated at the LMDTTP.	By diverting surface waters to the treatment system, contaminant loading is reduced through treatment. Groundwater is treated at the LMDTTP.
Terrestrial Ecosystem Exposure	Terrestrial ecosystem would not be restored or improved by Alternative W4 alone.	Terrestrial ecosystem would not be restored or improved by Alternative W5 alone.
Nonresidential Soils	No improvement in non-residential soils.	No improvement in non-residential soils.

Recommended Surface Water Control Alternative

Paired with source control Alternative S3, all of the surface water control alternatives will provide the flow capacity requirements that Alternative S3 lacks.

It should be noted that Alternatives W4 and W5 were designed chiefly as standalone alternatives (without a source control); however, neither of them can achieve all of the RAOs, namely they cannot control direct contact with materials contaminated with lead and cannot control airborne transport and surface erosion of contaminated materials.

By selecting a source control alternative such as Alternative S3, it is anticipated that the source control alternative will reduce surface water loading and therefore treatment of the surface water (i.e. Alternatives W4 and W5) will not be necessary.

The remaining alternatives W1, W2, and W3 will all rehabilitate the SHG channel in order to convey a 100-year, 24-hour storm event and would be designed for stability under flows resulting from a 500-year, 24-hour storm event. Alternatives W2 and W3 have the additional benefit of regulating flows arriving at the 5th Street headwall down to a rate that meets the capacity of the stormwater piping that runs along 5th Street. Alternative W2 can do this at little over half the cost of Alternative W3.

The selection of the surface water control alternative will be made after results of source control actions can be assessed through water quality sampling taken during seasonal runoff following construction of the source control.

provided to the public on March 19, 1997. During the specified comment period, the public had the opportunity to provide input on the proposed removal action. Comments received have been incorporated into this revision of the EE/CA.

1.2 REPORT ORGANIZATION

This EE/CA report has been modeled after the format suggested in the EPA guidance document entitled *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (USEPA, 1993b). Section 1.0 presents introductory material. Section 2.0 presents site background information and a summary of the site investigation findings. Section 3.0 discusses removal action objectives for each site drawn from the conclusions of the risk assessments and the survey of applicable or relevant and appropriate requirements (ARARs) and cultural resources. Section 4.0 identifies a range of technologies available to remediate each medium, and screens and selects the most applicable remedial options to be considered for OU6. A range of removal action alternatives built from the selected remedial options are assembled as well in Section 4.0. Those removal alternatives that address source control are described in detail and are evaluated using CERCLA screening criteria in Section 5.0. A comparative analysis of how these alternatives rank against the criteria is also discussed in Section 5.0. Those removal alternatives that address surface water control are described in detail and are evaluated using CERCLA screening criteria in Section 6.0. Similarly, a comparative analysis of how these alternatives rank against the criteria is also discussed in Section 6.0. Recommendations for the preferred removal-action alternative are given in Section 7.0. Section 8.0 contains references. Appendix A tabulates the site-specific ARARs and Appendix B shows the details of the cost estimates. Appendix C is a preliminary technical memorandum on the treatability study performed to evaluate the feasibility of solidification/stabilization of selected mine waste rock in OU6. Appendix D contains a stability analysis of mine waste rock piles proposed for removal action and Appendix E contains data maps from the soil sampling program conducted at SHG.

2.0 SITE CHARACTERIZATION

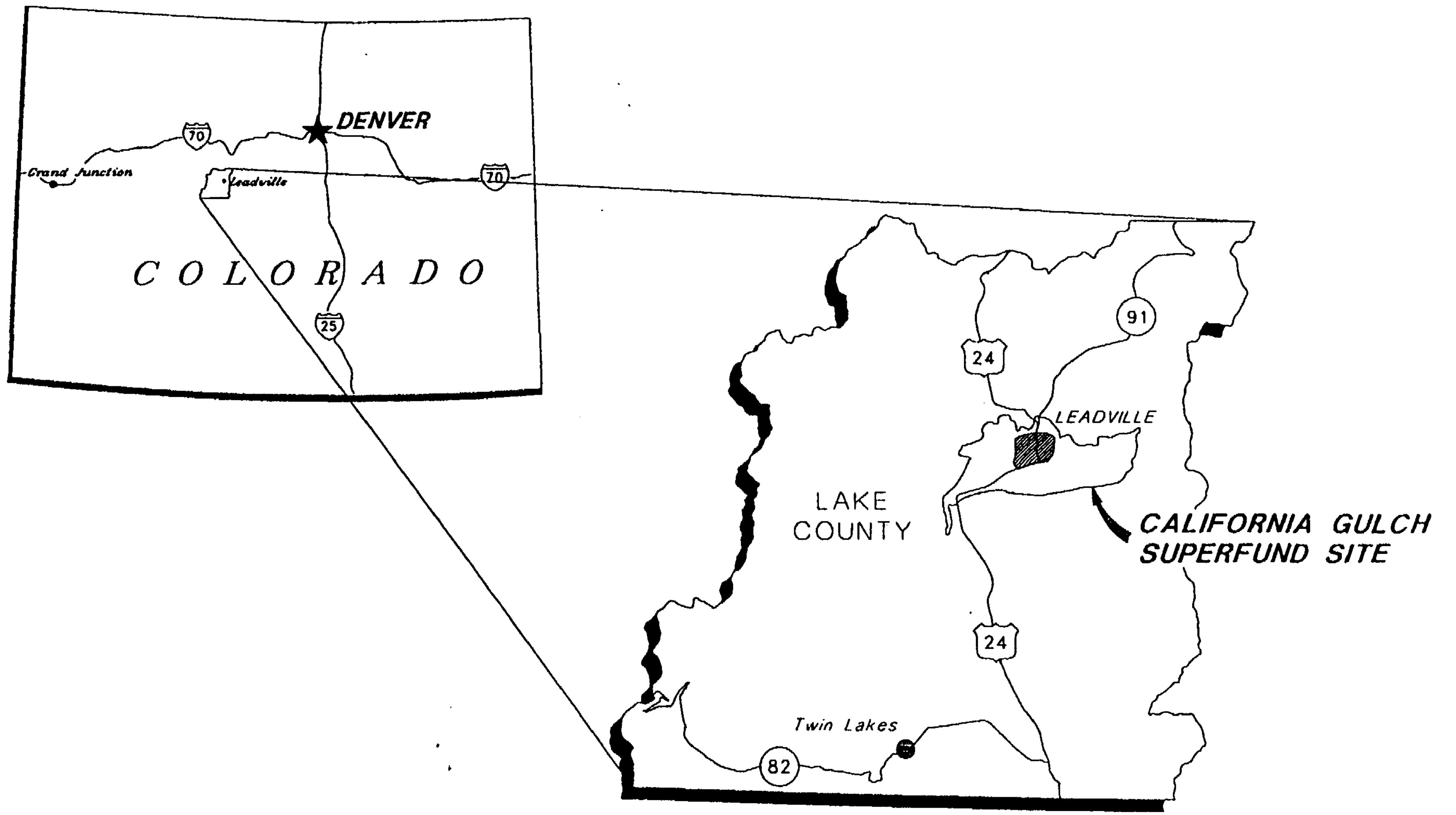
2.1 SITE LOCATION AND DESCRIPTION

The California Gulch Site is located in Lake County approximately 100 miles southwest of Denver, Colorado (Figure 2.1). The California Gulch Site includes, but is not limited to, the City of Leadville and OU 6. The predominantly rural county has a population of 6,007 (United States Bureau of the Census, 1990). The people residing within the Leadville city limits account for approximately half of the county's total population.

The OU6 site comprises approximately 3.4 (2,200 acres) of the 16.5 square miles of the California Gulch Site. OU6 includes nearly all of the SHG drainage, the upper portion and headwater of Evans Gulch, and the lower portion of Evans Creek to the intersection of United States (U.S.) Highway 24 and State Highway 91 (see Figure 2.2). On the western boundary, OU6 includes the eastern edge and portions of the City of Leadville, but does not include the heavily populated areas of Leadville. The OU6 site also includes a drainage corridor along 5th Street and Starr Ditch downstream of the confluence with the SHG drainage. Elevation ranges from approximately 10,000 feet above mean sea level (MSL) to 12,500 feet MSL on the eastern site boundary below Mosquito Pass.

2.2 SITE HISTORY

The California Gulch Site is located in a highly mineralized area of Colorado containing low-grade silver ore and several other precious mineral ores. Historical mining, mineral processing, and smelting activities have produced gold, silver, lead, and zinc for more than 130 years (USEPA, *Final Screening Feasibility Study forRemediation at the California Gulch NPL Site*, 1993a). Most of these operations occurred before the effects on the environment were fully recognized. Small-scale mining is still occurring within this site. Mining in the Leadville area began in 1859, when gold was discovered at the mouth of California Gulch by prospectors working the channels of Arkansas River tributaries. Initial activities consisted only of small-scale placer mining until 1868, when the first gold-ore veins were discovered along California



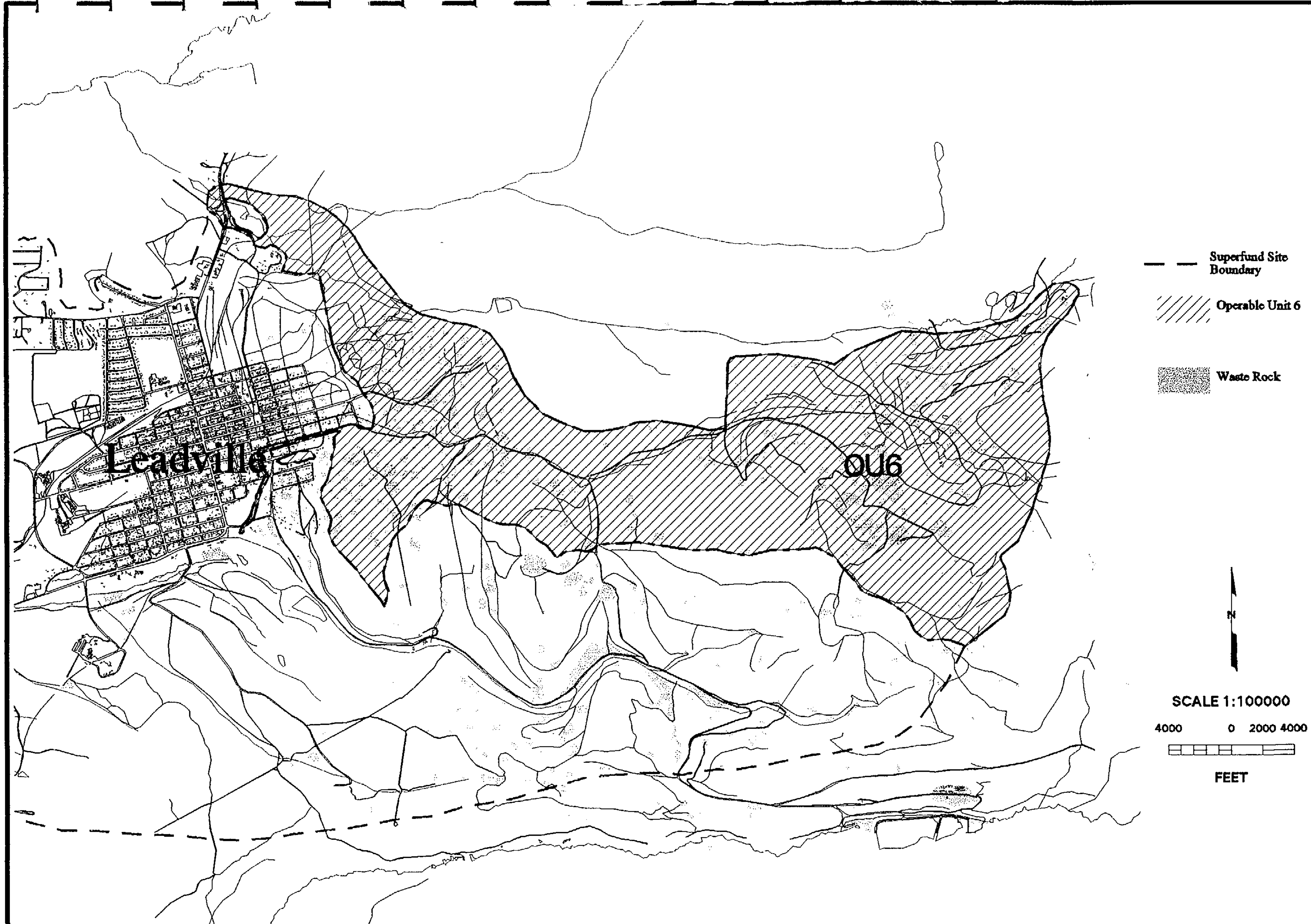
CDM Federal Programs Corporation

CALIFORNIA GULCH SUPERFUND SITE GENERAL LOCATION MAP
CALIFORNIA GULCH OU6 EE/CA
LEADVILLE, COLORADO

Figure 2.1

Color Map(s)

The following maps contain color that does not appear in the scanned images. To view the actual images please contact the Superfund Record Center at (303) 312-6473.



CDM Federal Programs Corporation

CALIFORNIA GULCH SUPERFUND SITE AND OPERABLE UNIT 6

CALIFORNIA GULCH OU6 EE/CA
LEADVILLE, COLORADO

Figure 2.2

Gulch. By 1872, however, problems with water, transportation, and labor made ore removal so difficult that most miners had left the area (Woodward-Clyde Consultants [Woodward-Clyde], *Mine Waste Piles Remedial Investigation Report*, 1994a).

In 1874, W.H. Stevens and A.B. Wood investigated the composition of a "heavy sand" that interfered with the recovery of gold in placer sluice boxes. The material proved to be a silver-bearing lead carbonate. Mining in the Leadville district boomed as news of this discovery spread and sources of carbonate ore were discovered (Woodward-Clyde, 1994a).

As the search for ore became widespread, extensive replacement deposits of lead and silver and, later on, rich gold ores associated with fissure veins were found. Copper, usually associated with the gold ore, assumed minor importance. Zinc and manganese minerals occurred with the lead-silver ores; they were of little value in the early days, but were later mined extensively (Woodward-Clyde, 1994a).

As surface veins diminished, miners tunneled deeper into the mountains. Underground mines were developed east and southeast of Leadville. As mines were developed, waste rock was excavated along with the ore. The waste rock was placed near the mine entrance, and the ore was transported to a mill (Woodward-Clyde, 1994a)

At the mill, ores were crushed and separated into metallic concentrates and waste products by physical processes. The metallic concentrations were then shipped elsewhere or further processed at a smelter in the area. The waste products (mill tailings) were generally placed near the mill in a tailings pond (Woodward-Clyde, 1994a).

In the smelters, the high-grade ores were refined and concentrated into higher-grade products. Waste product from the smelters included slag, dust, and off-gases. Forty-four known smelters were in the district (Woodward-Clyde, 1994a).

Groundwater, which began flooding into the mines, had to be pumped out continuously. As a result, mining costs became prohibitive. In 1889, the Yak Tunnel was constructed as an extension of the Silver Cord Tunnel to drain the Iron Hill area to facilitate mining exploration. With the portal at an elevation of 10,330 feet MSL, the Yak Tunnel was driven eastward to penetrate the Iron-Mikado fault system. The venture proved so successful that the tunnel was extended at various times, successively penetrating the Breece Hill, Ibex, and Resurrection areas. In 1912, it was terminated at the Resurrection No. 2 Mine (Woodward-Clyde, 1994a).

A surge of mining activity in the early 1920s in the Carbonate Hill and Iron Hill areas sparked new interest in using the Yak Tunnel for dewatering purposes. In May 1923, the Yak Tunnel was again extended to a total length of more than 3.5 miles. By that time, the tunnel drained a complex area of massive sulfide and carbonate mines through a maze of underground mine workings (Woodward-Clyde, 1994a).

With the advent of World War II, operating properties in the district increased production as a result of the federal support-premium price paid for copper, lead, and zinc. During World War II and the Korean War, a second tunnel was bored by the U.S. Bureau of Mines to drain the mine workings east of the city of Leadville. This tunnel, named the Leadville Mine Drainage Tunnel (LMDT), extends under the OU6 area and drains the groundwater and infiltrating surface water into the East fork of the Arkansas River. During the war, the major portion of the recorded production came from processing old dumps by the Ore and Chemical Company and John Hamm Milling Company; however, production increases were recorded from the Resurrection No. 2, Fortune, Eclipse, and Hellena shafts as well. Ore output essentially stopped after 1957 when the Irene shaft was closed due to low metal prices (Woodward-Clyde, 1994a).

In 1965, a joint venture between ASARCO Incorporated (ASARCO) and Resurrection Mining Company (Resurrection) reopened the Irene workings and substantial ore reserves were proven in the down-dropped block in the eastern portion of the Leadville district bordered by the Ball Mountain, Weston, and Garbutt faults. In 1969, a new shaft, the Black Cloud, was sunk in Iowa Gulch to access the newly found ore reserves. The Black Cloud mine and mill went into production in April 1971 and has operated continuously since that time. The other significant mine operating in the district since the Resurrection Mill shut down in 1957 is the Sherman Mine at the head of Iowa Gulch. This mine, now owned by the Leadville Corporation, was operated by

Day Mines and the Hecla Mining Company between 1976 and 1984, after which it was shut down for economic reasons. An estimated 26 million tons of ore were produced in the Leadville Mining District from 1859 through 1986 (Woodward-Clyde, 1994a).

More than 2,000 mine waste piles have been identified in the California Gulch Site. A few of these waste piles are located within the residential area of Leadville. Major tailings impoundments, slag piles with several smaller piles, and fluvial tailings still exist at the California Gulch Site. Contamination of soil and surface water drainage in populated areas occur throughout the California Gulch Site. The Yak Tunnel OU discharge is currently being remediated with a water treatment plant facility (USEPA, 1993a) operated by Resurrection and ASARCO. Drainage from the LMDT is treated at the Leadville Mine Drainage Tunnel Treatment Plant (LMDTTP) operated by United States Department of the Interior, Bureau of Reclamation (Reclamation).

The OU6 site comprises SHG and portions of the Evans Gulch drainage which collect acid rock drainage (ARD) from areas of old mine waste. The ARD produces surface runoff with low-pH and high concentrations of heavy-metal contaminants.

2.3 REGULATORY HISTORY

The USEPA proposed the National Priority List (NPL) listing of the California Gulch Site on December 30, 1982 and the site was formally listed on September 8, 1983 (USEPA, 1990a). The following is a historical account of the regulatory actions taken at OU6 site, listed in chronological order.

- 1982 – California Gulch Site proposed for the NPL
- 1983 – California Gulch Site formally added to the NPL.
- 1986 – USEPA emergency workers extended public water supply system lines to residences using private wells.

- 1987 – USEPA began an investigation of mine wastes at the site. The USEPA investigated the nature and extent of water pollution caused by mine tailings piles and ponds, smelter slags, and mine waste dumps. The USEPA identified 203 piles larger than 100,000 cubic yards. Forty-five sites were selected for field inspection for evidence of potential instability. Fifteen of these sites were judged potentially unstable. The 45 sites selected for field inspection were selected for sampling based on access, size, waste type, stability, and proximity to residential areas and/or watercourses. Eleven of these sites were mine waste piles, with the remainder being slag piles and tailings impoundments. Seven of the sampled mine waste piles are located in SHG and 4 mine waste piles are located in California Gulch (Woodward-Clyde, 1994a).

- 1993 – USEPA conducted the *Final Screening Feasibility Study for Remediation Alternatives at the California Gulch NPL Site* (USEPA, 1993a) to develop and evaluate possible response alternatives for addressing control of and/or remediation of the various sources at the California Gulch Site.

- 1994 – ASARCO conducted several remedial investigations (RIs) for the California Gulch Site including the *Mine Waste Piles Remedial Investigation Report, California Gulch Site* (Woodward-Clyde, 1994a), the *Tailings Disposal Area Remedial Investigation Report, California Gulch Site* (Woodward-Clyde, 1994b), and the *Hydrogeologic Remedial Investigation Report, California Gulch Site* (Golder Associates [Golder], 1996).

- 1994 – The United States, the State of Colorado, and the Potentially Responsible Parties (PRPs) entered into a Consent Decree (CD). The CD divided the California Gulch Site into 12 OUs for the cleanup of geographically-based areas within the Site. OU6 is one of these OUs.

- 1995 – Reclamation conducted the *Phase I: Feasibility Study, Water and Sediment Sampling and Hydrologic Measurement Program, Results and Findings, 1995 Spring Runoff for Operable Unit 6, California Gulch NPL Site* (Reclamation, 1996a) to characterize and assess the contribution of contaminant metals from various sources to the surface water drainages during seasonal snowmelt runoff in OU6.

- 1996 – Reclamation conducted the *Draft Environmental Geology of Operable Unit 6, Removal Action Design Data, California Gulch Superfund Site* (Reclamation, 1997) predesign investigation to assess the water and sediment chemistry, and characterize mine waste rock and mill tailings material.

- 1996 – Reclamation developed the *Value Analysis, Draft-Presentation Report, Project: California Gulch OU6 Removal Action Evaluation and Decision Phase* (Value Analysis Report) (Reclamation, 1996b) to evaluate alternatives for OU6.

- 1996 – USEPA modified and clarified the original Value Analysis Report and presented the findings in the *Revised Plan for Removal Action, Stray Horse Gulch Drainage, Operable Unit 6, California Gulch Superfund Site* (USEPA, 1996). The purpose of the revised plan was to address concerns, issues, and considerations raised by Lake County.

- 1997 – Reclamation evaluated the feasibility of in-situ solidification of selected mine waste piles in OU6 for purposes of 1) reducing or eliminating ARD and 2) preserving the historical value of these piles. (See Appendix C.)

2.4 PREVIOUS REMOVAL ACTIONS AT OU6

In 1990, ASARCO conducted a removal action that consisted of two types of site improvements along 5th Street and along the section of Starr Ditch between East 5th Street and the Harrison Street slag pile in Leadville. The site improvements involved converting the existing open ditches to covered culverts along both sides of East 5th Street and fencing the portion of Starr Ditch from just north of 5th Street to Monroe Street just east of the Harrison Street slag pile (*USEPA Region VIII Memo Number 1*, USEPA, 1995a).

During the summer of 1994, interim sediment control measures were implemented by Reclamation on behalf of USEPA at the Hamm's site tailings (USEPA, 1995a).

In August 1995, USEPA conducted an emergency removal (response) action on the Hamm's site drainage and sediment structures, which is part of the SHG portion of the Site. In addition, Starr Ditch was reestablished in the area of the Harrison Street slag piles. Details of the actions undertaken are described below (*USEPA Region VIII Memo Number 2*, USEPA, 1995b).

The 1995 action included repairs to several straw dams and sediment ponds in gullies, removal of tailings sediment from small sedimentation ponds, enlargement of sedimentation ponds, cleaning of drainage culverts, construction of a surface-water control ditch, and cleaning a portion of Starr Ditch (USEPA, 1995b).

- Hamm's #1 (the largest Hamm's erosion gully at 5th Street): Removed tailings sediment from both straw-dam ponds and the stockpile near the toe of the tailings impoundment slope. Performed minor rehabilitation of both straw dams.

- Hamm's #2 (erosion gully at northwest corner of impoundment with leakage under straw bales): Removed tailings sediment from the straw-dam pond. Performed minor rehabilitation of straw dam. Enlarged pond basin and grade (3 horizontal (H):1 vertical (V) maximum) for placement of straw bales near toe of the impoundment slope. Replaced sandbags on pond bottom and slopes with stockpiled tailings material.

- Hamm's #3 (south gully with abutment failure): Removed tailings sediment from straw-dam pond. Performed minor rehabilitation of straw dam. Rebuilt right (north) abutment where seepage failure occurred. Enlarged pond basin and grade (2.5H:1V maximum) for placement of straw bales. Stockpiled tailings material near toe of the impoundment slope. Replaced sandbags in dam groins. Covered sandbags on pond bottom and slopes with stockpiled tailings material.

- #3 Culvert (west of Hamm's #3 at Ash Street): Cleaned tailings material out of culvert and the portion of the channel that approaches the culvert. Hauled and placed tailings material on top of Hamm's with other piles of tailings. At basin just west of #3 culvert, enlarged basin and stockpiled tailings material at edge of basin with other piles. Removed existing straw-bale drop structure/dam and built new straw-bale drop structure across basin outlet. Placed sandbags in upstream groins of drop structure and covered the sandbags with tailing material.

- Hamm's Channel (between 5th Street and Hamm's upstream of concrete headwall): Removed material to form two small basins at appropriate locations (1st/top and 3rd drop structures). Stockpiled material nearby for reuse or use on Silt Dam construction. Constructed four straw-bale drop structures/dams in Hamm's Channel, including sandbags in drop groin.

- Concrete headwall (at 5th Street): Removed sediment from above both straw-bale drop structures and placed material in Hamm's tailings impoundment. Rehabilitated straw-bale drop structures as necessary.

- Hamm's Tailings Impoundment: Constructed up-gradient, run-on control ditch to divert water north across the upper portion of Hamm's tailings impoundment. Constructed siltation and sedimentation basin at receiving location to convey water to concrete headwall at 5th Street.

- Starr Ditch: Reestablished Starr Ditch at base of Harrison Street slag piles to ensure contaminated water and sediments do not flow onto Harrison Street.

In 1996, USEPA conducted an emergency removal action that involved removing sediment from the 5th Street Drainage Ditch starting at its headwall to its confluence with lower California Gulch along Starr Ditch. The sediment was transported and stockpiled at Hamm's tailings impoundment (*USEPA Region VIII Memo Number 3*, USEPA 1996b).

Also in 1996, USEPA conducted a removal action that involved removing the Penrose Mine Waste Pile and depositing the mine waste in the Hamm's tailings impoundment. The waste material in the impoundment was consolidated, reshaped, and graded to a stable configuration (USEPA, 1996b). The removal action includes future capping of the Hamm's tailings pile.

2.5 SITE USE

Mining and related industries are the major sources of income in both Lake County and Leadville. However, because of the "boom and bust" nature of mining, Leadville and Lake County are actively augmenting the development of a more stable, tourism-related economic base Woodward-Clyde, 1994a). The preservation of scenic, historic, and cultural features of the SHG area is a significant economic factor in the Leadville area and is one important factor in assessing future removal actions.

The land uses surrounding the California Gulch Site, including OU6, are predominantly mining, commercial, and residential. Along the Arkansas River valley, land uses include irrigated pastures and haylands, rangeland, and residential and recreation areas. Several wetlands support sport fishing and hunting in the county. In addition, several large lakes are located just west and southwest of Leadville. Lodges, private homes, and campgrounds have been developed in the vicinity of these lakes (Woodward-Clyde, 1994a).

Current site uses include limited mining activities, recreation, commercial activities, mine tourism, and residential. Little Stray Horse Gulch contains several famous historic mines, including the Matchless Mine of Baby Doe and Horace Tabor. Tours are held at the Matchless Mine throughout the summer months and SHG and Little Stray Horse Gulch receives numerous recreational/tourist visits.

2.6 SITE CHARACTERISTICS

This section provides a discussion of the site physiology, geology, hydrogeology, and climatology based on previous studies.

2.6.1 SITE PHYSIOLOGY

The OU6 and SHG lie in the Southern Rocky Mountain Physiographic Province of the United States as defined by Fenneman and Johnson (1946). This region of the Rocky Mountains is characterized by fault-block mountain ranges separated by intermontane valleys. Leadville and OU6 are located near the upper end of the Arkansas River Valley in an area which drains the east flank of the Continental Divide. Leadville lies on the east side of the Arkansas River Valley at the foot of Mount Evans and the outlet of Evans Gulch. Evans Gulch is a large glacial valley extending down the west slope of Mount Evans from elevations above 13,200 feet MSL to the floor of the Arkansas River Valley at an elevation of 9,900 feet MSL. Evans Gulch is flanked to the north by Prospect Mountain and to the south by Iron Hill, Breece Hill, and Ball Mountain. SHG lies on the south sidewall of the glacial valley, and is separated from the main portion of Evans Gulch by a lateral morraine from the Evans glacier and Yankee Hill.

2.6.2 GEOLOGY

The bedrock formations which underlie OU6 are a series of sedimentary strata that range in age from Cambrian to Pennsylvanian and consist of quartzite, limestone, dolomite, and shale. These Paleozoic sedimentary formations were intruded during the late Cretaceous or early Tertiary periods in several episodes by porphyry in "blanket" sills and dikes. These porphyry intrusions created the major portion of the mineralized zones and ore deposits in OU6 (Reclamation, 1997).

The entire sequence of intruded sedimentary formations and pre-Cambrian granitic bedrock was uplifted and faulted into a series of discrete bedrock blocks by north-south trending normal faults that step downward in elevation from approximately 13,000 feet at the Continental Divide on the east to about 9,600 feet at the Arkansas River Valley on the west. These series of faults controlled the depth and distribution of the ore bodies, as well as allowed groundwater to enter the mines in large quantities. Prior to the establishment of drainage tunnels, pumping groundwater from the mines was required to dewater the lower ore body levels. This procedure was performed throughout the mining district (Reclamation, 1997).

For a period of over 130 years, since the beginning of placer mining in 1859, the sedimentary bedrock units and intrusive ore deposits were mined, and mine wastes were deposited on the surface after grading and processing. During snow melt and rainstorm runoff, these mine waste materials are subject to weathering processes which oxidize, break down, and release remaining contaminant metals into the surface water drainages.

The metal ores that were mined in the Leadville Mining District were mapped and divided into five different ore body types (*Geology and Ore Deposits of the Leadville Mining District, Colorado*, Emmons, 1927). Because these ore bodies were intruded along and through sedimentary lithologies in lacotlith, or tabular-shaped bodies, the classification of three of the ores was related to the stratigraphic position relative to the "Blue Limestone, White Limestone, Gray and White Porphyry and 'Parting' Quartzite." In addition, there were two ores of more limited extent referred to as "Stockworks and blankets in siliceous ore, and Magnetite-quartz-pyrite-gold ore." Because the present-day mine waste and waste rock piles in OU6 are the product of the mining of these ore bodies, their composition reflects to some extent the lithologies and mineralogy of the bedrock that was mined and processed (Reclamation, 1996a)

The mineralogy and lithology of the metal ores can be divided between two primary types: sulfide ore and oxide ore minerals. Because of the capacity to generate acid through oxidation processes, the sulfide ores are one possible source of ARD in OU6. The sulfide ores were grouped (Emmons, 1927) according to their metallic content as follows (Reclamation, 1996a):

1. Massive sulfide ores, consisting of significant amounts of metallic sulfides:
   a. Pyritic or iron ores.
   b. Galena or lead ores.
   c. Sphalerite or zinc ores.
   d. Chalcopyrite-bearing mixed sulfides or copper ores.
   e. Mixed sulfides.
   f. Argentite-bismuthinite, or silver-bismuth ores.

2. Carbonate sulfide ores, consisting of mixtures of sulfides and large amounts of manganosiderite.

3. Siliceous sulfide ores, consisting of mixtures of sulfides with large amounts of quartz or jasperoid:

   a. Pyritic gold ores.

   b. Chalcopyritic gold ores.

The most abundant pyritic iron ores are described as "often extremely pure aggregates of pyrite with relatively small quantities of other sulfides." The distribution of these sulfide ore bodies includes a number of the major producing mines that were located in OU6 as described by Emmons below (Reclamation, 1996a):

> "Bodies of nearly pure pyrite are found in the mines of Iron Hill, Carbonate Hill, Graham Park, Breece Hill, and Evans Gulch....In some places the relatively pure pyrite forms the entire sulfide body, as in certain stopes of the Maid, R.A.M., Greenback, Mahala, Tuscon, Moyer, Wolftone, Ibex, and other properties."

The mineral composition of pyrite ore from the Henriett-Maid mine, which is located along the south side of SHG, was given as "Pyrite, 99.27 percent (%); chalcopyrite, 0.02 %; arsenopyrite, 0.02 %; argenite, 0.02 % (or 5 ounces of silver to the ton of ore)." It was also noted that the arsenopyrite "...indicates the source of the minute quantities of arsenic found in the flue dust of the smelter" (Emmons, 1927). The pyritic ore bodies in some of these mines can be described as massive. An appreciation for this description can be found in Reclamation (1996a), about the Henriette-Maid mine:

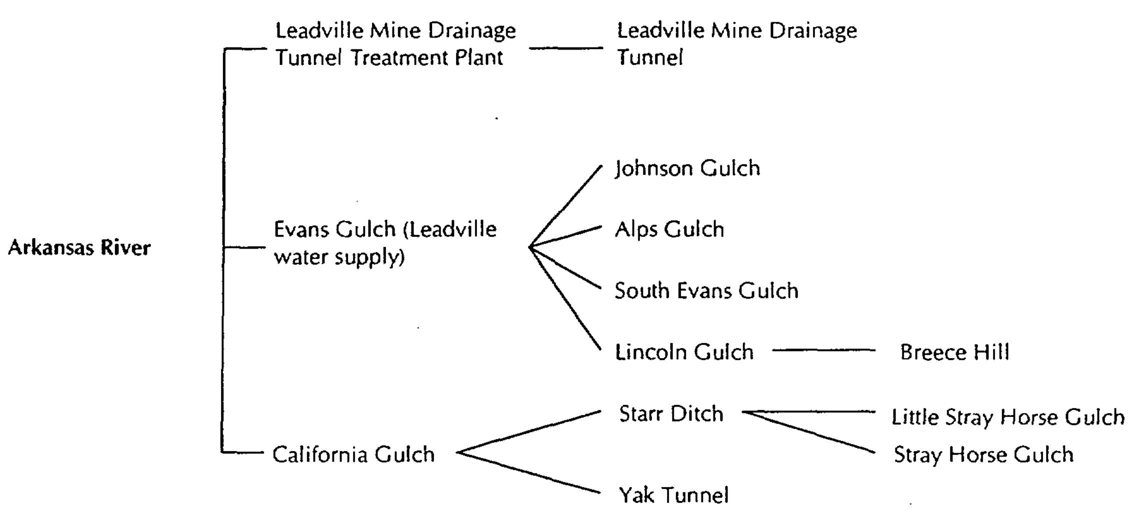
> "In this mine a body of sulfides extended from the Parting quartzite through the White limestone as far down as the Lower or Cambrian quartzite. The upper 30 feet consisted of a mixture of sphalerite and pyrite. The next 10 to 12 feet consisted of pyrite containing about 30 ounces of silver to the ton. The third layer, 20 feet thick, consisted of pyrite containing 15 ounces of silver to the ton. Beneath this was a mass of solid pyrite 80 feet thick containing streaks of chalcopyrite and a higher silver content than either of the two layers above."

Throughout much of the OU6 area, the bedrock is overlain with glacial deposits associated with the Evans Gulch glacier, which moved down the Evans valley depositing lateral morraines on both sides of the valley and a thin cover of ground morraine in the valley bottom. Geologic maps, referenced in Emmons (1927) showed the Evans valley to be bedrock; however, this mapping may have ignored the thin cover present on a photograph from the period. Today, the valley is densely vegetated with willow. On the hills adjacent to the south side of SHG there is a very thin cover of unconsolidated glacial or other soils left before mining activity totally removed or disrupted the original ground. Hills on the north side are covered with glacial moraine deposits. Glacial lake deposits are found in the upper end of the SHG drainage in Adelaide Park, which supports a small area of wetlands (Reclamation, 1996a).

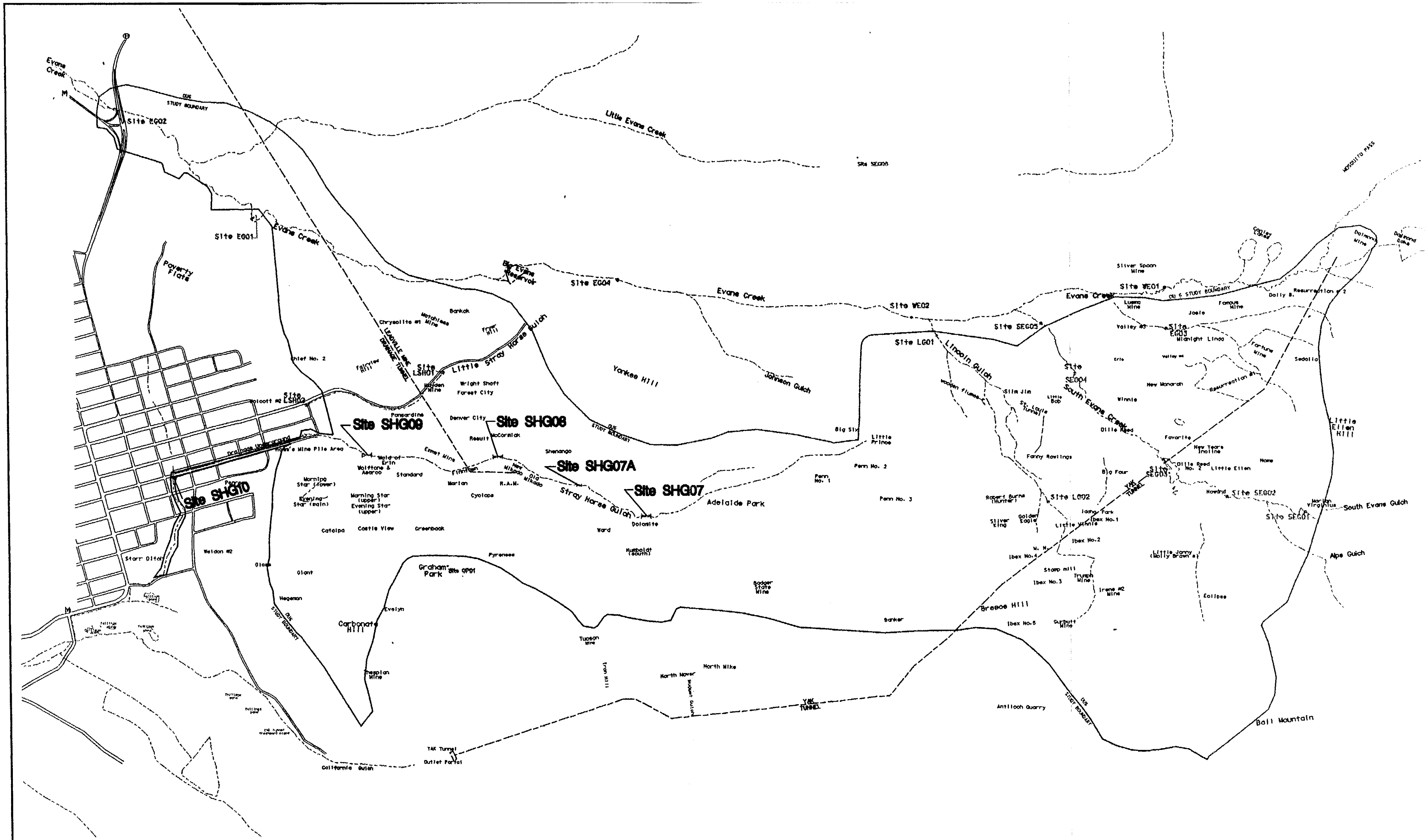
2.6.3 HYDROLOGY

There are two watersheds within OU6 which contribute surface runoff to the Arkansas River. These watersheds are the Evans Gulch drainage and the SHG drainage (See Figure 2.3 and the tributary diagram below).

OU6 STREAM TRIBUTARY DIAGRAM



Surface water runoff in the SHG drainage flows into the Starr Ditch which contributes flow to the California Gulch, a tributary to the Arkansas River. The small drainage called Little Stray



OPERABLE UNIT 6 TRIBUTARIES

Horse Gulch, also contributes runoff to California Gulch. Two smaller sub-drainage basins are also tributary to Evans Gulch. These are the South Evans Gulch and Lincoln Gulch. The area of the South Evans Gulch basin has extensive mine-workings and mine waste. Lincoln Gulch drains a significant portion of the area known as Breece Hill. Evans Gulch serves as the water supply source for the city of Leadville and is managed by the Parkville Water District. Another outlet that drains surface water and groundwater from OU6 are two mine drainage tunnels: LMDT and Yak Tunnel. These drainage tunnels are discussed in more detail in Section 2.6.4, Hydrogeology.

The SHG drainage course is 12,304 feet in length from Adelaide Park to the confluence with Starr Ditch, located in Leadville. The elevation is 11,175 feet at the source of SHG and 10,500 feet at Leadville resulting in a total change in elevation of 675 feet. SHG is an intermittent stream, only flowing during spring snowmelt runoff and thunderstorm events.

Flowrate data was collected during the spring runoff season in 1995 and 1996 (Reclamation, 1996a and Reclamation, 1997). During the 1995 season four stations were monitored along SHG; they are stations SHG07, SHG08, SHG09, and SHG10. A new station designated as SHG07A, located between SHG07 and SHG08, was added to the four existing stations and monitored during the 1996 spring runoff season. These stations are shown on Figure 2.3. Table 2.1 gives the maximum flows observed at these stations for the 1995 and 1996 seasons. The lateral drainage from SHG07 to SHG10 is 9300 feet.

Flow measurements taken during both seasons confirm that there is significant loss of surface flow to the subsurface. The majority of the loss occurs in the reach from SHG07 to SHG09. There was no net effective gain to stream flow in this reach of the drainage (Reclamation, 1997).

Probable storm flows have been calculated by Reclamation for the lower portion of SHG for 24-hour storm events equivalent to a frequency of occurrence of 1 in 100 years and 1 in 500 years. Values of these two events are reported Table 2.2.

TABLE 2.1
STRAY HORSE GULCH 1995 and 1996 MAXIMUM SPRING RUNOFF FLOWS (cfs)

Station	6/19/95	5/21/96
SHG07	3.76	2.7
SHG07A	----	2.5
SHG08	3.65	2.6
SHG09	3.55	3.0
SHG10	3.61	6.0

Notes:
1. Reclamation, 1996a and Reclamation, 1997
2. cfs - cubic feet per second
3. SHG07 through SHG09 are sampling locations along Stray Horse Gulch between Adelaide Park and Hamm's Mine. SHG10 is at the intersection of the Stray Horse Gulch underground drainage and Starr Ditch. SHG07A was established during the 1996 season.

TABLE 2.2
STRAY HORSE GULCH 100 AND 500 YEAR FLOOD EVENTS

Location	Cumulative Drainage Area (sq. mi)	Q (cfs)	
		100-Year	500-Year
Adelaide Park	0.58	90	192
Finn Town	0.76	120	253
Emmet Mine	1.03	165	355
5th Street Headwall	1.13	181	394

Notes:
1. Flow values calculated by Reclamation, 1997 using the U.S. Army Corps of Engineer's HEC-1 model.
2. Q - flow
3. cfs - cubic feet per second
4. sq. mi. - square mile

Snow melt runoff for the 10-, 25-, 50-, and 100-year events as calculated by Reclamation is provided in Table 2.3 below.

TABLE 2.3

STRAY HORSE GULCH SNOW MELT EVENT FLOW RATES AND VOLUMES

Snow Melt	Peak Flow (cfs)	Volume (acre-feet)
100-year	17	84
50-year	15	75
25-year	14	67
10-year	12	57

Notes:
1. Data from the Value Analysis, Draft-Presentation Report, April 17, 1996.
2. cfs - cubic feet per second
3. Calculated at the 5th St Headwall.

As reported in the *Hydrogeologic Remedial Investigation Report, California Gulch Site* (Hydrogeologic RI) (Golder, 1996), a spring is believed to be related to locally occurring groundwater in shallow surficial deposit (colluvium) which is recharged by the spring snowmelt. Discharge from the spring represents standing water in Adelaide Park. As previously discussed in Section 2.6.2, glacial lake deposits are found in the upper end of SHG drainage in Adelaide Park. These deposits and the apparent hydraulic regime support a small area of wetlands in Adelaide Park.

2.6.4 HYDROGEOLOGY

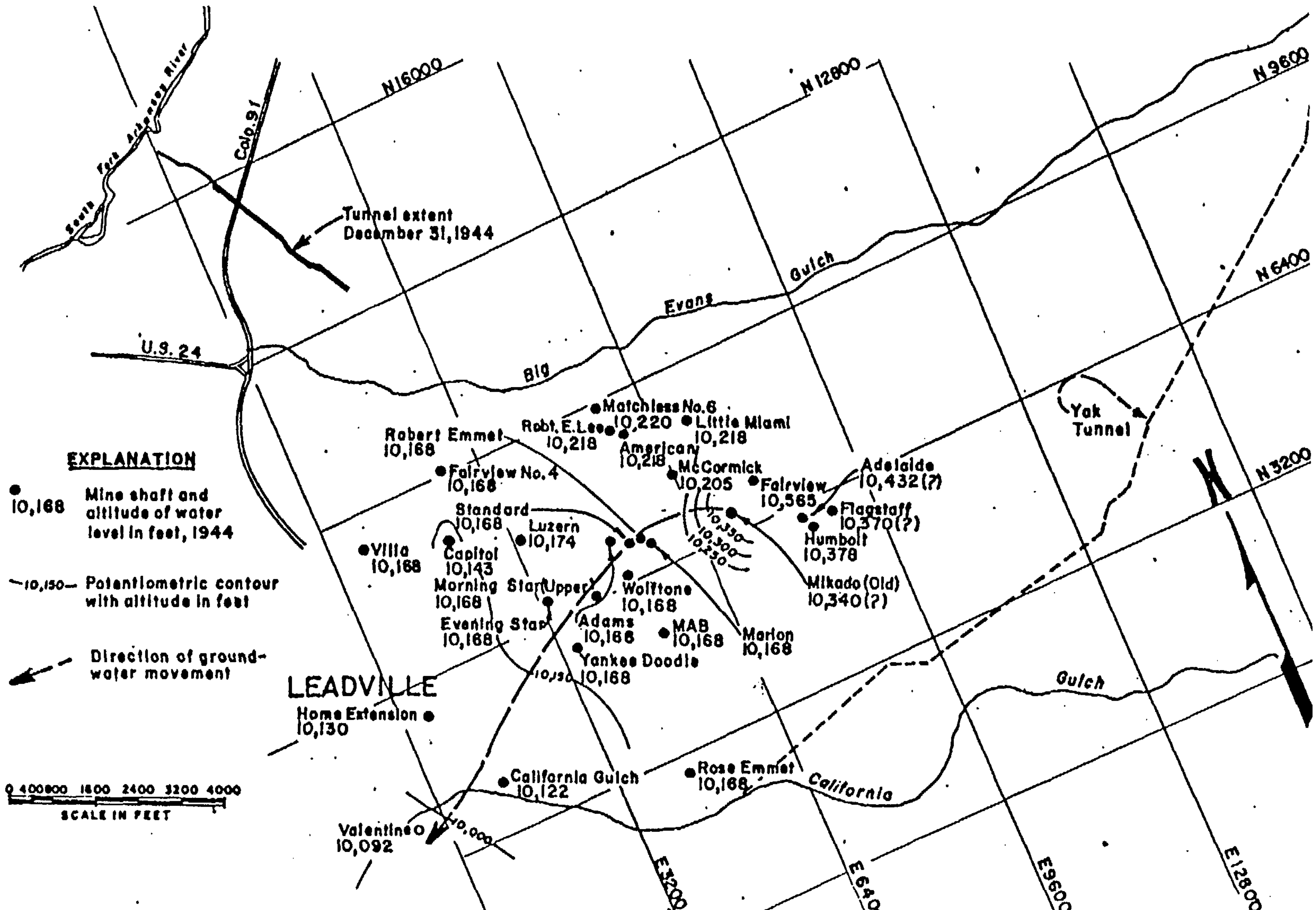
Groundwater occurs throughout the Leadville mining district in fractured granite, quartzite, limestone, sandstone, porphyry dikes, and unconsolidated material. These various rock types are considered a single aquifer system because they are hydraulically connected through contact, mine workings or through extensive faulting and fracturing of sedimentary formations. However, permeabilities vary throughout the system (*Study of the Effect on Plugging the Leadville Mine*

Drainage Tunnel, United States Department of the Interior, 1979). East-dipping fault blocks form "basins" such as Iron Hill and Carbonate Hill. These basins are bounded by postmineral faults containing more or less impervious fault gouges which prevent free circulation of groundwater between basins (*Report of Investigations, The Leadville Drainage Tunnel Second Project*, United States Department of the Interior, 1956).

The bedrock aquifer underlying OU6 is recharged by direct infiltration of precipitation. The normal annual precipitation for this area is about 20 inches, most of which is achieved through snowfall from October through April of each year (United States Department of Interior, 1979).

The occurrence of groundwater in OU6 was first noted with the development of hard-rock mining for lead ores around 1874. As mine shafts and other mine workings were constructed, mine-flooding problems developed due to the abundance of groundwater in the rock types comprising OU6. In an effort to control mine flooding in a cost effective manner, the Yak Tunnel was driven starting in 1895 at an elevation of 10,063 feet. This tunnel was so successful in draining Iron Hill mines that the tunnel was extended to connect with the Ibex and Resurrection mines (United States Department of Interior, 1956).

Since several mines had been explored through shafts at depths well below the Yak Tunnel elevation, an additional tunnel was required to control mine flooding at depths below 10,063 feet. During World War II, serious shortages of lead, zinc and manganese prompted the Federal Government to allot money to drive an additional tunnel (LMDT) through the Leadville mining district in order to dewater the lower parts of the Iron Hill basin and the Downtown, Fryer Hill, and Carbonate Hill basins. The LMDT was located at an elevation of 9,960 feet, 660 feet above the deepest shafts in the mining district, and was completed in two segments. The first segment, started in 1943 was ended at a length of 6,600 feet due to exhaustion of the original LMDT appropriation. Figure 2.4 (United States Department of Interior, 1979) shows groundwater elevations east of Leadville in 1944. The limited extent of the LMDT in 1944 as shown in the figure, was not sufficient to induce a change in mine drainage east of Leadville. An additional allotment was approved in October, 1949 and the second LMDT segment was completed by March, 1952 at a total length of 11,299 ft with a total grade rise of 25.9 feet. This tunnel was



Source: United States Department of the Interior, 1979

CDM FEDERAL PROGRAMS CORPORATION

1944 GROUNDWATER LEVELS

CALIFORNIA GULCH OU6 EE/CA
LEADVILLE, COLORADO

Figure 2.4

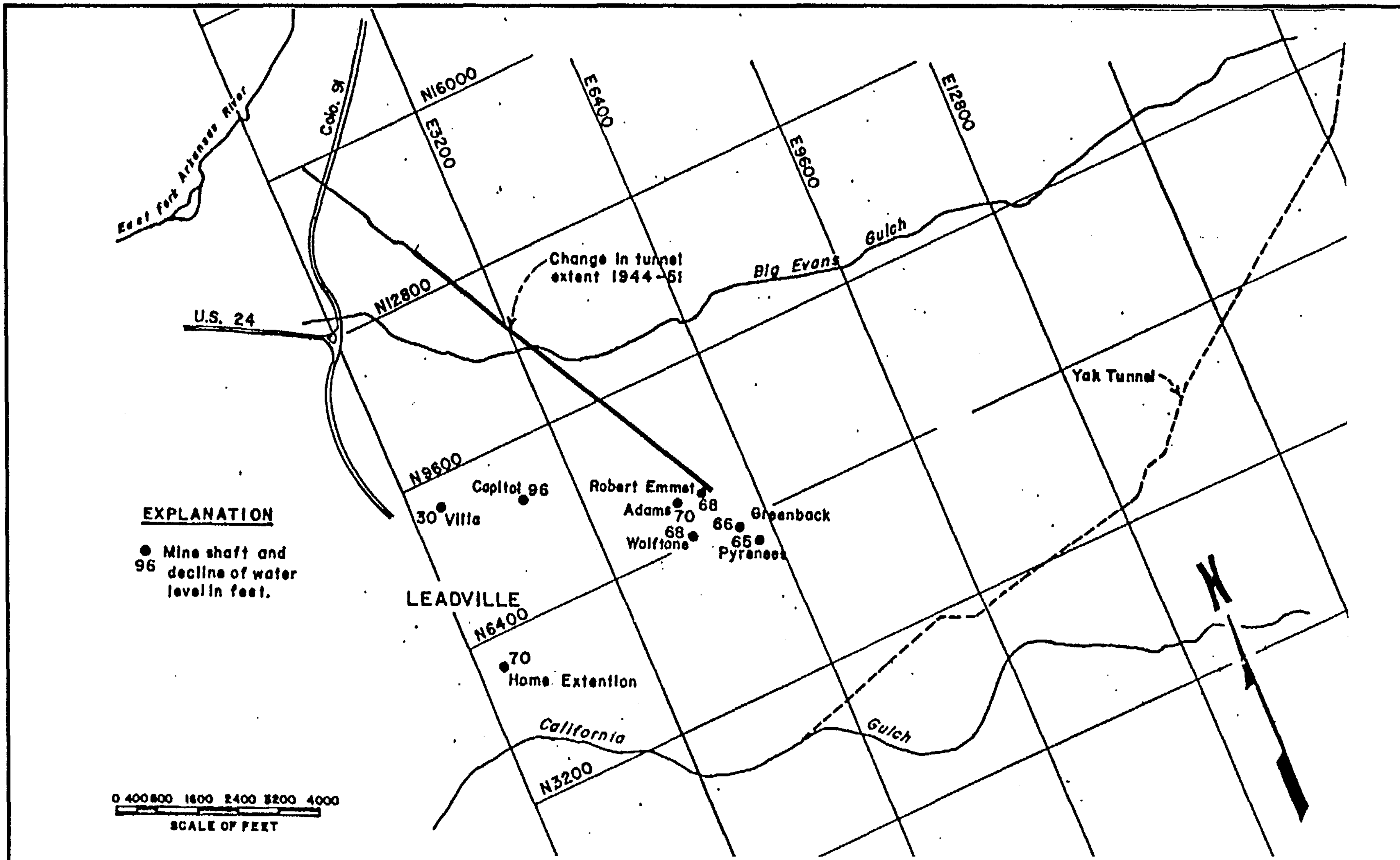
connected to both the Hayden and Robert Emmet mine shafts, the latter of which was also connected to the mines on the western slope of Iron Hill through the actual mine workings (United States Department of Interior, 1956).

Water levels directly attributable to the LMDT drainage were verified on Fryer Hill and Graham Park which included the Pyrenees, Greenback, Adams and other mines interconnected with the Robert Emmet shaft. For example, a log of the water levels in the Adams mine shows a drop from 10,163 feet in September, 1946 to 9,982 feet in February, 1952 upon completion of the second segment of the LMDT (United States Department of Interior, 1956). Figure 2.5 (United States Department of Interior, 1979) shows the decline in groundwater levels east of Leadville by 1951 prior to completion of the LMDT. Water levels in shafts in the SHG basin area had declined 65 to 70 feet.

In April, 1992, groundwater levels were measured to evaluate groundwater elevations, groundwater flow directions, and hydraulic gradients at the California Gulch Site (Golder, 1996). In the Hydrogeologic RI, a groundwater level surface elevation map was prepared using nine bedrock groundwater wells, and water levels at two tunnel discharges. Of the monitoring conducted during the Hydrogeologic RI, the LMDT, bedrock monitoring well BMW-3, and alluvial aquifer piezometer PZ-10 provide useful information in determining groundwater flow direction within OU6 (Figure 2.6).

Bedrock monitoring well BMW-3 had a groundwater level approximately 75 feet lower than the alluvial aquifer groundwater level in paired piezometer PZ-10. This difference of groundwater levels indicates a strong downward gradient between the aquifers. Although the data are quite limited, the downward gradient observed at the BMW-3 may result in a groundwater gradient in the bedrock aquifer toward the LMDT and locally deflects bedrock groundwater (Golder, 1996).

As mentioned above, a bedrock aquifer and an alluvial aquifer exist in OU6. As reported in the Hydrogeologic RI, a hydrogeologic unit consisting of up to several hundred feet of unconsolidated glacial outwash is overlain by thinner alluvial deposits. The hydrogeologic unit includes an alluvial aquifer which is primarily under unconfined conditions. There are locally



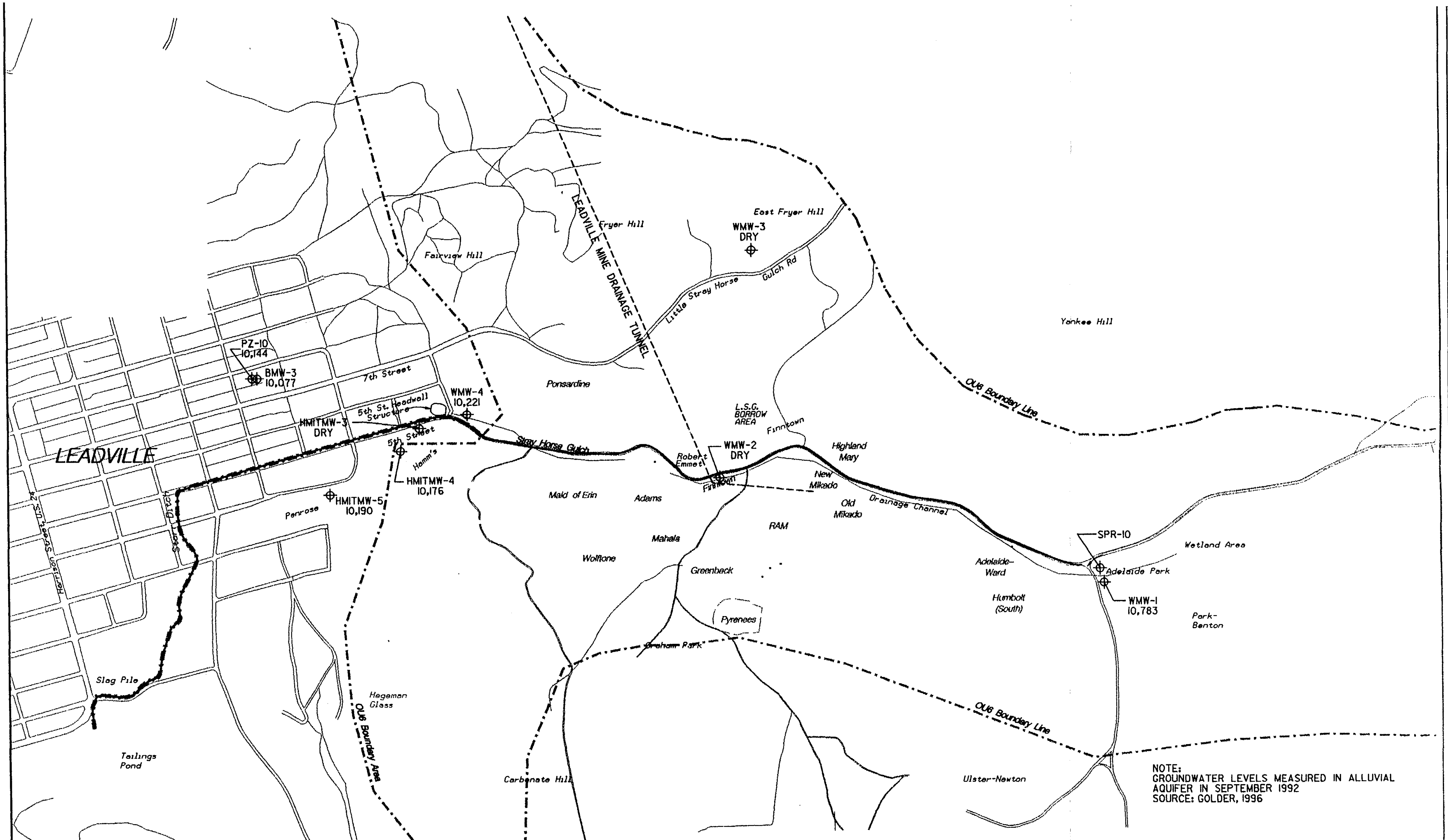
Source: United States Department of the Interior, 1979

CDM FEDERAL PROGRAMS CORPORATION

1951 DECLINE IN GROUNDWATER LEVELS

CALIFORNIA GULCH OU6 EE/CA
LEADVILLE, COLORADO

Figure 2.5



NOTE:
GROUNDWATER LEVELS MEASURED IN ALLUVIAL AQUIFER IN SEPTEMBER 1992
SOURCE: GOLDER, 1996

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HYDROGEOLOGIC REMEDIAL INVESTIGATION MONITORING LOCATIONS WITHIN OU6 occurring perched zones. Depth to groundwater in the alluvial aquifer varies from less than one to about 250 feet (Golder, 1996).

Along active surface water drainages, glacial outwash deposits have been locally reworked by recent fluvial processes. Within California Gulch drainage and near the SHG drainage (Hamm's Mill Tailing area), near-surface Recent-aged alluvium was encountered during monitoring well drilling. The Recent alluvium is up to 30 feet thick and is similar in lithology to the glacial outwash deposits, except that the Recent alluvium is more stratified, and contains a lower portion of silt- and clay-sized material. Both unconsolidated glacial outwash and Recent alluvial sediments are referred to in the Hydrogeologic RI as alluvium. Saturated glacial outwash and Recent alluvial sediments are referred to as the alluvial aquifer (Golder, 1996).

Thirty tailings monitoring wells (TMW) and four mine waste pile monitoring wells (WMW) have been installed at the California Gulch Site. Within SHG two tailings monitoring wells (HWM1TMW-3 and HM1TMW-4) and two mine waste pile monitoring wells were installed (WMW-1 and WMW-2) (Figure 2.6). These wells are reported to be completed within the alluvial aquifer (Golder, 1996).

As reported in the Hydrogeologic RI, an irregular groundwater flow occurs in the vicinity of the LMDT. Alluvial aquifer saturated thickness range from 0 to approximately 28 feet in this area, with decreasing saturated thickness towards the LMDT. Monitoring wells and piezometer located near the Hamm's Mill Tailings and Mine Waste Piles area are affected by drainage toward the LMDT. Several of these wells periodically go dry (HM1TM-4, WMW-2, WMW-3 and WMW-4). Flow may be influenced by specific hydrogeologic characteristics of unconsolidated deposits bounded by bedrock outcrops or the existence of a "highly permeable network" such as structural-preferential groundwater flow controls along fracture or faults (Golder, 1996).

The difference in groundwater levels between BMW-3 and PZ-10 indicates a downward gradient of 0.39 foot/foot between bedrock and alluvial aquifers. The downward gradient observed at the well BMW-3 suggests the potential for alluvial aquifer groundwater to flow into the bedrock aquifer. The LMDT may cause the relatively low hydraulic head in the bedrock aquifer due to subsurface drainage of the bedrock aquifer groundwater by the LMDT. There is no direct evidence of flow between bedrock and alluvial aquifer groundwater at the BMW-3/PZ-10 pair (Golder, 1996).

As discussed in Section 2.6.3 above, one spring was identified in SHG. The spring, SPR-10, is located in Adelaide Park downgradient of several mine waste piles (Figure 2.6). The spring is believed to be related to locally occurring groundwater in shallow surficial sediments consisting of slopewash which are recharged by spring snowmelt. No discharged was noted at the spring; however, standing water adjacent to the road in Adelaide Park was observed (Golder, 1996).

2.6.5 CLIMATOLOGY

The climate in the California Gulch area is considered to be normal for the mountainous areas of central Colorado. The severe local topographic features strongly influence local climatic variations in Lake County. Weather conditions are recorded at the National Weather Service's Leadville airport station, located two miles southwest of Leadville, and the Yak Tunnel meteorological station located near the Yak Tunnel Treatment Plant (Woodward-Clyde, 1994a).

The temperature extremes range from 86 degrees Fahrenheit (°F) to minus (-) 30°F, with the average minimum temperature being 21.9°F. The average frost-free season is 79 days. The wind is predominantly from the northwest and typically ranges from calm to 30 miles per hour Woodward-Clyde, 1994a).

Average annual precipitation is 18 inches. July and August record the most precipitation, while the months of lowest precipitation are December and January. Summertime precipitation is usually associated with convective showers. Annual snowfall depths for mountains in the area are between 200 and 300 inches. During winter months, the depth of snow on the ground in Leadville is commonly 6 inches with massive snowpack depths in the upper mountain basins. The annual peak snowmelt usually occurs in June (Woodward-Clyde, 1994a).

2.7 NATURE AND EXTENT OF CONTAMINATION

As stated in Section 1.1, Purpose of the EE/CA, this EE/CA is focused on the remediation of SHG. The nature and extent of contamination within the SHG watershed basin were investigated by Reclamation and others to evaluate the water quality, flow rate, and sediment and mine waste chemistry, and to characterize the extent of contamination.

2.7.1 GROUNDWATER

Two monitoring wells were monitored within SHG (monitoring wells WMW-1 and WMW-2 - see Section 2.6.4, Hydrogeology and Figure 2.6 for location) during the Mine Waste Pile RI (*Mine Waste Piles Remedial Investigation Report, California Gulch Site* (Woodward-Clyde, 1994a). Analytical results at these wells are summarized on Table 2.4.

Dissolved arsenic, cadmium, lead, and zinc were not detected in upgradient monitoring WMW-1. The other water quality parameters for this well fell within alluvial background upper tolerance limits (or the range for pH). Dissolved aluminum and iron were not detected above detection limits in this well, but dissolved manganese was detected. Despite the elevated detection limits and non-detection of some of the metals, data suggested upgradient well WMW-1 groundwater quality was comparable with alluvial aquifer background water quality (Golder, 1996).

Dissolved arsenic, cadmium, and lead were not detected in the downgradient monitoring well WMW-2. Dissolved aluminum and iron were not detected above detection limits in the well, although dissolved manganese was detected. Low concentrations of zinc were detected in the downgradient well. The groundwater sample from WMW-2 showed higher dissolved manganese, zinc, specific conductance, sulfate, and total dissolved solids than samples from WMW-1. The source of elevated parameters in the downgradient samples was unclear, but could represent natural weathering in a mineralized area and/or neutralization of ARD (particularly in the sample from well WMW-2) (Golder, 1996). Further information pertaining to bedrock groundwater quality can be found in the Hydrogeologic RI.

TABLE 2.4
1992 DISSOLVED CONCENTRATION FOR
MINE WASTE PILES GROUNDWATER SAMPLING AT STRAY HORSE GULCH

Analyte (ug/L)	Alluvial Background	WMW-1 1/09/1992	WMW-2 1/08/1992
Iron	NA	< 100	< 100
Aluminum	NA	< 200	< 200
Manganese	NA	183 J	272 J
Silica	18.9	27 J	31 J
Zinc	NA	< 20	22.8
Copper	NA	< 125	< 125
Lead	NA	< 15	< 15
Arsenic	NA	< 50	< 50
Cadmium	NA	< 25	< 25
Silver	NA	< 50	< 50
Sulfate (Total)	96.6	47	2,260
Total Dissolved Solids	237	108	3,140
Field pH (std. units)	NA	7.27	6.61
Field Specific Conductivity (uhmos/cm)	437	175	3,050

Notes:
1. Source: *Mine Waste Piles Remedial Investigation Report, California Gulch Site* (Woodward-Clyde, 1994a)
2. ug/L - micrograms per liter unless otherwise noted
3. NA - Not applicable, Statistic not calculated.
4. Alluvial Background based on 95% Upper Tolerance Limit
5. < - less than
6. J - estimated
7. uhmos/cm - micro hmo per centimeter
8. std. - standard

Two other monitoring wells located next to the Hamm's Mill impoundment (monitoring wells HM1TMW-4 and HM1TMW-5 - see Section 2.6.4, Hydrogeology and Figure 2.6 for location) were also monitored during the Mine Waste Pile RI. As reported in the Hydrogeologic RI, due to lack of upgradient and tailings (source area) groundwater data, downgradient well results for the Hamm's Mill monitoring wells can only be compared to the results from the alluvial aquifer background wells. Table 2.5 is a summary of the groundwater sampling results for monitoring wells HM1TMW-4 and HM1TMW-5 (Golder, 1996).

Dissolved arsenic, cadmium, and lead were not detected in samples from wells HM1TMW-4 and HM1TMW-5. Dissolved zinc, aluminum, and iron were not detected above the detection limits in either well sample. Dissolved manganese was detected in the HM1TMW-4 and HM1TMW-5 samples. Results for the other water quality parameters in the HM1TMW-4 sample were essentially within alluvial background upper tolerance limits. Results for field pH were slightly lower than the alluvial background range for pH, and results for most other water quality parameters in well HM1-TMW-5 exceeded alluvial background upper tolerance limits. Despite the high detection limits of some of the metals and the resultant non-detection of several metals, analytical results suggested that groundwater quality in downgradient wells HM1TMW-4 and HM1TMW-5 were generally comparable with, or slightly elevated above, alluvial aquifer background water quality (Golder, 1996).

Site-wide groundwater will be further assessed by OU12.

2.7.2 SURFACE WATER

Surface water flow occurs in SHG typically only during periods of intense and/or extended precipitation events and seasonal snownmelt. During the Hydrogeologic RI surface water samples were taken at SG-1 located in the SHG above the culvert at Fifth Street (see Figure 2.6) during Ice-off 1991, Spring 1991, and Summer 1991 (Golder, 1996). Surface water sampling results are presented in Table 2.6 and 2.7. The spring discharge from SPR-10 discussed in Section 2.6.4 was also monitored during the Hydrogeologic RI. Table 2.8 is a summary of the results (Golder, 1996).

TABLE 2.5
1992 DISSOLVED CONCENTRATION FOR HAMM'S MILL IMPOUNDMENT GROUNDWATER SAMPLING AT STRAY HORSE GULCH

Analyte (ug/L)	Alluvial Background	HM1TMW-4 1/08/1992	HM1TMW-5 1/08/1992
Iron	NA	< 100	< 100
Aluminum	NA	< 200	< 200
Manganese	NA	107 J	795 J
Silica	18.9	17 J	35 J
Zinc	NA	< 20	< 20
Copper	NA	< 125	< 125
Lead	NA	< 15	< 15
Arsenic	NA	< 50	< 50
Cadmium	NA	< 25	< 25
Silver	NA	< 50	< 50
Sulfate (Total)	96.6	76	117
Total Dissolved Solids	237	240	372
Field pH (std. units)	NA	7.56	6.85
Field Specific Conductivity (uhmos/cm)	437	396	559

Notes:
1. Source: *Mine Waste Piles Remedial Investigation Report, California Gulch Site* (Woodward-Clyde, 1996)
2. ug/L - micrograms per liter unless otherwise noted
3. NA - Not applicable, Statistic not calculated.
4. Alluvial Background based on 95% Upper Tolerance Limit
5. < - less than
6. J - estimated
7. uhmos/cm - micro hmo per centimeter
8. std - standard

TABLE 2.6
1991 TOTAL AND DISSOLVED CONCENTRATION FOR SG-1 SURFACE WATER SAMPLING AT STRAY HORSE GULCH

Analyte (ug/L)	Ice-off 5/02/1991	Spring 6/12/1991	Summer 7/24/1991
Iron Total	10,800	18,200	1,170,000
Dissolved	49.7 BJ	17,600 J	1,080,000
Aluminum Total	1,660	10,800 J	65,800
Dissolved	<50	12,300 J	52,200
Manganese Total	4,160	13,400	50,000
Dissolved	REJECTED	14,800	50,600 J
Silica Total	2	28 J	7
Zinc Total	15,600 J	43,500	92,800 J
Dissolved	REJECTED	50,700 J	94,800 J
Copper Total	145 J	709 J	7,970
Dissolved	38.9	801 J	7,880
Lead Total	2,490 J	203	8,990
Dissolved	313	208	1,420
Arsenic Total	18.2	2.1 BJ	1,130
Dissolved	<1	<1	1,110
Cadmium Total	163 J	344 J	959
Dissolved	165 J	393 J	934
Silver Total	8.8	0.81 BJ	144
Dissolved	<0.5	<0.5	5.4 J

Notes:
1. Source: *Mine Waste Piles Remedial Investigation Report* (Woodward-Clyde, 1994a)
2. ug/L - micrograms per liter
3. All surface water samples collected at SG01
4. < - less than
5. J - estimated
6. B- value above instrument detection limit and below contract required detection limit

TABLE 2.7
1991 TOTAL CONCENTRATIONS FOR SG-1 SURFACE WATER SAMPLING AT STRAY HORSE GULCH

Analyte (ug/L)	Ice-off 5/02/1991	Spring 6/12/1991	Summer 7/24/1991
pH (std. Units)	4.23	3.22	2.52
Total Aluminum	1,660	10,800	65,800
Total Iron	10,800	18,200	1,170,000
Total Manganese	4,160	13,400	50,000

Notes:
1. Source: *Hydrogeologic Remedial Investigation Report, California Gulch Site* (Golder, 1996)
2. ug/L - micrograms per liter
3. All surface water samples collected at SG01
4. std - standard

TABLE 2.8
1991/1992 WATER QUALITY AND DISSOLVED METAL CONCENTRATIONS FOR SPR-10 SPRING WATER SAMPLING AT STRAY HORSE GULCH

Analyte (ug/L)	Alluvial Background	SPR-10 10/17/1991	SPR-10 9/15/1992
pH (std. Units)	7.33 - 7.97	6.27	5.26
Total Dissolved Solids	23.29	17	10
Field Specific Conductivity	436.53	212	259
Iron (Dissolved)	NA	57,000	1,640
Lead (Dissolved)	NA	10.2	< 3
Manganese (Dissolved)	NA	3,450	443
Zinc (Dissolved)	NA	413 J	385 J

Notes:
1. Source: *Hydrogeologic Remedial Investigation Report, California Gulch Site* (Golder, 1996)
2. ug/L - micrograms per liter unless otherwise noted
3. NA - Not applicable, Statistic not calculated.
4. Alluvial Background based on 95% Upper Tolerance Limit
5. < - less than
6. J - estimated
7. std - standard

To gather more detailed information on surface water quality in SHG, Reclamation monitored four surface water stations along SHG during the 1995 spring runoff season. These four locations are shown as SHG07, SHG08, SHG09, and SHG10 on Figure 2.3. Table 2.9 and 2.10 is a summary of the median concentrations found during this sampling event. Sample procedures and results are discussed in greater detail in the report titled *Phase 1 Feasibility Study Water and Sediment Sampling and Hydrologic Measurement Program Results and Findings 1995 Spring Runoff for Operable Unit 6* (Reclamation, 1996a).

The major ion chemistry of SHG was dominated by acidic, sulfate rich water indicative of ARD. The exception is the uppermost station, SHG07, which has near-neutral pH and a small amount of bicarbonate ion. However, even SHG07 showed elevated sulfate, and appeared to be near the neutralizing capacity in this part of the SHG drainage. The downstream stations showed progressively lower pH, significantly higher sulfate, and elevated calcium and magnesium. The slightly lower concentrations seen in SHG10 compared to SHG09 may be due in part to dilution with cleaner drainage of upper Starr Ditch (Reclamation, 1996a).

Spring runoff sampling was collected again by Reclamation in 1996. A new station designated as SHG07A, located between SHG07 and SHG08, was added to the four existing stations and monitored during the 1996 spring runoff season. The 1996 spring runoff started several weeks earlier than in 1995 and did not last as long. Sampling was conducted for 7 weeks from May 18 through June 25, 1996. Because of the smaller snow pack and lack of precipitation in June, the runoff quantities dropped off dramatically at sampling locations by mid-June (Reclamation, 1997). Surface-water and sediment sampling data displayed characteristics similar to the 1995 spring runoff sampling program. In SHG, the concentrations for metals were initially high and suspended sediment metals dropped off as runoff flow continued. The metal concentrations increased as flowrate decreased (Reclamation, 1997). Table 2.11 is a summary of the median concentrations found during this sampling event. Sample locations and procedures are discussed in greater detail in the report titled *Environmental Geology of Operable Unit 6 Removal Action Design Data* (Reclamation, 1997).

TABLE 2.9
1995 MEDIAN TOTAL, DISSOLVED, AND FREE ION CONCENTRATIONS FOR STRAY HORSE GULCH

Analyte		Concentration at Station (μg/L)			
		SHG07	SHG08	SHG09	SHG10
Iron	Total	135	41,400	175,400	236,000
	Dissolved	130	21,700	131,000	49,100
Aluminum	Total	553	5,830	42,300	41,400
	Dissolved	329	3,660	30,800	16,700
Manganese	Total	345	6,340	54,600	49,900
	Dissolved	409	5,240	43,000	18,300
Silica	Dissolved	6,920	7,490	13,100	10,800
Zinc	Total	1,290	18,700	160,000	146,000
	Dissolved	1,360	16,100	127,000	61,300
Copper	Total	98.8	596	3,070	3,000
	Dissolved	94.2	470	2,280	1,150
Lead	Total	19.5	401	859	4,700
	Dissolved	8.22	119	371	329
Arsenic	Total	3.16	22.2	45	169
	Dissolved	1.27	4.93	16.4	8.14
Cadmium	Total	13.1	158	1,220	1,120
	Dissolved	13.5	127	1,040	467
Silver	Total	<0.500	5	15.1	28.4
	Dissolved	<0.500	<0.500	<0.500	<0.500

Notes:
1. μg/L - microgram per liter
2. SHG07 through SHG09 are sampling locations along Stray Horse Gulch between Adelaide Park and Hamm's Mine. SHG10 is at the intersection of the Stray Horse Gulch underground drainage and Starr Ditch.
3. < - less than
4. Source: Reclamation, 1996a

TABLE 2.10
1995 MEDIAN ION CONCENTRATIONS FOR STRAY HORSE GULCH

Analyte	Concentration at Station (mg/L)			
	SHG07	SHG08	SHG09	SHG10
Field pH	6.51	3.64	3.00	2.99
Calcium	19.5	30.9	76.1	52.6
Magnesium	7.79	16.1	85.6	42.2
Sodium	1.6	1.62	2.55	2.12
Potassium	1.54	1.4	<1	<1
Sulfate	103	284	730	722
Chloride	1.35	<1	2.16	1.27
Bicarbonate	5.82	<1	<1	<1

Notes:
1. Median ion concentrations in milligrams per liter (mg/L).
2. SHG07 through SHG09 are sampling locations along Stray Horse Gulch between Adelaide Park and Hamm's Mine. SHG10 is at the intersection of the Stray Horse Gulch underground drainage and Starr Ditch.
3. Source: Reclamation, 1996a

TABLE 2.11
1996 MEDIAN TOTAL, DISSOLVED AND FREE ION CONCENTRATION FOR STRAY HORSE GULCH

Analyte	Concentration at Station (ug/L)				
	SHG07	SHG07A	SHG08	SHG09	SHG10
Iron Total	6,006	2,008	13,324	53,362	59,583
Dissolved	99.9	74	6,355	43,298	32,550
Aluminum Total	7,827	2,256	3,594	26,303	18,503
Dissolved	280	385	1,163	23,126	12,123
Manganese Total	450	512	1,802	26,677	16,111
Dissolved	228	489	1,976	26,090	15,333
Silica Dissolved	765	7,735	7,845	15,031	10,748
Zinc Total	1,325	2,618	6,484	83,075	50,966
Dissolved	802	2,447	7,264	81,050	50,166
Copper Total	114	96	151	1,327	955
Dissolved	72	103	154	1,291	845
Lead Total	234	209	397	816	4,190
Dissolved	18	96	82	226	314
Arsenic Total	6.8	3.1	11	14	48
Dissolved	0.8	0.8	1.3	4.5	3.8
Cadmium Total	11	34	62	649	390
Dissolved	9	30	65	611	369
Silver Total	2.1	1.5	3.1	6.2	18.1
Dissolved	< 0.8	< 0.8	< 0.8	3.4	< 0.7
Field pH (units)	6.2	6.2	5.4	3.1	3.0

Notes:
1. ug/L - micrograms per liter unless otherwise noted
2. SHG07 through SHG09 are sampling locations along Stray Horse Gulch between Adelaide Park and Hamm's Mine. SHG10 is at the intersection of the Stray Horse Gulch underground drainage and Starr Ditch.
3. < - less than
4. Source: Reclamation, 1997

2.7.3 SEDIMENTS

In 1995, Reclamation monitored four sediment sampling stations along SHG during the 1995 spring runoff season. These four locations are shown as SHG07, SHG08, SHG09, and SHG10 on Figure 2.3. Table 2.12 below is a summary of the median concentrations found during this sampling event. Sample procedures and results are discussed in greater detail in the report titled *Phase 1 Feasibility Study Water and Sediment Sampling and Hydrologic Measurement Program Results and Findings 1995 Spring Runoff for Operable Unit 6* (Reclamation, 1996a).

As seen with the aqueous concentration data, SHG07 showed significantly lower sediment concentrations (especially for Pb, As, and Ag) for most elements compared to lower SHG stations.

Sediment sampling was collected again by Reclamation in 1996. A new station designated as SHG07A, located between SHG07 and SHG08, was added to the four existing stations. Table 2.13 is a summary of the median concentrations found during this sampling event. Sample locations and procedures are discussed in greater detail in the report titled *Environmental Geology of Operable Unit 6 Removal Action Design Data* (Reclamation, 1997).

2.7.4 ACID ROCK DRAINAGE

Since the nature of the surface water contamination discussed above appears to be indicative of ARD, a general overview of how ARD arises is given here.

As mentioned previously in Section 2.6.2, sulfide ores in particular are linked to ARD. When the sulfide ore waste material is exposed to oxidative weathering processes, the breakdown and alteration of the sulfide minerals generates low-pH (acidic) water by the reactions shown in Figure 2.7.

Acidic water can dissolve remaining trace metals and generate elevated metal-concentrations contaminants in the water drainages. This type of runoff is generally referred to as either ARD or

TABLE 2.12
1995 MEDIAN SEDIMENT CONCENTRATIONS FOR STRAY HORSE GULCH

Analyte	Station (mg/kg)			
	SHG07	SHG08	SHG09	SHG10
Iron	9,510	70,300	50,500	52,400
Aluminum	5,200	2,610	2,470	2,470
Manganese	491	607	1,320	5,620
Zinc	320	809	2,400	4,550
Copper	83.1	114	216	334
Lead	188	2,720	4,690	3,880
Arsenic	5.68	106	91.3	98.5
Cadmium	1.64	6.03	14.5	26.0
Silver	1.06	44.5	16.4	18.8

Notes:
1. Median concentrations in milligrams per kilogram (mg/kg). Method 3051 digestion.
2. Source: Reclamation, 1996a

TABLE 2.13
1996 MEDIAN SEDIMENT CONCENTRATION FOR STRAY HORSE GULCH

Analyte	Concentration at Station (mg/kg)				
	SHG07	SHG07A	SHG08	SHG09	SHG10
Iron	13,914	55,328	63,485	56,037	51,500
Aluminum	3,988	4,317	2,165	2,968	3,856
Manganese	907	993	1,224	1,694	2,595
Zinc	737	1,067	1,298	2,422	2,980
Copper	107	222	106	139	274
Lead	422	3,005	2,110	3,798	3,856
Arsenic	30	89	75	81	85
Cadmium	4.3	5.8	9.1	15.1	17.5
Silver	2.1	27.1	17.6	17.4	17.3

Notes:
1. mg/kg - milligrams per kilogram
2. SHG07 through SHG09 are sampling locations along Stray Horse Gulch between Adelaide Park and Hamm's Mine. SHG10 is at the intersection of the Stray Horse Gulch underground drainage and Starr Ditch.
3. < - less than
4. Source: Reclamation, 1997

FIGURE 2.7

GENERATION OF ACIDIC DRAINAGE - OXIDATION REACTIONS

Initiator Reaction:

$$FeS_2 + 3.5\ O_2 + H_2O \rightarrow Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+$$

Pyrite → Acidity

Propagation Cycle:
Bacteria (T. ferroxidans)

$$Fe^{2+} + 0.25\ O_2 + H^+ \rightarrow 0.5\ H_2O + Fe^{3+}$$

$$14\ Fe^{3+} + FeS_2 + H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+$$

Acidity

Low pH reaction is slow
High pH reaction is fast

Notes:
Fe - iron
S - sulfur
O - oxygen
H - Hydrogen

as acid mine drainage. For the purpose of this report, this type of runoff will be referred to as ARD. Secondary iron (Fe) minerals that precipitate from these drainage waters or from oxidation of pyrite in the mine waste are indicative of the pH and oxidation environment of the mine waste material. As noted in the reaction shown above, the presence of bacteria (*T. ferroxidans*) accelerates the oxidation process below pH of 4. The oxidation from ferrous Fe (Fe^{2+}) to ferric Fe (Fe^{3+}) drives the pH lower by generating 16 moles of hydrogen (H^+), or 8 times more than the reaction rate above pH of 4 (Reclamation, 1997).

The presence of specific secondary Fe minerals is a function of both the solubility of the mineral and the pH environment in which it forms (Bigham, *Mineralogy of Precipitates Formed by the Biogeochemical Oxidation of Fe(II) in Mine Drainage*, 1992 and Alpers, *Secondary Minerals* *and Acid Mine-Water Chemistry*, 1994). The presence of *T. ferroxidans*, which drives the pH below 4, greatly influences the weathering process and the sequential formation of secondary Fe minerals (Reclamation, 1997).

The minerals listed in Table 2.14 are used as key indicators of ARD-generating areas and as representative indicators of stages in the weathering oxidation of pyrite. Locations where these minerals are found in abundance are potential sources of metal-contaminant loading to local drainages and groundwater in OU6 from ARD (Reclamation, 1997). Their relative levels of potential for ARD generation range from the highest potential with pyrite to hematite. Contaminant metals associated with other types of ore bodies (i.e. oxides, carbonates, etc.) may also be of environmental significance because of their ability to migrate to the environment via erosion, wind and water transport, or through direct contact with people and animals (Reclamation, 1996a). However, because weathering of these minerals does not produce acidic runoff, the concentrations of contaminant metals in these drainages (e.g., Evans Gulch) are significantly lower, in some cases by several orders of magnitude (Reclamation, 1997).

TABLE 2.14
PYRITE AND SECONDARY MINERALS

Mineral	Chemical Formula
Pyrite	FeS2
Copiapite	$(Fe,Mg,Zn)Fe_3(SO_4)_2(OH)_6$
Jarosite	$(Na,K)Fe_3(SO_4)_2(OH)_6$
Goethite	alpha-FeO(OH)
Hematite	alpha-Fe_2O_3

Notes:
Fe - iron; Zn - zinc; O - oxygen; Na - sodium
Mn - manganese; S - sulfur; H - hydrogen; K - potassium
Source: Reclamation, 1996a

2.7.5 MINE WASTE

A number of RI studies have been conducted on the California Gulch Site, including *Mine Waste Piles Remedial Investigation Report, California Gulch Site, Leadville, Colorado* (Woodward-Clyde Consultants, 1994a). This report and other RI reports address general site-wide mine waste pile investigations and other issues. The above referenced report was a reconnaissance level sampling effort that included a visual classification of mineralogy of the waste rock piles and subsurface investigations. The investigations included several mine waste piles in OU6, namely the Maid of Erin, New Mikado, Old Mikado, RAM, Evening Star, Humboldt, Chrysolite, Hayden, and Denver City. The first six of these piles are located within the SHG basin. Of particular interest is the slope stability analysis performed for these piles. The piles were analyzed for stability against mass failure under static and seismic conditions using the computer slope stability program UTEXAS3. The piles were also analyzed for stability against slope failure under static and seismic conditions using the procedure developed by the U.S. Army Corps of Engineers. Mass failure refers to downslope movement of mine waste material in response to gravitational and/or earthquake forces. Mass failure does not include downslope movement due to erosional forces although erosion can contribute to mass instability by breaching the oxidized crust which effectively armors many mine waste slopes or by undercutting the toe of the slope (Woodward-Clyde Consultants, 1994a).

The calculated factor of safety refers to the ratio of the sum of forces resisting slope failure to the sum of forces causing slope failure. A factor of safety greater than 1.0 indicates that the calculated driving forces are less than the resisting forces and implies that the slope is stable. Due to risks to human health and the environment in the event of failure and release of impounded water and settled solids, active tailing impoundments are typically evaluated using earth dam stability criteria. Minimum acceptable factors of safety for earth dams as established by the U.S. Army Corps of Engineers are as high as 1.5 for longterm steady state loading conditions and as low as 1.0 for earthquake conditions. However, mine waste dumps and inactive tailing impoundments are often evaluated using less conservative stability criteria. The U.S. Forest Service recommends minimum factors of safety of 1.3 for base translation under reclaimed conditions and 1.0 for earthquake loading conditions (Woodward-Clyde Consultants, 1994a). The individual factors of safety calculated for the above mentioned SHG waste rock piles are summarized in Table 2.15. Greater detail on results for each pile and the methods used in evaluating the pile stability are found in *Mine Waste Piles Remedial Investigation Report, California Gulch Site, Leadville, Colorado* (Woodward-Clyde Consultants, 1994a).

In 1996, Reclamation conducted a more detailed sampling and investigation program to assess the mine waste piles found in OU6. Due to the large areal extent of OU6 and the large number of historic waste rock and tailing piles, new methods in remote sensing technology were used in this investigation for mapping the distribution of minerals to define source areas of ARD. The remote sensing data used in this investigation, is referred to as Airborne Visible and Infra-Red Imaging Spectroscopy (AVIRIS). AVIRIS data is acquired by a National Aeronautics and Space Administration ER-2 aircraft from an altitude of about 65,000 feet and produces digital data as a resolution of approximately 17 meters. Spectra of reflected light over 224 channels are compared against laboratory mineral spectra and are used to classify the predominant mineral over the 17 meter pixel area. Calibrated AVIRIS reflectance data were spectroscopically mapped using the United State Geological Survey Tricorder algorithm. Tricorder is an expert system which is capable of simultaneously analyzing spectra of solids, liquids, and gases. After Tricorder processing and mineral classification, the AVIRIS image was registered to the site topography using a number of geographic control points. AVIRIS mapping methodology, calibration, ground-truthing, and data quality levels are discussed in greater detail in the report titled *Environmental Geology of Operable Unit 6 Removal Action Design Data* (Reclamation, 1997).

Plate 2.1, produced from the AVIRIS image, is a map of the Fe-bearing mineral distribution of the waste rock and tailings piles at OU6. On this map, blue, purple and yellow colors show minerals which cause ARD high in dissolved metals like cadmium, zinc, and lead. Areas in green have minerals that are more neutral but are still of concern. Other colors (red and orange) are minerals contributing less to water contamination. No Fe-bearing minerals were identified in areas shown in black (Reclamation, 1997).

TABLE 2.15
SLOPE STABILITY EVALUATIONS OF SELECTED MINE WASTE PILES

Parameter	Mine Waste Pile					
	Maid of Erin	New Mikado	Old Mikado	RAM	Evening Star	Humboldt
Plan Area (acres)	0.4	1.2	1.81	1.43	2.3	1.2
Pile Height (feet)	25	60	60	30	50	50
Outslopes (H:V)	3:1	1.5:1 to 2.5:1	1.5:1 to 2:1	2:1 to 3:1	2:1 to 4:1	2:1 to 2.5:1
Unit Weight	100	115	115	99	100	105
Friction Angle	32	34	30	33	30	30
Effective Cohesion	0	0	0	0	0	0
UTEXAS3 Static Factor of Safety	1.03 to 1.46	1.1	0.97 to 1.01	0.92 to 1.59	1.0 to 1.21	1.2 to 1.25
UTEXAS3 Seismic Factor of Safety	0.93 to 1.32	0.99	0.87 to 0.91	0.85 to 1.4	0.90 to 1.08	1.07 to 1.11
Infinite Slope Static Factor of Safety*	0.86	1.04	0.96	0.85	0.89	0.86
Infinite Slope Seismic Factor of Safety*	0.78	0.93	0.86	0.76	0.8	0.77

Source: Woodward-Clyde Consultants, 1994a
H - horizontal
V - vertical
*Developed by US Army Corps of Engineers

Mapping of secondary weathering minerals by AVIRIS indicates that ARD minerals form roughly concentric zones around pyrite-rich areas at the surface. They have pyrite or jarosite in the center surrounded by a jarosite-goethite zone, in turn surrounded by either goethite or hematite forming bull's eyes around the hot spots of pyrite oxidation. These patterns can be used to locate point-sources of ARD at Leadville by marking areas of low pH and potential trace metal mobility (Reclamation, 1997).

The AVIRIS imagery maps potential sources of ARD using mineral classification as a key indicator, but does not give information about metal concentrations. Surface sampling of pile materials are needed to measure contaminated metal concentrations. Between November 1995 and November 1996, Reclamation collected a total of 666 waste rock and tailing material samples and analyzed these grab samples in the laboratory using X-ray fluorescence and X-ray diffraction. In addition to the surficial pile sampling, a number of test pits were dug in November 1996 for geotechnical investigations of removal action alternatives. Plate 2.2 shows the sampling locations of this effort. The sample data collected in this investigation were used to generate maps of the actual values for the X-ray fluorescence metals lead, cadmium, silver, and zinc. These maps are reproduced in Appendix E of this EE/CA.. In addition, representational two dimensional surfaces were generated for lead and soil pH. These maps along with sample procedures and results are discussed in greater detail in *Environmental Geology of Operable Unit 6 Removal Action Design Data* (Reclamation, 1997).

AVIRIS mineral mapping indicates that the Ward-Humboldt and Penn Mine groups of mine waste piles along SHG and above Adelaide Park, respectively, contain ARD-generating minerals (Plate 2.1). This was verified by surface sampling. However, water sampling conducted downstream of these mine waste piles during the 1996 runoff season has also shown that ARD contaminants may not be significantly affecting SHG surface water due to topography and/or infiltration of snow melt runoff into the ground. Runoff sampling summarized in Section 2.7.2 shows the Mikado group and those waste rock piles west of the Mikado group and on the south side of Stray Horse Gulch Road to be the major producers of ARD within SHG (Reclamation, 1997).

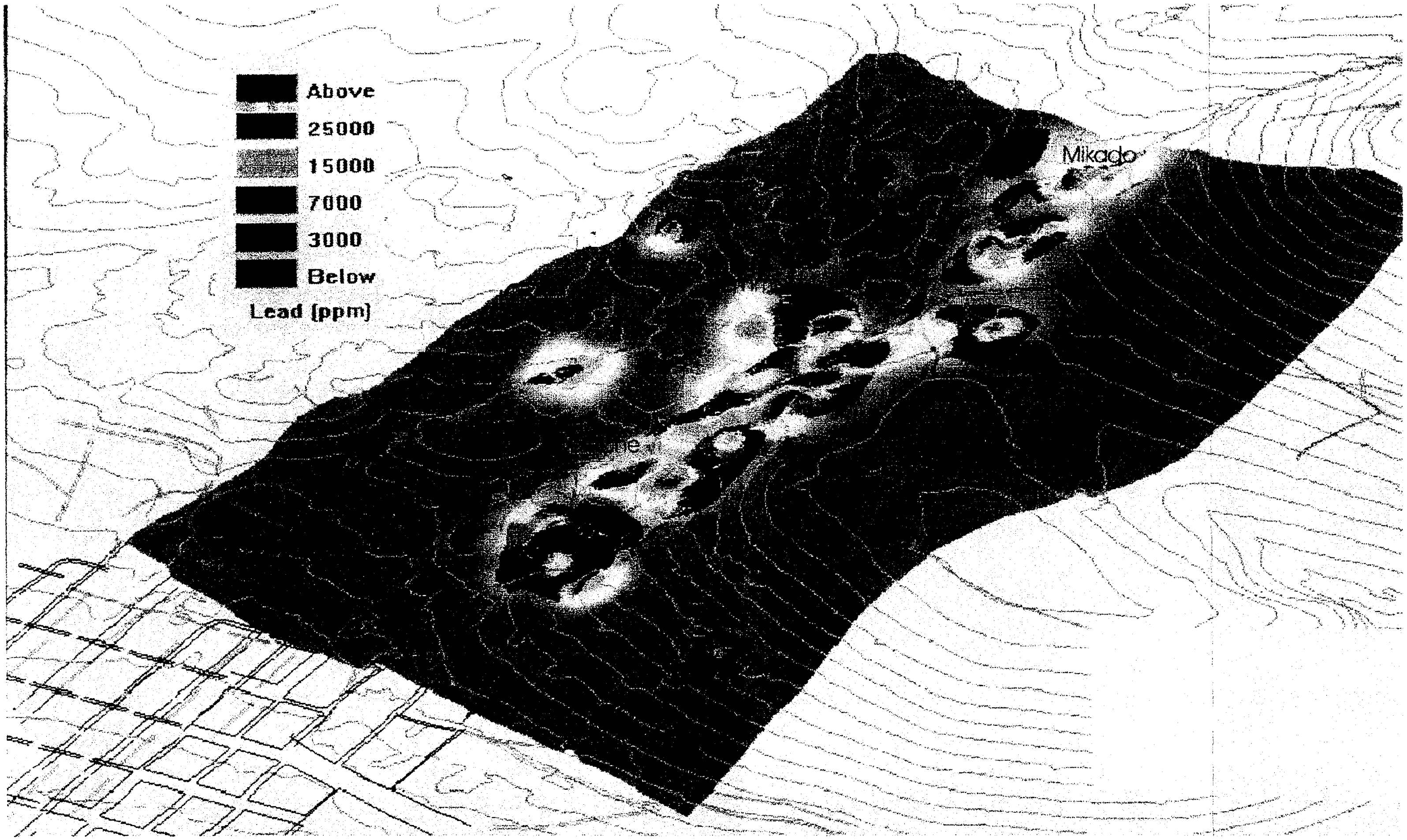
The surface water sampling and pile investigations conducted by Reclamation show the majority of ARD and contaminant metals originating from surficial runoff of snow melt and rain and not from deeper subsurface drainage through or under the piles. As snow melt runoff begins, there is an initial flushing of extremely high concentrations of contaminant metals and sediment. In places, a thick rind of oxidized material composed of secondary minerals mantles unoxidized pyrite and other sulfides. If the rind is impermeable to water, then the underlying pyrite will be effectively isolated from the aqueous environment. On south facing or steep slopes, where freeze-thaw cycles cause debris flows, erosion will expose unoxidized pyrite, which in gaining access to the atmosphere can readily oxidize and produce a low pH zone rich in jarosite. These areas may be the dominant sources of ARD because oxidation proceeds most rapidly at the surface. It is possible that acid waters can enter the groundwater through old covered shafts that go undetected by AVIRIS. Other investigations of mine waste rock and tailing materials have shown that an oxidation zone or 'weathering rind' may form on the outer surface of the materials and may prevent deep oxidation of pyrite and other sulfide materials (Reclamation, 1997).

Areas mapped by AVIRIS as covered by goethite and hematite still contain contaminant metals, but they will not be as mobile in the absence of low-pH water, normally found in the jarosite-rich areas. The mine waste piles on the west side of Carbonate Hill are good examples of this relationship. Because of the heterogeneity of the mine waste piles, the minerals at the surface of the mine waste piles and tailings may not reflect the waste rock composition at depth. Depending on the amount of precipitation and the level of the groundwater table, unoxidized sulfides may be mantled by a layer of nonacid-generating secondary minerals. In this case, surficial mineral maps will not show the acid-generating capacity of the mine waste piles and tailings beneath the surface (Reclamation, 1997). Again, this rind would serve to isolate the sulfides from the surface aqueous environment.

In addition to the potential sources of ARD generation is the concern about the possible extent of surface heavy metal exposure to human health. Principle among these metals are lead and arsenic (see Section 3.2.1, Human Health Risks). Figure 2.8 is a mapping of X-ray fluorescence lead concentration data for the SHG group of waste rock piles (collected during the 1995/1996

Color Map(s)

The following maps contain color that does not appear in the scanned images. To view the actual images please contact the Superfund Record Center at (303) 312-6473.



Source: United States Department of the Interior, 1997

CDM FEDERAL PROGRAMS CORPORATION

3-D MAPPING OF LEAD CONCENTRATIONS WITHIN THE STRAY HORSE GULCH WATERSHED

CALIFORNIA GULCH OU6 EE/CA
LEADVILLE, COLORADO

Figure 2.8

F:\ACAD\...\DWG\...\FIG1 00/00/00

investigation described above.) The creation of this map is discussed in detail in *Environmental Geology of Operable Unit 6 Removal Action Design Data* (Reclamation, 1997).

Arsenic was not determined by X-ray fluorescence due to limitations of the X-ray fluorescence method used (Reclamation, 1997). Arsenic concentrations were however measured during the Mine Waste Piles RI. Table 2.16 is a summary of the results of sampling arsenic at piles located within the SHG group. Sample locations and procedures are discussed in greater detail in the report titled *Mine Waste Piles Remedial Investigations Report* (Woodward-Clyde Consultants, 1994a).

The actual areas and volumes of mine waste to be targeted within the SHG watershed basin by this removal action are discussed in Section 3.6 following an analysis of the pertinent risks and ARARs posed by the contamination summarized above in Section 2.0.

TABLE 2.16
ARSENIC ANALYTICAL RESULTS FOR SAMPLES COLLECTED FROM MINE WASTE AND FOUNDATION SOILS, STRAY HORSE GULCH

Pile	Surface Composite (mg/kg)	Subsurface Mine Waste (mg/kg)	Foundation Soil (mg/kg)
Maid of Erin	73.4	96.7 - 283.5	ND - 42.8
New Mikado	139	33.8 - 71.3	33.8 - 71.3
Old Mikado	REJECTED	ND - 151	ND - 76.2
RAM	89	ND - 3.2	4.1 - 5.8
Evening Star	74.2	47.3 - 65.9	29.8 - 54.8
Humboldt	147	81.5 - 84.9	3.4 - 141

Notes:
1. mg/kg - milligrams per kilogram
2. ND - Not Detected
3. Source: Woodward-Clyde, 1994a

EPA REGION VIII
SUPERFUND DOCUMENT MANAGEMENT SYSTEM

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IMAGERY COVER SHEET
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SITE NAME: CALIFORNIA GULCH

REPORT OR DOCUMENT TITLE: ENGINEERING, EVALUATION COST ANALYSIS FOR STRAY HORSE GULCH, OPERABLE UNIT 6

DATE OF DOCUMENT: 06/01/97

DESCRIPTION: OVERSIZED COLOR MAPS (2)

Risks were evaluated for commercial workers exposed to soil and dust. The ingestion pathway was the only pathway evaluated. Exposure to soil and/or dust through other exposure pathways (e.g., dermal, inhalation) were considered to be of minor concern.

Calculated site-wide risks indicate there is little potential for noncancer risks from arsenic exposure to commercial workers. The site-wide hazard quotient (HQ) for commercial workers ranged from 2×10^{-2} to 8×10^{-2}. A HQ equal to or less than one indicates there is likely no significant risk from exposure to that particular contaminant at the site. Cancer risks calculated for commercial workers from exposure to arsenic ranged from 1×10^{-6} to 7×10^{-6}. These risks are within USEPAs acceptable risk range (1×10^{-4} to 1×10^{-6}). This does not necessarily mean that OU6 or specific sublocations within OU6 don't contain arsenic concentrations in soil and dust high enough to result in cancer or noncancer risks to workers at these sublocations. Action levels developed for arsenic for the commercial worker exposure scenario (described below) may be used to determine whether arsenic in soil at OU6 presents a risk to commercial workers.

Site-wide evaluation of lead risks indicates that commercial workers, including the sensitive subpopulation of pregnant and nursing women, are unlikely to be exposed to lead concentrations of concern. This does not ensure that sublocations within OU6 do not contain lead concentrations in dust or soil at concentrations potentially resulting in health risks. Action levels developed for lead for the commercial worker scenario (described below) may be used to determine whether lead in soil at OU6 presents a risk to commercial workers.

3.2.1.2 Recreational Visitors

Risks to recreational visitors were not evaluated in the preliminary RA (Weston, 1991) or in the subsequent RA (Weston, 1995a,c). Rather, USEPA has developed action levels for arsenic and lead for a recreational exposure scenario (Weston, 1995a,c). Soil ingestion was the only exposure pathway used to develop these action levels. Exposure to soil through other exposure pathways (e.g., dermal, inhalation) and exposure to other media were considered to be of minor concern for recreational visitors.

Rather than calculate risks for recreational visitors, USEPA compared action levels developed for arsenic and lead to average concentrations of these contaminants site-wide. The results of this comparison indicate that site-wide mean concentrations of arsenic and lead are unlikely to result in risks to recreational visitors. Average concentrations of arsenic throughout the site are well below the most stringent action levels. Average concentrations of lead throughout the site do not exceed action levels for recreational visitors. There is more than a 90% likelihood that at least 95% of the most susceptible population of recreational visitors (pregnant women) will not be exposed to lead above a level of concern under present site conditions.

The comparison of action levels was on a site-wide basis. There may still be specific sublocations where concentrations of lead and arsenic may present a risk to recreational visitors. The recreational action levels can be used to determine if concentrations of lead and arsenic are of concern at any locations presently used for recreational purposes. Recreational action levels are applicable to OU6 and are described below.

3.2.1.3 Action Levels

Commercial Workers -- Action levels were developed for commercial workers for exposure to arsenic and lead. For lead, concentrations in the range of 6,100 to 7,700 milligrams per kilogram (mg/kg) are likely to be protective with a reasonable degree of confidence (Weston, 1995b). Pregnant female workers are a sensitive subpopulation to the effects of lead; the action level for lead is protective of this subpopulation. For arsenic, the range of action levels ranges from 330 to 1,300 mg/kg, with average values ranging from 610 to 690 mg/kg (Weston, 1995b). These action levels can be compared to mean concentrations in an exposure area to determine if commercial workers are at risk from exposure to arsenic and lead.

Recreational Visitors -- Action levels were developed for recreational visitors for exposure to arsenic and lead. For lead, the nominal concentration was 16,000 mg/kg (Weston, 1995c). For arsenic, action levels ranged from 1,400 to 3,200 mg/kg (Weston, 1995c). Mean concentrations of arsenic and lead in an exposure area are compared to these action levels to determine if these contaminants pose a risk to recreational visitors.

3.2.2 ECOLOGICAL RISKS

RAs performed at the California Gulch Site have included an evaluation of ecological risks. Both aquatic and terrestrial risks have been evaluated for the Site (Weston, 1995d, 1997). Risks to ecological receptors are described below.

3.2.2.1 Terrestrial Ecological Risks

The terrestrial ecological RA (Weston, 1997) evaluates the potential for negative impacts on the terrestrial environment or terrestrial receptors due to contamination within the California Gulch Site. Media evaluated included soil, slag, waste rock, and tailings in uplands areas, and fluvial tailings and sediment in riparian areas. Only the top two inches of these media were evaluated in the risk assessment. Surface water was also evaluated. Exposure pathways included ingestion of all media evaluated and ingestion of food items such as vegetation, invertebrates, or small mammals. Contaminants of concern (COCs) for the terrestrial RA consisted of arsenic, antimony, barium, beryllium, cadmium, chromium, copper, lead, nickel, manganese, mercury, silver, thallium, and zinc.

In situations where an OU was composed of several nonconnected areas, the terrestrial ecological RA divided the OU into smaller exposure units. OU6 was divided into OU6a and OU6b. OU6a comprises the majority of OU6, with the exception of a small area in the western portion of the OU. This area, containing Starr Ditch, is OU6b.

Contaminant intakes were calculated for upland and riparian receptors. The upland receptors were blue grouse, mountain bluebird, American kestrel, red-tailed hawk, bald eagle, least chipmunk, mule deer, and red fox. The wetland receptors were the belted kingfisher, spotted sandpiper, red-winged blackbird, and long-tailed vole. Some receptors occur in both general habitat types (i.e., bald eagle, red-tailed hawk, mule deer).

Toxicological literature was reviewed to derive acceptable contaminant intake values for birds and mammals. Resulting benchmark values were termed Toxicity Benchmark Values (TBV). These TBVs were compared to calculated contaminant intakes for upland and riparian receptors.

HQs were calculated for all COCs for each receptor. An HQ less than one indicates there is little potential for adverse effects to occur. An HQ greater than one indicates a potential for risk but does not necessarily mean that adverse effects will occur. The sum of the HQs is the hazard index (HI). For the purposes of the EE/CA, terrestrial risk at OU6 are described in terms of HIs for each receptor (Table 3.1).

TABLE 3.1

HAZARD INDICES FOR SURFACE MEDIA BY RECEPTOR FOR OU6

OU	Blue Grouse	Mtn. Bluebird	American Kestrel	Red-tail Hawk	Bald Eagle	Least Chipmunk	Mule Deer	Red Fox
OU6a	25	634	18	12	14	41	3	16
OU6b	3	463	0	0	0	31	0	0

As shown in Table 3.1, HIs at OU6a and OU6b exceed 1 for several terrestrial receptors. At OU6a, HIs exceed one for all receptors. HIs at OU6b exceed one for the blue grouse, mountain bluebird, and least chipmunk. This indicates there is potential risk to terrestrial receptors at OU6 from exposure to COCs. Action levels were not developed for terrestrial receptors.

3.2.2.2 Aquatic Ecological Risk Assessment

The aquatic ecological RA identifies the impact of mine waste contamination on the aquatic ecosystem at the California Gulch Site. Mine waste, including waste rock, tailings piles, and smelter wastes in the form of slag, flue dust, and stack emissions have caused increased metal loadings to surface water and sediments in the California Gulch area and the Arkansas River.

The potential exposure pathways for aquatic receptors are ingestion of surface water, sediments, and dietary items, and direct contact with surface water, sediments, and modeled concentrations of dissolved contaminants in sediment pore water. Only the direct contact pathways were evaluated quantitatively. Ecological receptors evaluated include aquatic plants, benthic macroinvertebrates, and fish (primarily trout species). COCs for the aquatic RA consisted of aluminum, antimony, arsenic, barium, cadmium, copper, iron, lead, manganese, nickel, selenium, and zinc.

Data were evaluated by sampling station rather than by OU. Sample stations of concern for OU6 are located within SHG and Starr Ditch. The physical limitations of these and other tributaries preclude the support of aquatic life, therefore, risk evaluations were focused on California Gulch and the Arkansas River. However, surface water and sediment data indicate that SHG and Starr Ditch are contributing sources to the ongoing metal contamination of surface water and sediment in California Gulch and the Arkansas River.

3.3 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA), requires that remedial actions attain a degree of cleanup that assures protection of human health and the environment. Section 121(d)(2) of CERCLA, Title 42 of United States Code (42 USC) Section 9621(d)(2), limits federal ARARs to those federal environmental laws that set a standard, requirement, criterion, or limitation that is legally applicable or relevant and appropriate to those hazardous substances, pollutants, or contaminants that will remain onsite following remediation. For contaminants that will be transferred offsite, Section 121(d) of CERCLA requires that the transfer be to a facility that is operating in compliance with applicable federal and state laws.

3.3.1 DEFINITION OF ARARS

A requirement under environmental laws may be either "applicable" or "relevant and appropriate," to a site-specific remedial action, but not both. The distinction is critical to understanding the constraints imposed on remedial alternatives by environmental regulations other than CERCLA. Identification of ARARs must be done on a site-specific basis and involves a two-part analysis: first, a determination whether a given requirement is applicable; then, if it is not applicable, a determination whether it is both relevant <u>and</u> appropriate.

3.3.1.1 Applicable Requirements

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at the site. Only those state standards that are more stringent than, or exist independent of, federal requirements may be applicable. Applicable requirements must be met to the full extent required by law.

3.3.1.2 Relevant and Appropriate Requirements

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

3.3.1.3 Other Requirements to be Considered

These requirements pertain to federal and state criteria, advisories, guidelines, or proposed standards that are not generally enforceable but are advisory and that do not have the status of potential ARARs. Guidance documents or advisories "to be considered" (TBCs) in determining the necessary level of cleanup for protection of human health or the environment may be used where no specific ARARs exist for a chemical or situation, or where such ARARs are not sufficient to be protective.

A list of documents identified as TBCs is included in the Preamble to the NCP, 55 Federal Register 8765 (March 8, 1990). Those documents, plus any additional similar or related documents issued since that time, will also be considered.

3.3.2 IDENTIFICATION OF ARARs

Based on CERCLA statutory requirements, the alternatives developed for this EE/CA were analyzed for compliance with federal and state environmental regulations. This process involved initial identification of potential requirements for applicability or relevance and appropriateness, and finally, a determination of the ability of the remedial alternatives to achieve the ARARs.

The identification of ARARs begins with a review of the universe of federal and state requirements to determine the potential ARARs and TBCs that may be applied to a site. As information regarding site contaminants, media, remedial actions, and locations affected becomes known, the universe of ARARs is screened to identify requirements specific to the contaminants, release types, site conditions, and proposed actions. ARAR identification is an iterative process during which the list of potential ARARs is refined as remedial alternatives are developed. New ARARs may be identified as the final remedy is developed.

After the universe of ARARs is developed, it is evaluated to determine which ARARs are applicable to the site. Applicable requirements are identified by determining whether the jurisdictional prerequisites of a requirement fully address the circumstances at the site or the proposed remedial activity. If so, the requirement is applicable. If not, the requirement is reviewed to determine whether it addresses similar situations or problems (i.e., is relevant) and is well-suited to the particular site (i.e., is appropriate). If the requirement addresses both determinations, the requirement is deemed relevant and appropriate. If the requirement does not address one of the determinations, it is not relevant and appropriate and is deemed not to be an ARAR. Federal and state ARARs are presented and screened in Appendix A.

For those situations or chemicals where no ARAR may exist, or where the ARAR is not protective of human health or the environment, TBC information is evaluated. Guidance documents and nonpromulgated standards can be used in the development of "criteria" for remedial actions. This step involves review of advisories, guidance, and nonpromulgated standards to aid in development of other considerations for site remedial activities.

ARARs are classified into three types: chemical-specific, action-specific, and location-specific requirements.

- Chemical-specific: These requirements set protective remediation levels for the contaminants of concern.
- Action-specific: These requirements set controls or restrictions on the design, implementation, and performance levels of activities related to the management of hazardous substances.
- Location-specific: These requirements restrict remedial actions based on the characteristics of the site or its immediate surroundings.

Chemical-specific ARARs include those laws and regulations governing the release of materials possessing certain chemical or physical characteristics, or containing specified chemical compounds. Chemical-specific requirements are health-, risk-, or technology-based values that establish an acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment. These requirements provide protective site remediation levels for the contaminants of concern in the designated media.

Action-specific ARARs are technology-based, establishing performance, design, or other similar action-specific controls or regulations for activities related to the management of hazardous substances or pollutants. Action-specific requirements are triggered by the particular remedial alternatives that are selected to accomplish the cleanup of hazardous wastes.

Location-specific ARARs are design requirements or activity restrictions based on the geographical or physical positions of the site and its surrounding area. Location-specific requirements set restrictions on the types of remedial activities that can be performed based on site-specifics or location. Examples include areas in a floodplain, a wetland, or a historic site.

3.3.3 CERCLA WAIVER CRITERIA FOR ARARS

CERCLA Section 121 provides that under certain circumstances an otherwise applicable or relevant and appropriate requirement may be waived. These waivers apply only to meeting ARARs with respect to remedial actions on-site; other statutory requirements, such as that remedies be protective of human health and the environment, cannot be waived. A waiver must be invoked for each ARAR that will not be attained or exceeded. The waivers provided by CERCLA Section 121(d)(4), are included for cases where the action is an interim measure (CERCLA Section 121(d)(4)(A)), where actions taken to comply with an ARAR will result in a greater risk to health and the environment (CERCLA Section 121(d)(4)(B)), where compliance with the ARAR is technically impractical from an engineering perspective (CERCLA Section 121(d)(4)(C)), where an ARAR stipulates use of a particular design or operating standard, but equivalent or better remedial results could be achieved using an alternative design (CERCLA Section 121(d)(4)(D)), where a State has not consistently applied the ARAR in similar circumstances at other remedial actions (CERCLA Section 121(d)(4)(E)), and where meeting an ARAR at a Fund-lead site would entail such a cost that funding to respond to other sites would be jeopardized.

3.4 CULTURAL RESOURCES

The Leadville area has been classified as a National Historic Landmark. Therefore, the identification and evaluation of the potential effects of remediation of historic properties must be conducted in the initial stages of the EE/CA.

The federal government mandates examination of the cultural resources for the California Gulch Site based on the National Historic Preservation Act of 1966 (as amended), the Archaeological and Historic Preservation Act of 1974, the Federal Land Policy and Management Act of 1976, the Archaeological Resource Protection Act of 1979 (as amended), the Native American Graves and Repatriation Act, and the implementing regulations of the Advisory Council on Historic Preservation (36 CFR 800). Compliance with statutes is based on the inventory, evaluation of National Register of Historic Places (NRHP) eligibility, and management recommendations regarding visible cultural resources. The following four inventories were conducted for OU6:

- *Cultural Resource Inventory Report of a Proposed 15-Acre Borrow Area and Access Road, Operable Unit 6, California Gulch Superfund Site* (Alpine Archaeological\ Consultants, Inc. [Alpine], 1996);
- *Cultural Resource Inventory of Two High Priority Survey Areas, California Gulch Superfund Site, Operable Unit 6* (Alpine, 1997a);
- *Cultural Resource Inventory Report of Three Remediation Areas at the California Gulch Superfund Site, Operable Unit 6* (Alpine, 1997b);
- *Cultural Resource Inventory Report of a Remediation Area at the California Gulch Superfund Site, Operable Unit 6* (Alpine, 1997c);

The 15-Acre Borrow Area and Access Road lies between SHG and Little Stray Horse Gulch. This area is entirely on private patented mining claims owned by Leadville Silver & Gold, Inc. The cultural inventory was conducted in June 1996 (Alpine, 1996).

A cultural resource inventory was conducted in June 1996 of Two High Priority Survey Areas in OU6 (Alpine, 1997a). The inventory areas were in two separate tracts. The first tract was an irregularly shaped corridor running along the lower slope of Iron Hill between SHG on the north and Graham Park on the south; the tract measures 42.7 acres. The second tract was on the northwest slope of Little Ellen Hill, south of Evans Gulch; the tract measures 46.9 acres.

The Three Remediation Areas comprise three small, non-contiguous tracts of land on private patented mining claims. All tracts are located east of the City of Leadville. Tracts 1 and 2 are on the south side of Little Stray Horse Gulch and measures 1.8 acres and 3.7 acres, respectively. Tract 3 lies mostly to the north of Little Stray Horse Gulch and is centered on Fryer Hill; it measures 22 acres. The cultural inventory was conducted from June to July 1996 (Alpine, 1997b).

The Remediation Area is an irregularly shaped parcel that measure 76.2 acres. This parcel is entirely on private patented mining claims with various owners. The parcel lies south of Stray Horse Ridge, on the north side of Carbonate Hill. Iron Hill is to the southeast and Yankee Hill is to the northeast. The cultural inventory was conducted from June to July 1996 (Alpine, 1997c).

Figure 3.1 illustrates the locations of the inventoried areas.

The recorded cultural resources from all four inventories are presented in Table 3.2. If a site was recommended for NRHP or contributes to the Leadville Mining District (5LK856) then avoidance to disturbing the site is recommended. If avoidance is not possible then a mitigation plan should be developed and implemented prior to any disturbance at the site. Suitable mitigation plans for NRHP might include documentation through photography, measured drawings, and/or further investigations. If a site contributes to the Leadville Mining District then the mitigation plan might include documentation through photography. Such mitigation plans are currently being prepared for the sites recommended as individually eligible for inclusion on the NRHP.

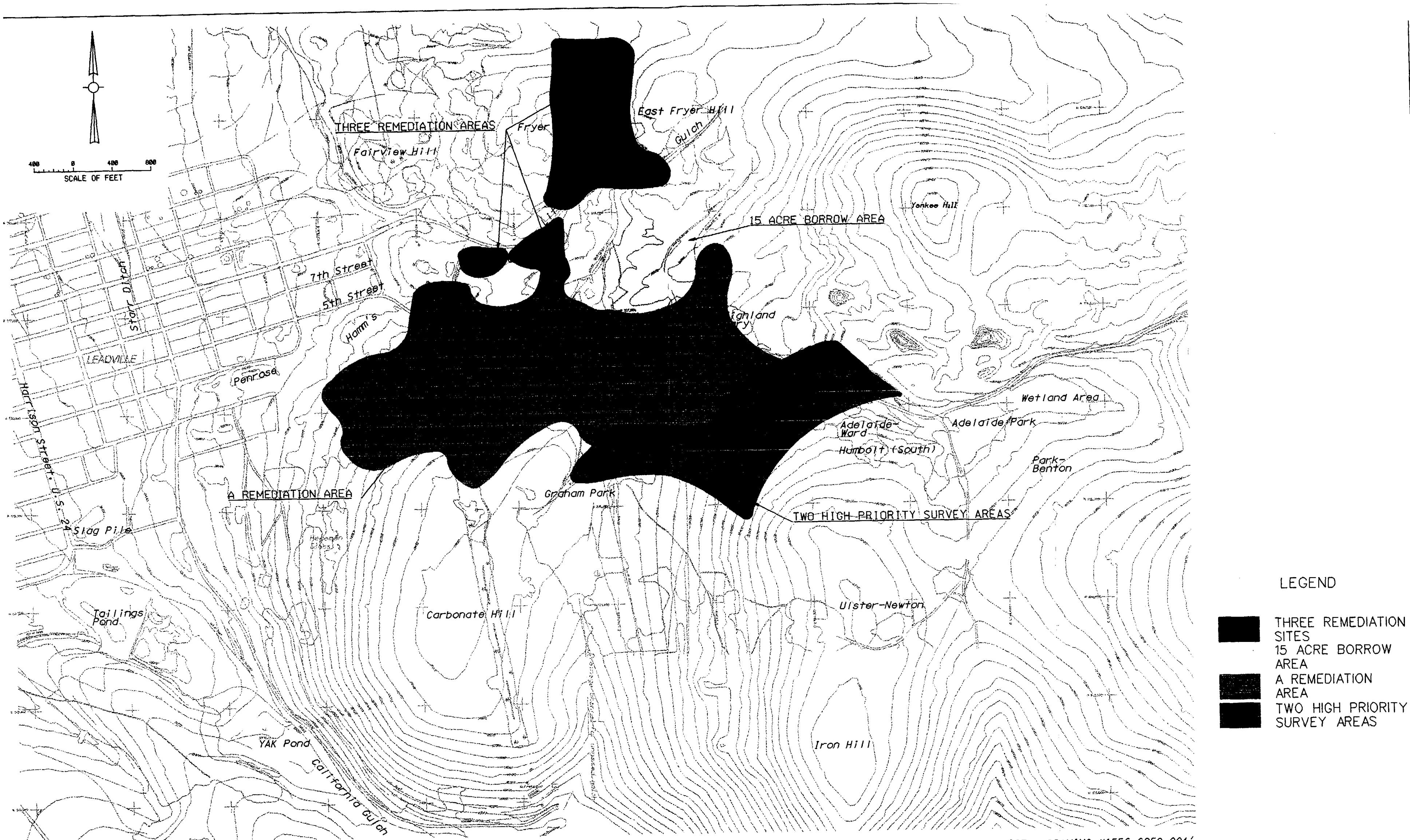
3.5 REMOVAL ACTION OBJECTIVES

As stated in Section 1.1, Purpose of the EE/CA, this removal action will focus on the watershed basin of SHG within the boundaries of OU6. Based on the investigations summarized in Section 2.0, SHG is a major contributor of contaminated surface water from OU6 to the Arkansas River.

As discussed below, this removal action will also address surface lead contamination that exceed the action level. Some of these areas, although immediately outside of the SHG watershed basin, are in close proximity to the City of Leadville.

Color Map(s)

The following maps contain color that does not appear in the scanned images. To view the actual images please contact the Superfund Record Center at (303) 312-6473.



BASE INFORMATION TAKEN FROM 'BUREAU OF RECLAMATION - EE/CA SITE PLAN - DATED MARCH 16, 1997 - DRAWING #1556-6052-001'

CULTURAL RESOURCE INVENTORY AREAS

TABLE 3.2
CULTURAL RESOURCE RECORDED

Site No.	Site Name	NRHP Eligibility	Contributes to Leadville Mining District	Ref., Alpine
5LK50.1	Denver & Rio Grande Railroad grade	Not Eligible	No	1996
5LK50.2	Denver & Rio Grande Railroad grade	Eligible†	Yes	1996, 1997a, 1997c
5LK50.3	McCormick Mine Spur of the D&RG Railroad	Not Eligible	No	1996
5LK50.4	Pyrenees Mine Spur of the D&RG Railroad	Eligible†	Yes	1997a, 1997c
5LK50.5	Denver & Rio Grande Railroad grade	Eligible‡	Yes	1997a
5LK50.6	Denver & Rio Grande Railroad grade	Eligible‡	No	1997a
5LK50.7	Denver & Rio Grande Railroad grade	Eligible‡	No	1997a
5LK50.8	Denver & Rio Grande Railroad grade	Eligible†	Yes	1997a
5LK50.9	Denver & Rio Grande Railroad grade	Eligible†	Yes	1997a
5LK50.10	Denver & Rio Grande Railroad grade	Eligible†	Yes	1997b, 1997c
5LK50.11	Morning Star, Evening Star, and Crescent Mines Spur of the D&RG Railroad	Eligible†	Yes	1997c
5LK50.12	Adams Mine Spur of the D&RG Railroad	Eligible†	Yes	1997c
5LK50.14	Denver & Rio Grande Railroad grade	Eligible‡	No	1997b
5LK50.15	Denver & Rio Grande Railroad grade	Eligible‡	No	1997b
5LK50.17	Denver & Rio Grande Railroad grade	Eligible†	Yes	1997c
5LK50.18	Wolftone Mine Spur No. 1 of the D&RG Railroad	Eligible†	Yes	1997c
5LK50.19	Wolftone Mine Spur No. 2 of the D&RG Railroad	Eligible‡	No	1997c

TABLE 3.2 (Continued)
CULTURAL RESOURCE RECORDED

Site No.	Site Name	NRHP Eligibility	Contributes to Leadville Mining District	Ref., Alpine
5LK50.20	Brookland Spur of the D&RG Railroad	Eligible‡	No	1997c
5LK50.21	New Mikado Spur of the D&RG Railroad	Eligible†	Yes	1997c
5LK50.22	Old Mikado Spur of the D&RG Railroad	Eligible‡	No	1997c
5LK57	Matchless No. 6 Mine	Eligible	Yes	1997b
5LK441	Castle View, Big Chief, Clontarf, Brookland, and Wolftone Mines	Eligible	Yes	1997c
5LK442	Upper Morning Star (Upper Waterloo) Mine	Eligible	Yes	1997c
5LK443	Lower Morning Star Mine	Eligible	Yes	1997c
5LK444	McHarg and Porter Shafts	Not Eligible	Yes	1997c
5LK445	Blonger (Bullion), Haytrossar and Ypsilanti Mines	Eligible	Yes	1997c
5LK498.2	Leadville Mineral Belt Railway grade	Eligible†	Yes	1996,1997a, 1997b, 1997c
5LK498.3	Leadville Mineral Belt Railway grade	Eligible†	Yes	1997a
5LK498.4	Greenback Mine Spur of the LMB Railway	Eligible‡	No	1997a, 1997c
5LK498.5	R.A.M. and Pyrenees Mines Spur of the LMB Railway	Eligible‡	No	1997a, 1997c
5LK498.6	Leadville Mineral Belt Railway grade	Eligible‡	No	1997a, 1997c
5LK498.7	R.A.M. Mine Spur of the LMB Railway	Eligible‡	No	1997c
5LK498.8	Leadville Mineral Belt Railway grade	Eligible†	Yes	1997b
5LK498.9	Leadville Mineral Belt Railway grade	Eligible†	Yes	1997b

TABLE 3.2 (Continued)
CULTURAL RESOURCE RECORDED

Site No.	Site Name	NRHP Eligibility	Contributes to Leadville Mining District	Ref., Alpine
5LK498.10	Leadville Mineral Belt Railway grade	Eligible†	Yes	1997b
5LK498.11	Leadville Mineral Belt Railway grade	Eligible‡	No	1997b
5LK498.13	Robert Emmet Mine Spur of the LMB Railway	Eligible†	Yes	1997c
5LK498.14	Empire Zinc Company Spur of the LMB Railway	Eligible‡	No	1997c
5LK498.15	Mahala Lead Spur of the LMB Railway	Eligible†‡	Yes/No	1997c
5LK498.16	Mahala Mine Spur of the LMB Railway	Eligible‡	No	1997c
5LK498.17	Upper Morning Star Mine Spur of the LMB Railway	Eligible†	Yes	1997c
5LK498.18	Catalpa Spur of the LMB Railway	Eligible‡	No	1997c
5LK687	Denver City Mine	Eligible	Yes	1996
5LK689	Robert Emmet Mine	Eligible	Yes	1997c
5LK921	Shamus O'Brien and Quadrilateral Mines	Eligible	Yes	1996
5LK922	McCormick Mine	Eligible	Yes	1996
5LK923	Result Mine	Eligible	Yes	1996
5LK925	Finntown	Eligible	Yes	1996, 1997c
5LK926	Graham Park Community/Late Prehistoric lithic scatter	Eligible/ Not Eligible	Yes	1997a
5LK927	Greenback and Mahala Mines	Eligible	Yes	1997a, 1997c
5LK928	Pyrenees (Rialto) Mine	Eligible	Yes	1997a
5LK929	Cumberland Mine	Eligible	Yes	1997a
5LK930	Hermes Mine	Eligible	Yes	1997a

TABLE 3.2 (Continued)
CULTURAL RESOURCE RECORDED

Site No.	Site Name	NRHP Eligibility	Contributes to Leadville Mining District	Ref., Alpine
5LK931	Venus Mine	Eligible	Yes	1997a, 1997c
5LK932	New Mikado and Old Mikado Mines	Eligible	Yes	1997a, 1997c
5LK933	Camp Bird Tunnel, Argentine Tunnel, Devlin Mine and Terrible Mine	Eligible	Yes	1997a
5LK934	Frenchman, Adelaide (Ward), Loker, Terrible 2, and Humboldt North Mines	Eligible	Yes	1997a
5LK958	Unknown Mine	Not Eligible	No	1997a
5LK959	Unknown Mine	Not Eligible	No	1997a
5LK960	Penfield Mine	Eligible	Yes	1997a
5LK961	Fortune, Sedalia, and Resurrection No. 1 Mines	Eligible	Yes	1997a
5LK973	Virginius No. 1 Mine	Eligible	Yes	1997b
5LK974	[unnamed historic residential area]	Eligible	Yes	1997b
5LK974	[prehistoric component]	Not Eligible	--	1997b
5LK975	Dunkin No. 4 Mine	Eligible	Yes	1997b
5LK978	Bangkok and Cora Belle Mines	Eligible	Yes	1997b
5LK979	Matchless No. 5 Mine	Eligible	Yes	1997b
5LK980	Dunkin No. 3, Virginius Nos. 2 and 3, Climax No. 1, Amie No. 5, and Little Diamond Mines	Eligible	Yes	1997b
5LK988	Robert E. Lee, Matchless Discovery, Hibernia, and Climax Contract Mines	Eligible	Yes	1997b

TABLE 3.2 (Continued)
CULTURAL RESOURCE RECORDED

Site No.	Site Name	NRHP Eligibility	Contributes to Leadville Mining District	Ref., Alpine
5LK989	Tip Top, Forepaugh, and Little Silver Mines, and the Union Leasing and mining Company Office	Eligible	Yes	1997b
5LK990	Joe Davies Mine	Eligible	Yes	1997b
5LK994	Lickscumdidricks Mine and Residential Area	Eligible	Yes	1997b
5LK995	American Shaft and Tip Top Dump	Not Eligible	Yes	1997b
5LK996	Pittsburg Mine	Eligible	Yes	1997b
5LK1007	Raven and Right Angle Mines	Eligible	Yes	1997c
5LK1009	Adams and Denman Mines	Eligible	Yes	1997c
5LK1011	Stonewall Jackson	Not Eligible	Yes	1997b
5LK1013	Ponsardine	Eligible	Yes	1997b
5LK1015	Unnamed mine and associated habitation area	Eligible	Yes	1997c
5LK1016	Vanderbilt Mine	Not Eligible	Yes	1997c
5LK1017	Tarshish Mine	Eligible	Yes	1997c
5LK1019	Indiana, Shenango, and Highland Mary Nos. 1 and 2 Mines	Eligible	Yes	1997c
5LK1021	Maid of Erin and Adams Mines, Adams Mill, Hamm's Mill, and Jones Shaft	Eligible	Yes	1997c
5LK1022	R.A.M. Mine (Marian Lease)	Eligible	Yes	1997c
5LK1023	Mahala No. 1, Standard, Agassiz, and Gonabrad Mines	Eligible	Yes	1997c

TABLE 3.2 (Continued)
CULTURAL RESOURCE RECORDED

Site No.	Site Name	NRHP Eligibility	Contributes to Leadville Mining District	Ref., Alpine
5LK1024	Evening Star No. 5, Main Evening Star, Lower Evening Star, Morning Star, Lower Crescent, New Catalpa, Niles-Augusta, and Wildcat Mines; Forsaken, Kitchen, and New Porter Shafts	Eligible	Yes	1997c
5LK1025	Crescent No. 3 Mine	Eligible	Yes	1997c
5LK1027	Middle Yankee Doodle, Yankee Doodle Incline, Washburne, Crescent Incline, and Crescent No. 1 Mines	Eligible	Yes	1997c
5LK1028	Upper Evening Star and Upper Catalpa Mines	Eligible	Yes	1997c
5LK1071	[unnamed mine exploration pit - isolated find]	Not Eligible	No	1997b
5LK1084	Isolated find - mining prospect pit	Not Eligible	No	1997c
5LK1093	Isolated find - mining prospect pit	Not Eligible	No	1997c

† Contributing element of a significant site
‡ Noncontributing element of a significant site

The RAOs developed for this non-time-critical removal action are drawn from the NCP (40 CFR Part 300.430 (a) (1) (I)). The national goal of the remedy selection process according to the NCP is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste.

The following are the specific RAOs for this removal action at OU6.

- Control airborne transport of contaminated materials.
- Control erosion of contaminated materials into local water courses.
- Control leaching and migration of metals from contaminated materials into surface water.
- Control leaching and migration of metals from contaminated materials into groundwater.
- Control direct contact with and ingestion of contaminated materials.
- Maintain/preserve historic and cultural features of the OU consistent with the NRHP and current tourism draw.

These RAOs are consistent with the remedial action objectives defined for the California Gulch Site in the SFS (USEPA, 1993a) as well as historical preservation requirements and concerns specific to OU6.

Specific water quality goals for surface streams and groundwater contamination have not been established at this time. USEPA has agreed to establish specific surface and groundwater requirements at a later date when USEPA, Colorado Department of Public Health and Environment, and the PRPs have reached agreement on the allowable heavy-metals contaminant loadings for each of the contributing source areas (operable units) for the entire California Gulch Site. Although the objectives of controlling leaching and migration of metals from contaminated sources into surface waters and groundwater can not be quantified at this time, to be consistent with longterm remedial action for OU6, the EE/CA aims to select a removal action that from the start attempts to maximize the reduction in concentration of contaminants in the waters emanating from the SHG watershed by remediating those source areas that are the most likely contributors to the degradation of water quality based on the investigations summarized in Section 2.7.

The future land use at OU6 will largely be recreational. In meeting the objective of controlling direct contact with, or ingestion of, contaminated materials, lead is considered the principal risk to the recreational visitor. Section 3.2.1.3 developed an action level of 16,000 mg/kg under this exposure pathway. This removal action will remediate contaminated materials with a concentration greater than 16,000 mg/kg.

Section 3.2.1.3 also developed an action level of 610 to 690 mg/kg for arsenic; however, based on the information given in Section 2.7.5 these levels do not appear to be exceeded in the SHG watershed basin.

3.6 TARGET MEDIA AREAS AND VOLUMES

3.6.1 GROUNDWATER

Groundwater will not be directly addressed by this removal action. As stated above, the RAOs for this removal action included controlling leaching and migration of metals into groundwater by remediating source areas sitewide. Groundwater will be addressed by OU12.

3.6.2 SURFACE WATER

This removal action will target the surface water within SHG watershed basin. Flowrates and concentrations are summarized in Section 2.7.2.

3.6.3 SEDIMENTS

This removal action will target the sediments within SHG and Starr Ditch. The total volume of sediments is estimated at 15,600 cubic yards.

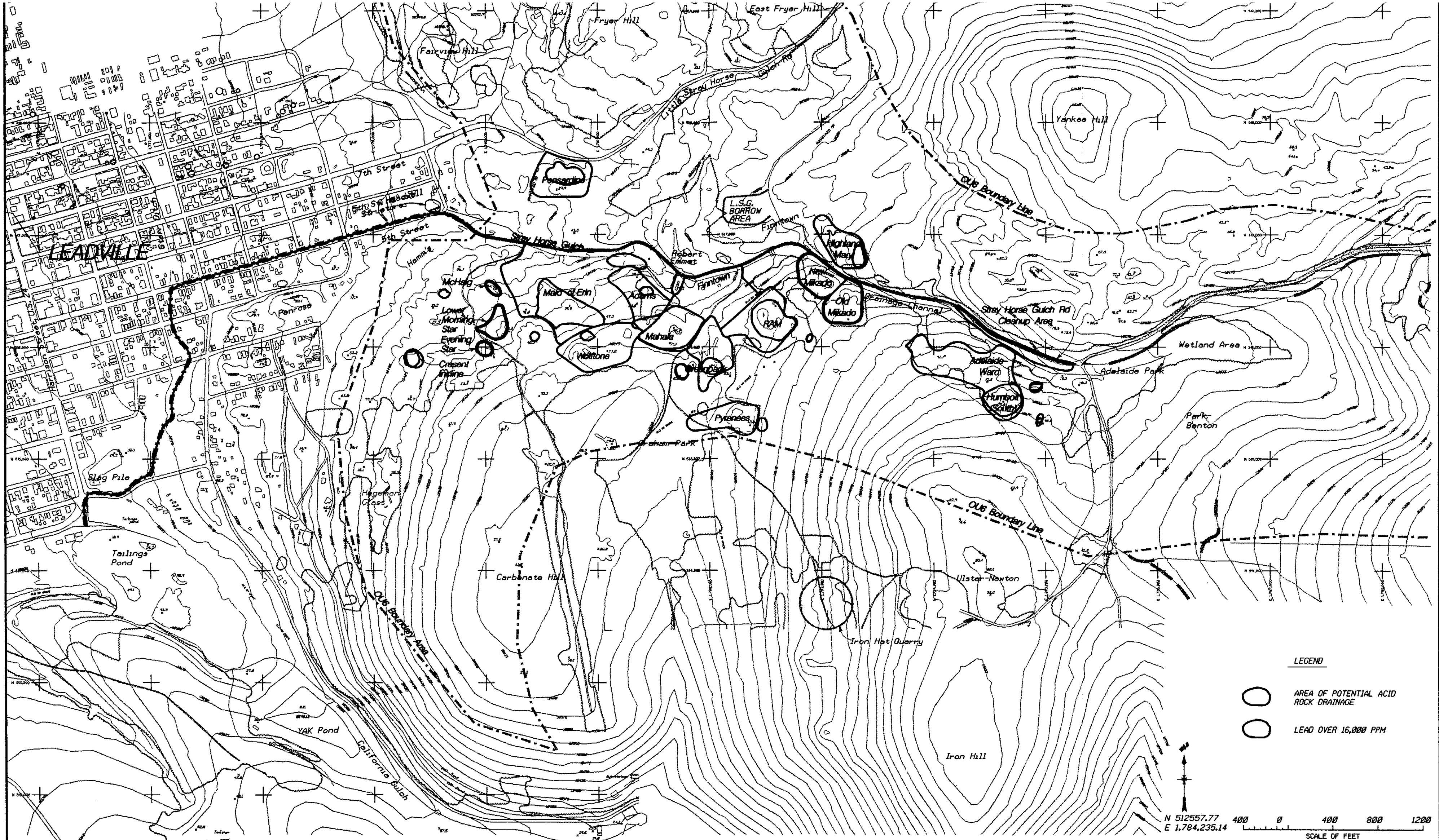
3.6.4 MINE WASTE

This removal action will target those mine waste areas identified by AVIRIS (see Section 2.7.2) as the ARD-generating sources within the SHG watershed basin. Those areas are outlined on Figure 3.2. (Although the Ponsardine waste pile is outlined as ARD-generating, it drains to the Little Stray Horse Gulch not SHG. It is being targeted by this removal action principally due to lead contamination. Also, the surface water from the Pyrenees mine waste pile historically drained to the south into OU4 and California Gulch. In 1996 at the request of Resurrection, the drainage from the Pyrenees pile was diverted by USEPA from entering OU4 and now completely drains into SHG.) The volume of this material was estimated by comparing the pre-mining topography of the SHG area with the existing topography. Existing 5-foot contour topography was supplied by Roy F. Weston, Inc. in the form of digital elevation computer design files. The pre-mining topography (the ground surface located beneath the mine waste rock pile) was estimated by interpretation of existing topography, aerial photographs, historical photographs, United States Geographic Survey plates and figures in the report by Emmons (Emmons, 1927), and examination of the SHG area by Reclamation engineers and geologists. Triangulated Irregular Network models were then calculated from point, linear, and area features of topography, for either the existing or pre-mining surface as required. The appropriate area boundary was drawn in the design file and was chosen as the limiting perimeter for volume calculations. The Intergraph computer system, using the Modular Geographic Information System Environment software and Terrain Analyst components, compared the upper and lower surfaces within the bounding perimeters to calculate the volumes for each source area. These volumes are given in Table 3.3.

This removal action will also target surficial lead-contaminated mine waste located within SHG watershed basin and in the vicinity of Leadville. The action level for lead is 16,000 mg/kg (see Section 3.2.1.3). Those areas exceeding 16,000 mg/kg lead are also demarcated in Figure 3.2. Much of the lead-contaminated areas overlap the areas described above as being ARD-generating. Those areas that do not overlap are also included in the quantity given in Table 3.3.

Color Map(s)

The following maps contain color that does not appear in the scanned images. To view the actual images please contact the Superfund Record Center at (303) 312-6473.



TARGET AREAS FOR ACID ROCK DRAINAGE AND LEAD

STATION\DGN\3280-016\FIG3-2 06/05/97

TABLE 3.3
ESTIMATED MINE WASTE VOLUME

WASTE AREA	ESTIMATED VOLUME (CUBIC YARDS)
Maid of Erin	186,000
Lower Morning Star/McHaig	10,000
Adams Mill	7,000
Wolftone	52,000
Mahala	33,000
Greenback	44,000
RAM	24,800
Old Mikado	42,000
New Mikado	44,000
Highland Mary	27,000
Ponsardine	11,000
Adelaide/Ward/Humboldt	54,000
Evening Star	2,000
Pyrenees	60,500
Finntown Area	1,000
Stray Horse Gulch Road near Adelaide	2,250
Additional Miscellaneous Lead Locations	4,000
Total Volume	604,550

Source: U.S. Bureau of Reclamation

3.7 REMOVAL SCHEDULE

The EE/CA was presented to the public in draft form in a public meeting held on March 19, 1997. The EE/CA considers comments received during the public comment period held from March 19 through April 18, 1997. After review of the comments and incorporation of the comments into this final EE/CA, an Action Memorandum will be prepared finalizing the selected remedy. A notification to the contractor to proceed must be provided 30 days prior to the on-site construction start date which will be required by the contract. To optimize the use of the limited summer work season at the site, the notice to proceed is scheduled for June 1997. The removal action construction work will continue until winter sets in late October or November. Work is scheduled to resume in May 1998 as needed to complete the action, with completion by October 1998. The schedule milestones as planned at this time are as follows:

Release of the draft EE/CA	March 19, 1997
Public Comment Period Closes	April 18, 1997
Start of On Site Construction	July 1997
End of 1997 Construction Season	Late October or November 1997
Begin 1998 Construction Activities	May 1998
Project Construction Completion	October 1998 or earlier

4.0 IDENTIFICATION OF REMOVAL ACTION ALTERNATIVES

In the SFS, site-wide remedial technologies and process options for waste rock piles, impounded tailings, fluvial tailings, stream sediments, slag, and non-residential area soils were identified, evaluated, and screened based on information contained in the RIs and in other collected data. Technologies and process options retained after the screening were used to develop specific alternatives for the various source areas. Section 4.1 summarizes the screening of the technologies and process options. Section 4.2 develops specific alternatives from the technologies and process options retained in Section 4.1. Section 4.3 defines the evaluation criteria that will be used to analyze the alternatives developed in Section 4.2

4.1 IDENTIFICATION AND SCREENING OF REMOVAL ACTION TECHNOLOGIES

The treatment technologies describe broad technology categories used in treatment alternatives, but do not address details such as performance data associated with specific process options. The treatment technologies identified in SFS for the California Gulch Site are summarized in Table 4.1.

For each technology, there may be more than one process available that utilizes that technology in its design. The process options are detailed enough to evaluate their applicability based on performance data and costs. These process options are also given in Table 4.1.

The SFS evaluated the process options presented in Table 4.1 for applicability to each type of source of contamination found at the California Gulch Site. The criteria for this evaluation included the potential effectiveness, implementability and cost of the process option. Table 4.2 shows the process options that were retained for further consideration for each type of source identified at OU6. The reader is referred to the SFS itself for a more complete discussion of the evaluation and screening of the process options.

TABLE 4.1
DESCRIPTION AND INITIAL SCREENING OF POTENTIALLY APPLICABLE REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

General Response Actions	Remedial Technology	Process Option	Description of Option	Screening Comments	Retained
No Action	None	None	No action would be taken. The source area remains in its existing condition.	Required by NCP as baseline for comparison.	Yes
Institutional Controls	Land Use Controls	Zoning, Deed Restrictions	Source site would have zoning and deed restrictions governing land use of the site.	Technically feasible and potentially applicable.	Yes
	Access Restrictions	Fencing and Posted Warnings	Source would be enclosed by fences and warning signs to control access.	Technically feasible and potentially applicable.	Yes
	Community Awareness	Information and Education Programs	Community information and educational programs would be undertaken to enhance awareness of potential hazards and remedies.	Technically feasible and potentially applicable.	Yes
Containment	Surface Water Controls	Diversion Ditches	Surface water runon would be diverted around and away from source.	Technically feasible and potentially applicable.	Yes
		Channelization	Surface water flowing through sources would be controlled in constructed channels.	Technically feasible and potentially applicable.	Yes
	Source Surface Controls	Grading	Contouring of source material surfaces.	Technically feasible and potentially applicable.	Yes
		In-situ Mixing	Surficial source material of high contaminant concentration is mixed with underlying low concentration material.	Technically feasible and potentially applicable.	Yes
		Revegetation	Develop or import growth medium and plant capped or uncapped areas with native vegetation.	Technically feasible and potentially applicable.	Yes
		Simple Cover	Contaminated material would be covered with a layer of borrow soil or rock or inert mine waste.	Technically feasible and potentially applicable.	Yes
		Multi-Layer Cover	Contaminated material would be covered with an appropriate multi-layer cover.	Technically feasible and potentially applicable.	Yes

TABLE 4.1 (Continued)
DESCRIPTION AND INITIAL SCREENING OF POTENTIALLY APPLICABLE REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

General Response Actions	Remedial Technology	Process Option	Description of Option	Screening Comments	Retained
Containment (cont.)	Barriers	Retaining Structures	Source surfaces would be stabilized by retaining structures.	Technically feasible and potentially applicable.	Yes
		Sediment Dams/Traps	Sedimentation dams and traps would be constructed to capture solids from run-off.	Technically feasible and potentially applicable.	Yes
		Constructed Wetlands	Natural marshes, bogs, wet meadows, peat lands, and swamps would be used to reduce concentrations of suspended solids.	Technically feasible and potentially applicable.	Yes
Removal, Transport, Disposal	Removal	Mechanical Excavation/Dredging	Source material would be excavated from the source site using mechanical excavation methods.	Technically feasible and potentially applicable.	Yes
		Vacuum Dredging	Source material would be dredged using vacuum dredging methods.	Technically feasible and potentially applicable.	Yes
		Demolition	Contaminated structures would be demolished in preparation for disposal.	Technically feasible and potentially applicable.	Yes
		Decontamination	Through industrial-type cleaning using professionally trained labor and industrial strength equipment and supplies.	Technically feasible and potentially applicable.	Yes
		Purchase/Replacement	Purchase/replacement of contaminated household fixture (e.g., curtains, insulation).	Technically feasible and potentially applicable.	Yes
	Transport	Truck Hauling	Excavation source would be hauled by truck to disposal site.	Potentially applicable and technically feasible.	Yes
		Slurrying	Excavated source would be piped in slurry form for disposal.	Potentially applicable and technically feasible.	Yes
	Disposal	On-Site Repository	Excavated or slurried source would be disposed at new on-site landfill or on-site impoundment.	Potentially applicable and technically feasible.	Yes
		On-Site Consolidation	Consolidation of waste from multiple sites at existing on-site tailing pile or impoundment.	Potentially applicable and technically feasible.	Yes

TABLE 4.1 (Continued)
DESCRIPTION AND INITIAL SCREENING OF POTENTIALLY APPLICABLE REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

General Response Actions	Remedial Technology	Process Option	Description of Option	Screening Comments	Retained
Removal, Transport, Disposal (cont.)	Disposal (cont.)	Underground	Source would be introduced to mine shafts as underground fill material.	Not feasible for site application.	No
		Offsite Disposal	Material would be transported offsite for disposal at a commercial facility.	Not feasible for site application	No
Treatment	Physical/Chemical	Soil Washing	Excavated source would be washed with a site-specific washing solution, by-products would be collected for further treatment.	Potentially applicable and technically feasible.	Yes
		In-situ Soil Flushing	Washing solution (as with soil washing) circulated through contaminated media with the use of injection and extraction wells or trenches.	Not feasible for site application.	No
		Electrokinetics	In-situ waste material is electrically charged with direct current, causing the transport/removal of ions, particles, and water.	Not feasible for site application	No
		Physical Separation	Excavated source would be remilled by crushing, grinding, screening, and/or floating to separate heavy metals.	Potentially applicable and technically feasible.	Yes
		Neutralization	Source would be treated by addition of lime, phosphate, or neutralizing agents.	Potentially applicable and technically feasible.	Yes
		Stabilization	Source would be excavated and mixed with cement, lime, fly ash, bituminous asphalt, or pozzolanic stabilizing additives.	Potentially applicable and technically feasible.	Yes
		In-situ Stabilization	Source would be stabilized in-situ by a deep soil-mixing technique.	Potentially applicable and technically feasible.	Yes
	Thermal Treatment	Molten Glass	Incineration using heat generated from a bath of molten glass to incorporate inorganics in a vitrified glass matrix.	Not feasible for site application.	No

TABLE 4.1 (Continued)
DESCRIPTION AND INITIAL SCREENING OF POTENTIALLY APPLICABLE REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

General Response Actions	Remedial Technology	Process Option	Description of Option	Screening Comments	Retained
Treatment (cont.)	Thermal Treatment (cont.)	Plasma Arc	Transfer of electric energy to plasma to waste which is broken down and pyrolyzed.	Not feasible for site application.	No
		In-situ Vitrification	An electrical current passed between electrodes inserted into contaminated media causes melting. Matrix is then allowed to cool into solid mass.	Not feasible for site application.	No
	Resource Recovery	Smelting	Excavated source would be processed to produce oxides and inert slag.	Not feasible for site application.	No
Resource Utilization			Source material is used or reused in its existing or physically altered condition as a commercial product.	Technically feasible and potentially applicable.	Yes

Source: Final Screening Feasibility Study (USEPA, 1993a).

TABLE 4.2
RETAINED PROCESS OPTIONS FOR THE VARIOUS SOURCE AREAS IDENTIFIED IN OU6.

Alternatives	Technologies/Process Options	Waste Rock Piles	Stream Sediments	Fluvial Tailings	Impounded Tailings	Non-Residential Soils	Slag
Institutional Controls	No Action	X	X	X	X	X	X
	Deed Restrictions	X	X	X	X	X	X
	Fencing	X	X	X	X	X	X
	Educational Programs	X	X	X	X	X	X
Surface Water Controls	Diversion	X	X	X	X	X	
	Channelization	X	X	X	X		
Surface Source Controls	Grading	X		X			
	Revegetation	X		X	X	X	X
	Simple Cover	X		X	X	X	X
	Multi-Layer Cover	X		X	X	X	X
Barriers	Retaining Structures	X		X	X	X	
	Constructed Wetlands		X	X			
	Sediment Dams	X	X	X	X	X	X
Removal	Mechanical Excavation	X	X	X	X	X	X
Transport	Slurrying		X	X	X		
	Hauling	X	X	X	X	X	X
Disposal	On-Site Repository	X	X	X	X	X	
	On-Site Consolidation	X	X	X		X	X
Treatment	Physical Separation						X
	In Situ Stabilization	X*					

*Although not originally retained in the Screening Feasibility Study (USEPA, 1993a), in situ stabilization has subsequently been reconsidered as a process option for waste rock piles and is the subject of a treatability study.

4.2 IDENTIFICATION OF REMOVAL ACTION ALTERNATIVES

In this section, the process options selected in Section 4.1 are combined into removal action alternatives. The alternatives developed represent a workable number of options that appear to adequately address the contaminated areas found at OU6. Each alternative may consist of an individual technology or a combination of technologies. The development and analysis of alternatives within this EE/CA is purposely divided into two subgroups. One subgroup of alternatives were developed to study the feasibility of controlling the migration of contamination by remediating the areas/materials that are presumed to be the sources of contamination. The second subgroup of alternatives approach various methods of either reducing the migration of contamination by diverting surface water away from the sources of contamination or separating (treating) the contaminants from the surface water after it has come in contact with the sources of contamination. It is anticipated that the removal action selected for meeting the RAOs of this EE/CA will ultimately be comprised of a pairing of one alternative from each subgroup.

The following removal action alternatives have been developed to address the source areas found at OU6:

Alternative S1:	Sediment Removal
Alternative S2:	Consolidation into Single Repository with Capping
Alternative S3:	Consolidation into Multiple Piles with Capping
Alternative S4:	Consolidation into Multiple Piles with Solidification

Separately, the following removal action alternatives have been developed to control the surface water within OU6:

Alternative W1:	Rehabilitation of the SHG Channel
Alternative W2:	Detention of Surface Waters within SHG
Alternative W3:	Diversion of Surface Waters via Graham Park
Alternative W4:	Diversion of Surface Waters to LMDT
Alternative W5:	Treatment of Surface Waters within SHG

A summary of the developed alternatives is presented in Table 4.3. A detailed description of each alternative is given in Section 5.0 for the source control alternatives and in Section 6.0 for the surface water control alternatives.

4.3 CRITERIA FOR ANALYSIS OF ALTERNATIVES

The alternatives developed in Section 4.2 above will be analyzed in Sections 5.0 and 6.0 using two sets of criteria. The first set of criteria, the NCP criteria, are the conventional criteria used in EE/CAs as defined in the EPA guidance document *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (USEPA, 1993b) and as required by the NCP. The second set of criteria, the Work Area Management Plan (WAMP) criteria, are additional site-specific criteria beyond the required NCP criteria. This set of criteria has been developed for evaluating remedial alternatives for the OUs at the California Gulch Site. These criteria are consistent with the PRP WAMP attached to the CD for the California Gulch Site.

4.3.1 NCP CRITERIA

The alternatives are evaluated against the short- and long-term aspects of three criteria: effectiveness, implementability, and cost. Each alternative is evaluated for a period of performance of 30 years. The 30-year period represents a basis for comparison of alternatives and is not an estimate of the post-closure care period.

4.3.1.1 Effectiveness

The effectiveness of an alternative is a measure of the degree that it protects human health and the environment, and its ability to meet RAOs within the scope of the removal action. The protectiveness of an alternative refers to how it will reduce, control, or eliminate risks at the site. The specific components of the effectiveness criteria, as established in the guidance (USEPA, 1993b), includes:

TABLE 4.3
DEVELOPMENT OF REMOVAL ACTION ALTERNATIVES FOR OU6

Alternative	Title	Process Options Employed
S1	Sediment Removal	Hauling
S2	Consolidation into Single Repository with Capping	Multi-Layer Cover Grading Mechanical Excavation Hauling On-Site Repository
S3	Consolidation into Multiple Piles with Capping	Multi-Layer Cover Grading Mechanical Excavation Hauling On-Site Consolidation
S4	Consolidation into Multiple Piles with Solidification	Grading Mechanical Excavation Hauling On-Site Consolidation In Situ Stabilization
W1	Rehabilitation of SHG Channel	Channelization
W2	Detention of Surface Waters within SHG	Channelization Retaining Structures Sediment Dams
W3	Diversion of Surface Waters via Graham Park	Diversion Channelization Retaining Structures
W4	Diversion of Surface Waters to LMDT	Diversion Channelization Retaining Structures Off-site Treatment by Physical/Chemical Separation at LMDT
W5	Surface Water Collection and Treatment	Diversion Channelization Retaining Structures Sediment Dams On-site Treatment by Physical/Chemical Separation

- Protectiveness
  - Protection of public health and community
  - Protection of workers during implementation
  - Protection of the environment
  - Compliance with ARARs

- Ability to achieve RAOs
  - Effects of residuals
  - Level of treatment/containment
  - Performance and control

4.3.1.2 Implementability

The implementability criterion addresses the technical and administrative feasibility of implementing an alternative and includes:

- Technical feasibility
  - Construction and operational considerations
  - Demonstrated performance of the alternative's technology
  - Adaptability to environmental conditions
  - Contribution to overall remedial performance
  - Ability to be implemented within removal action schedule
  - Availability of required equipment, personnel, and services

- Administrative feasibility
  - Acceptance of regulatory/permitting agencies and the public
  - Permits required
  - Easements or right-of-ways required
  - Impact on adjoining property
  - Ability to impose institutional controls
  - Likelihood of obtaining an exemption from statutory limits (if needed)

4.3.1.3 Cost

Cost estimates are developed for each alternative. The type of costs that are assessed include the following:

- Capital costs, including both direct and indirect costs
- Annual operations and maintenance (O&M) costs
- Net present worth of capital and O&M costs

The present worth analysis is used to evaluate expenditures that occur over different time periods by discounting all costs incurred in the future to a common base year. This allows the cost of removal action alternatives to be compared on the basis of a single figure representing the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the removal action over its planned life.

Based on USEPA guidance presented in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final* (USEPA, 1988), costs are accurate from -30% to +50% and are developed for the sole purpose of providing a basis for comparing alternatives.

In conducting the present worth analysis, a discount rate of 7% will be applied. Inflation and depreciation are not considered in preparing the present worth costs. In addition, the period of performance for costing purposes, as recommended by Superfund, does not exceed 30 years for the purpose of the detailed analysis.

4.3.2 WORK AREA MANAGEMENT PLAN (WAMP) CRITERIA FOR ANALYSIS

The WAMP criteria described below assist in the evaluation of the effectiveness of each proposed alternative to meet ARARs for the site:

4.3.2.1 Surface Erosion Stability

Removal action alternatives for source material are required to ensure surface erosion stability through the development of surface configurations and implementation of erosion protection measures. The removal action shall meet the following criteria:

a. Erosional releases of waste material will be predicted by use of computer modeling or other engineering procedures. Engineering analyses will include wind erosion soil loss equations and precipitation runoff erosion for site-specific storm-flow conditions set forth below.

b. Remediated surfaces located within the 500-year floodplain will be stable under 500-year, 24-hour and 2-hour storm events. Remediated surfaces located outside the 500 year floodplain will be stable under 100-year, 24-hour and 2-hour storm events. On source embankments or where the slope of the reconstructed source is steeper than 5:1, surface flow will be concentrated by a factor of 3 for purposes of evaluating erosion stability.

4.3.2.2 Slope Stability

Source removal action alternatives will ensure geotechnical stability through the development of embankments or slope contours. The removal action shall meet the following:

a. Impounding embankments will be designed with a Factor of Safety of 1.5 for static conditions and 1.0 for pseudo-static conditions.

b. Recontoured slopes will be designed with a Factor of Safety of 1.5 for static conditions and 1.0 for pseudo-static conditions.

c. Analysis of geotechnical stability will be performed using an acceptable computer model for slope stability and liner designs. Material and geometry input parameters will be obtained from available data.

4.3.2.3 Flow Capacity and Stability

Removal action alternatives utilizing retaining structures, diversion ditches, or reconstructed stream channels will ensure sufficient capacity and erosional stability of those structures. The removal action shall meet the following criteria:

a. Capacity: Diversion ditches will be sized to convey the 100-year, 24-hour and 2-hour storm events. Reconstructed stream channels will be sized to convey flow equal to or greater than the flow capacity immediately upstream of the reconstruction.

b. Stability: Erosional releases of waste material from ditches, stream channels, or retaining structures as determined by all or some of the following models and engineering methods:

U.S. Army Corps of Engineers Hydrologic Engineering Center HEC-1 (U.S. Army Corps of Engineers, 1991) and HEC-2 (U.S. Army Corps of Engineers, 1990) models.

1) Diversion Ditches and Reconstructed Stream Channels: Remedial construction located within the 500-year floodplain will be designed to be stable under flows resulting from a 500-year, 24-hour and 2-hour storm events. Remedial construction outside of the 500-year floodplain will be designed to withstand flows resulting from 100-year, 24-hour and 2-hour storm events. Reconstructed stream channels will be configured to the extent practicable to replicate naturally occurring channel patterns.

2) Retaining structures: Structures such as gabions, earth dikes, or riprap will be designed to be stable under the conditions stated above under item 5.1.2.3.b.1) for the diversion ditch or stream channel with which the structure is associated. If riprap is to be placed in stream channels or ditches, the riprap will be sized utilizing generally accepted engineering methods. Selection of one of these methods will be based on the site specific flow and slope conditions encountered.

4.3.2.4 Surface Water and Groundwater Loading Reduction

Removal action alternatives are to ensure reduction of mass loading of COCs, including total suspended solids (TSS) and sulfate, as defined in the Aquatic Ecosystem RA (Weston, 1995d), and change in pH, resulting from run-on, runoff and infiltration from source areas. The alternatives will be evaluated with the following methods:

a. The present concentrations of COCs (including TSS and sulfate) and present pH measurements have been previously determined for both surface water and ground water.

b. For each source of contamination evaluated, the net loading reduction of COCs (including TSS and sulfate) and change in pH resulting from implementation of each remedial alternative will be calculated for surface water and ground water following post implementation sampling. The final effectiveness of this mass load reduction will be discussed in the Record of Decision (ROD).

4.3.2.5 Terrestrial Ecosystem Exposure

Evaluation of remedial action alternatives with respect to reduction of risk to the terrestrial ecosystem within each OU will be based on area-wide estimations of risk to receptor populations. Exposure estimations for assessing this risk consider factors that affect frequency and duration of contact with contaminated media, such as (1) the concentrations and areal extent of contamination, and (2) the effect of home range on the amount of time a given species will spend in contact with contaminated media. The reduction of the potential exposure will be calculated following implementation of the removal action and collection of post-implementation sample data.

4.3.2.6 Nonresidential Soils

Nonresidential soils are in areas zoned agricultural/forest, highway/business, and industrial mining. The nonresidential areas within OU6 include all of the areas of removal action except the soils on the slopes immediately above the Hamm's area and in the areas of Leadville residential development. These areas have been evaluated in the ecological risk assessments and in this EE/CA consistent with current and likely future land use. Given existing zoning and land use development patterns, EPA expects that current agricultural/forest, industrial/mining and highway/business land uses will not change substantially.

5.0 DESCRIPTION AND ANALYSIS OF REMOVAL ACTION ALTERNATIVES FOR SOURCE CONTROL

Each of the alternatives developed to address the source areas within the watershed basin at SHG are described and analyzed individually in this section. At the end of the section these alternatives are compared with each other using the evaluation criteria defined previously in Section 4.3.

5.1 ALTERNATIVE S1 - SEDIMENT REMOVAL

5.1.1 DESCRIPTION

In this alternative contaminated sediment would be removed from SHG and Starr Ditch and placed at a designated disposal site such as the Hecla tailings impoundment at OU2. This alternative would leave mine waste in place and untouched. The extent of sediment removal is shown on Figure 5.1. The removal of sediments and fluvial tailing may precipitate the need to restructure sections of the SHG channel; thus, one of the surface water control alternatives presented in Section 6.0 may be required as an adjunct to the selection of this alternative as the Removal Action. Surface water would continue to be monitored.

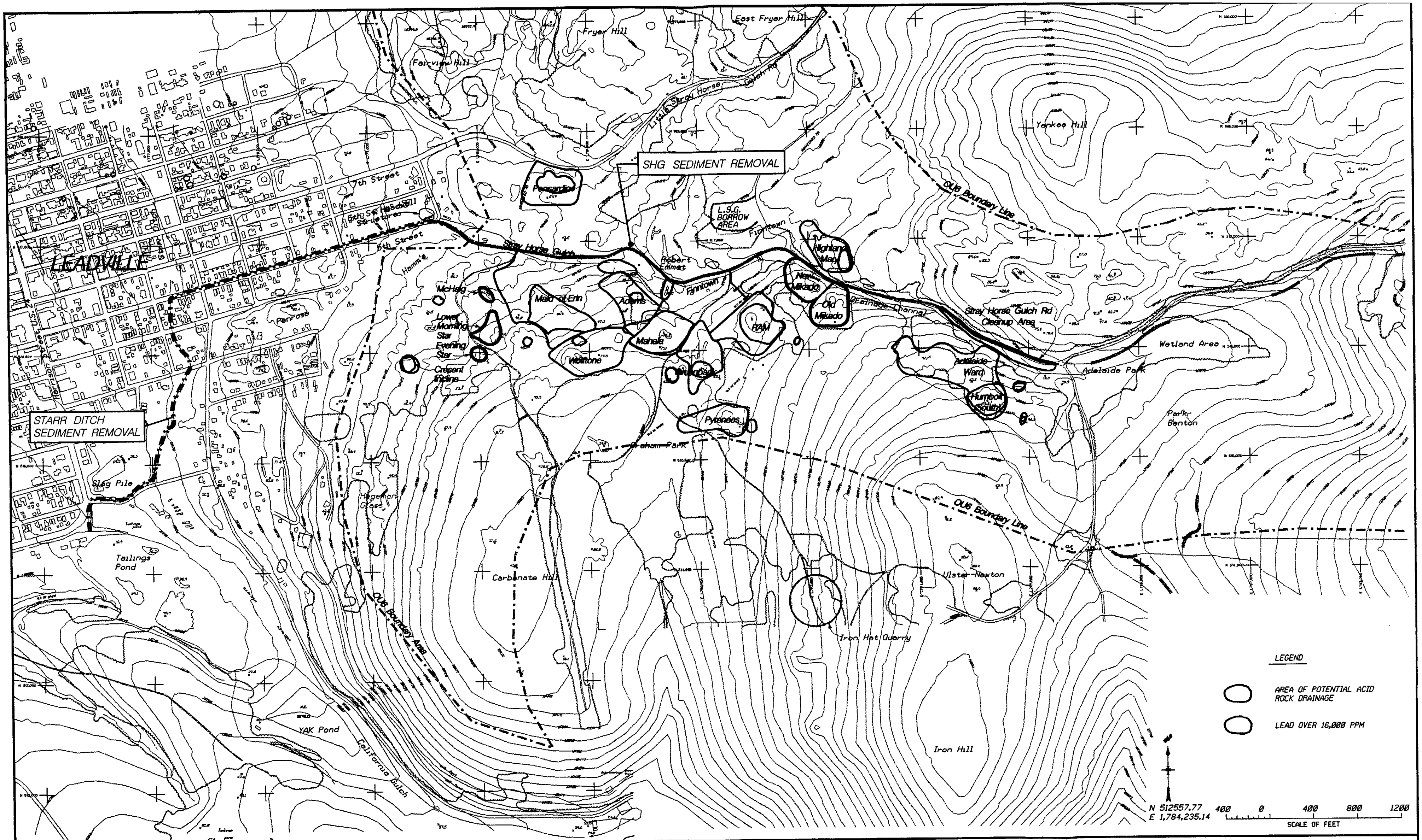
5.1.2 NCP CRITERIA

5.1.2.1 Effectiveness

Protectiveness — Alternative S1 would to a limited degree reduce heavy metals loading into Starr Ditch and California Gulch. However the true source of this contamination originates with the mine piles. This alternative does little to prevent the erosion of material into SHG from the piles. Further, it does not protect the public health during heavy rainfall events that carry contamination briskly through SHG. Alternative S1 could however be combined with one of the surface water control alternatives (presented in Section 6.0) that redirect the SHG waters to a treatment system (Alternative W4 or W5). This combination of alternatives would mitigate the

Color Map(s)

The following maps contain color that does not appear in the scanned images. To view the actual images please contact the Superfund Record Center at (303) 312-6473.



SEDIMENT REMOVAL
ALTERNATIVE S1

migration of heavy metals from SHG to Starr Ditch and California Gulch. Either by itself or in combination with any of the surface water control alternatives, Alternative S1 would not protect the public or the environment against direct contact with lead-contaminated materials. Selecting this alternative alone will not address all the ARARs for control of waste sources and contaminated environmental media.

Ability to Achieve Removal Objectives — Alternative S1 would meet neither the RAO of controlling erosion of contaminated materials into local water courses nor the RAO of controlling airborne transport of contaminated materials. If coupled with one of the treatment-oriented surface water control alternatives (W4 or W5) presented in Section 6.0, Alternative S1 could control, to a limited extent, the migration of metals from contaminated materials into surface water. Leaching and migration of metals into the groundwater would not be controlled by this alternative; however, as discussed in Section 2.6.4 most of the groundwater within the area targeted by this EE/CA (lower SHG watershed basin) is currently captured by the LMDT and treated at the LMDTTP. Alternative S1 does not achieve the RAO of controlling direct contact with and ingestion of contaminated materials. On the other hand, this alternative will not adversely impact the historic and cultural features of the OU that are considered a part of the NRHP and current tourism draw.

5.1.2.2 Implementability

Technical Feasibility — Implementing Alternative S1 does not present any technical feasibility issues.

Availability — The technology for excavating and/or dredging is well established and utilizes readily available equipment and materials. The labor force should be available locally.

Administrative Feasibility — This alternative may not be acceptable to State and Federal regulatory agencies with statutory responsibility for protection of human health and the environment.

5.1.2.3 Cost

Capital cost for Alternative S1 is estimated at $201,000; annual O&M cost is estimated at $56,600 per year; and the total net present worth is estimated at $850,000. These costs are shown in Table 5.1. A further breakdown of these cost estimates is presented in Appendix B.

The following general assumptions were made when conceptually designing this system for the purpose of estimating costs for Alternative S1. The spreadsheets provided in Appendix B show the materials and quantities assumed in developing the cost estimates.

- Sediments and fluvial tailings would be removed from SHG and Starr Ditch.
- Sediment would continue to be removed from the channels through Year 30.
- Surface water monitoring would be conducted on a yearly basis. A site evaluation inspection would be required every five years. The five-year inspection would require data collection which may include an AVIRIS fly over.

5.1.3 WAMP CRITERIA

5.1.3.1 Surface Erosion Stability

Alternative S1 will not ensure erosional stability of the existing mine piles. Remediated surfaces located within the 500-year floodplain will be designed for stability under 500-year, 24-hour and 2-hour storm events.

5.1.3.2 Slope Stability

There would be no improvement to the stability of mine waste piles. In particular, the current factor of safety under static conditions for the Mikados, the Maid of Erin, and the Humboldt are greater than 1 but less than 1.5 (Woodward-Clyde Consultants, 1994a). Existing surfaces would not be stable for the 100-year, 24-hour storm event, and heavy sediment loading of the stream

Table 5.1
CALIFORNIA GULCH NPL SITE
OPERABLE UNIT 6
Estimated Cost of Alternative S1:
Sediment Removal

A. CAPITAL COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Mobilization/Site Preparation	LS	1	$6,000	$6,000	1	$6,000
Sediment Removal	LS	1	$113,000	$113,000	1	$113,000
Sediment Removal Confirmation Sampling	LS	1	$10,000	$10,000	1	$10,000
Air Monitoring	LS	1	$5,000	$5,000	1	$5,000
Subtotal			$134,000	$134,000		$134,000
2. Indirect Costs						
Field Indirect (2%)				$2,680		$2,680
Supervision, Inspection, & Overhead (4%)				$5,360		$5,360
Contractor Profit (10%)				$13,400		$13,400
Contractor Bonds (5%)				$6,700		$6,700
Design (6%)				$8,040		$8,040
Resident Engineering (3%)				$4,020		$4,020
Contingency (20%)				$26,800		$26,800
TOTAL CAPITAL COSTS				$201,000		$201,000

B. O & M COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Stray Horse Gulch Sediment Removal	LS	1	$8,600	$8,600	2 thru 30	$98,676
SHG Sediment Load and Haul to Disposal Facility	LS	1	$9,600	$9,600	2 thru 30	$110,150
Starr Ditch Sediment Removal	LS	1	$1,100	$1,100	2 thru 30	$12,621
Starr Ditch Sediment Load and Haul to Disposal Facility	LS	1	$1,600	$1,600	2 thru 30	$18,358
5 Year Site Reviews	EA/YR	0.20	$78,000	$15,600	2 thru 30	$178,994
Surface Water Monitoring	LS	1	$4,200	$4,200	2 thru 30	$48,191
Subtotal			$103,100	$40,700		$466,992
2. Indirect Costs						
Supervision, Inspection, & Overhead (4%)				$1,628		$18,680
Contractor Bonds (5%)				$2,035		$23,350
Contractor Profit (10%)				$4,070		$46,699
Contingency (20%)				$8,140		$93,398
TOTAL O&M COSTS				$56,600		$649,100
TOTAL ALTERNATIVE COSTS						$850,000

LS - Lump Sum
EA - Each
YR - Year

SHG - Stray Horse Gulch

ROLLS1.XLS6/4/97

and widespread erosion may be expected. Widespread erosion may include stream channel blockages during high stream flow conditions and over bank flooding.

5.1.3.3 Flow Capacity and Stability

After removal of the sediments, the alternative selected from the surface water control alternatives in Section 6.0 would include at least the rehabilitation of SHG sized to properly convey the 100-year, 24-hour and 2-hour storm events. In addition, the reconstructed channel would be designed for stability under flows resulting from 500-year, 24-hour and 2-hour storm events.

5.1.3.4 Surface Water and Groundwater Loading Reduction

In the short-term, the quality of surface water should improve after sediment removal; however, to achieve this limited benefit, sediment would have to be removed from SHG on a continual and frequent basis due to the continual erosion and deposition of contaminated material originating from the mine waste piles. Further, heavy rainfall events that carry contamination through SHG would not have time to settle out total solids prior to leaving SHG basin. The actual net load reduction will be determined after the alternative is implemented and post-remediation sampling is conducted. The final remediation of OU6 will be discussed in the ROD.

Groundwater contamination would continue to be captured and removed at Reclamation's LMDTTP.

5.1.3.5 Terrestrial Ecosystem Exposure

Terrestrial ecosystems would not be restored or improved and risk to all species would remain unchanged.

5.1.3.6 Nonresidential Soils

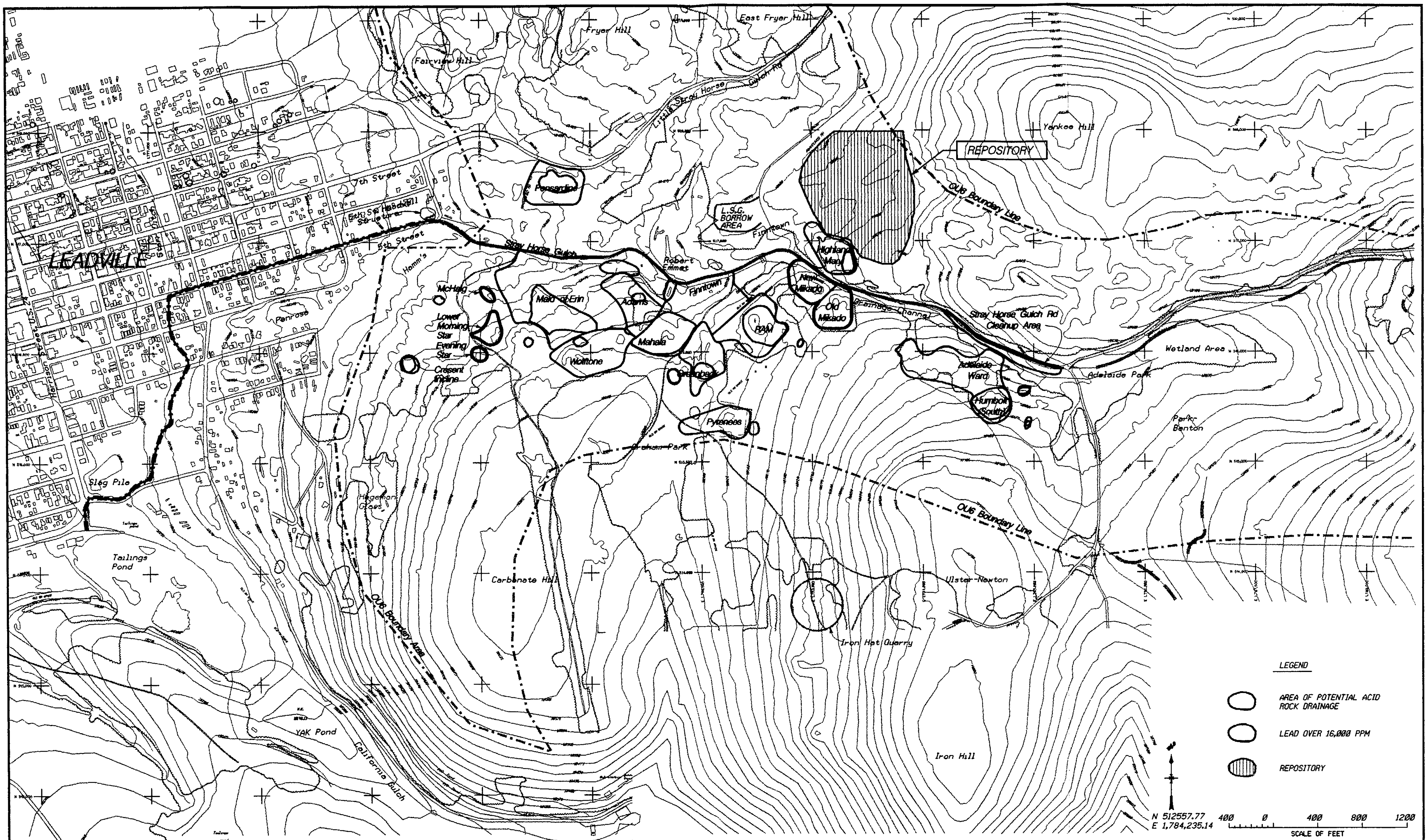
There would be no improvement in nonresidential soils in SHG. In some areas, surface soil Pb values exceed 16,000 mg/kg for recreational human health exposure. The area would continue to be a health hazard area and unsuitable for development or recreational use.

5.2 ALTERNATIVE S2 - CONSOLIDATION INTO SINGLE REPOSITORY WITH CAPPING

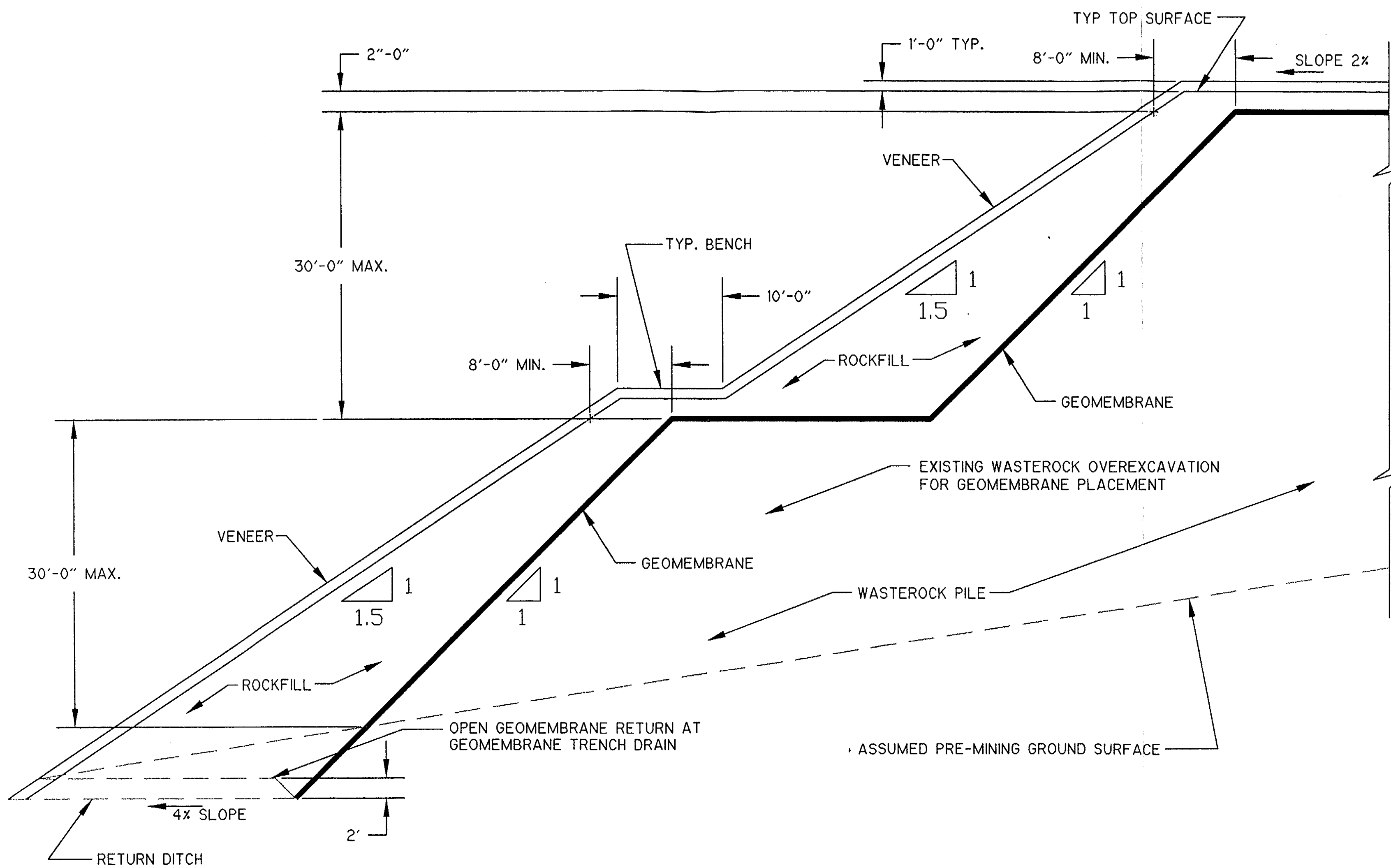
5.2.1 DESCRIPTION

Alternative S2 is depicted graphically in Figure 5.2. This alternative includes the construction of a single large repository in the SHG area which will contain the entire estimated 604,550 cubic yards of mine waste from the source areas identified in Section 3.6. The repository pile would be capped with an impervious geomembrane liner. To maintain the historic appearance in the region, the surface would be vegetated or covered with dolomite waste rock from the Sherman Mine source. The geomembrane would be underlain and overlain by a protective, cushioning layer of geotextile fabric. The geomembrane would also be covered by a layer of rock to protect the geomembrane and provide a more aesthetic appearance. The steeper pile slopes would be a maximum of 1½H:1V. Benches across the higher slopes would be required to control erosion of the pile cap. Assuming an average waste-pile thickness of 45 feet, the pile would require an area of about 10 acres. Drainage ditches would be constructed around the repository to control water run-on and runoff. The pile cap may need to be protected from damage by recreational users. A typical cross section illustrating the waste repository design is presented in Figure 5.3.

A potential location for a repository is north of SHG Road on the flank of Yankee Hill. It is not known at this time whether all land rights to the location can be obtained. However, this site has a large, existing gully that may provide the necessary space for the repository. The area north of the road contains glacial debris material. It is proposed that excavation of the glacial debris created for cover borrow material could be enlarged or deepened to minimize the aboveground size of the repository.



CONSOLIDATION INTO SINGLE REPOSITORY WITH CAPPING
ALTERNATIVE S2



CAP CROSS-SECTION

[redacted]

The cleanup removal activity of the source areas would be accomplished through conventional earthmoving techniques using existing roads, temporary haul roads, and SHG Road, depending on location. The waste rock would be removed to a variable depth based on an estimate of the pre-mining ground surface. The post-removal ground surface would be revegetated with indigenous species to the extent practicable. The mine waste to be moved and placed in the repository has been identified and divided into approximately 20 source removal areas based on remote spectral/geochemical sensing of mineral assemblages, ground-surface sampling, and laboratory analyses. Performance verification of the cleaned-up ground surface would be based on quality control testing, such as X-ray fluorescence testing and/or a hand held spectrometer.

Contaminated sediments and fluvial tailings from SHG and Starr Ditch would be removed and also placed in the single repository. This removal of sediments and tailings would precipitate the need to restructure sections of the SHG channel; thus, one of the surface water control alternatives presented in Section 6.0 may be required as an adjunct to the selection of this alternative as the Removal Action. Sediment cleanout may be required for the short-term as the watershed flushes out the remaining contaminants.

Surface water would continue to be monitored.

5.2.2 NCP CRITERIA

5.2.2.1 Effectiveness

Protectiveness — Alternative S2 would provide for isolation of the majority of the ARD source rock and the lead-contaminated materials. Some smaller and less mineralized source areas will be left in place. This alternative provides for protection of the environment by capping mine wastes in a single repository and controlling run-on and runoff. Contaminated sediments in SHG would also be excavated and capped in the repository. Isolating the contaminated materials that come in contact with the surface water will minimize the degradation of the surface water. In addition, the impervious layer used to cap the materials will be designed to reduce the quantity of infiltration through the contaminated material. Alternative S2 would further protect the public and the environment by eliminating direct contact with lead-contaminated materials.

This alternative addresses the vast majority of the SHG watershed basin identified as source areas in Section 2.x. Capping is not a treatment alternative and does not reduce the toxicity or volume of the waste, but will serve to reduce the mobility of the heavy-metal contaminants by preventing their contact with surface water and precipitation. The effectiveness of this alternative could of course be undermined by overlooked source areas not identified as having lead contamination and/or ARD potential. Nonetheless, this alternative is anticipated to show a quantifiable improvement in the quality of the SHG surface water. A monitoring program will ultimately determine whether this improvement is sufficient to meet as-of-yet unestablished target surface water quality levels.

During implementation of Alternative S2, some short-term risks to workers and the community could occur, particularly during consolidation of the piles using heavy equipment (dozers, scrapers, etc.). Workers would be protected by adhering to the personal protective equipment requirements addressed in the site-specific health and safety plan. Use of dust suppression techniques and air monitoring should control public exposures to airborne particulates.

Alternative S2 would comply with most ARARs with the possible exception of the NRHP requirements if any of the material or debris to be removed is being considered for inclusion on the NRHP listing.

Ability to Achieve Removal Objectives — Alternative S2 would meet the RAOs of controlling erosion of contaminated materials into local water courses and controlling airborne transport of contaminated materials. The RAOs of controlling leaching and migration of metals from contaminated materials into surface water and groundwater would also be achieved as well as the RAO of controlling direct contact with and ingestion of contaminated materials.

Consolidating the waste piles in a single repository does not achieve the specific RAO of maintaining and preserving historic and cultural features associated with past mining activities.

Historic waste piles and structures would be destroyed during construction and one large waste repository would obstruct the historic vistas relating to tourism interests.

5.2.2.2 Implementability

Technical Feasibility — Geomembranes are a reliable technology for covering waste piles. Care must be used in preparing the surface to be capped and laying down a protective covering so that heavy equipment does not damage the liner. The cap design specifies strict compaction criteria for the waste pile and the use of a protective geotextile fabric beneath the geomembrane liner as well as over the liner. For lining of surface impoundments or landfills, geomembrane seams are typically welded or glued. Seams can be a weak point in the integrity of the liner; however, for the waste pile capping proposed in this alternative, liner sheets will be overlapped and held in place by rock. This would eliminate the need for sealing the seams and provide a better overall surface for shedding precipitation and snowmelt off the repository. Institutional controls, such as signs or fencing, may be used to prevent recreational use of the repository and possible damage to the liner.

Availability — The technology for consolidating and capping tailings is well established and utilizes readily available equipment and materials. The labor force should be available locally but may need additional training in the installation of geomembrane liner materials.

Administrative Feasibility — This alternative will involve gaining admittance to many mining properties with multiple ownership. Site access problems and acquisition of land for the repository could cause serious delays to project start-up. Due to the NRHP eligibility of several of the mining locations, this alternative may not be administratively feasible.

This proposed alternative exceeds the statutory limits of $2 million for removal actions and would require approval of the USEPA Regional Administrator or the Division Director. Also, obtaining easements and right-of-way agreements, and acquiring land for the consolidated piles could affect the administrative feasibility and impact construction schedules.

5.2.2.3 Cost

Capital cost for Alternative S2 is estimated at $8,076,000; annual O&M cost is estimated at $54,900 per year; and the total net present worth is estimated at $8,574,000. These costs are shown in Table 5.2. A further breakdown of these cost estimates is presented in Appendix B.

The following general assumptions were made when conceptually designing this system for the purpose of estimating costs for Alternative S2. The spreadsheets provided in Appendix B show the materials and quantities assumed in developing the cost estimates.

- Existing large waste piles and wide-spread waste rock would be excavated down to the estimated pre-mining ground level where possible. Air monitoring and confirmation sampling would be conducted during excavation and consolidation. Confirmation sampling would include field X-ray fluorescence sampling and pH potential testing along a 100-foot grid with 10% of samples verified in a laboratory for quality control.
- A single large repository covering ten acres and containing approximately 605,000 cubic yards would be constructed and covered with a geomembrane cap (or its engineered equivalent) and a minimum of two feet of rock cover on the crest and benches (extending a minimum of eight feet laterally on the sloped surfaces) followed by a 1-foot veneer of white porphyry and dolomite.
- Excavated areas would be revegetated.
- Abandoned mine shafts would be capped.
- Sediments and fluvial tailings would be removed from SHG and Starr Ditch.
- Sediment would continue to be removed from the channels for an estimated three years as residual contamination is flushed out of the watershed basin.
- Cap repair and maintenance is estimated as a percent of installation costs.
- Surface water monitoring would be conducted on a yearly basis. A site evaluation inspection would be required every five years. The five-year inspection would require data collection which may include an AVIRIS fly over.

Table 5.2
CALIFORNIA GULCH NPL SITE
OPERABLE UNIT 6
Estimated Cost of Alternative S2:
Consolidation into Single Repository with Capping

A. CAPITAL COSTS						
1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Mobilization/Site Preparation	LS	1	$249,000	$249,000	1	$249,000
Strip Repository Area	LS	1	$15,000	$15,000	1	$15,000
Waste Rock Piles Excavation and Consolidation	LS	1	$3,325,000	$3,325,000	1	$3,325,000
Excavation Confirmation Sampling	LS	1	$50,000	$50,000	1	$50,000
Geomembrane (with Geotextile) installed	LS	1	$423,000	$423,000	1	$423,000
Rockfill Cap Material	LS	1	$697,000	$697,000	1	$697,000
White Porphyry/Dolomite Veneer	LS	1	$121,000	$121,000	1	$121,000
Hydromulch Revegetation	LS	1	$84,000	$84,000	1	$84,000
Perimeter Ditch around Repository	LS	1	$14,000	$14,000	1	$14,000
Cap Mine Shafts	LS	1	$198,000	$198,000	1	$198,000
Sediment Removal	LS	1	$113,000	$113,000	1	$113,000
Sediment Removal Confirmation Sampling	LS	1	$10,000	$10,000	1	$10,000
Dust Control	LS	1	$25,000	$25,000	1	$25,000
Air Monitoring	LS	1	$60,000	$60,000	1	$60,000
Subtotal			$5,384,000	$5,384,000		$5,384,000
2. Indirect Costs						
Field Indirect (2%)				$107,680		$107,680
Supervision, Inspection, & Overhead (4%)				$215,360		$215,360
Contractor Profit (10%)				$538,400		$538,400
Contractor Bonds (5%)				$269,200		$269,200
Design (6%)				$323,040		$323,040
Resident Engineering (3%)				$161,520		$161,520
Contingency (20%)				$1,076,800		$1,076,800
TOTAL CAPITAL COSTS				$8,076,000		$8,076,000
B. O & M COSTS						
1. Direct Costs						
Stray Horse Gulch Sediment Removal	LS	1	$4,300	$4,300	2 thru 4	$10,544
SHG Sediment Load and Haul to Disposal Facility	LS	1	$4,800	$4,800	2 thru 4	$11,770
Starr Ditch Sediment Removal	LS	1	$600	$600	2 thru 4	$1,471
Starr Ditch Sediment Load and Haul to Disposal Facility	LS	1	$800	$800	2 thru 4	$1,962
Cap Maintenance and Repair	LS	1	$7,200	$7,200	2 thru 30	$82,613
5 Year Site Reviews	EA/YR	0.20	$78,000	$15,600	2 thru 30	$178,994
Quarterly Inspection	EA	4	$500	$2,000	2 thru 30	$22,948
Surface Water Monitoring	LS	1	$4,200	$4,200	2 thru 30	$48,191
Subtotal			$100,400	$39,500		$358,492
2. Indirect Costs						
Supervision, Inspection, & Overhead (4%)				$1,580		$14,340
Contractor Bonds (5%)				$1,975		$17,925
Contractor Profit (10%)				$3,950		$35,849
Contingency (20%)				$7,900		$71,698
TOTAL O&M COSTS				$54,900		$498,300
TOTAL ALTERNATIVE COSTS						$8,574,000

LS - Lump Sum
EA - Each
YR - Year

SHG - Stray Horse Gulch

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5.2.3 WAMP CRITERIA

5.2.3.1 Surface Erosion Stability

Mine waste surfaces would be stabilized in lower SHG, including the majority of the mine waste and all of the large piles in this area. No slope stabilization improvements would be implemented above Adelaide Park. Many smaller waste piles would be left on the slopes visible from the central portion of Leadville. Surfaces in the remediated areas will be stable for precipitation and runoff flows up to a 100-year storm event. Remediated surfaces within the 500-year flood plain will be made stable under the 500-year storm event.

The "hot-spots" identified through the AVIRIS studies and ground surface sampling in the vicinity of residential areas will be removed to the repository. Some surface erosion by wind of fine-grained waste in the small piles on the slope overlooking Leadville would probably continue, however, these are generally below the clean-up action levels.

5.2.3.2 Slope Stability

The mine waste will be placed in an engineered waste repository designed to be stable with respect to both shallow and deep slope stability. Detailed analyses of the slope stability would be performed during the design process. This alternative would use a design factor of safety of 1.5. See Appendix D. Slopes in the removal areas would be recontoured to as close to the pre-mining configurations and slope stability configurations as practicable.

5.2.3.3 Flow Capacity and Stability

After removal of the sediments, the alternative selected from the surface water control alternatives in Section 6.0 would include at least the rehabilitation of SHG sized to properly convey the 100-year, 24-hour and 2-hour storm events. In addition, the reconstructed channel would be designed for stability under flows resulting from 500-year, 24-hour and 2-hour storm events.

5.2.3.4 Surface Water and Groundwater Loading Reduction

Removal of the wide-spread surface waste to a covered repository will isolate most of the metal-contaminated material from the precipitation and runoff system. This alternative is anticipated to show a quantifiable improvement in the quality of the SHG surface water especially over the long-term. The actual net load reduction will be determined after the alternative is implemented and post-remediation sampling is conducted. The cap will use an impervious layer designed to reduce the quantity of infiltration through the contaminated material. In addition, groundwater in the immediate SHG watershed area will continue to be captured and removed at Reclamation's LMDTTP. The final remediation of OU6 will be discussed in the ROD.

5.2.3.5 Terrestrial Ecosystem Exposure

Removal of the wide-spread surface waste to a covered repository will isolate most of the ARD and lead-contaminated waste from the terrestrial species in the area. Substantial reduction of risk to the terrestrial ecosystem should be realized, and will improve with the growth of vegetation in some of the remediated historic habitat areas.

5.2.3.6 Nonresidential Soils

The majority of the heavy-metals contaminated soils and rock in the nonresidential areas of the project will be removed to the covered waste repository. Particularly, this alternative would remove areas of nonresidential soils and waste rock exceeding 16,000-mg/kg lead that pose risk to recreational users in the immediate vicinity of the City of Leadville and in the lower SHG watershed basin. Ecological risk in the nonresidential areas would be substantially reduced.

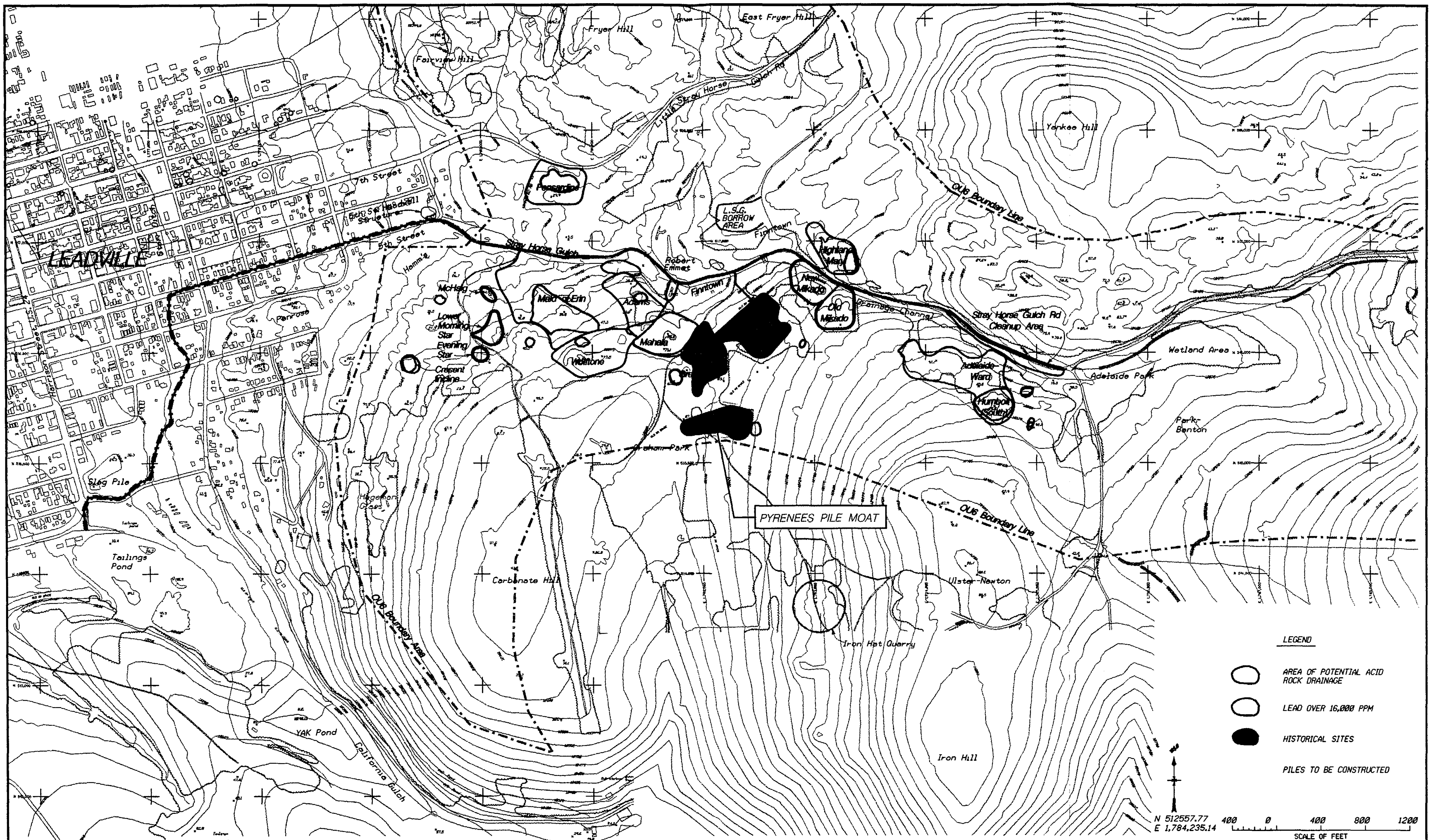
5.3 ALTERNATIVE S3 - CONSOLIDATION INTO MULTIPLE PILES WITH CAPPING

5.3.1 DESCRIPTION

Similar to Alternative S2, this alternative will mitigate the mine waste from the source areas identified in Section 3.6; except instead of creating a single repository, Alternative S3, would consolidate and/or isolate the mine waste into several piles as shown in Figure 5.4. This consolidation would permit the placement of a capping material over the waste to control direct contact with the contaminated material, minimize infiltration of rainwater and snowmelt, reduce leaching of the heavy metals, and improve the quality of surface-water runoff. Most of the mine waste will be consolidated into seven piles with a geomembrane cap to mitigate runoff contamination.

The remediation of the remaining piles which have substantial historic, cultural, and visual significance will more carefully address preservation of appearance, configuration, and coloration of the piles, and preservation or restoration of historic structures such as crib walls, buildings, and mine head frames. Innovative technology may be used to preserve the cultural aspects of the these piles. This alternative would be designed to minimize the impact on the historic mining vistas as seen from the roadway.

The mine waste to be moved and placed in the selected piles has been identified based on remote spectral/geochemical sensing of mineral assemblages, ground surface sampling, and laboratory analyses as discussed in Section 2.7.5. The larger existing mine waste piles within each area would be used as the final waste piles in order to minimize the amount of waste to be moved and the haul distance. The cleanup removal activity of the source areas would be accomplished through conventional earthmoving techniques using existing roads, temporary haul roads, and SHG Road, depending on location of the source areas. The waste rock would be removed to a variable depth based on an estimate of the pre-mining ground surface. Approval of the cleaned-up ground surface would be based on quality-control testing, such as X-ray fluorescence testing and/or a hand-held spectrometer.



CONSOLIDATION INTO MULTIPLE PILES WITH CAPPING
ALTERNATIVE S3

Approximately 325,500 cubic yards would be excavated from the areas identified in Figure 3.2 and consolidated onto the remaining following seven piles:

Maid of Erin
Wolftone
Adelaide-Ward
Mikados
Mahala
Highland Mary
Ponsardine.

The volume of mine waste already existing within each consolidated pile area has an estimated volume totaling 279,050 cubic yards (including the three piles discussed below). This work will involve partial reconstruction of some piles previously reduced by reprocessing activities; consolidation of waste; capping of the consolidated waste with geomembranes; and covering the membrane with an aesthetic rock face. The waste material will be placed and compacted into piles simulating the original heaps. The piles will be built in stages and the side slopes will be blanketed by geomembrane material as the pile goes up. Successive horizontal layers will be added with each side slope covering membrane placed to overlap the previous membrane strip. As the pile is constructed vertically and the membrane is placed, the side slope will be covered and structurally buttressed by rock fill that will provide protection and aesthetic appearance. The geomembrane liner used would include a protective, cushioning layer of geotextile fabric on both faces of the membrane. The geomembrane liner would be covered by a layer of rock, either dolomite from the Sherman Mine or another local rock type, to protect the geomembrane liner. A veneer of white porphyry and white porphyry mixed with dolomite would be placed on the surface to provide a more aesthetic appearance.

Most of the above work would be implemented in the 1997 work season with the remainder of the work to be completed during the 1998 work season.

The following piles will be treated differently than those described above:

Pyrenees
Greenback
RAM

The treatment of these piles will more carefully address preservation of appearance, configuration, and coloration of the piles; and preservation or restoration of historic structures such as crib walls, buildings, and mine head frames. Innovative technologies and design would be considered for the preservation of the cultural aspects of these three piles.

Preservation may include a chemical stabilization agent to mitigate acid production and metals leaching; containment of surface water runoff on a site-by-site basis with a "moat"; removing the rock faces of the piles with placement of a cover or soil cement and replacement of the face material; consolidation of waste materials behind the piles, with capping of the backside of the piles only; covering of the piles with limerock; or grading of the piles and capping of the entire piles.

As a pilot test, it is proposed that during the summer 1997 work season a surface-water containment moat or ditch would be constructed around the base of the Pyrenees waste pile. This moat would serve to detain and isolate surface waters which contact the Pyrenees pile. It is anticipated that the impounded water will be reduced in volume through evaporation and direct infiltration into the subsurface rock mass. Lime rock lining may be used to buffer low pH runoff captured within the moat. According to the hydrogeology of the area discussed in Section 2.6.4, water infiltrating into the subsurface in this area would be eventually intercepted by the LMDT and receive treatment at Reclamation's existing LMDTTP. Removal of sediments that have eroded from the pile may require removal on at least an annual basis as well as the replacement of lime rock. The sediments would be placed at a designated disposal site such as the Hecla tailings impoundment at OU2. If this method proves effective, it may be used in the following work season for the Greenback and RAM piles.

In addition, treatability studies have been conducted solidifying/stabilizing samples from the RAM and the Pyrenees mine waste piles using four types of additives: cement, cement/flyash, proprietary additive "KB", and proprietary additive "TB". Preliminary results of these treatability studies indicate that adding 25% cement by mass of dry waste met the requirements for the Toxic Characteristic Leaching Procedure (TCLP), compressive strength, wetting-drying durability, and freezing-thawing durability. These preliminary results are discussed in more detail in Appendix C. This cement/waste mixture can also be made to resemble the original colors of the piles.

Also, after monitoring runoff following the summer 1997 work, an evaluation will be conducted to determine if remediation of these three piles is still necessary to meet the RAOs for OU6 and the California Gulch Site as a whole.

Contaminated material from SHG and Starr Ditch would be removed and placed in one of the capped piles or at a designated disposal site such as the Hecla tailings impoundment. The subsequent rehabilitation of the SHG channel would be determined by the selection of one of the surface water control alternatives analyzed in Section 6.0. Sediment cleanout may be required for the short-term as the watershed flushes out the remaining contaminants.

Surface water would continue to be monitored.

5.3.2 NCP CRITERIA

5.3.2.1 Effectiveness

Protectiveness — Alternative S3 would provide for isolation of the majority of the ARD source rock and the lead-contaminated materials. Some smaller and less mineralized source areas will be left in place. This alternative provides for protection of the environment by capping mine wastes in multiple piles and controlling run-on and runoff. Contaminated sediments in SHG would also be excavated and capped in one or more of the piles. Isolating the contaminated materials that come in contact with the surface water will minimize the degradation of the surface water. In addition, the impervious layer used to cap the materials will be designed to reduce the quantity of infiltration through the contaminated material. Alternative S3 would further protect the public and the environment by eliminating direct contact with lead-contaminated materials.

The Pyrenees pile would be handled differently. In lieu of a cap, the pile would maintain its historic appearance through the construction of a moat around the base of the pile to collect contaminated runoff, which would be lost by infiltration to groundwater and evaporation. Surface soils exceeding the action levels set for lead will be either covered or public access will be limited.

The two remaining piles (RAM and Greenback), which have the historic and cultural significance, would be reshaped during the second year and capped in a manner that would preserve their original appearance. The piles may be stabilized using soil-cement solidification recently evaluated in treatability studies (see Appendix C). Depending on the results of the construction at the Pyrenees pile, moats or other technologies may be proposed around these historic piles as well rather than the use of a cap.

This alternative addresses the vast majority of the SHG watershed basin identified as source areas in Section 2.7. Capping is not a treatment alternative and does not reduce the toxicity or volume of the waste, but will serve to reduce the mobility of the heavy-metal contaminants by preventing their contact with surface water and precipitation. The effectiveness of this alternative could of course be undermined by overlooked source areas not identified as having lead contamination and/or ARD potential. Nonetheless, this alternative is anticipated to show a quantifiable improvement in the quality of the SHG surface water. A monitoring program will ultimately determine whether this improvement is sufficient to meet as-of-yet unestablished target surface water quality levels.

The option of installing moats around the Pyrenees pile and possibly the RAM and Greenback piles would require institutional controls to prevent human contact with ARD water and localized lead-contaminated locations, if any.

During implementation of Alternative S3, some short-term risks to workers and the community could occur, particularly during consolidation of the piles using heavy equipment (dozers, scrapers, etc.). Workers would be protected by adhering to the personal protective equipment requirements addressed in the site-specific health and safety plan. Use of dust suppression techniques and air monitoring should control public exposures to airborne particulates.

Alternative S3 would comply with most ARARs including NRHP requirements. Because there is no direct treatment of the surface water, this alternative will only meet ARARs if it effectively controls the migration of contaminants from the source areas.

Ability to Achieve Removal Objectives — Alternative S3 would meet the RAOs of controlling erosion of contaminated materials into local water courses and controlling airborne transport of contaminated materials. The RAOs of controlling leaching and migration of metals from contaminated materials into surface water and groundwater would also be achieved as well as the RAO of controlling direct contact with and ingestion of contaminated materials. Consolidating the waste piles in multiple piles also addresses the RAO of maintaining and preserving historic and cultural features of OU6 consistent with the NRHP and current tourism draw. Historic waste piles and structures would be preserved to the extent possible during construction. Consolidating wastes in multiple piles should not obstruct the historic vistas that are important to Lake County citizens and tourists.

5.3.2.2 Implementability

Technical Feasibility — Geomembranes are a reliable technology for lining impoundments and covering waste piles. Care must be used in preparing the surface to be capped and laying down a protective covering so that heavy equipment does not damage the liner. The cap design specifies strict compaction criteria for the waste pile and the use of a protective geotextile fabric beneath the geomembrane liner as well as over the liner. For lining of surface impoundments or landfills, geomembrane seams are typically welded or glued. Seams can be a weak point in the integrity of the liner; however, for the waste pile capping proposed in this alternative, liner sheets will be overlapped and held in place by rock. This would eliminate the need for sealing the seams and provide a better overall surface for shedding precipitation and snowmelt.

Preliminary results of the solidification/stabilization treatability study (see Appendix C) indicate that solidification using 25% cement is a viable alternative for the historic mine waste piles.

Institutional controls, such as signs or fencing, may be required to prevent public access to standing surface water in moats or recreational use of capped waste piles and possible damage to the capping material.

Availability — The technology for consolidating and capping tailings is well established and utilizes readily available equipment and materials. The labor force should be available locally but may need additional training in the installation of capping materials. The solidification test methods summarized in Appendix C use materials that are commercially available.

Administrative Feasibility — Alternative S3 will involve gaining site access at many mining properties with multiple ownership. Problems with site access and land acquisition could cause some delays to project start-up. This alternative would preserve the historic and cultural features of the area and may elicit the approval and cooperation of Lake County officials and concerned citizens.

Climatic conditions above 10,000 feet at Leadville provide only a short construction season, hence this alternative would be implemented over two years and would exceed the one-year time frame for removal actions.

This proposed alternative exceeds the statutory limits of $2 million for removal actions and would require approval of the USEPA Regional Administrator or the Division Director. Also, obtaining easements and right-of-way agreements, and acquiring land for the consolidated piles could affect the administrative feasibility and impact construction schedules.

5.3.2.3 Cost

Capital cost for Alternative S3 is estimated at $7,189,000; annual O&M cost is estimated at $63,500 per year; and the total net present worth is estimated at $7,786,000. These costs are shown in Table 5.3. A further breakdown of these cost estimates is presented in Appendix B.

The following general assumptions were made when conceptually designing this system for the purpose of estimating costs for Alternative S3. The spreadsheets provided in Appendix B show the materials and quantities assumed in developing the cost estimates.

- An estimated 325,000 cubic yards of wide-spread waste rock would be excavated down to the estimated pre-mining ground level where possible and consolidated into seven selected waste piles for capping. Air monitoring and confirmation sampling would be conducted during excavation and consolidation. Confirmation sampling would include field X-ray fluorescence sampling and pH potential testing along a 100-foot grid with 10% of samples verified in a laboratory for quality control.
- Capped waste piles would be shaped to simulate the general configurations and appearance of the original piles. The piles would be covered with a geomembrane/geotextile cap (or its engineered equivalent) and a minimum of two feet of rock cover on the crest and benches (extending a minimum of eight feet laterally on the sloped surfaces) followed by a 1-foot veneer of white porphyry and dolomite.
- Cribbing, particularly at the Maid of Erin pile, would be preserved and/or reconstructed.
- A moat would be constructed at the Pyrenees pile.
- As stated in Section 5.3.1, there are several approaches that would be considered for remediating the RAM and Greenback piles. For the purpose of this cost estimate, it is assumed that the outer face of these piles (approximately three feet) would be cut and mixed with a solidifying agent. The mixture would then be reapplied to the piles. This work would be conducted during the second construction season.
- Excavated areas would be revegetated.
- Approximately 36 abandoned mine shafts would be capped
- Sediments and fluvial tailings would be removed from SHG and Starr Ditch.
- Sediment would continue to be removed from the channels for an estimated three years as residual contamination is flushed out of the watershed basin.

Table 5.3
CALIFORNIA GULCH NPL SITE
OPERABLE UNIT 6
Estimated Cost of Alternative S3:
Consolidation into Multiple Piles with Capping

A. CAPITAL COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Mobilization/Site Preparation	LS	1	$226,000	$226,000	1	$226,000
Waste Rock Piles Excavation and Consolidation	LS	1	$1,253,000	$1,253,000	1	$1,253,000
Excavation Confirmation Sampling	LS	1	$35,000	$35,000	1	$35,000
Geomembrane (with Geotextile) installed	LS	1	$728,000	$728,000	1	$728,000
Rockfill Cap Material	LS	1	$1,201,000	$1,201,000	1	$1,201,000
White Porphyry/Dolomite Veneer	LS	1	$209,000	$209,000	1	$209,000
Hydromulch Revegetation	LS	1	$35,000	$35,000	1	$35,000
Perimeter Ditch around Waste Rock Piles	LS	1	$32,000	$32,000	1	$32,000
Reconstruction of Cribbing	LS	1	$134,000	$134,000	1	$134,000
Moat Construction at Pyrenees	LS	1	$18,000	$18,000	1	$18,000
Cap Mine Shafts	LS	1	$198,000	$198,000	1	$198,000
Sediment Removal	LS	1	$113,000	$113,000	1	$113,000
Sediment Removal Confirmation Sampling	LS	1	$10,000	$10,000	1	$10,000
Solidification/Stabilization Treatment Study	LS	1	$65,000	$65,000	1	$65,000
Solidification of Historic Waste Rock Piles (Greenback/RAM)	LS	1	$533,000	$533,000	2	$465,522
Dust Control	LS	1	$25,000	$25,000	1	$25,000
Air Monitoring	LS	1	$45,000	$45,000	1	$45,000
Subtotal			$4,860,000	$4,860,000		$4,792,522
2. Indirect Costs						
Field Indirect (2%)				$97,200		$95,850
Supervision, Inspection, & Overhead (4%)				$194,400		$191,701
Contractor Profit (10%)				$486,000		$479,252
Contractor Bonds (5%)				$243,000		$239,626
Design (6%)				$291,600		$287,551
Resident Engineering (3%)				$145,800		$143,776
Contingency (20%)				$972,000		$958,504
TOTAL CAPITAL COSTS				$7,290,000		$7,189,000

B. O & M COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Stray Horse Gulch Sediment Removal	LS	1	$4,300	$4,300	2 thru 4	$10,544
SHG Sediment Load and Haul to Disposal Facility	LS	1	$4,800	$4,800	2 thru 4	$11,770
Starr Ditch Sediment Removal	LS	1	$600	$600	2 thru 4	$1,471
Starr Ditch Sediment Load and Haul to Disposal Facility	LS	1	$800	$800	2 thru 4	$1,962
Cap Maintenance and Repair	LS	1	$13,400	$13,400	2 thru 30	$153,752
5 Year Site Reviews	EA/YR	0.20	$78,000	$15,600	2 thru 30	$178,994
Quarterly Inspection	EA	4	$500	$2,000	2 thru 30	$22,948
Surface Water Monitoring	LS	1	$4,200	$4,200	2 thru 30	$48,191
Subtotal			$106,600	$45,700		$429,631
2. Indirect Costs						
Supervision, Inspection, & Overhead (4%)				$1,828		$17,185
Contractor Bonds (5%)				$2,285		$21,482
Contractor Profit (10%)				$4,570		$42,963
Contingency (20%)				$9,140		$85,926
TOTAL O&M COSTS				$63,500		$597,200
TOTAL ALTERNATIVE COSTS						$7,786,000

LS - Lump Sum SHG - Stray Horse Gulch
EA - Each
YR - Year

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- Cap repair and maintenance is estimated as a percent of installation costs.
- Surface water monitoring would be conducted on a yearly basis. A site evaluation inspection would be required every five years. The five-year inspection would require data collection which may include an AVIRIS fly over.

5.3.3 WAMP CRITERIA

5.3.3.1 Surface Erosion Stability

Mine waste surfaces would be stabilized in lower SHG, including the majority of the mine waste and all of the large piles in this area. No slope stabilization improvements would be implemented above Adelaide Park. Many smaller waste piles would be left on the slopes visible from the central portion of Leadville.

Surfaces in the remediated areas will be stable for precipitation and runoff flows up to a 100-year storm event. Remediated surfaces within the 500-year flood plain will be designed for stability under the 500-year storm event. If moats are used to capture runoff from historic waste piles, rather than reshaping and capping these piles, the surfaces would be susceptible to erosion.

The "hot-spots" identified through the AVIRIS studies and ground surface sampling in the vicinity of residential areas will be removed to the contained waste piles. Some surface erosion by wind of fine-grained waste in the small piles on the slope overlooking Leadville would probably continue, however, these are generally below the clean-up action levels.

5.3.3.2 Slope Stability

The mine waste will be placed in multiple engineered waste piles designed to be stable with respect to both shallow and deep slope stability. Detailed analyses of the slope stability would be performed during the design process. This alternative would use a design factor of safety of 1.5. See Appendix D. Slopes in the removal areas would be recontoured to as close to the pre-mining configurations and slope stability configurations as practicable. Again, if moats are used to capture runoff from historic waste piles, rather than reshaping and capping these piles, the existing slopes are marginally stable and would require longterm monitoring.

5.3.3.3 Flow Capacity and Stability

After removal of the sediments, the alternative selected from the surface water control alternatives in Section 6.0 would include at least the rehabilitation of SHG sized to properly convey the 100-year, 24-hour and 2-hour storm events. In addition, the reconstructed channel would be designed for stability under flows resulting from 500-year, 24-hour and 2-hour storm events.

5.3.3.4 Surface Water and Groundwater Loading Reduction

Removal and consolidation of the wide-spread surface waste into multiple engineered and covered waste repositories will isolate most of the metal-contaminated material from the precipitation and runoff system. This alternative is anticipated to show a quantifiable improvement in the quality of the SHG surface water especially over the long-term. The actual net load reduction will be determined after the alternative is implemented and post-remediation sampling is conducted. The cap design will include an impervious layer designed to reduce the quantity of infiltration through the contaminated material. In addition, groundwater in the immediate SHG watershed area will continue to be captured and removed at Reclamation's LMDTTP. The final remediation of OU6 will be discussed in the ROD.

5.3.3.5 Terrestrial Ecosystem Exposure

Removal of the wide-spread surface waste into covered repositories will isolate most of the ARD and lead-contaminated waste from the terrestrial species in the area. Substantial reduction of risk to the terrestrial ecosystem should be realized, and will improve with the growth of vegetation in some of the remediated historic habitat areas.

5.3.3.6 Nonresidential Soils

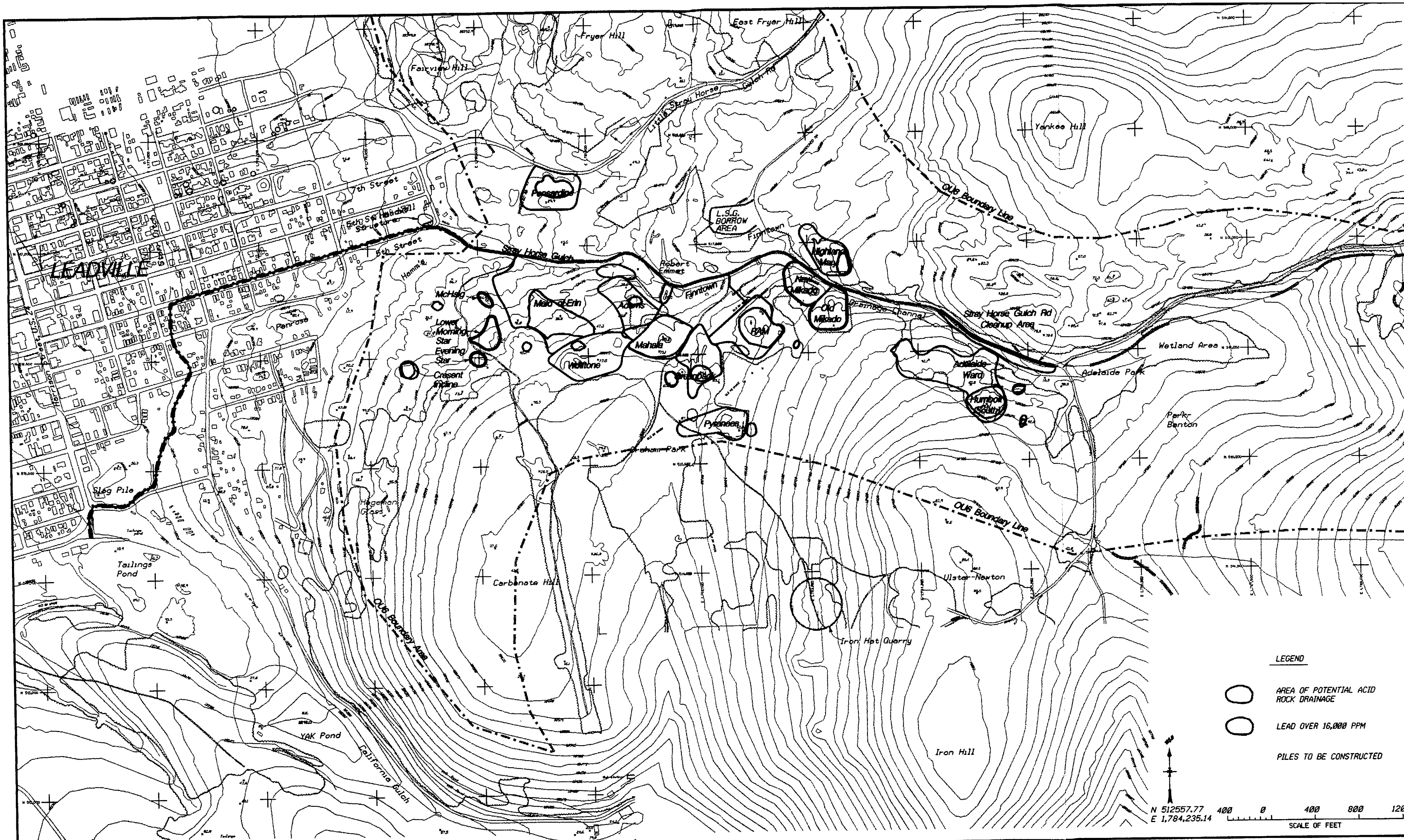
The majority of the heavy-metals contaminated soils and rock in the nonresidential areas of the project will be removed to the covered waste repositories. Particularly, this alternative would remove areas of nonresidential soils and waste rock exceeding 16,000-mg/kg lead that pose risk to recreational users in the immediate vicinity of the City of Leadville and in the lower SHG watershed basin. Ecological risk in the nonresidential areas would be substantially reduced.

5.4 ALTERNATIVE S4 - CONSOLIDATION INTO MULTIPLE PILES WITH SOLIDIFICATION

5.4.1 DESCRIPTION

This alternative is essentially identical to Alternative S3 with the difference being the method of capping the mine waste piles. In lieu of the geomembrane cap used in Alternative S3, Alternative 4 would employ the use of a solidification and/or stabilization agent to minimize infiltration and/or runoff contact with the mine waste. Alternative S4, would consolidate and/or isolate the mine waste into several piles as shown in Figure 5.5. This consolidation would permit the reduction of contamination and facilitate the pugmill mixing of a solidification/stabilization material with the top 3 to 5 feet of the compacted waste piles. The consolidation and treatment of the locations which have substantial historic, cultural, and visual significance would carefully address preservation of appearance, configuration, and coloration of the piles and preservation or restoration of historic structures such as crib walls, buildings, and mine head frames. As in Alternative S3, this alternative would be designed to minimize the impact on the historic mining vistas as seen from the roadway.

The mine waste to be moved and placed in the selected piles has been identified based on remote spectral/geochemical sensing of mineral assemblages, ground surface sampling, and laboratory analyses as discussed in Section 2.7.5. The larger existing mine waste piles within each area would be used as the final waste piles in order to minimize the amount of waste to be moved and the haul distance. The cleanup removal activity of the source areas would be accomplished



CONSOLIDATION INTO MULTIPLE PILES WITH SOLIDIFICATION
ALTERNATIVE S4

through conventional earthmoving techniques using existing roads, temporary haul roads, and SHG Road, depending on location of the source areas. The waste rock would be removed to a variable depth based on an estimate of the pre-mining ground surface. Approval of the cleaned-up ground surface would be based on quality-control testing, such as X-ray fluorescence testing and/or a hand-held spectrometer.

Approximately 325,500 cubic yards would be excavated from the areas identified in Figure 3.2 and consolidated onto the remaining following piles:

Maid of Erin
Wolftone
Adelaide-Ward
Mikados
Mahala
Highland Mary
Ponsardine.

No excavation or consolidation would occur at the following piles:

Pyrenees
RAM
Greenback.

The volume of mine waste already existing within each consolidated pile area has an estimated volume totaling 279,050 cubic yards.

This alternative would involve solidification/stabilization of the piles and site areas with reduced impact to their appearance and historic features. Treatability studies have been conducted solidifying/stabilizing samples from the RAM and the Pyrenees mine waste piles using four types of additives: cement, cement/flyash, proprietary additive "KB", and proprietary additive "TB". Preliminary results of these treatability studies indicate that adding 25% cement by mass of dry waste met the requirements for the TCLP, compressive strength, wetting-drying durability, and freezing-thawing durability. These preliminary results are discussed in more detail in Appendix C. This cement/waste mixture can also be made to resemble the original colors of the piles.

Most of the above work would be implemented in the 1997 work season with the remainder of the work to be completed during the 1998 work season.

The treatment of the Pyrenees, Greenback, and RAM piles would carefully address preservation of appearance, configuration, and coloration of the piles and preservation or restoration of historic structures such as crib walls, buildings, and mine head frames. This application may use innovative techniques and possibly new technology to preserve the cultural aspects of the sites and piles. This work would commence during the summer 1998 work season.

Contaminated material from SHG and Starr Ditch would be removed and placed in one of the capped piles or at a designated disposal site such as the Hecla tailings impoundment. The subsequent rehabilitation of the SHG channel would be determined by the selection of one of the surface water control alternatives analyzed in Section 6.0. Sediment cleanout may be required for the short-term as the watershed flushes out the remaining contaminants.

Surface water would continue to be monitored.

5.4.2 NCP CRITERIA

5.4.2.1 Effectiveness

Protectiveness — Alternative S4 would provide for isolation of the majority of the ARD source rock and the lead-contaminated materials by encapsulating contaminants, including nonresidential soils with high lead concentrations, in the upper 3 to 5 feet of the waste piles. Isolating the contaminated materials that come in contact with the surface water will minimize the degradation of the surface water. In addition, the impervious material used to solidify the contaminated materials will be designed to reduce the quantity of infiltration through the contaminated material. Results of the treatability studies for compressive strength and durability are given in Appendix C. Alternative S4 would further protect the public and the environment by eliminating direct contact with lead-contaminated materials.

This alternative addresses the vast majority of the SHG watershed basin identified as source areas in Section 2.7. Alternative S4 reduces the toxicity of the waste solidified in the upper three to five feet of the waste pile and reduces the mobility of the heavy-metal contaminants throughout the pile by preventing their contact with surface water and precipitation. The effectiveness of this alternative could of course be slightly undermined by smaller and less mineralized source areas left in place after completion of the removal action. Nonetheless, this alternative is anticipated to show a quantifiable improvement in the quality of the SHG surface water. A monitoring program will ultimately determine whether this improvement is sufficient to meet as-of-yet unestablished target surface water quality levels.

During implementation of Alternative S4, some short-term risks to workers and the community could occur, particularly during consolidation of the piles using heavy equipment (dozers, scrapers, etc.). Workers would be protected by adhering to the personal protective equipment requirements addressed in the site-specific health and safety plan. Use of dust suppression techniques and air monitoring should control public exposures to airborne particulates.

Alternative S4 would comply with most ARARs including NRHP requirements. Because there is no direct treatment of the surface water, this alternative will only meet ARARs if it effectively controls the migration of contaminants from the source areas.

Ability to Achieve Removal Objectives — Alternative S4 would meet the RAOs of controlling erosion of contaminated materials into local water courses and controlling airborne transport of contaminated materials. The RAOs of controlling leaching and migration of metals from contaminated materials into surface water and groundwater would also be achieved as well as the RAO of controlling direct contact with and ingestion of contaminated materials. Consolidating the waste piles in multiple piles also addresses the RAO of maintaining and preserving historic and cultural features of OU6 consistent with the NRHP and current tourism draw. Historic waste piles and structures would be preserved to the extent possible during construction. Consolidating wastes in multiple piles should not obstruct the historic vistas that are important to Lake County citizens and tourists.

5.4.2.2 Implementability

Technical Feasibility — Preliminary results of the solidification/stabilization treatability study (see Appendix C) indicate that solidification using 25% cement is a viable alternative for the historic mine waste piles.

Availability — Consolidation of source areas would be accomplished using conventional earth moving methods and equipment that are readily available in the Leadville area. The technology for capping tailings with solidification/stabilization agents may require importing specialized equipment from off-site. The solidification test methods summarized in Appendix C use materials that are commercially available. The labor force should be available locally although additional training may be necessary in solidification/stabilization techniques.

Administrative Feasibility — Alternative S4 will involve gaining site access at many mining properties with multiple ownership. Problems with site access and land acquisition could cause some delays to project start-up. This alternative would preserve the historic and cultural features of the area and may elicit the approval and cooperation of Lake County officials and concerned citizens.

Climatic conditions above 10,000 feet at Leadville provide only a short construction season, hence this alternative would be implemented over two years and would exceed the one-year time frame for removal actions.

This proposed alternative exceeds the statutory limits of $2 million for removal actions and would require approval of the USEPA Regional Administrator or the Division Director. Also, obtaining easements and right-of-way agreements, and acquiring land for the consolidated piles could affect the administrative feasibility and impact construction schedules.

5.4.2.3 Cost

Capital cost for Alternative S4 is estimated at \$9,887,000; annual O&M cost is estimated at \$58,400 per year; and the total net present worth is estimated at \$10,425,000. These costs are shown in Table 5.4. A further breakdown of these cost estimates is presented in Appendix B.

The following general assumptions were made when conceptually designing this system for the purpose of estimating costs for Alternative S4. The spreadsheets provided in Appendix B show the materials and quantities assumed in developing the cost estimates.

- An estimated 325,000 cubic yards of wide-spread waste rock would be excavated down to the estimated pre-mining ground level where possible and consolidated into seven selected waste piles for solidification. Air monitoring and confirmation sampling would be conducted during excavation and consolidation. Confirmation sampling would include field X-ray fluorescence sampling and pH potential testing along a 100-foot grid with 10% of samples verified in a laboratory for quality control.

- The waste piles would be shaped to simulate the general configurations and appearance of the original piles. Prior to placement, the outer three feet of the piles would be mixed with a solidifying agent. The mixture would then be applied to the piles.

- Cribbing, particularly at the Maid of Erin pile, would be preserved and/or reconstructed.

- The outer face of the Pyrenees, RAM and Greenback piles (approximately three feet) would be cut and mixed with a solidifying agent. The mixture would then be reapplied to the piles. This work would be conducted during the second construction season.

- Excavated areas would be revegetated.

- Approximately 36 abandoned mine shafts would be capped

- Sediments and fluvial tailings would be removed from SHG and Starr Ditch.

- Sediment would continue to be removed from the channels for an estimated three years as residual contamination is flushed out of the watershed basin.

- Cap repair and maintenance of the solidified piles is estimated as a percent of installation costs.

Table 5.4
CALIFORNIA GULCH NPL SITE
OPERABLE UNIT 6
Estimated Cost of Alternative S4:
Consolidation into Multiple Piles with Solidification

A. CAPITAL COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Mobilization/Site Preparation	LS	1	$321,000	$321,000	1	$321,000
Waste Rock Piles Excavation and Consolidation	LS	1	$1,253,000	$1,253,000	1	$1,253,000
Excavation Confirmation Sampling	LS	1	$35,000	$35,000	1	$35,000
Solidification of Waste Rock Piles	LS	1	$3,582,000	$3,582,000	1	$3,582,000
Hydromulch Revegetation	LS	1	$35,000	$35,000	1	$35,000
Perimeter Ditch around Waste Rock Piles	LS	1	$32,000	$32,000	1	$32,000
Reconstruction of Cribbing	LS	1	$134,000	$134,000	1	$134,000
Cap Mine Shafts	LS	1	$198,000	$198,000	1	$198,000
Sediment Removal	LS	1	$113,000	$113,000	1	$113,000
Sediment Removal Confirmation Sampling	LS	1	$10,000	$10,000	1	$10,000
Solidification/Stabilization Treatment Study	LS	1	$65,000	$65,000	1	$65,000
Solidification of Historic Waste Rock Piles (Pyrenees/RAM/Greenbac	LS	1	$851,000	$851,000	2	$743,263
Dust Control	LS	1	$25,000	$25,000	1	$25,000
Air Monitoring	LS	1	$45,000	$45,000	1	$45,000
Subtotal			$6,699,000	$6,699,000		$6,591,263
2. Indirect Costs						
Field Indirect (2%)				$133,980		$131,825
Supervision, Inspection, & Overhead (4%)				$267,960		$263,651
Contractor Profit (10%)				$669,900		$659,126
Contractor Bonds (5%)				$334,950		$329,563
Design (6%)				$401,940		$395,476
Resident Engineering (3%)				$200,970		$197,738
Contingency (20%)				$1,339,800		$1,318,253
TOTAL CAPITAL COSTS				$10,049,000		$9,887,000

B. O & M COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Stray Horse Gulch Sediment Removal	LS	1	$4,300	$4,300	2 thru 4	$10,544
SHG Sediment Load and Haul to Disposal Facility	LS	1	$4,800	$4,800	2 thru 4	$11,770
Starr Ditch Sediment Removal	LS	1	$600	$600	2 thru 4	$1,471
Starr Ditch Sediment Load and Haul to Disposal Facility	LS	1	$800	$800	2 thru 4	$1,962
Cap Maintenance and Repair	LS	1	$9,700	$9,700	2 thru 30	$111,298
5 Year Site Reviews	EA/YR	0.20	$78,000	$15,600	2 thru 30	$178,994
Quarterly Inspection	EA	4	$500	$2,000	2 thru 30	$22,948
Surface Water Monitoring	LS	1	$4,200	$4,200	2 thru 30	$48,191
Subtotal			$102,900	$42,000		$387,177
2. Indirect Costs						
Supervision, Inspection, & Overhead (4%)				$1,680		$15,487
Contractor Bonds (5%)				$2,100		$19,359
Contractor Profit (10%)				$4,200		$38,718
Contingency (20%)				$8,400		$77,435
TOTAL O&M COSTS				$58,400		$538,200
TOTAL ALTERNATIVE COSTS						$10,425,000

LS - Lump Sum
EA - Each
YR - Year
SHG - Stray Horse Gulch

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- Surface water monitoring would be conducted on a yearly basis. A site evaluation inspection would be required every five years. The five-year inspection would require data collection which may include an AVIRIS fly over.

5.4.3 WAMP CRITERIA

5.4.3.1 Surface Erosion Stability

Mine waste surfaces would be stabilized in lower SHG, including the majority of the mine waste and all of the large piles in this area. No slope stabilization improvements would be implemented above Adelaide Park. Many smaller waste piles would be left on the slopes visible from the central portion of Leadville.

Surfaces in the remediated areas will be stable for precipitation and runoff flows up to a 100-year storm event. Remediated surfaces within the 500-year flood plain will be designed for stability under the 500-year storm event.

Initial treatability study results (Appendix C) show the 25% cement/waste mixture to have a compressive strength of 1000 pounds per square inch at 28 days of curing. Durability meets the requirements for wetting-drying and freezing-thawing.

The "hot-spots" identified through the AVIRIS studies and ground surface sampling in the vicinity of residential areas will be removed to the contained waste piles. Some surface erosion by wind of fine-grained waste in the small piles on the slope overlooking Leadville would probably continue, however, these are generally below the clean-up action levels.

5.4.3.2 Slope Stability

The mine waste will be placed in multiple engineered waste piles designed to be stable with respect to both shallow and deep slope stability. Detailed analyses of the slope stability would be performed during the design process. This alternative would use a design factor of safety of 1.5. With a tested compressive strength of 1000 pounds per square inch, an estimated shear strength greater or equal to the waste rock (due to the continued curing and adhesion of the solidified material after placement), and a smaller slope than required of the geomembrane in Alternative S3, the factor of safety for the cement-soil thick shell constructed in Alternative S4 are anticipated to meet or exceed that calculated in Appendix D. Slopes in the removal areas would be recontoured to as close to the pre-mining configurations and slope stability configurations as practicable.

5.4.3.3 Flow Capacity and Stability

After removal of the sediments, the alternative selected from the surface water control alternatives in Section 6.0 would include at least the rehabilitation of SHG sized to properly convey the 100-year, 24-hour and 2-hour storm events. In addition, the reconstructed channel would be designed for stability under flows resulting from 500-year, 24-hour and 2-hour storm events.

5.4.3.4 Surface Water and Groundwater Loading Reduction

Removal and consolidation of the wide-spread surface waste into multiple engineered and covered waste repositories will isolate most of the metal-contaminated material from the precipitation and runoff system. This alternative is anticipated to show a quantifiable improvement in the quality of the SHG surface water especially over the long-term. The actual net load reduction will be determined after the alternative is implemented and post-remediation sampling is conducted. The cap design will include an impervious layer designed to reduce the quantity of infiltration through the contaminated material. In addition, groundwater in the immediate SHG watershed area will continue to be captured and removed at Reclamation's LMDTTP. The final remediation of OU6 will be discussed in the ROD.

5.4.3.5 Terrestrial Ecosystem Exposure

Removal of the wide-spread surface waste into covered repositories will isolate most of the ARD and lead-contaminated waste from the terrestrial species in the area. Substantial reduction of risk to the terrestrial ecosystem should be realized, and will improve with the growth of vegetation in some of the remediated historic habitat areas.

5.4.3.6 Nonresidential Soils

The majority of the heavy-metals contaminated soils and rock in the nonresidential areas of the project will be removed to the covered waste repositories. Particularly, this alternative would remove areas of nonresidential soils and waste rock exceeding 16,000-mg/kg lead that pose risk to recreational users in the immediate vicinity of the City of Leadville and in the lower SHG watershed basin. Ecological risk in the nonresidential areas would be substantially reduced.

5.5 COMPARATIVE ANALYSIS OF SOURCE CONTROL ALTERNATIVES

In this section, the relative performance of each alternative is evaluated in relation to the NCP and WAMP criteria. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another in order to reach a balanced judgement for the selection of the preferred alternative.

5.5.1 NCP CRITERIA

Table 5.5 provides a detailed comparison of each alternative against the three main NCP criteria: effectiveness, implementability and cost.

By controlling the sources of ARD and lead-contamination, Alternatives S2, S3, and S4 are much more effective at protecting human health and the environment than Alternative S1. Alternative S2 however will not achieve the RAO of preserving features consistent with the NRHP. Alternatives S3 and S4 will achieve all RAOs. Additionally, Alternative S4 provides some reduction in toxicity via treatment. Alternative S1 could be paired with either Alternative W4 or W5 to afford greater protection of human health by treating the surface water, yet it still falls short of addressing erosion and direct contact with lead-contaminated waste.

TABLE 5.5.
COMPARISON OF SOURCE CONTROL ALTERNATIVES USING NCP CRITERIA

NCP Criteria	Alternative S1 Sediment Removal	Alternative S2 Consolidation into Single Repository with Capping	Alternative S3 Consolidation into Multiple Piles with Capping
EFFECTIVENESS Protectiveness	Limited short-term effect. Will have no direct impact on the source of contamination, namely the mine waste piles. Will not protect against contact with lead contamination.	This alternative provides for protection of human health and the environment by capping mine wastes and isolating the contaminated materials that come in contact with run-on and precipitation.	This alternative provides for protection of human health and the environment by capping mine wastes and isolating the contaminated materials that come in contact with run-on and precipitation.
Ability to Achieve Removal Objectives	Achieves the RAO for preserving historical features but does not achieve any of the other RAOs.	Achieves all of the RAOs except preserving historical features.	Achieves all of the RAOs.
IMPLEMENTABILITY Technical Feasibility	There are no anticipated technical difficulties with implementing this alternative.	Geomembranes are a reliable technology for covering waste piles.	Geomembranes are a reliable technology for covering waste piles.
Availability	Utilizes readily available materials and labor.	Utilizes readily available materials and labor.	Utilizes readily available materials and labor.
Administrative Feasibility	May not be acceptable to governmental agencies responsible for protection of human health and the environment.	Site access and land acquisition may be difficult and could delay the project. Due to the NRHP eligibility of several of the mining locations, this alternative may not be administratively feasible.	Site access may pose delays to the project.
COST Net Present Worth	$850,000	$8,574,000	$7,786,000

TABLE 5.5 (Continued)
COMPARISON OF SOURCE CONTROL ALTERNATIVES USING NCP CRITERIA

NCP Criteria	Alternative S4 Consolidation into Multiple Piles with Solidification
EFFECTIVENESS Protectiveness	This alternative provides for protection of human health and the environment by encapsulating mine wastes and isolating the contaminated materials that come in contact with run-on and precipitation.
Ability to Achieve Removal Objectives	Achieves all of the RAOs.
IMPLEMENTABILITY Technical Feasibility	Preliminary treatability study results show the use of solidification to be technically viable.
Availability	The materials and equipment used for soil-cement solidification are readily available.
Administrative Feasibility	Site access may pose delays to the project.
COST Net Present Worth	$10,425,000

Alternative S1 would be the simplest to implement. Implementing Alternative S3 may have a slight advantage over implementing Alternative S2 due to the lesser amount of material being excavated and hauled; however, Alternative S3 involves more design work to recreate the individual mine piles and time to grade and cap these piles. Alternative S4 would be the most difficult to implement. Alternative S4 involves many of same design and time issues as Alternative S3 but uses a nonstandard technology that is not as widely utilized. Alternatives S2, S3 and S4 use materials designed for longevity with the intent of reducing O&M costs over the longterm.

The range of costs vary from $850,000 to $10,425,000, with Alternative S1 on the low side and Alternative S4 on the high side. Alternatives S2 and S3 fall in between at $8,574,000 and $7,786,000 respectively.

5.5.2 WAMP CRITERIA

Table 5.6 provides a detailed comparison of each alternative against the six main WAMP criteria as discussed in the alternatives analysis in Section 5.0.

Alternative S1 will not ensure erosion or slope stability for any of the existing piles. Erosion or slope stability would be directly addressed by the design of either Alternative S2, S3, or S4. In these alternatives a factor of safety of 1.5 is used in designing slope stability. For Alternative S4, erosion and slope stability was a factor used in the solidification treatability study in selecting which materials would be suitable for use in this alternative.

None of the Source Control Alternatives directly address flow capacity and stability. If removal of the sediments from SHG requires some reconstruction of the channel, one of the Surface Water Control Alternatives would have to be selected in conjunction with the Source Control Alternative.

In the short-term, Alternative S1 should show some improvement in the loading of metals to the surface water. The alternative is not a longterm solution as erosion will continue to deposit

TABLE 5.6
COMPARISON OF SOURCE CONTROL ALTERNATIVES USING WAMP CRITERIA

WAMP Criteria	Alternative S1 Sediment Removal	Alternative S2 Consolidation into Single Repository with Capping	Alternative S3 Consolidation into Multiple Piles with Capping
Surface Erosion Stability	No measures would be taken to ensure erosional stability of SHG and waste piles.	Surfaces in the remediated areas would be designed for stability during storm events.	Surfaces in the remediated areas would be designed for stability during storm events.
Slope Stability	No improvement to the stability of the mine waste piles.	A slope factor of safety of 1.5 will be achieved by the design of the cap.	A slope factor of safety of 1.5 will be achieved by the design of the cap.
Flow Capacity and Stability	The selection of a surface water control alternative from Section 6.0 would be required to meet WAMP criteria.	The selection of a surface water control alternative from Section 6.0 would be required to meet WAMP criteria.	The selection of a surface water control alternative from Section 6.0 would be required to meet WAMP criteria.
Surface Water and Groundwater Contaminant Load Reduction	Short-term reduction of loading from sediments; however the source of the contaminated sediments (the mine piles) will continue to redeposit in SHG.	Most of the source areas will be isolated from precipitation and run-on, resulting in contaminant loading reductions to surface water and groundwater as measured by comparison of baseline and post-removal monitoring results.	Most of the source areas will be isolated from precipitation and run-on, resulting in contaminant loading reductions to surface water and groundwater as measured by comparison of baseline and post-removal monitoring results.
Terrestrial Ecosystem Exposure	Terrestrial ecosystem would not be restored or improved and risk to all species would remain unchanged.	Sources of contamination would be isolated from the terrestrial ecosystem through capping.	Sources of contamination would be isolated from the terrestrial ecosystem through capping.
Nonresidential Soils	No improvement in non-residential soils .	The risk to recreational users posed by nonresidential soils would be minimized.	The risk to recreational users posed by nonresidential soils would be minimized.

TABLE 5.6 (Continued)
COMPARISON OF SOURCE CONTROL ALTERNATIVES USING WAMP CRITERIA

WAMP Criteria	Alternative S4 Consolidation into Multiple Piles with Solidification
Surface Erosion Stability	Surfaces in the remediated areas would be designed for stability during storm events.
Slope Stability	A slope factor of safety of 1.5 will be achieved by the design of the solidified cap.
Flow Capacity and Stability	The selection of a surface water control alternative from Section 6.0 would be required to meet WAMP criteria.
Surface Water and Groundwater Contaminant Load Reduction	Most of the source areas will be isolated from precipitation and run-on, resulting in contaminant loading reductions to surface water and groundwater as measured by comparison of baseline and post-removal monitoring results.
Terrestrial Ecosystem Exposure	Sources of contamination would be isolated from the terrestrial ecosystem through encapsulation.
Nonresidential Soils	The risk to recreational users posed by nonresidential soils would be minimized.

sediments into SHG. Coupled with either surface water control alternative W4 or W5, the combination would be effective at removing metals loading from the surface water. Groundwater contamination would continue to be captured and removed at Reclamation's LMDTTP.

Alternatives S2, S3, and S4 all use covered waste repositories to isolate metal-contaminated material from surface water runoff and infiltration. Since all three of these alternatives seek to equally remediate the mine waste targeted in Section 3.6.4, they should be comparatively effective at reducing surface water and groundwater metals loading.

Alternative S1 would show little improvement to either the terrestrial ecosystem or to nonresidential soils. Alternatives S2, S3, and S4, on the other hand, would be equally effective at reducing exposure of contaminated materials to the ecosystem and at removing lead-contaminated nonresidential soils from the vicinity of Leadville.

6.0 DESCRIPTION AND ANALYSIS OF REMOVAL ACTION ALTERNATIVES FOR SURFACE WATER CONTROL

Each of the alternatives developed to address surface water within the SHG watershed basin are described and analyzed individually in this section. At the end of the section these alternatives are compared with each other using the evaluation criteria defined previously in Section 4.3.

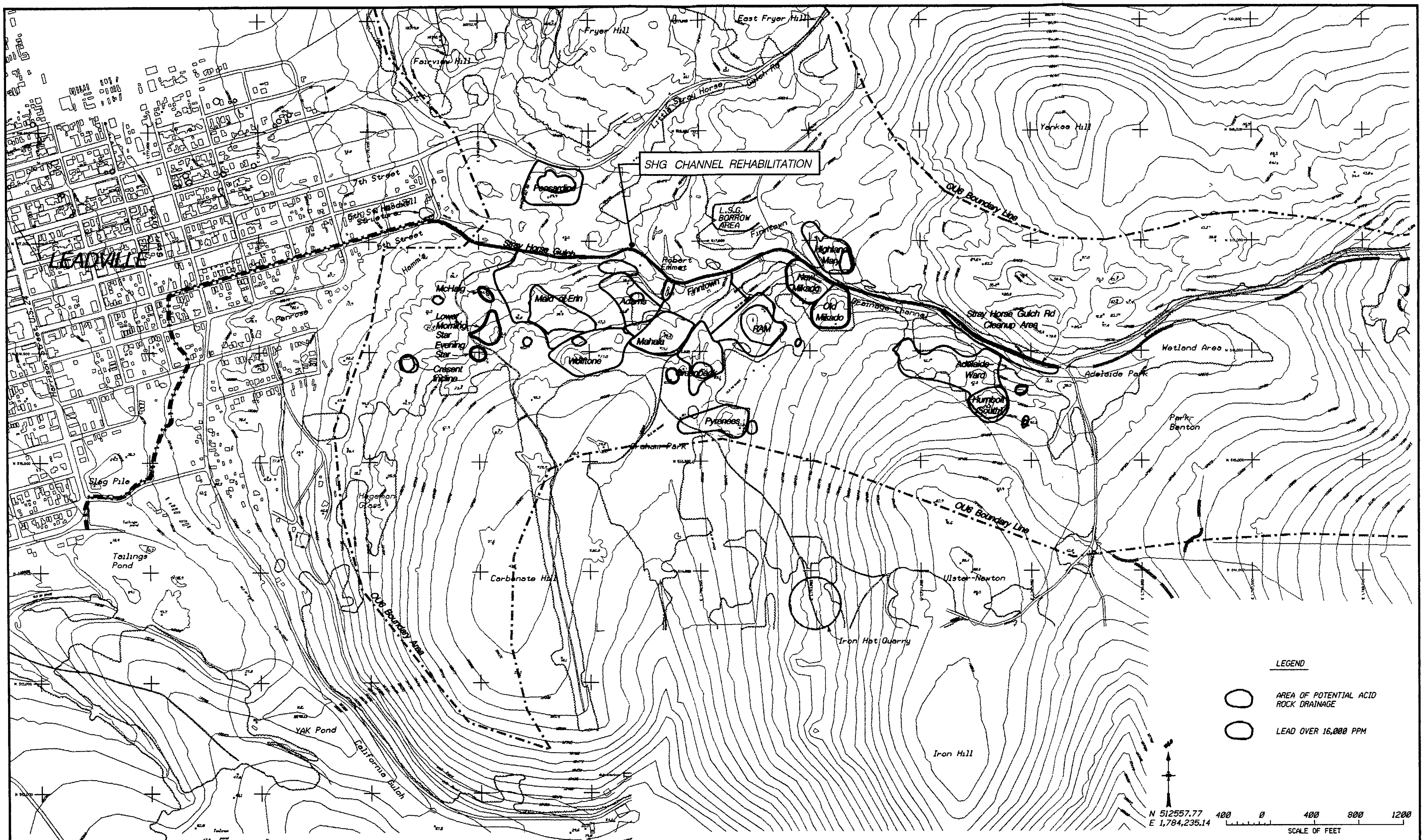
6.1 ALTERNATIVE W1 - REHABILITATION OF THE SHG CHANNEL

6.1.1 DESCRIPTION

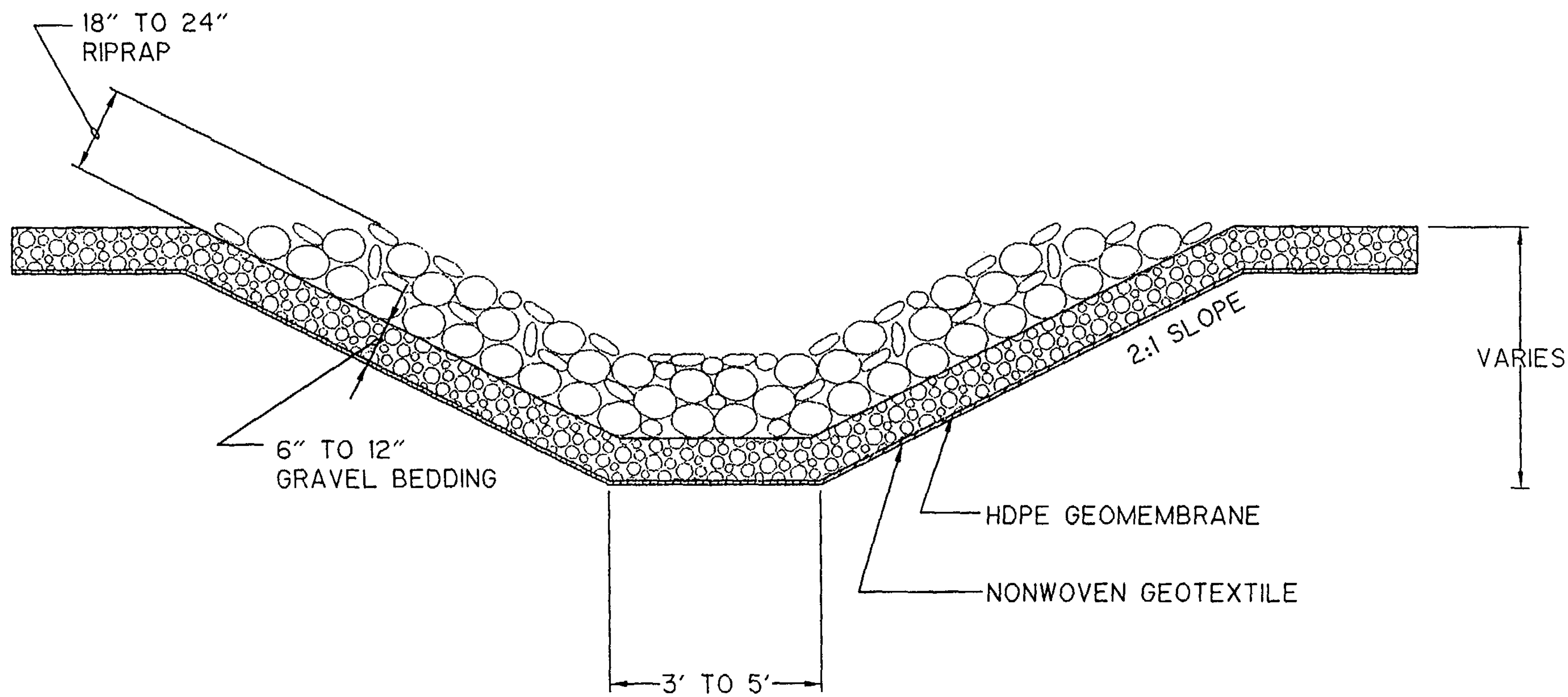
In this alternative the SHG channel would be rehabilitated, lined, and armored to safely convey the 100-year storm and be stable for storm flows up to the 500-year storm event. The location(s) of the channel work is shown in Figure 6.1 and a typical cross-section is detailed in Figure 6.2. Lining of the channel would also reduce the quantity of water infiltrating to the LMDT, thus offering some control on the quantity of water requiring treatment at the LMDTTP.

Alternative W1 would be considered as a potential surface water control if either Alternative S2, Alternative S3, or Alternative S4 is selected as the source control alternative. Alternative W1 provides for the rehabilitation of the SHG channel necessitated by the sediment and fluvial tailing removal that occurs as a component of these source control alternatives.

This alternative would not control exceedances of the city drainage system capacity along 5th Street, and continued flooding of streets and residential areas could occur during significant runoff or storm events.



REHABILITATION OF THE STRAY HORSE GULCH CHANNEL



CDM FEDERAL PROGRAMS CORPORATION

CHANNEL CROSS-SECTION

CALIFORNIA GULCH OU6 EECA
LEADVILLE, COLORADO

Figure 6-2

6.1.2 NCP CRITERIA

6.1.2.1 Effectiveness

Protectiveness — Alternative W1 alone would be neither protective of public health nor the environment. Exposure pathways remain open for human contact with contaminated surface water and mine waste materials. Pairing Alternative W1 with S1 would also have little effect on protecting the public or the environment against direct contact with lead-contaminated materials. However this alternative could be paired with either Alternative S2, S3, or S4. Such a pairing would provide the protectiveness discussed within the analysis of these alternatives in Section 5.0.

Ability to Achieve Removal Objectives — By itself Alternative W1 would meet none of the RAOs with the possible exception of maintaining and preserving the historic and cultural features of the area. Paired with one of the source control alternatives described in Section 5.0, the combination would achieve the RAOs to the extent described under each source control alternative in Section 5.0. Again the primary purpose of Alternative W1 would be to rehabilitate the SHG channel after sediment removal.

6.1.2.2 Implementability

Technical Feasibility — Implementing Alternative W1 does not present any technical feasibility issues.

Availability — The technology for channel rehabilitation is well established and utilizes readily available equipment and materials. The labor force should be available locally.

Administrative Feasibility — This alternative either by itself or in combination with Alternative S1 may not be acceptable to State and Federal regulatory agencies with statutory responsibility for protection of human health and the environment. Also, this alternative either by itself or with any of the source control alternatives may not meet with local acceptance due to the continued potential for flooding.

6.1.2.3 Cost

Capital cost for Alternative W1 is estimated at $474,000; annual O&M cost is estimated at $4,700 per year; and the total net present worth is estimated at $524,000. These costs are shown in Table 6.1. A further breakdown of these cost estimates is presented in Appendix B.

The following general assumptions were made when conceptually designing this system for the purpose of estimating costs for Alternative W1. The spreadsheets provided in Appendix B show the materials and quantities assumed in developing the cost estimates.

- Construction is assumed to occur in Year 2.
- SHG channel would be reconstructed to convey a 100-year, 24-hour storm (estimated to reach 181 cubic feet per second (cfs) at the 5th Street headwall).
- SHG channel maintenance is estimated as a percentage of the construction cost.
- Sediment removal, surface water monitoring, and five-year site reviews would be included in whichever source control alternative that Alternative W1 is coupled with.

6.1.3 WAMP CRITERIA

6.1.3.1 Surface Erosion Stability

Remediated surfaces located within the 500 year floodplain would be designed for stability under 500-year, 24-hour and 2-hour storm events.

6.1.3.2 Slope Stability

Stream embankments would be designed with a Factor of Safety of 1.5.

Table 6.1
CALIFORNIA GULCH NPL SITE
OPERABLE UNIT 6
Estimated Cost for Alternative W1:
Rehabilitation of the Stray Horse Gulch Channel

A. CAPITAL COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Mobilization/Site Preparation	LS	1	$17,227	$17,227	2	$15,046
Stray Horse Gulch Channel Rehabilitation	LS	1	$344,556	$344,556	2	$300,935
Subtotal			$361,783	$361,783		$315,981
2. Indirect Costs						
Field Indirect (2%)				$7,236		$6,320
Supervision, Inspection, & Overhead (4%)				$14,471		$12,639
Contractor Profit (10%)				$36,178		$31,598
Contractor Bonds (5%)				$18,089		$15,799
Design (6%)				$21,707		$18,959
Resident Engineering (3%)				$10,853		$9,479
Contingency (20%)				$72,357		$63,196
TOTAL CAPITAL COSTS				$543,000		$474,000

B. O & M COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
SHG Channel Annual Maintenance	LS	1	$4,500	$3,400	3 thru 30	$36,040
SHG/Starr Ditch Sediment Removal (Included in Source	LS	1	$0	$0	3 thru 30	$0
5 Yr. Site Review (Included in Source Control Alternativ	EA/5 YR	0.20	$0	$0	3 thru 30	$0
Surface Water Monitoring (Included in Source Control A	LS	1	$0	$0	3 thru 30	$0
Subtotal			$4,500	$3,400		$36,040
2. Indirect Costs						
Supervision, Inspection, & Overhead (4%)				$136		$1,442
Contractor Bonds (5%)				$170		$1,802
Contractor Profit (10%)				$340		$3,604
Contingency (20%)				$680		$7,208
TOTAL O&M COSTS				$4,700		$50,100
TOTAL ALTERNATIVE COSTS						$524,000

LS - Lump Sum   SHG - Stray Horse Gulch
EA - Each
YR - Year

ROLLW1.XLS6/4/97

6.1.3.3 Flow Capacity and Stability

The SHG stream channel would be regraded, lined, and armored against stream flow erosional instability up to a 500-year, 24-hour storm event. The channel would be reconfigured to hold flows up to a 100-year storm event, and while stable for a 500-year event, some overflow of the channel could occur for flows over the 100-year storm event.

This alternative would not control exceedances of the city drainage system capacity along 5th Street, and continued flooding of streets and residential areas could occur during significant runoff or storm events.

6.1.3.4 Surface Water and Groundwater Loading Reduction

No mass load reduction of the surface waters and groundwater would be achieved by Alternative W1 alone. Loading reduction would occur when Alternative W1 is paired with a source control alternative from Section 5.0.

6.1.3.5 Terrestrial Ecosystem Exposure

Terrestrial ecosystems would not be restored or improved and risk to all species would remain unchanged through implementing Alternative W1 alone or in combination with source control alternative S1 from Section 5.0. Exposure reduction would occur when Alternative W1 is paired with either source control alternative S2, S3, or S4.

6.1.3.6 Nonresidential Soils

There would be no improvement in nonresidential soils in SHG through implementing Alternative W1 alone or in combination with source control alternative S1 from Section 5.0. However this alternative could be paired with either Alternative S2, S3, or S4 that do remove areas of nonresidential soils and waste rock exceeding 16,000-mg/kg lead that pose risk to recreational users in the immediate vicinity of the City of Leadville and in the lower SHG watershed basin.

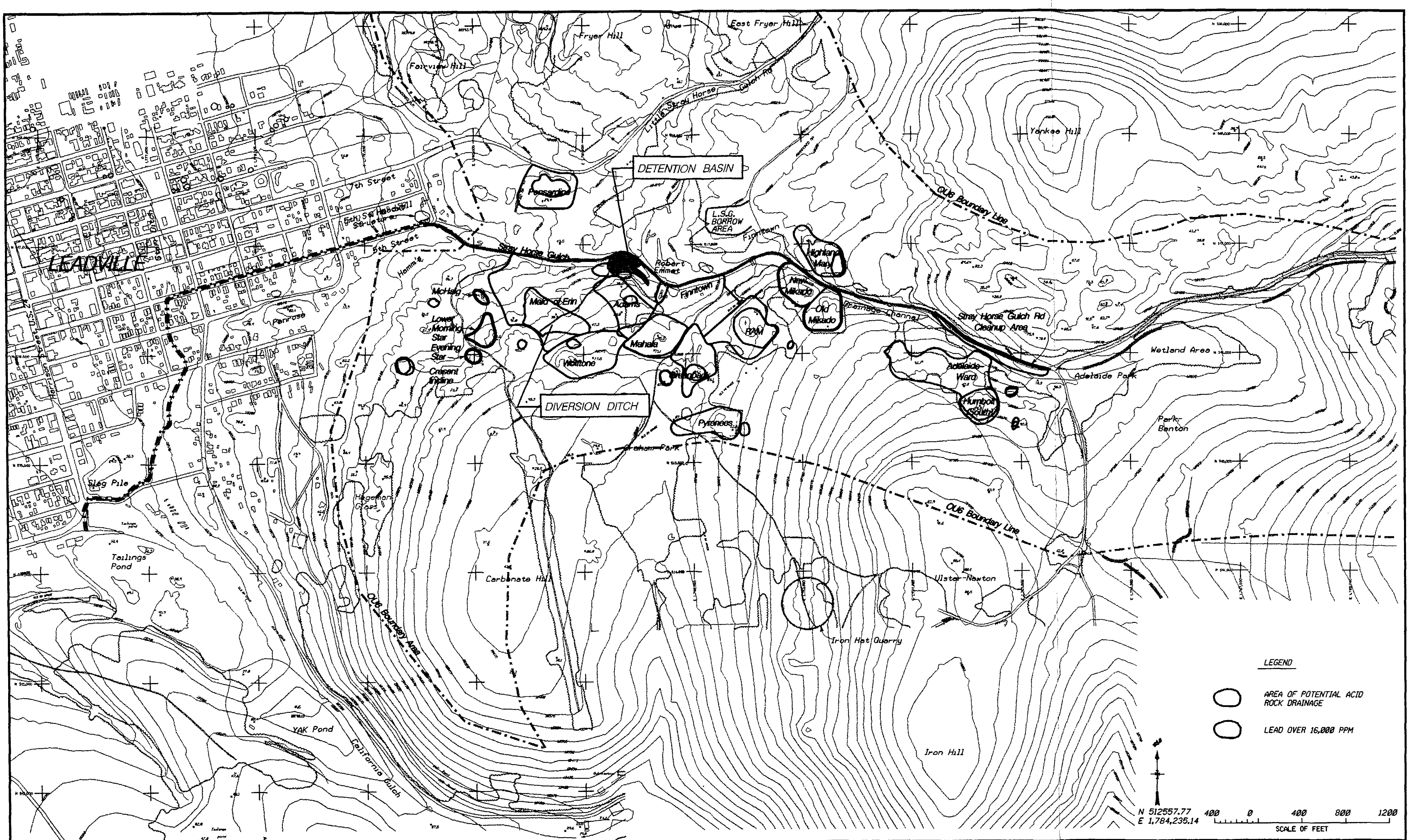
6.2 ALTERNATIVE W2 - DETENTION OF SURFACE WATERS WITHIN SHG

6.2.1 DESCRIPTION

With Alternative W2, the SHG channel would be rehabilitated, lined, and armored in the same manner as Alternative W1 in order to safely convey the 100-year storm and be stable for storm flows up to the 500-year storm event. In addition, stream flow rates at the lower end of SHG would be controlled through the construction of a detention basin and dam. As illustrated in Figure 6.3, the surface-water detention basin would be constructed in the SHG channel in a small existing basin area immediately below Finn Town and near the Robert Emmet Mine. The detention basin would be constructed through a combination of excavation and construction of a small earthfill dam across the channel. The basin and dam would be sized to retain up to 100-year, 24-hour storm flows while controlling releases at a flow rate of approximately 30 cfs to match the conveyance capacity of the pipelines along 5th Street. The 100-year, 24-hour storm flood size is estimated to be a peak flow rate of 153 cfs at the location of the basin. To accommodate such a flood size, the dam embankment would be approximately 15 feet high. In addition, the dam will be designed to safely withstand a 500-year storm event. Figures 6.4 and 6.5 show a plan view and a cross-sectional view, respectively, of the proposed basin and dam.

This detention basin will allow some of the storm-water sediment to settle out of the water. This will further improve the water quality. Periodic removal of the sediment will be required after storm flows. The sediment may contain heavy-metal constituents and will be removed and placed at a designated disposal facility such as the Hecla tailings impoundment located at OU2.

To preserve cultural resources, the detention basin will be designed to blend in with the landscape to the maximum extent practicable. Innovative techniques will be used to construct the face of the pond embankment to make it resemble a mine pile. The pond bottom will be


LEADVILLE
Fryer Hill
East Fryer Hill
Fairview Hill
Little Stray Horse Gulch Rd
Yankee Hill
DETENTION BASIN
L.S.G. BORROW AREA
OU6 Boundary Line
7th Street
5th Street
Stray Horse Gulch
Robert Emmet
Finntown
Highland Mary
New Mikado
Old Mikado
Drainage Channel
Stray Horse Gulch Rd Cleanup Area
Wetland Area
Adelaide Park
Adelaide Ward
Humboldt South
Park-Benton
Pendery
McHale
Maid of Erin
Adams
Mahala
RAM
Lower Morning Star
Evening Star
Cresent Incline
Wolftone
DIVERSION DITCH
Pyrenees
Graham Park
Penrose
Harrison
Slag Pile
Hagerman Grass
Tailings Pond
Carbonate Hill
OU6 Boundary Area
Iron Hat Quarry
Ulster-Newton
YAK Pond
California Gulch
Iron Hill
LEGEND
AREA OF POTENTIAL ACID ROCK DRAINAGE
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N 512557.77
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SCALE OF FEET

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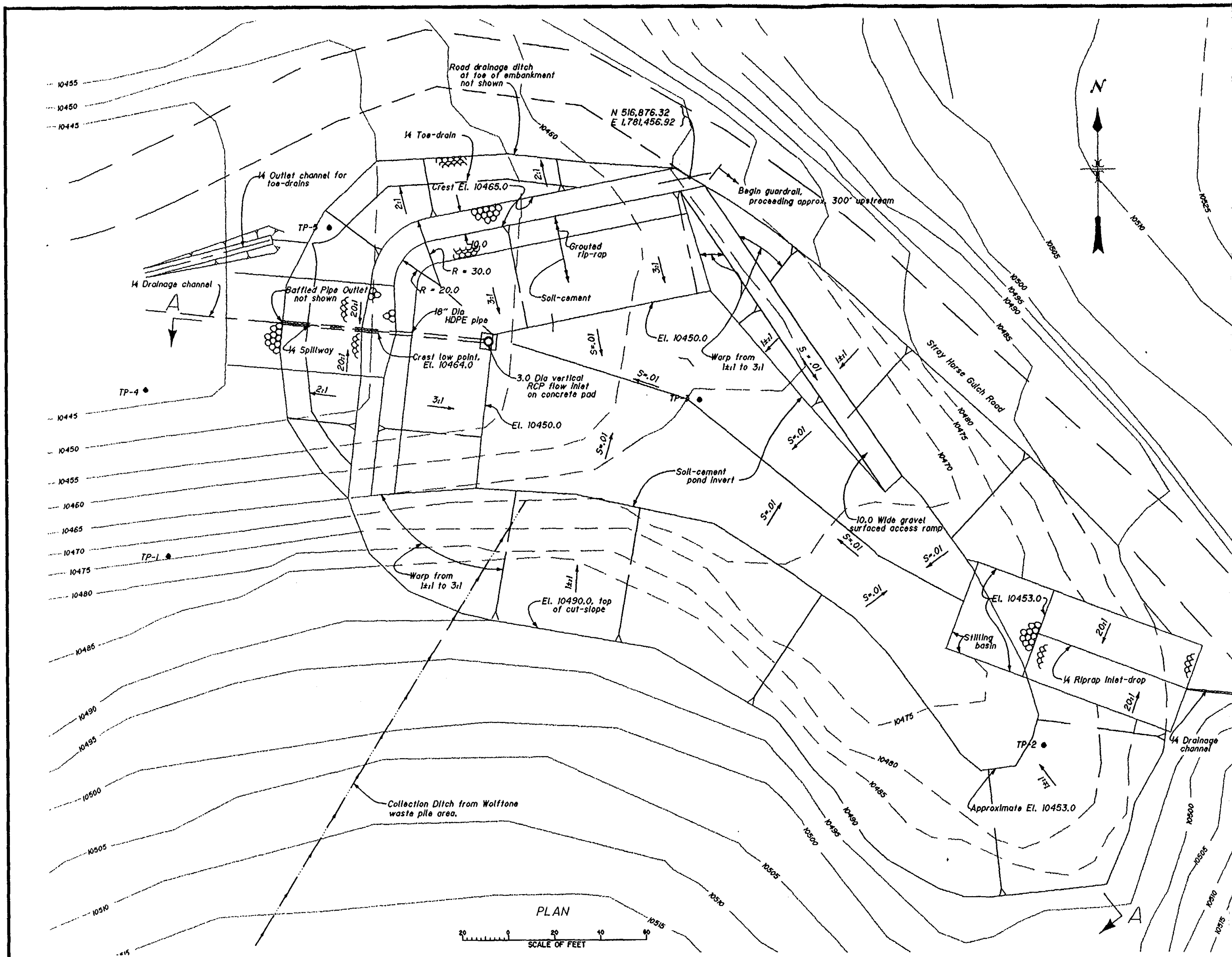
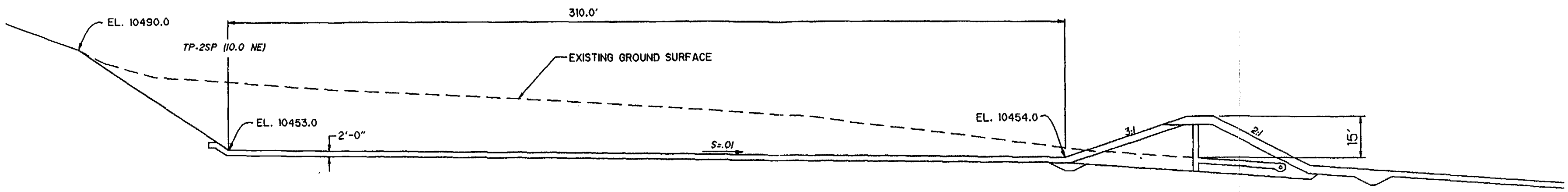


NOTES

The sediment pond will contain the 100-yr thunderstorm flood event with 3-0 ft of free board. At crest elevation 10465, the pond volume is 10 acre feet.
The overexcavation for pond construction shown on Section A-A is measured from the ground surface contours as shown.
The channel downstream shall be aligned with the ¼ of the spillway.

DETENTION BASIN PLAN



DETENTION BASIN

SECTION (A / 6-4)

1" = 40'

DETENTION BASIN

[redacted]

"hardened" in a manner that minimizes visual impacts, such as using soil-cement that resembles soil rather than concrete.

6.2.2 NCP CRITERIA

6.2.2.1 Effectiveness

Protectiveness — Alternative W2 alone would be neither protective of public health nor the environment. Exposure pathways remain open for human contact with contaminated surface water and mine waste materials. Pairing Alternative W2 with S1 would also have little effect on protecting the public or the environment against direct contact with lead-contaminated materials. However this alternative could be paired with either Alternative S2, S3, or S4. Such a pairing would provide the protectiveness discussed within the analysis of these alternatives in Section 5.0.

Ability to Achieve Removal Objectives — By itself Alternative W2 would meet none of the RAOs with the possible exception of maintaining and preserving the historic and cultural features of the area. Paired with one of the source control alternatives described in Section 5.0, the combination would achieve the RAOs to the extent described under each source control alternative in Section 5.0. Again the primary purpose of Alternative W2 would be to rehabilitate the SHG channel after sediment removal and control the flow of SHG consistent with the capacity of the pipelines along 5th Street.

6.2.2.2 Implementability

Technical Feasibility — Implementing Alternative W2 does not present any technical feasibility issues.

Availability — Construction of surface-water diversion, detention, and conveyance structures utilizes conventional methods and equipment that are readily available. The labor force should be available locally.

Administrative Feasibility — This alternative either by itself or in combination with Alternative S1 may not be acceptable to State and Federal regulatory agencies with statutory responsibility for protection of human health and the environment. Paired with Alternative S2, the combination may not meet with local acceptance. A more plausible combination would a pairing of Alternative W2 with either Alternative S3, or S4. Depending on its height, the installation of the dam for the detention basin would have to meet the substantive requirements of the State Engineer's Office. Also, the size of the detention basin and its potential impact on the views of the vista present a concern to the Lake County officials.

6.2.2.3 Cost

Capital cost for Alternative W2 is estimated at $960,000; annual O&M cost is estimated at $34,800 per year; and the total net present worth is estimated at $1,328,000. These costs are shown in Table 6.2. A further breakdown of these cost estimates is presented in Appendix B.

The following general assumptions were made when conceptually designing this system for the purpose of estimating costs for Alternative W2. The spreadsheets provided in Appendix B show the materials and quantities assumed in developing the cost estimates.

- Construction is assumed to occur in Year 2.
- A detention basin would be constructed just below Finn Town near the Emmet Mine to retain a 100-year, 24-hour storm (estimated to reach 153 cfs at the detention basin). The basin would be constructed through a combination of excavation and construction of a 15-foot high earthfill embankment across the channel. The basin would be lined with a geomembrane. A hardened soil-cement floor would be used to protect the lining.
- SHG channel would be reconstructed to convey a 100-year, 24-hour storm (estimated to reach 153 cfs at the detention basin).
- Sediment would be mucked from the basin periodically. Inspection of the basin would be conducted on a quarterly basis. Repairs of the basin are estimated as a percentage of the construction cost. It is anticipated that the basin liner would be replaced every ten years.
- SHG channel maintenance is estimated as a percentage of the construction cost.

Table 6.2
CALIFORNIA GULCH NPL SITE
OPERABLE UNIT 6
Estimated Cost for Alternative W2:
Detention of Surface Waters within Stray Horse Gulch

A. CAPITAL COSTS						
1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Mobilization/Site Preparation	LS	1	$34,000	$34,000	2	$29,696
Detention Basin	LS	1	$349,000	$349,000	2	$304,817
Stray Horse Gulch Channel Rehabilitation	LS	1	$345,000	$345,000	2	$301,323
Air Monitoring	LS	1	$5,000	$5,000	2	$4,367
Subtotal			$733,000	$733,000		$640,202
2. Indirect Costs						
Field Indirect (2%)				$14,660		$12,804
Supervision, Inspection, & Overhead (4%)				$29,320		$25,608
Contractor Profit (10%)				$73,300		$64,020
Contractor Bonds (5%)				$36,650		$32,010
Design (6%)				$43,980		$38,412
Resident Engineering (3%)				$21,990		$19,206
Contingency (20%)				$146,600		$128,040
TOTAL CAPITAL COSTS				$1,100,000		$960,000
B. O & M COSTS						
1. Direct Costs						
SHG Channel Annual Maintenance	LS	1	$3,400	$3,400	3 thru 30	$36,040
Muck Sediment from Basin	LS	1	$5,100	$5,100	3 thru 30	$54,060
Maintenance of Basin	LS	1	$10,300	$10,300	3 thru 30	$109,180
Replacement of Basin Liners (Every 10 years)	EA/YR	0.10	$50,000	$5,000	3 thru 30	$53,000
SHG/Starr Ditch Sediment Removal (Included in Source C	LS	1	$0	$0	3 thru 30	$0
Quarterly Inspection	EA	4	$300	$1,200	3 thru 30	$12,720
5 Yr. Site Review (Included in Source Control Alternative)	EA/5 YR	0.20	$0	$0	3 thru 30	$0
Surface Water Monitoring (Included in Source Control Alte	LS	1	$0	$0	3 thru 30	$0
Subtotal			$69,100	$25,000		$265,000
2. Indirect Costs						
Supervision, Inspection, & Overhead (4%)				$1,000		$10,600
Contractor Bonds (5%)				$1,250		$13,250
Contractor Profit (10%)				$2,500		$26,500
Contingency (20%)				$5,000		$53,000
TOTAL O&M COSTS				$34,800		$368,400
TOTAL ALTERNATIVE COSTS						$1,328,000

LS - Lump Sum
EA - Each
YR - Year

SHG - Stray Horse Gulch

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- Sediment removal, surface water monitoring, and five-year site reviews would be included in whichever source control alternative that Alternative W2 is coupled with.

6.2.3 WAMP CRITERIA

6.2.3.1 Surface Erosion Stability

Remediated surfaces located within the 500 year floodplain would be designed for stability under 500-year, 24-hour and 2-hour storm events.

6.2.3.2 Slope Stability

Slopes of impoundment embankments would be designed with a Factor of Safety of 1.5.

6.2.3.3 Flow Capacity and Stability

The SHG stream channel would be regraded, lined, and armored against stream flow erosional instability up to a 500-year, 24-hour storm event. The channel would be reconfigured to hold flows up to a 100-year storm event, and while stable for a 500-year event, some overflow of the channel could occur for flows over the 100-year storm event. The in-stream drainage detention structure would be designed to contain and control stream flows up to a 100-year storm event and to be stable up to a 500-year storm event. This means storm flows over a 100-year event would be passed through a spillway structure or over a structurally sound dam section protected by armor against erosion. The stream channel would be reconfigured to the extent practicable to replicate the naturally occurring stream channel.

The flow control structures included in this alternative will reduce and regulate flows arriving at the 5th Street headwall down to a maximum of approximately 30 cfs for storm events up to a 100-year event. This will result in reduced flooding of the streets and residential areas of Leadville.

6.2.3.4 Surface Water and Groundwater Loading Reduction

No mass load reduction of the surface waters and groundwater would be achieved by Alternative W2 alone. Loading reduction would occur when Alternative W2 is paired with a source control alternative from Section 5.0.

6.2.3.5 Terrestrial Ecosystem Exposure

Terrestrial ecosystems would not be restored or improved and risk to all species would remain unchanged through implementing Alternative W2 alone or in combination with source control alternative S1 from Section 5.0. Exposure reduction would occur when Alternative W2 is paired with either source control alternative S2, S3, or S4.

6.2.3.6 Nonresidential Soils

There would be no improvement in nonresidential soils in SHG through implementing Alternative W2 alone or in combination with source control alternative S1 from Section 5.0. However this alternative could be paired with either Alternative S2, S3, or S4 that do remove areas of nonresidential soils and waste rock exceeding 16,000-mg/kg lead that pose risk to recreational users in the immediate vicinity of the City of Leadville and in the lower SHG watershed basin.

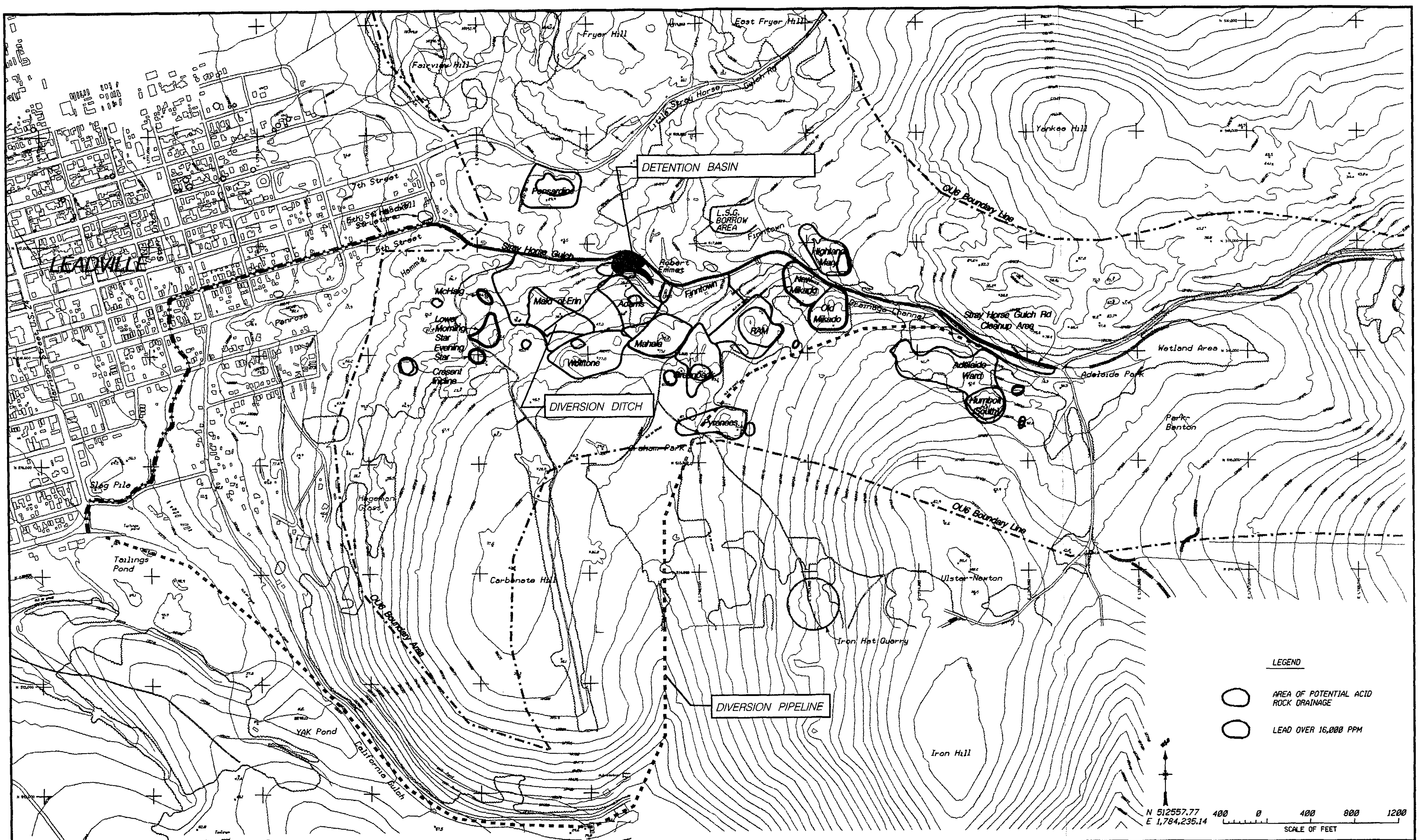
6.3 ALTERNATIVE W3 - DIVERSION OF SURFACE WATERS VIA GRAHAM PARK

6.3.1 DESCRIPTION

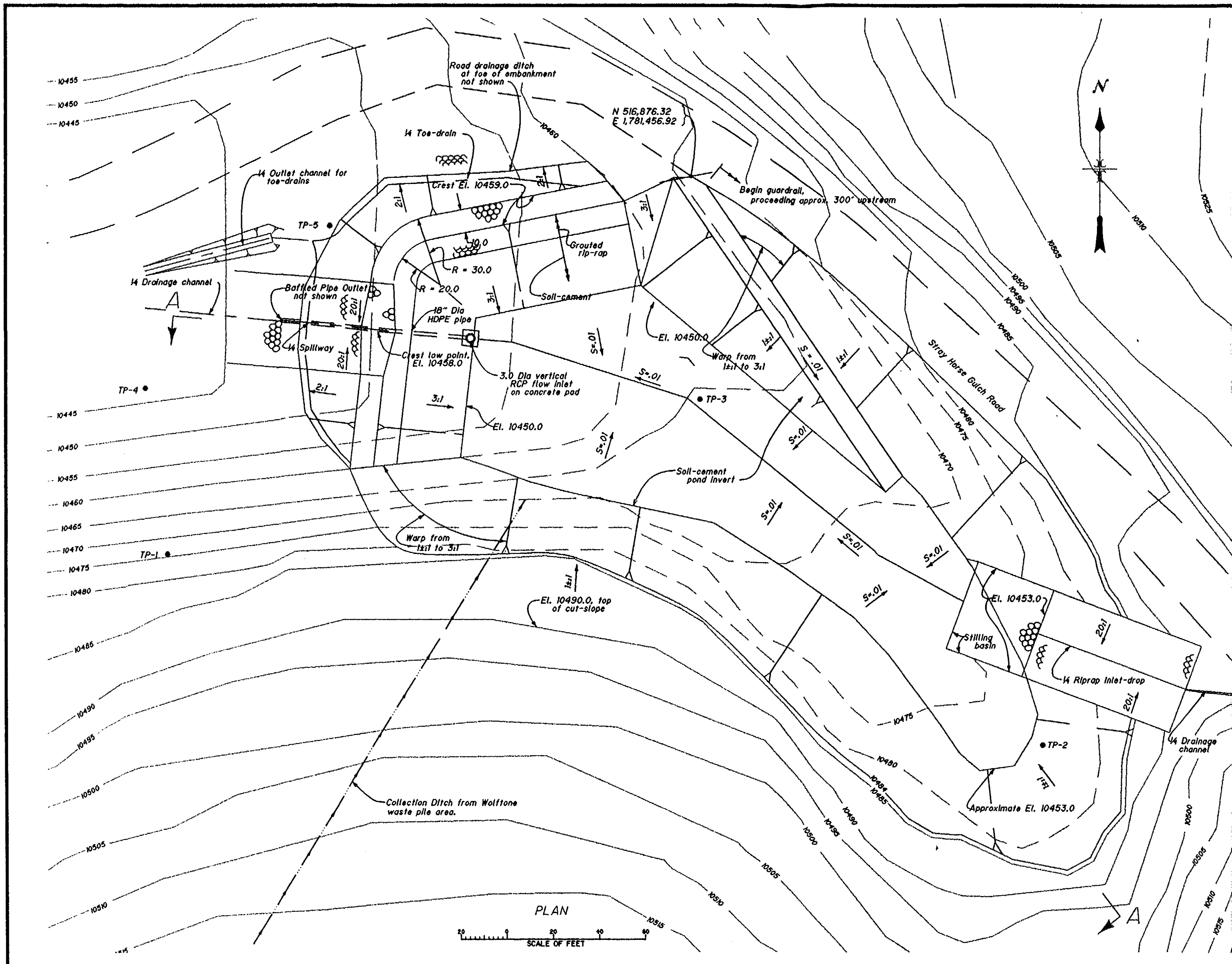
Alternative W3 is similar to Alternative W2 but in order to reduce the capacity of the detention basin, the upper reaches of SHG would be diverted to California Gulch via Graham Park. (Diversion to Evans Gulch is another possibility; however, its effect on Leadville's drinking water supply would have to be considered. For that reason, diverting to California Gulch appears to be a more viable approach.)

The SHG surface water sampling summarized in Section 2.7.2 shows the water exiting Adelaide Park to have higher water quality than the section of SHG downstream of the Adelaide-Ward and especially below the Mikado mine piles. In order to reduce the storage requirements of the detention basin proposed in Alternative W2 and to reduce the quantity of surface water that is degraded by the ARD-generating sources throughout lower SHG, Alternative W3 would construct a pipeline or ditch to convey the water from below the wetlands of Adelaide Park (and upstream of the Mikado Mine waste piles) to the main channel of California Gulch (see Figure 6.6). The flow through the pipe during the 100-year, 24-hour storm event is anticipated to be 90 cfs. The proposed construction would be a buried pipeline through a steep drainage ditch between Iron Hill and Carbonate Hill into California Gulch. Since the California Gulch drainage above and below the Yak Pond and treatment system was not designed for these additional flows, the buried pipeline would be continued through the main channel of California Gulch to the point where Starr Ditch discharges into the channel.

As with Alternative W1, the SHG channel would be rehabilitated, lined, and armored in order to safely convey the 100-year storm and be stable for storm flows up to the 500-year storm event. And similar to Alternative W2, the surface-water detention basin would be constructed in the SHG channel in a small existing basin area immediately below Finn Town and near the Robert Emmet Mine. The detention basin would be constructed through a combination of excavation and construction of a small earthfill dam across the channel. The basin and dam would be sized to retain up to 100-year, 24-hour storm flows while controlling releases at a flow rate of approximately 30 cfs to match the conveyance capacity of the pipelines along 5th Street. After diverting the waters from upper SHG at Adelaide Park, the 100-year, 24-hour storm size in lower SHG is estimated to be a peak flow rate of 63 cfs at the detention basin. To accommodate such a flood size, the dam embankment would be approximately 9 feet high. In addition, the dam will be designed to safely withstand a 500-year storm event. Figures 6.7 and 6.8 show a plan view and a cross-sectional view, respectively, of the proposed basin and dam.


LEADVILLE
Fryer Hill
East Fryer Hill
Fairview Hill
Little Stray Horse Gulch Rd
DETENTION BASIN
Yankee Hill
OU6 Boundary Line
L.S.G. BORROW AREA
Finntown
Robert Emmet
Stray Horse Gulch
7th Street
5th Street
Penrose
McHaig
Lower Morning Star
Evening Star
Cresent Incline
Maid of Erin
Adams
Mahala
Wolftone
Fanntown
RAM
Highland Mary
New Mikado
Old Mikado
Drainage Channel
Stray Horse Gulch Rd Cleanup Area
Wetland Area
Adelaide Park
Adelaide Ward
Humbolt South
Park-Benton
Pyrenees
DIVERSION DITCH
Graham Park
Slag Pile
Hageman Glass
Tailings Pond
Carbonate Hill
OU6 Boundary Area
Ulster-Newton
Iron Hat Quarry
DIVERSION PIPELINE
YAK Pond
California Gulch
Iron Hill
LEGEND
AREA OF POTENTIAL ACID ROCK DRAINAGE
LEAD OVER 16,000 PPM
N 512557.77
E 1,784,235.14
400 0 400 800 1200
SCALE OF FEET

[redacted]



NOTES

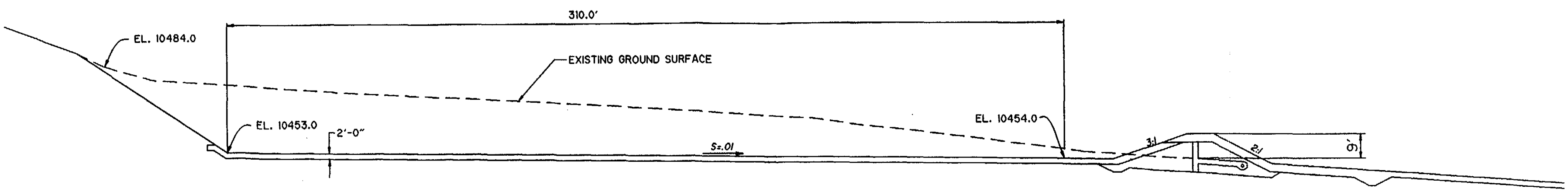
The sediment pond will contain the 100-yr thunderstorm flood event with 3-0 ft of free board. At crest elevation 10459, the pond volume is 7 acre feet.

The overexcavation for pond construction shown on Section A-A is measured from the ground surface contours as shown.

The channel downstream shall be aligned with the ¼ of the spillway.

ALTERNATE DETENTION BASIN PLAN

C:\ADRI2\DWG\3280-016\FIG6-7 06/05/97



DETENTION BASIN

SECTION A 6-7

1" = 40'

ALTERNATE DETENTION BASIN

This detention basin will allow some of the storm-water sediment to settle out of the water. This will further improve the water quality. Periodic removal of the sediment will be required after storm flows. The sediment may contain heavy-metal constituents and will be removed and placed at a designated disposal facility such as the Hecla tailings impoundment located at OU2.

To preserve cultural resources, the detention basin will be designed to blend in with the landscape to the maximum extent practicable. Innovative techniques will be used to construct the face of the pond embankment to make it resemble a mine pile. The basin bottom will be "hardened" in a manner that minimizes visual impacts, such as using soil-cement that resembles soil rather than concrete.

6.3.2 NCP CRITERIA

6.3.2.1 Effectiveness

Protectiveness — Alternative W3 alone would be neither protective of public health nor the environment. Exposure pathways remain open for human contact with contaminated surface water and mine waste materials. Pairing Alternative W3 with S1 would also have little effect on protecting the public or the environment against direct contact with lead-contaminated materials. However this alternative could be paired with either Alternative S2, S3, or S4. Such a pairing would provide the protectiveness discussed within the analysis of these alternatives in Section 5.0.

Ability to Achieve Removal Objectives — By itself Alternative W3 would meet none of the RAOs with the possible exception of maintaining and preserving the historic and cultural features of the area. Paired with one of the source control alternatives described in Section 5.0, the combination would achieve the RAOs to the extent described under each source control alternative in Section 5.0. Again the primary purpose of Alternative W3 would be to rehabilitate the SHG channel after sediment removal and control the flow of SHG consistent with the capacity of the pipelines along 5th Street.

6.3.2.2 Implementability

Technical Feasibility — The implementation of channel reconstruction and detention basin do not present any technical feasibility issues at this site. Pumping or lift stations will not be required since gravitational flow will deliver the waters.

Silt blockages or ice dams may occur regularly in the buried piping requiring costly repairs. The pipe construction would be too large in diameter for the use of rotary cleaning devices or hydraulic jetting, and too small for manned entry. A surface-laid pipeline using bell and spigot concrete pipe could be designed in lieu of the buried pipeline to provide easier access for blockages, but its presence may not be consistent with future land use.

Availability — Construction of surface-water diversion, detention, and conveyance structures utilizes conventional methods and equipment that are readily available. The labor force should be available locally.

Administrative Feasibility — The diversion pipeline to Graham Park will cross the Resurrection Mine properties and could impact future remedial activities in OU4 and OU6. Depending on its height, the installation of the dam for the detention basin would have to meet the substantive requirements of the State Engineer's Office. The construction of the diversion embankment at Adelaide Park would be performed so as not to impact the wetlands upstream.

This alternative either by itself or in combination with Alternative S1 may not be acceptable to State and Federal regulatory agencies with statutory responsibility for protection of human health and the environment. Paired with Alternative S2, the combination may not meet with the approval of Lake County officials and concerned citizens. A more plausible combination would a pairing of Alternative W3 with either Alternative S3, or S4.

Assurances would be made to confirm that the diversion will not affect downstream water rights.

This proposed alternative exceeds the statutory limits of $2 million for removal actions and would require approval of the USEPA Regional Administrator or the Division Director.

6.3.2.3 Cost

Capital cost for Alternative W3 is estimated at $1,968,000; annual O&M cost is estimated at $67,300 per year; and the total net present worth is estimated at $2,681,000. These costs are shown in Table 6.3. A further breakdown of these cost estimates is presented in Appendix B.

The following general assumptions were made when conceptually designing this system for the purpose of estimating costs for Alternative W3. The spreadsheets provided in Appendix B show the materials and quantities assumed in developing the cost estimates.

- Construction is assumed to occur in Year 2.
- A water diversion structure would be constructed below Adelaide Park and a buried 12,000-foot pipeline designed to carry the 100-year, 24-hour storm (approximately 90 cfs) from the upper portion of SHG to California Gulch would be installed via Graham Park. Requisition of land may be required for the pipeline.
- A detention basin would be constructed just below Finn Town near the Emmet Mine to retain the 100-year, 24-hour storm from below the diversion (estimated to reach 63 cfs at the detention basin). The basin would be constructed through a combination of excavation and construction of a 9-foot high earthfill embankment across the channel. The basin would be lined with a geomembrane. A hardened soil-cement floor would be used to protect the lining.
- SHG channel would be reconstructed to convey a 100-year, 24-hour storm (estimated to reach 63 cfs at the detention basin).
- Sediment would be mucked from the basin periodically. Inspection of the basin would be conducted on a quarterly basis. Repairs of the basin are estimated as a percentage of the construction cost. It is anticipated that the basin liner would be replaced every ten years.
- Diversion and pipeline maintenance is estimated as a percentage of the construction cost.
- SHG channel maintenance is estimated as a percentage of the construction cost.

Table 6.3
CALIFORNIA GULCH NPL SITE
OPERABLE UNIT 6
Estimated Cost for Alternative W3:
Diversion of Surface Waters via Graham Park

A. CAPITAL COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Mobilization/Site Preparation	LS	1	$71,000	$71,000	2	$62,011
Land Requisitions	LS	1	$100,000	$100,000	2	$87,340
Detention Basin	LS	1	$251,000	$251,000	2	$219,223
Stray Horse Gulch Channel Rehabilitation	LS	1	$212,000	$212,000	2	$185,161
Diversion of Channel to California Gulch	LS	1	$863,000	$863,000	2	$753,744
Air Monitoring	LS	1	$5,000	$5,000	2	$4,367
Subtotal			$1,502,000	$1,502,000		$1,311,847
2. Indirect Costs						
Field Indirect (2%)				$30,040		$26,237
Supervision, Inspection, & Overhead (4%)				$60,080		$52,474
Contractor Profit (10%)				$150,200		$131,185
Contractor Bonds (5%)				$75,100		$65,592
Design (6%)				$90,120		$78,711
Resident Engineering (3%)				$45,060		$39,355
Contingency (20%)				$300,400		$262,369
TOTAL CAPITAL COSTS				$2,253,000		$1,968,000

B. O & M COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Maintenance of Diversion and Pipeline to Cal Gulch	LS	1	$25,900	$25,900	3 thru 30	$274,540
SHG Channel Annual Maintenance	LS	1	$2,100	$2,100	3 thru 30	$22,260
Muck Sediment from Basin	LS	1	$6,800	$6,800	3 thru 30	$72,080
Maintenance of Basin	LS	1	$7,400	$7,400	3 thru 30	$78,440
Replacement of Basin Liners (Every 10 years)	EA/YR	0.10	$50,000	$5,000	3 thru 30	$53,000
SHG/Starr Ditch Sediment Removal (Included in Source Co	LS	1	$0	$0	3 thru 30	$0
Quarterly Inspection	EA	4	$300	$1,200	3 thru 30	$12,720
5 Yr. Site Review (Included in Source Control Alternative)	EA/5 YR	0.20	$0	$0	3 thru 30	$0
Surface Water Monitoring (Included in Source Control Alte	LS	1	$0	$0	3 thru 30	$0
Subtotal			$92,500	$48,400		$513,040
2. Indirect Costs						
Supervision, Inspection, & Overhead (4%)				$1,936		$20,522
Contractor Bonds (5%)				$2,420		$25,652
Contractor Profit (10%)				$4,840		$51,304
Contingency (20%)				$9,680		$102,608
TOTAL O&M COSTS				$67,300		$713,100
TOTAL ALTERNATIVE COSTS						$2,681,000

LS - Lump Sum
EA - Each
YR - Year

SHG - Stray Horse Gulch

ROLLW3.XLS6/4/97

- Sediment removal, surface water monitoring, and five-year site reviews would be included in whichever source control alternative that Alternative W3 is coupled with.

6.3.3 WAMP CRITERIA

6.3.3.1 Surface Erosion Stability

Remediated surfaces located within the 500 year floodplain would be designed for stability under 500-year, 24-hour and 2-hour storm events.

6.3.3.2 Slope Stability

Slopes of impoundment embankments would be designed with a Factor of Safety of 1.5.

6.3.3.3 Flow Capacity and Stability

The SHG stream channel would be regraded, lined, and armored against stream flow erosional instability up to a 500-year, 24-hour storm event. The channel would be reconfigured to hold flows up to a 100-year storm event, and while stable for a 500-year event, some overflow of the channel could occur for flows over the 100-year storm event. The in-stream drainage detention structures would be designed to contain and control stream flows up to a 100-year storm event and to be stable up to a 500-year storm event. This means storm flows over a 100-year event would be passed through a spillway structure or over a structurally sound dam section protected by armor against erosion. The stream channel would be reconfigured to the extent practicable to replicate the naturally occurring stream channel. The diversion pipeline would be sized to divert the bulk of the 100-year storm event volume exiting Adelaide Park with the overflow being captured by the lower SHG channel (overdesigned to handle this overflow).

The flow control structures included in this alternative will reduce and regulate flows arriving at the 5th Street headwall down to a maximum of approximately 30 cfs for storm events up to a

100-year event. This will result in reduced flooding of the streets and residential areas of Leadville.

6.3.3.4 Surface Water and Groundwater Loading Reduction

By diverting upper SHG waters away from the ARD-generating sources within the lower SHG watershed basin, the quantity of contaminated surface water running through SHG and infiltrating into the groundwater would be reduced; however, a smaller more concentrated flow would exit lower SHG to California Gulch possibly negating any net reductions. More beneficial loading reduction would occur when Alternative W3 is paired with a source control alternative from Section 5.0.

The actual net load reduction will be determined after the alternative is implemented and post-remediation sampling is conducted. The final remediation of OU6 will be discussed in the ROD.

Groundwater contamination would continue to be captured and removed at Reclamation's LMDTTP

6.3.3.5 Terrestrial Ecosystem Exposure

Terrestrial ecosystems would not be restored or improved and risk to all species would remain unchanged through implementing Alternative W3 alone or in combination with source control alternative S1 from Section 5.0. Exposure reduction would occur when Alternative W3 is paired with either source control alternative S2, S3, or S4.

6.3.3.6 Nonresidential Soils

There would be no improvement in nonresidential soils in SHG through implementing Alternative W3 alone or in combination with source control alternative S1 from Section 5.0. However this alternative could be paired with either Alternative S2, S3, or S4 that do remove areas of nonresidential soils and waste rock exceeding 16,000-mg/kg lead that pose risk to recreational users in the immediate vicinity of the City of Leadville and in the lower SHG watershed basin.

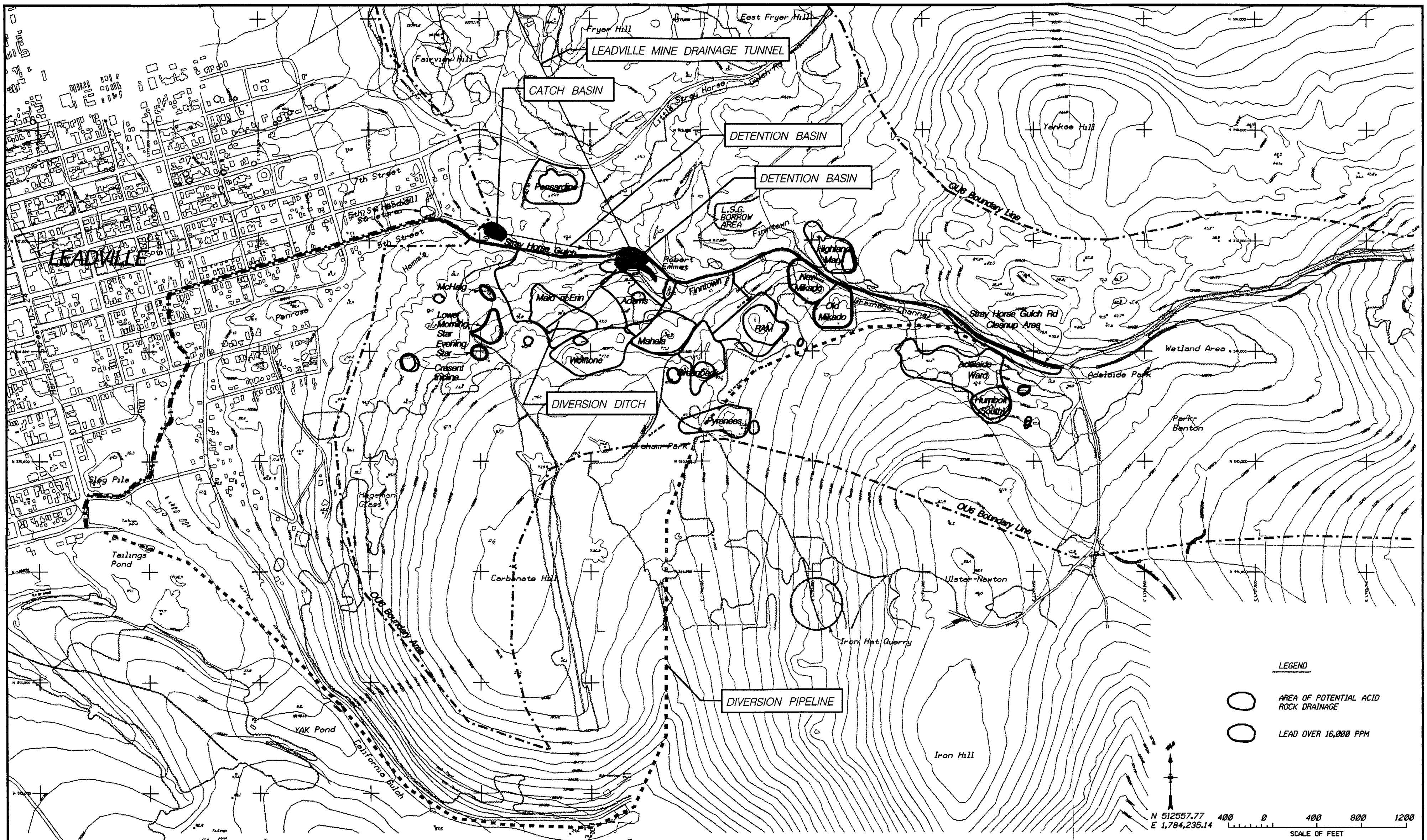
6.4 ALTERNATIVE W4 - DIVERSION OF SURFACE WATERS TO LMDT

6.4.1 DESCRIPTION

Alternative W4 is similar to Alternative W3 except the poor quality water of the lower SHG (below the Adelaide Park diversion) would be diverted to the LMDT in lieu of the 5th Street headwall.

The SHG surface water sampling summarized in Section 2.7.2 shows the water exiting Adelaide Park to have higher water quality than the section of SHG downstream of the Adelaide-Ward and especially below the Mikado mine piles. In order to reduce the storage requirements of the detention basin proposed in Alternative W2 and to reduce the quantity of surface water that is degraded by the ARD-generating sources throughout lower SHG, Alternative W4 would construct a pipeline or ditch to convey the water from below the wetlands of Adelaide Park (and upstream of the Mikado Mine waste piles) to the main channel of California Gulch (see Figure 6.9). The flow through the pipe during the 100-year, 24-hour storm event is anticipated to be 90 cfs. The proposed construction would be a buried pipeline through a steep drainage ditch between Iron Hill and Carbonate Hill into California Gulch. Since the California Gulch drainage above and below the Yak Pond and treatment system was not designed for these additional flows, the buried pipeline would be continued through the main channel of California Gulch to the point where Starr Ditch discharges into the channel.

As with Alternative W1, the SHG channel would be rehabilitated, lined, and armored in order to safely convey the 100-year storm and be stable for storm flows up to the 500-year storm event. And similar to Alternative W3, the surface-water detention basin would be constructed in the SHG channel in a small existing basin area immediately below Finn Town and near the Robert Emmet Mine. The detention basin would be constructed through a combination of excavation and construction of a small earthfill dam across the channel. The basin and dam would be sized



DIVERSION OF SURFACE WATERS TO LEADVILLE MINE DRAINAGE TUNNEL to retain up to 100-year, 24-hour storm flows while controlling releases at a flow rate of approximately 30 cfs to match the conveyance capacity of the pipelines along 5th Street. After diverting the waters from upper SHG at Adelaide Park, the 100-year, 24-hour storm size in lower SHG is estimated to be a peak flow rate of 63 cfs at the detention basin. To accommodate such a flood size, the dam embankment would be approximately 9 feet high. In addition, the dam will be designed to safely withstand a 500-year storm event. Figures 6.7 and 6.8 show a plan view and a cross-sectional view, respectively, of the proposed basin and dam.

An additional smaller catch basin would be located just upstream of the point where the Stray Horse stream flow enters the 5th Street headwall and drainage pipelines. This catch basin would collect any contaminated flows entering the channel from the lower watershed area below the primary detention basin discussed above and west of the Wolftone ditch. The catch basin would be sized to retain 28 cfs and meter it via a pipeline to the larger detention basin.

The two basins will allow some of the storm-water sediment to settle out of the water. This will further improve the water quality. Periodic removal of the sediment will be required after storm flows. The sediment may contain heavy-metal constituents and will be removed and placed at a designated disposal facility such as the Hecla tailings impoundment located at OU2. This sediment removal will reduce process requirements, including sludge and sediment removal at the LMDTTP. The LMDTTP was not designed for receiving this sediment-laden water. In addition, there is some risk with respect to sedimentation in inaccessible sections of the LMDT creating a blockage and potentially impacting the facilities treatment of drainage.

The two basins would also be used to stabilize and regulate the rate of runoff flow being diverted to the Emmet Shaft. The primary detention basin would be used to divert the water through a 400-foot-long angle-drill hole lined with casing or conveyance pipe sloping down at a minimum incline of approximately 5 percent to the rehabilitated Robert Emmet Shaft. Regulation of this flow will allow the use of a smaller-diameter conveyance pipe and minimize high-flow erosion of the shaft and tunnel. The conveyance pipe could be placed by angle-hole drilling methods with a lining and/or conveyance pipe designed to maintain hole integrity and resist corrosion. These construction methods will minimize the risks and cost associated with tunnel construction through old, deteriorated mine workings. Use of a drill hole will also minimize waste rock generated by a larger opening.

Rehabilitation of the Emmet Shaft would be necessary to convey these flows and allow the construction of a control drop structure. The drop structure would be needed to dissipate the energy of the water dropping down the Emmet Shaft. The water would then flow through the LMDT to the LMDTTP where the remaining sediment and heavy-metals contamination would be removed. The water would then be discharged into the East Fork of the Arkansas River. Upgrades to the LMDTTP would probably be necessary to handle the increased flows. Further, additional annual operations and chemical costs would be required for the increased flows.

To preserve cultural resources, the basins will be designed to blend in with the landscape to the maximum extent practicable. Innovative techniques will be used to construct the face of the basin embankment to make it resemble a mine pile. The basin bottoms will be "hardened" in a manner that minimizes visual impacts, such as using soil-cement that resembles soil rather than concrete.

6.4.2 NCP CRITERIA

6.4.2.1 Effectiveness

Protectiveness — Alternative W4 either alone or paired with source control alternative S1 would reduce heavy metals loading into Starr Ditch and California Gulch by diverting the contaminated waters to the LMDT. Further, by treating the water at the LMDTTP, the toxicity of these waters would be addressed directly. However, this combination does little to prevent the erosion of material into SHG from the mine piles and it does not protect the public and the environment against direct contact with lead-contaminated materials.

Also, if Alternative W4 is implemented without any source controls, the surface-water diversion and containment structures, the Emmet Shaft, and the LMDTTP would have to operate indefinitely. Long-term operation may cause high post-removal site costs associated with O&M,

borehole and shaft maintenance, possible plant expansion, and eventual replacement of the plant and the shaft. These costs must be part of a cost-sharing agreement between State and Federal agencies. The life cycle of concrete structures may be significantly reduced due to the corrosivity of low-pH ARD water, resulting in high replacement costs earlier in the life of the project.

Yet, this alternative could be paired with either Alternative S2, S3, or S4. Such a pairing would provide the protectiveness discussed within the analysis of these alternatives in Section 5.0.

In the short-term, construction of the Emmet Shaft could present potential physical hazards for workers during installation of the 24-inch drill hole and pipe liner, due to potential collapse of underground mine workings. During construction of this alternative, engineered controls would be used to reduce exposures to the community and site workers. Fugitive dust emissions should be minor since the waste piles would be left untouched.

Treatment residuals consist of metal hydroxide sludges at the LMDTTP and sediment trapped behind the sedimentation basin structures. These are handled effectively by existing waste management procedures at the treatment plant and periodic dredging of sediment from the basins, which is included in the O&M costs of this alternative.

Ability to Achieve Removal Objectives — Alternative W4 would meet neither the RAO of controlling erosion of contaminated materials into local water courses nor the RAO of controlling airborne transport of contaminated materials. Alternative W4 would not control the migration of metals from contaminated materials into surface water but it would directly treat the contaminated surface water. Leaching and migration of metals into the groundwater would not be controlled by this alternative; however, as discussed in Section 2.6.4 most of the groundwater within the area targeted by this EE/CA (lower SHG watershed basin) is currently captured by the LMDT and treated at the LMDTTP. Alternative W4 does not achieve the RAO of controlling direct contact with and ingestion of contaminated materials. On the other hand, this alternative will not adversely impact the historic and cultural features of the OU that are considered a part of the NRHP and current tourism draw.

Paired with one of the source control alternatives described in Section 5.0, the combination would achieve the RAOs to the extent described under each source control alternative in Section 5.0.

6.4.2.2 Implementability

Technical Feasibility — Implementing Alternative W4 would be difficult due to technical concerns with diverting surface water to the LMDTTP. The boring and lining of the Emmet Shaft may pose technical problems because of old mine workings. During the last rehabilitation effort, great difficulty was experienced in re-establishing the shaft through a large caved or filled stope that crossed the shaft. If problems are encountered during construction, project delays could occur. Environmental conditions in Leadville limit the construction phase to the summer months, such that there is little tolerance for construction delays.

There are also concerns with discharging large volumes of surface water to underground mine workings. Force from the increased flows could induce caving and blockage along the LMDT. Further, the LMDTTP may not have the capacity to handle additional flows and changed water chemistry from the tunnel, potentially affecting water quality in the East Fork of the Arkansas River unless capacity is increased. The SHG surface water has a lower pH with increased suspended and dissolved metals than the water currently being treated at LMDTTP.

Availability — Construction of aboveground structures for the diversion, containment, and conveyance of surface water uses conventional methods and readily available equipment. Specialized drilling equipment for installation of the Emmet Shaft borehole and pipe liner may not be available in the Leadville area. The equipment would need to be brought in from outside and scheduled well in advance. Any delays during drilling due to unanticipated site conditions could incur high standby costs or delays in the project schedule.

Administrative Feasibility — The diversion pipeline to Graham Park will cross the Resurrection Mine properties and could impact future remedial activities in OU4 and OU6. Depending on its height, the installation of the dam for the detention basin would have to meet the substantive requirements of the State Engineer's Office. The construction of the diversion embankment at Adelaide Park would be performed so as not to impact the wetlands upstream.

The additional heavy-metals loading on the LMDTTP could affect operational efficiency and lead to National Pollutant Discharge Elimination System (NPDES) permit violations. If the plant requires construction of additional treatment trains to handle the increased flow, changes to the permit may be required. Also, Reclamation may need congressional approval to receive funding for the modifications.

The diversion of water from Starr Ditch to the LMDT could potentially affect downstream water rights at California Gulch.

This proposed alternative exceeds the statutory limits of $2 million for removal actions and would require approval of the USEPA Regional Administrator or the Division Director. Also, obtaining easements, right-of-way agreements, and acquiring land for construction of diversion and detention structures may affect the administrative feasibility and could impact construction schedules.

6.4.2.3 Cost

Capital cost for Alternative W4 is estimated at $3,596,000; annual O&M cost is estimated at $361,600 per year; and the total net present worth is estimated at $7,429,000. These costs are shown in Table 6.4. A further breakdown of these cost estimates is presented in Appendix B.

The following general assumptions were made when conceptually designing this system for the purpose of estimating costs for Alternative W4. The spreadsheets provided in Appendix B show the materials and quantities assumed in developing the cost estimates.

- Construction is assumed to occur in Year 2.
- A water diversion structure would be constructed below Adelaide Park and a buried 12,000-foot pipeline designed to carry the 100-year, 24-hour storm (approximately 90 cfs)

Table 6.4
CALIFORNIA GULCH NPL SITE
OPERABLE UNIT 6
Estimated Cost for Alternative W4:
Diversion of Surface Waters to Leadville Mine Drainage Tunnel

A. CAPITAL COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Mobilization/Site Preparation	LS	1	$130,000	$130,000	2	$113,542
Land Requisitions	LS	1	$100,000	$100,000	2	$87,340
Detention Basin	LS	1	$251,000	$251,000	2	$219,223
Catch Basin	LS	1	$132,000	$132,000	2	$115,289
Pipelined Borehole - Detention Basin to Emmet Shaft	LS	1	$288,000	$288,000	2	$251,539
Pipeline - Catch Basin to Detention Basin	LS	1	$40,000	$40,000	2	$34,936
Emmet Shaft Rehabilitation	LS	1	$724,000	$724,000	2	$632,342
Stray Horse Gulch Channel Rehabilitation	LS	1	$212,000	$212,000	2	$185,161
Diversion of Channel to California Gulch	LS	1	$863,000	$863,000	2	$753,744
Air Monitoring	LS	1	$5,000	$5,000	2	$4,367
Subtotal			$2,745,000	$2,745,000		$2,397,483
2. Indirect Costs						
Field Indirect (2%)				$54,900		$47,950
Supervision, Inspection, & Overhead (4%)				$109,800		$95,899
Contractor Profit (10%)				$274,500		$239,748
Contractor Bonds (5%)				$137,250		$119,874
Design (6%)				$164,700		$143,849
Resident Engineering (3%)				$82,350		$71,924
Contingency (20%)				$549,000		$479,497
TOTAL CAPITAL COSTS				$4,118,000		$3,596,000

B. O & M COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Maintenance of Diversion and Pipeline to Cal Gulch	LS	1	$25,900	$25,900	3 thru 30	$274,540
SHG Channel Annual Maintenance	LS	1	$2,100	$2,100	3 thru 30	$22,260
Muck Sediment from Basins	LS	1	$20,500	$20,500	3 thru 30	$217,300
Maintenance of Basins	LS	1	$11,300	$11,300	3 thru 30	$119,780
Replacement of Basin Liners (Every 10 years)	EA/YR	0.10	$72,000	$7,200	3 thru 30	$76,320
Maintenance of Emmet Shaft	LS	1	$30,400	$30,400	3 thru 30	$322,240
Add'l O&M Costs incurred at LMDT Treatment Plant	LS	1	$140,000	$140,000	3 thru 30	$1,484,000
Quarterly Inspection	EA	4	$300	$1,200	3 thru 30	$12,720
5 Yr. Site Review (Assuming no Source Control)	EA/5 YR	0.20	$78,000	$15,600	3 thru 30	$165,360
Pumping Station O&M	LS	1	$5,910	$5,910	3 thru 30	$62,646
Surface Water Monitoring (Included in Treatment Plant)	LS	1	$0	$0	3 thru 30	$0
Subtotal			$386,410	$260,110		$2,757,166
2. Indirect Costs						
Supervision, Inspection, & Overhead (4%)				$10,404		$110,287
Contractor Bonds (5%)				$13,006		$137,858
Contractor Profit (10%)				$26,011		$275,717
Contingency (20%)				$52,022		$551,433
TOTAL O&M COSTS				$361,600		$3,832,500
TOTAL ALTERNATIVE COSTS						$7,429,000

LS - Lump Sum
EA - Each
YR - Year

SHG - Stray Horse Gulch

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from the upper portion of SHG to California Gulch would be installed via Graham Park. Requisition of land may be required for the pipeline.

- A detention basin would be constructed just below Finn Town near the Emmet Mine to retain the 100-year, 24-hour storm from below the diversion (estimated to reach 63 cfs at the detention basin). The basin would be constructed through a combination of excavation and construction of a 9-foot high earthfill embankment across the channel. The basin would be lined with a geomembrane. A hardened soil-cement floor would be used to protect the lining.

- A smaller catch basin would be constructed closer to the 5th Street headwall to catch stormwater flowing west of the Wolftone ditch. Since Alternative W4 may not be coupled with a source control alternative, this water would be contaminated. The catch basin would be sized to retain 28 cfs and meter it to the larger detention basin.

- Water from the detention basin would be metered to Emmet Shaft through a 400-foot long, 24-inch diameter drill hole.

- 500 vertical feet of the Emmet Shaft would be reconstructed to allow construction and maintenance access.

- SHG channel would be reconstructed to convey a 100-year, 24-hour storm (estimated to reach 63 cfs at the detention basin).

- Sediment would be mucked from the basins periodically. Inspection of the basins would be conducted on a quarterly basis. Repairs of the basins are estimated as a percentage of the construction cost. It is anticipated that the basin liners would be replaced every ten years.

- Diversion and pipeline maintenance is estimated as a percentage of the construction cost.

- Maintenance of the Emmet Shaft is estimated as a percentage of its construction cost.

- An allowance is given for the additional costs incurred annually at the LMDTTP to treat the SHG waters.

- SHG channel maintenance is estimated as a percentage of the construction cost.

- Sediment along SHG would not be removed under this alternative.

- Surface water monitoring would be included under the LMDTTP monitoring.

- A site evaluation inspection would be required every five years. The five-year inspection would require data collection which may include an AVIRIS fly over.

6.4.3 WAMP CRITERIA

6.4.3.1 Surface Erosion Stability

Remediated surfaces located within the 500 year floodplain would be designed for stability under 500-year, 24-hour and 2-hour storm events.

6.4.3.2 Slope Stability

Slopes of impoundment embankments would be designed with a Factor of Safety of 1.5.

6.4.3.3 Flow Capacity and Stability

The SHG stream channel would be regraded, lined, and armored against stream flow erosional instability up to a 500-year, 24-hour storm event. The channel would be reconfigured to hold flows up to a 100-year storm event, and while stable for a 500-year event, some overflow of the channel could occur for flows over the 100-year storm event. The in-stream drainage detention structures would be designed to contain and control stream flows up to a 100-year storm event and to be stable up to a 500-year storm event. This means storm flows over a 100-year event would be passed through a spillway structure or over a structurally sound dam section protected by armor against erosion. The stream channel would be reconfigured to the extent practicable to replicate the naturally occurring stream channel. The diversion pipeline would be sized to divert the bulk of the 100-year storm event volume exiting Adelaide Park with the overflow being captured by the lower SHG channel (overdesigned to handle this overflow).

Current flow from the LMDT and through the LMDTTP is approximately 1.7 million gallons per day. The storage capacity of the LMDT is estimated at 35 acre-feet.

6.4.3.4 Surface Water and Groundwater Loading Reduction

By diverting upper SHG waters away from the ARD-generating sources within the lower SHG watershed basin, the quantity of contaminated surface water running through SHG and infiltrating into the groundwater would be reduced. The surface water flows in the lower portion of SHG would be diverted to and treated at the LMDTTP to reduce heavy-metal contaminants to NPDES standards. The actual net load reduction will be determined after the alternative is implemented and post-remediation sampling is conducted. The final remediation of OU6 will be discussed in the ROD.

Groundwater contamination would continue to be captured and removed at Reclamation's LMDTTP

6.4.3.5 Terrestrial Ecosystem Exposure

Terrestrial ecosystems would not be restored or improved and risk to all species would remain unchanged through implementing Alternative W4 alone or in combination with source control alternative S1 from Section 5.0. Exposure reduction would occur when Alternative W3 is paired with either source control alternative S2, S3, or S4.

6.4.3.6 Nonresidential Soils

There would be no improvement in nonresidential soils in SHG through implementing Alternative W4 alone or in combination with source control alternative S1 from Section 5.0. However this alternative could be paired with either Alternative S2, S3, or S4 that do remove areas of nonresidential soils and waste rock exceeding 16,000-mg/kg lead that pose risk to recreational users in the immediate vicinity of the City of Leadville and in the lower SHG watershed basin.

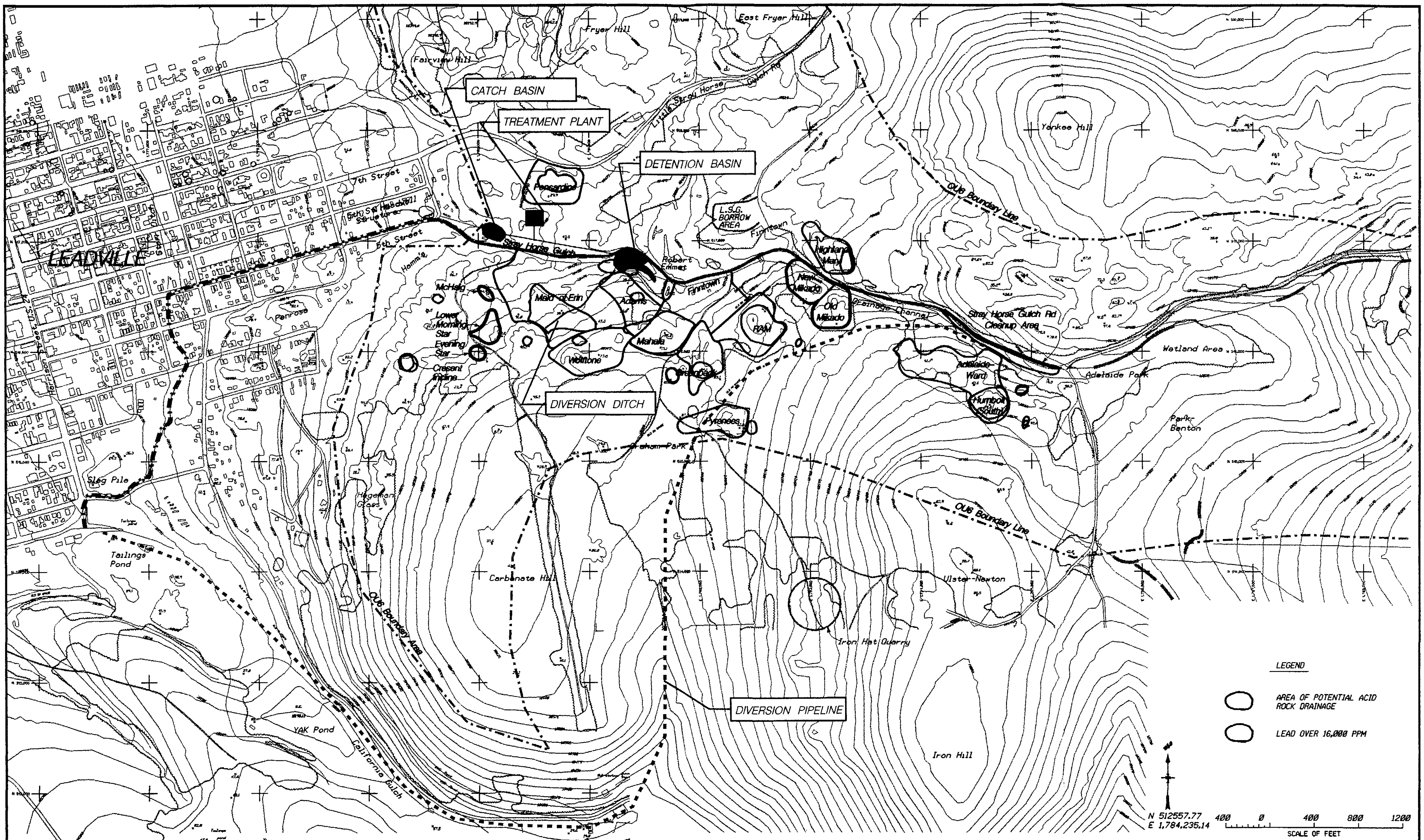
6.5 ALTERNATIVE W5 - TREATMENT OF SURFACE WATERS WITHIN SHG

6.5.1 DESCRIPTION

Alternative W5 is similar to Alternative W4 except in lieu of diverting the poor quality water of the lower SHG (below the Adelaide Park diversion) to the LMDT, the surface waters would be treated in a newly constructed treatment plant (located on site) and metered at a rate not to exceed the conveyance capacity of the pipelines along 5th Street.

The SHG surface water sampling summarized in Section 2.7.2 shows the water exiting Adelaide Park to have higher water quality than the section of SHG downstream of the Adelaide-Ward and especially below the Mikado mine piles. In order to reduce the storage requirements of the detention basin proposed in Alternative W2 and to reduce the quantity of surface water that is degraded by the ARD-generating sources throughout lower SHG, Alternative W5 would construct a pipeline or ditch to convey the water from below the wetlands of Adelaide Park (and upstream of the Mikado Mine waste piles) to the main channel of California Gulch (see Figure 6.10). The flow through the pipe during the 100-year, 24-hour storm event is anticipated to be 90 cfs. The proposed construction would be a buried pipeline through a steep drainage ditch between Iron Hill and Carbonate Hill into California Gulch. Since the California Gulch drainage above and below the Yak Pond and treatment system was not designed for these additional flows, the buried pipeline would be continued through the main channel of California Gulch to the point where Starr Ditch discharges into the channel.

As with Alternative W1, the SHG channel would be rehabilitated, lined, and armored in order to safely convey the 100-year storm and be stable for storm flows up to the 500-year storm event. And similar to Alternative W4, the surface-water detention basin would be constructed in the SHG channel in a small existing basin area immediately below Finn Town and near the Robert Emmet Mine. The detention basin would be constructed through a combination of excavation and construction of a small earthfill dam across the channel. The basin and dam would be sized to retain up to 100-year, 24-hour storm flows while controlling releases at a flow rate of approximately 4 cfs to match the anticipated capacity of the new treatment system. After



TREATMENT OF SURFACE WATERS WITHIN STRAY HORSE GULCH diverting the waters from upper SHG at Adelaide Park, the 100-year, 24-hour storm size in lower SHG is estimated to be a peak flow rate of 63 cfs at the detention basin. To accommodate such a flood size, the dam embankment would be approximately 9 feet high. In addition, the dam will be designed to safely withstand a 500-year storm event. Figures 6.7 and 6.8 show a plan view and a cross-sectional view, respectively, of the proposed basin and dam.

An additional smaller catch basin would be located just upstream of the point where the Stray Horse stream flow enters the 5th Street headwall and drainage pipelines. This catch basin would collect any contaminated flows entering the channel from the lower watershed area below the primary detention basin discussed above and west of the Wolftone ditch. The catch basin would be sized to retain 28 cfs and meter it via a pipeline to the treatment plant.

The two basins will allow some of the storm-water sediment to settle out of the water. This will further improve the water quality. Periodic removal of the sediment will be required after storm flows. The sediment may contain heavy-metal constituents and will be removed and placed at a designated disposal facility such as the Hecla tailings impoundment located at OU2. This sediment removal will reduce process requirements, including sludge and sediment removal at the treatment plant.

The on-site treatment plant would be situated downstream of the main detention basin at a location were the gulch widens and flattens sufficiently to permit construction and arrangement of the treatment components. Based on the seasonal runoff rates described in Section 2.6.3, the treatment plant would probably be sized to handle normal spring runoff flow rates on the order of 4 cfs. The specific type of treatment will be selected to be compatible with the contaminants of concern, the flow-through volume requirement, the sediment load, and consistency with other treatment technologies in use in the California Gulch Site and vicinity. It is most likely that the treatment will be based on chemical precipitation (see Figure 6.11). The treatment site would probably be located approximately 800 feet east of the east end of 5th Street and the discharge flow would be conveyed through a pipe or ditch to a discharge point just upstream of the concrete headwall at 5th Street. Large storm flows (i.e. 500-year flood events) exceeding the detention pond and plant capacities will bypass the plant. Treated water will be required to meet

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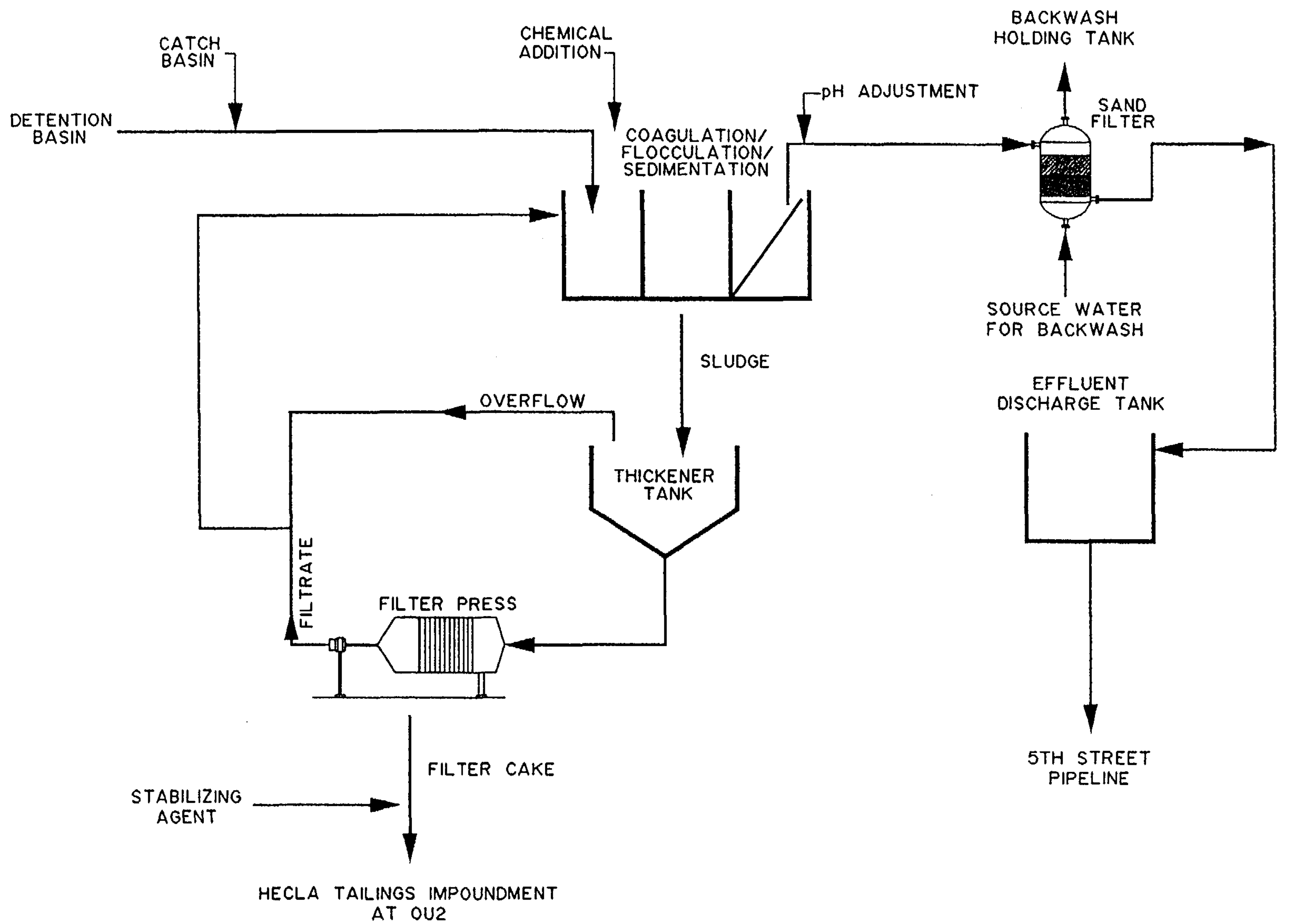

CDM FEDERAL PROGRAMS CORPORATION

ALTERNATIVE W5
TREATMENT SYSTEM
CHEMICAL PRECIPITATION

CALIFORNIA GULCH OPERABLE UNIT 6
LEADVILLE, COLORADO

Figure 6.11

NPDES requirements. Operation would include sediment and sludge removal for disposal at the Hecla tailings impoundment.

To preserve cultural resources, the basins will be designed to blend in with the landscape to the maximum extent practicable. Innovative techniques will be used to construct the face of the basin embankment to make it resemble a mine pile. The basin bottoms will be "hardened" in a manner that minimizes visual impacts, such as using soil-cement that resembles soil rather than concrete.

6.5.2 NCP CRITERIA

6.5.2.1 Effectiveness

Protectiveness — Alternative W5 either alone or paired with source control alternative S1 would reduce heavy metals loading into Starr Ditch and California Gulch by treating the SHG waters at a treatment system prior to exiting SHG. Further, by treating the water, the toxicity of these waters would be addressed directly. However, this combination does little to prevent the erosion of material into SHG from the mine piles and it does not protect the public and the environment against direct contact with lead-contaminated materials.

Also, if Alternative W5 is implemented without any source controls, the surface-water diversion and containment structures, and the treatment system would have to operate indefinitely. Long-term operation may cause high post-removal site costs associated with O&M, possible plant expansion, and eventual replacement of the plant. The life cycle of concrete structures may be significantly reduced due to the corrosivity of low-pH ARD water, resulting in high replacement costs earlier in the life of the project.

Yet, this alternative could be paired with either Alternative S2, S3, or S4. Such a pairing would provide the protectiveness discussed within the analysis of these alternatives in Section 5.0.

The construction of the treatment plant and the detention and catch basins in lower SHG may produce some fugitive dust emissions, which would be managed with engineering controls. Health impacts to site workers and the community would be minimal because the source areas will not be touched.

Treatment residuals consist of metal hydroxide sludges at the treatment plant and sediment trapped behind the sediment basin structures. These will be handled effectively by under waste management procedures at the treatment plant and periodic dredging of sediment from the basins, which is included in the O&M costs of this alternative.

Discharge from the treatment system would meet ARARs.

Ability to Achieve Removal Objectives — Alternative W5 would meet neither the RAO of controlling erosion of contaminated materials into local water courses nor the RAO of controlling airborne transport of contaminated materials. Alternative W5 would not control the migration of metals from contaminated materials into surface water but it would directly treat the contaminated surface water. Leaching and migration of metals into the groundwater would not be controlled by this alternative; however, as discussed in Section 2.6.4, most of the groundwater within the area targeted by this EE/CA (lower SHG watershed basin) is currently captured by the LMDT and treated at the LMDTTP. Alternative W5 does not achieve the RAO of controlling direct contact with and ingestion of contaminated materials. On the other hand, this alternative will not adversely impact the historic and cultural features of the OU that are considered a part of the NRHP and current tourism draw.

Paired with one of the source control alternatives described in Section 5.0, the combination would achieve the RAOs to the extent described under each source control alternative in Section 5.0.

6.5.2.2 Implementability

Technical Feasibility — The implementation of channel reconstruction and detention basin do not present any technical feasibility issues at this site.

Silt blockages or ice dams may occur regularly in the buried piping requiring costly repairs. The pipe construction would be too large in diameter for the use of rotary cleaning devices or hydraulic jetting, and too small for manned entry. A surface-laid pipeline using bell and spigot concrete pipe could be designed in lieu of the buried pipeline to provide easier access for blockages, but its presence may not be consistent with future land use.

Construction and long-term operation of the on-site treatment plant would be technically feasible. The materials of construction specified in the design for the treatment plant will account for the low-pH influent and adverse weather conditions. If problems are encountered during construction, project delays could occur and, if they are serious, could affect construction time frames. Environmental conditions in Leadville limit the construction phase to the summer months, such that there is little tolerance for construction delays.

Availability — Construction of surface-water diversion, detention, and conveyance structures utilizes conventional methods and equipment that are readily available. Tanks, pumps, chemicals, and other equipment and materials required for construction of the treatment plant may not be available in the immediate area but can be easily ordered and transported from Denver, approximately 100 miles away.

Administrative Feasibility — The diversion pipeline to Graham Park will cross the Resurrection Mine properties and could impact future remedial activities in OU4 and OU6. Depending on its height, the installation of the dam for the detention basin would have to meet the substantive requirements of the State Engineer's Office. Local permits required for construction of the treatment building can be expedited and, with good project planning, should not delay construction. The construction of the diversion embankment at Adelaide Park would be performed so as not to impact the wetlands upstream.

Assurances would be made to confirm that the diversion will not affect downstream water rights

This proposed alternative exceeds the statutory limits of $2 million for removal actions and would require approval of the USEPA Regional Administrator or the Division Director.. Also, obtaining easements, right-of-way agreements, and acquiring land for construction of diversion and detention structures may affect the administrative feasibility and could impact construction schedules.

6.5.2.3 Cost

Capital cost for Alternative W5 is estimated at $7,081,000; annual O&M cost is estimated at $1,700,500 per year; and the total net present worth is estimated at $25,107,000. These costs are shown in Table 6.5. A further breakdown of these cost estimates is presented in Appendix B.

The following general assumptions were made when conceptually designing this system for the purpose of estimating costs for Alternative W5. The spreadsheets provided in Appendix B show the materials and quantities assumed in developing the cost estimates.

- Construction is assumed to occur in Year 2.
- A water diversion structure would be constructed below Adelaide Park and a buried 12,000-foot pipeline designed to carry the 100-year, 24-hour storm (approximately 90 cfs) from the upper portion of SHG to California Gulch would be installed via Graham Park. Requisition of land may be required for the pipeline.
- A detention basin would be constructed just below Finn Town near the Emmet Mine to retain the 100-year, 24-hour storm from below the diversion (estimated to reach 63 cfs at the detention basin). The basin would be constructed through a combination of excavation and construction of a 9-foot high earthfill embankment across the channel. The basin would be lined with a geomembrane. A hardened soil-cement floor would be used to protect the lining.
- A smaller catch basin would be constructed closer to the 5th Street headwall to catch stormwater flowing west of the Wolftone ditch. Since Alternative W5 may not be coupled with a source control alternative, this water would be contaminated. The catch basin would be sized to retain 28 cfs.

Table 6.5
CALIFORNIA GULCH NPL SITE
OPERABLE UNIT 6
Estimated Cost for Alternative W5:
Treatment of Surface Waters within Stray Horse Gulch

A. CAPITAL COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Mobilization/Site Preparation	LS	1	$257,000	$257,000	2	$224,464
Land Requisitions	LS	1	$100,000	$100,000	2	$87,340
Detention Basin	LS	1	$251,000	$251,000	2	$219,223
Catch Basin	LS	1	$132,000	$132,000	2	$115,289
Pipeline - Detention Basin to Treatment Plant	LS	1	$40,000	$40,000	2	$34,936
Pipeline - Catch Basin to Treatment Plant	LS	1	$17,000	$17,000	2	$14,848
Wastewater Treatment Plant	LS	1	$3,528,000	$3,528,000	2	$3,081,355
Stray Horse Gulch Channel Rehabilitation	LS	1	$212,000	$212,000	2	$185,161
Diversion of Channel to California Gulch	LS	1	$863,000	$863,000	2	$753,744
Air Monitoring	LS	1	$5,000	$5,000	2	$4,367
Subtotal			$5,405,000	$5,405,000		$4,720,727
2. Indirect Costs						
Field Indirect (2%)				$108,100		$94,415
Supervision, Inspection, & Overhead (4%)				$216,200		$188,829
Contractor Profit (10%)				$540,500		$472,073
Contractor Bonds (5%)				$270,250		$236,036
Design (6%)				$324,300		$283,244
Resident Engineering (3%)				$162,150		$141,622
Contingency (20%)				$1,081,000		$944,145
TOTAL CAPITAL COSTS				$8,108,000		$7,081,000

B. O & M COSTS

1. Direct Costs	Unit	Quantity	Unit Cost	Cost	Years	Present Worth
Maintenance of Diversion and Pipeline to Cal Gulch	LS	1	$25,900	$25,900	3 thru 30	$274,540
SHG Channel Annual Maintenance	LS	1	$2,100	$2,100	3 thru 30	$22,260
Muck Sediment from Basins	LS	1	$20,500	$20,500	3 thru 30	$217,300
Maintenance of Basins	LS	1	$11,300	$11,300	3 thru 30	$119,780
Replacement of Basin Liners (Every 10 years)	EA/YR	0.10	$72,000	$7,200	3 thru 30	$76,320
Wastewater Treatment O&M, Labor	LS	1	$1,133,700	$1,133,700	3 thru 30	$12,017,220
Quarterly Inspection	EA	4	$300	$1,200	3 thru 30	$12,720
5 Yr. Site Review (Assuming no Source Control)	EA/5 YR	0.20	$78,000	$15,600	3 thru 30	$165,360
Pumping Station O&M	LS	1	$5,910	$5,910	3 thru 30	$62,646
Surface Water Monitoring (Included in Treatment Plant)	LS	1	$0	$0	3 thru 30	$0
Subtotal			$1,349,710	$1,223,410		$12,968,146
2. Indirect Costs						
Supervision, Inspection, & Overhead (4%)				$48,936		$518,726
Contractor Bonds (5%)				$61,171		$648,407
Contractor Profit (10%)				$122,341		$1,296,815
Contingency (20%)				$244,682		$2,593,629
TOTAL O&M COSTS				$1,700,500		$18,025,700
TOTAL ALTERNATIVE COSTS						$25,107,000

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- Water from the basins would be metered at a combined flow of 4 cfs to a treatment plant constructed on site about 800 feet east of the 5th Street headwall.

- The treatment system would consist of two 900-gallons-per-minute trains (4 cfs total) operating seven months per year. Each train would include coagulation, flocculation, and sedimentation vessels followed by a pH adjustment and sand filtration. Chemical addition would include mostly caustic soda and smaller amounts of iron sulfide. If necessary, cake from the filter press would be solidified/stabilized prior to disposal.

- SHG channel would be reconstructed to convey a 100-year, 24-hour storm (estimated to reach 63 cfs at the detention basin).

- Operation of the treatment system includes labor, chemical addition, electricity, sludge disposal, and performance monitoring. See spreadsheet in Appendix B for details.

- Sediment would be mucked from the basins periodically. Inspection of the basins would be conducted on a quarterly basis. Repairs of the basins are estimated as a percentage of the construction cost. It is anticipated that the basin liners would be replaced every ten years.

- Diversion and pipeline maintenance is estimated as a percentage of the construction cost.

- SHG channel maintenance is estimated as a percentage of the construction cost.

- Sediment along SHG would not be removed under this alternative.

- Surface water monitoring would be included under the treatment plant monitoring.

- A site evaluation inspection would be required every five years. The five-year inspection would require data collection which may include an AVIRIS fly over.

6.5.3 WAMP CRITERIA

6.5.3.1 Surface Erosion Stability

Remediated surfaces located within the 500 year floodplain would be designed for stability under 500-year, 24-hour and 2-hour storm events.

6.5.3.2 Slope Stability

Slopes of impoundment embankments would be designed with a Factor of Safety of 1.5.

6.5.3.3 Flow Capacity and Stability

The SHG stream channel would be regraded, lined, and armored against stream flow erosional instability up to a 500-year, 24-hour storm event. The channel would be reconfigured to hold flows up to a 100-year storm event, and while stable for a 500-year event, some overflow of the channel could occur for flows over the 100-year storm event. The in-stream drainage detention structures would be designed to contain and control stream flows up to a 100-year storm event and to be stable up to a 500-year storm event. This means storm flows over a 100-year event would be passed through a spillway structure or over a structurally sound dam section protected by armor against erosion. The stream channel would be reconfigured to the extent practicable to replicate the naturally occurring stream channel. The diversion pipeline would be sized to divert the bulk of the 100-year storm event volume exiting Adelaide Park with the overflow being captured by the lower SHG channel (overdesigned to handle this overflow).

6.5.3.4 Surface Water and Groundwater Loading Reduction

By diverting upper SHG waters away from the ARD-generating sources within the lower SHG watershed basin, the quantity of contaminated surface water running through SHG and infiltrating into the groundwater would be reduced. The surface water flows in the lower portion of SHG would be diverted to and treated at an onsite treatment plant to reduce heavy-metal contaminants to NPDES standards. The actual net load reduction will be determined after the alternative is implemented and post-remediation sampling is conducted. The final remediation of OU6 will be discussed in the ROD.

Groundwater contamination would continue to be captured and removed at Reclamation's LMDTTP

6.5.3.5 Terrestrial Ecosystem Exposure

Terrestrial ecosystems would not be restored or improved and risk to all species would remain unchanged through implementing Alternative W5 alone or in combination with source control alternative S1 from Section 5.0. Exposure reduction would occur when Alternative W5 is paired with either source control alternative S2, S3, or S4.

6.5.3.6 Nonresidential Soils

There would be no improvement in nonresidential soils in SHG through implementing Alternative W5 alone or in combination with source control alternative S1 from Section 5.0. However this alternative could be paired with either Alternative S2, S3, or S4 that do remove areas of nonresidential soils and waste rock exceeding 16,000-mg/kg lead that pose risk to recreational users in the immediate vicinity of the City of Leadville and in the lower SHG watershed basin.

6.6 COMPARATIVE ANALYSIS OF SURFACE WATER CONTROL ALTERNATIVES

In this section, the relative performance of each alternative is evaluated in relation to the NCP and WAMP criteria. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another in order to reach a balanced judgement for the selection of the preferred alternative.

6.6.1 NCP CRITERIA

Table 6.6 provides a detailed comparison of each alternative against the three main NCP criteria: effectiveness, implementability and cost.

Neither Alternative W1, W2, nor W3 are expected to achieve much protection of human health and the environment on their own. They were designed chiefly as SHG rehabilitation alternatives

TABLE 6.6
COMPARISON OF SURFACE WATER CONTROL ALTERNATIVES USING NCP CRITERIA

NCP Criteria	Alternative W1 Rehabilitation of the SHG Channel	Alternative W2 Detention of Surface Waters within SHG	Alternative W3 Diversion of Surface Waters via Graham Park
EFFECTIVENESS Protectiveness	Alternative W1 alone would be neither protective of public health nor the environment. This alternative is designed chiefly to complement a source control alternative from Section 5.0.	Alternative W2 alone would be neither protective of public health nor the environment. This alternative is designed chiefly to complement a source control alternative from Section 5.0.	Alternative W3 alone would be neither protective of public health nor the environment. This alternative is designed chiefly to complement a source control alternative from Section 5.0.
Ability to Achieve Removal Objectives	By itself, the only RAO Alternative W1 would achieve is preservation of historic features.	By itself, the only RAO Alternative W2 would achieve is preservation of historic features.	By itself, the only RAO Alternative W3 would achieve is preservation of historic features.
IMPLEMENTABILITY Technical Feasibility	There are no anticipated technical difficulties with implementing this alternative.	There are no anticipated technical difficulties with implementing this alternative.	Silt blockages or ice dams may occur regularly in the buried piping requiring costly repairs.
Availability	Utilizes readily available materials and labor.	Utilizes readily available materials and labor.	Utilizes readily available materials and labor.
Administrative Feasibility	There are no administrative issues for Alternative W1. There may however be issues surrounding the source control alternative that is selected to complement it.	The size of the detention basin and its potential impact on the views of the vista present a concern to the Lake County officials.	The diversion pipeline to Graham Park could impact future remedial activities and/or land use in OU4 and OU6. Site access and land acquisition may be difficult and could delay the project.
COST Net Present Worth	$524,000	$1,328,000	$2,681,000

TABLE 6.6 (Continued)
COMPARISON OF SURFACE WATER CONTROL ALTERNATIVES USING NCP CRITERIA

NCP Criteria	Alternative W4 Diversion of Surface Waters to LMDT	Alternative W5 Treatment of Surface Waters within SHG
EFFECTIVENESS Protectiveness	Alternative W4 would reduce heavy metals loading into Starr Ditch and California Gulch. The alternative does not protect against direct contact with lead-contaminated materials.	Alternative W5 would reduce heavy metals loading into Starr Ditch and California Gulch. The alternative does not protect against direct contact with lead-contaminated materials.
Ability to Achieve Removal Objectives	By itself, the only RAO Alternative W4 would achieve is preservation of historic features. Although the alternative will not control migration of metals from contaminated materials into the surface water, it will directly treat the contaminated surface water and groundwater.	By itself, the only RAO Alternative W5 would achieve is preservation of historic features. Although the alternative will not control migration of metals from contaminated materials into the surface water, it will directly treat the contaminated surface water.
IMPLEMENTABILITY Technical Feasibility	The large volume of water diverted during a storm event may be deterimental to the stability of the Emmet Shaft and LMDT. The LMDTTP may have difficulty handling the increase flow and variation in chemistry.	Materials of construction specified in the design of the treatment plant would have to account for the low-pH influent and adverse weather conditions. Treatment system utilizes conventional process units.
Availability	Specialized equipment may be required in refurbishing the Emmet Shaft.	Equipment and materials for treatment plant may not be available locally. Difficult to implement in short construction season.
Administrative Feasibility	The diversion pipeline to Graham Park could impact future remedial activities and/or land use in OU4 and OU6. Site access and land acquisition may be difficult and could delay the project. Further, the second diversion of water to the LMDT may affect water rights along California Gulch.	The diversion pipeline to Graham Park could impact future remedial activities and/or land use in OU4 and OU6. Site access and land acquisition may be difficult and could delay the project.
COST Net Present Worth	$7,429,000	$25,107,000

to accompany the selection of either Alternative S2, S3, or S4. Through wastewater treatment, Alternatives W4 and W5, on the other hand, could offer standalone protection of the California Gulch and the Arkansas River from contaminated surface water originating in SHG. These two treatment alternatives though would have difficulty by themselves achieving protection against exposure to surface lead contamination.

Alternative W1 would be the simplest to implement. Implementing Alternative W3 is more difficult than Alternative W2 due to the added component of diverting and piping water from Adelaide Park to California Gulch in addition to constructing a detention basin within SHG. Alternatives W4 and W5 are the most difficult to implement. Alternative W4 may have a slight advantage over Alternative W5 because it uses the existing LMDTTP (with some modifications) versus constructing and starting up a new facility; however, it is unknown to what extent the Emmett Shaft and the LMDT can handle the high flood volumes that would be diverted to them.

Alternative W1 is expected to cost approximately $524,000 Alternatives W2 and W3 follow at $1,328,000 and $2,681,000, respectively. The two treatment alternatives, Alternatives W4 and W5 are anticipated to cost much higher at roughly $7,429,000 and $25,107,000, respectively.

6.6.2 WAMP CRITERIA

Table 6.7 provides a detailed comparison of each alternative against the six main WAMP criteria as discussed in the alternatives analysis above.

All of the surface water control alternatives would be designed to convey the 100-year flood and withstand erosion during the 500-year flood. Additionally, those alternatives that have retention basins (W2, W3, W4, and W5) would be designed with a Factor of Safety of 1.5 for static conditions and 1.0 for pseudo-static conditions.

Alternatives W1, W2, and W3 do not reduce mass loading. Loading reduction would occur when one of these alternatives is paired with a source control alternative as discussed in Section 5.0. Alternatives W4 or W5, on the other hand, would achieve mass loading reduction either

TABLE 6.7
COMPARISON OF SURFACE WATER CONTROL ALTERNATIVES USING WAMP CRITERIA

WAMP Criteria	Alternative W1 Rehabilitation of the SHG Channel	Alternative W2 Detention of Surface Waters within SHG	Alternative W3 Diversion of Surface Waters via Graham Park
Surface Erosion Stability	Surfaces in remediated areas would be designed for stability during storm events.	Surfaces in remediated areas would be designed for stability during storm events.	Surfaces in remediated areas would be designed for stability during storm events.
Slope Stability	Slopes of embankments would be designed with a Factor of Safety of 1.5.	Slopes of impoundment embankments would be designed with a Factor of Safety of 1.5.	Slopes of impoundment embankments would be designed with a Factor of Safety of 1.5.
Flow Capacity and Stability	The SHG stream channel would carry flows up to a 100-year storm event while stable for a 500-year storm event. No additional measures would be taken to control exceedances of the 5th St headwall.	The SHG stream channel would carry flows up to a 100-year storm event while stable for a 500-year storm event. Measures would be taken to control exceedances of the 5th St headwall.	The SHG stream channel would carry flows up to a 100-year storm event while stable for a 500-year storm event. Measures would be taken to control exceedances of the 5th St headwall.
Surface Water and Groundwater Contaminant Load Reduction	No mass load reduction would be achieved by Alternative W1 alone. Loading reduction would occur when the alternative is paired with a a source control alternative.	No mass load reduction would be achieved by Alternative W2 alone. Loading reduction would occur when the alternative is paired with a a source control alternative.	No mass load reduction would be achieved by Alternative W3 alone. Loading reduction would occur when the alternative is paired with a a source control alternative.
Terrestrial Ecosystem Exposure	Terrestrial ecosystem would not be restored or improved by Alternative W1 alone.	Terrestrial ecosystem would not be restored or improved by Alternative W2 alone.	Terrestrial ecosystem would not be restored or improved by Alternative W3 alone.
Nonresidential Soils	No improvement in non-residential soils.	No improvement in non-residential soils.	No improvement in non-residential soils.

TABLE 6.7 (Continued)
COMPARISON OF SURFACE WATER CONTROL ALTERNATIVES USING WAMP CRITERIA

WAMP Criteria	Alternative W4 Diversion of Surface Waters to LMDT	Alternative W5 Treatment of Surface Waters within SHG
Surface Erosion Stability	Surfaces in remediated areas would be designed for stability during storm events.	Surfaces in remediated areas would be designed for stability during storm events.
Slope Stability	Slopes of impoundment embankments would be designed with a Factor of Safety of 1.5.	Slopes of impoundment embankments would be designed with a Factor of Safety of 1.5.
Flow Capacity and Stability	The SHG stream channel would carry flows up to a 100-year storm event while stable for a 500-year storm event. Measures would be taken to control exceedances of the 5th St headwall.	The SHG stream channel would carry flows up to a 100-year storm event while stable for a 500-year storm event. Measures would be taken to control exceedances of the 5th St headwall.
Surface Water and Groundwater Contaminant Load Reduction	By diverting surface waters to LMDTTP, contaminant loading is reduced through treatment. Groundwater is also treated at the LMDTTP.	By diverting surface waters to the treatment system, contaminant loading is reduced through treatment. Groundwater is treated at the LMDTTP.
Terrestrial Ecosystem Exposure	Terrestrial ecosystem would not be restored or improved by Alternative W4 alone.	Terrestrial ecosystem would not be restored or improved by Alternative W5 alone.
Nonresidential Soils	No improvement in non-residential soils.	No improvement in non-residential soils.

alone or combined with a source control alternative. Alternative W5 has the advantage of offering more control of the conveyance of stormwater to the treatment plant and a higher efficiency at treating the metals compared with Alternative W4 Groundwater contamination would continue to be captured and removed at Reclamation's LMDTTP.

By themselves, the Surface Water Control alternatives would show little improvement to either the terrestrial ecosystem or to nonresidential soils. They would have to be paired off with either Alternatives S2, S3, and S4 to be effective at reducing exposure of contaminated materials to the ecosystem and at removing lead-contaminated nonresidential soils from the vicinity of Leadville.

7.0 RECOMMENDED REMOVAL ACTION ALTERNATIVE

7.1 RECOMMENDED SOURCE CONTROL ALTERNATIVE

The recommended alternative is Alternative S3. Alternative S3 meets all of the RAOs developed for OU6. Alternative S3 will control airborne transport of contaminated materials, control erosion of contaminated materials into local water courses, control leaching and migration of metals from contaminated materials into surface water and groundwater, control direct contact with and ingestion of contaminated materials, and maintain/preserve historic and cultural features of the OU. Alternative S1 by itself cannot achieve most of these RAOs. If paired with one of the surface water treatment alternatives (W4 or W5), the combination could reduce the concentration of metals in the surface water but would have no impact on the surface lead contamination. Alternative S2 achieves most of the RAOs but at the expense of not being able to preserve the historic features consistent with the NRHP. Alternatives S4 will achieve all of these RAOs but at a higher cost than Alternative S3.

Alternative S3 will also conform to all the WAMP criteria with the exception of the flow capacity criteria. Alternative S3 will meet surface erosion and slope stability requirements. It will reduce surface water and groundwater loading and reduce exposure of the terrestrial ecosystem. This alternative is anticipated to show a quantifiable improvement in the quality of the SHG surface water. The actual net load reduction will be determined after Alternative S3 is implemented and post-remediation sampling is conducted.

To conform with the flow capacity criteria, Alternative S3 will require the selection of a surface water control alternative.

7.2 RECOMMENDED SURFACE WATER CONTROL ALTERNATIVE

Paired with source control Alternative S3, all of the surface water control alternatives will provide the flow capacity requirements that Alternative S3 lacks.

It should be noted that Alternatives W4 and W5 were designed chiefly as standalone alternatives (without a source control); however, neither of them can achieve all of the RAOs, namely they cannot control direct contact with materials contaminated with lead and cannot control airborne transport and surface erosion of contaminated materials.

By selecting a source control alternative such as Alternative S3, it is anticipated that the source control alternative will reduce surface water loading and therefore treatment of the surface water (i.e. Alternatives W4 and W5) will not be necessary.

The remaining alternatives W1, W2, and W3 will all rehabilitate the SHG channel in order to convey a 100-year, 24-hour storm event and would be designed for stability under flows resulting from a 500-year, 24-hour storm event. Alternatives W2 and W3 have the additional benefit of regulating flows arriving at the 5th Street headwall down to a rate that meets the capacity of the stormwater piping that runs along 5th Street. Alternative W2 can do this at little over half the cost of Alternative W3.

The selection of the surface water control alternative will be made after results of source control actions can be assessed through water quality sampling taken during seasonal runoff following construction of the source control.

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APPENDIX A

Applicable or Relevant and Appropriate Requirements

APPENDIX A ACRONYM LIST

APEN	Air Pollution Emission Notice
ARAR	Applicable or Relevant and Appropriate Requirements
CCR	Code of Colorado Regulations
CFR	Code of Federal Regulations
CRS	Colorado Revised Statutes
CWA	Clean Water Act
EPA	United States Environmental Protection Agency
LDR	Land Disposal Restrictions
NAAQS	National Ambient Air Quality Standards
NHPA	National Historic Preservation Act
OU	Operable Unit
RCRA	Resource Conservation and Recovery Act
SIP	State Implementation Plan
TSP	Total Suspended Particulate Matter
USC	United States Code

SUMMARY OF POTENTIAL FEDERAL AND STATE CHEMICAL-SPECIFIC ARARS

Standard, Requirement, Criteria, or Limitation	Citation	Potentially Applicable	Potentially Relevant and Appropriate	Description
FEDERAL				
Clean Air Act, National Primary and Secondary Ambient Air Quality Standards	40 CFR Part 50	No	No	National ambient air quality standards (NAAQS) are implemented through the New Source Review Program and State Implementation Plans (SIPs). The federal New Source Review program address only major sources. Emissions associated with proposed removal action in OU6 will be limited to fugitive dust emissions associated with earth moving activities during construction. These activities will not constitute a major source. Therefore, attainment and maintenance of NAAQS pursuant to the New Source Review Program are not ARARs. See Colorado Air Pollution Prevention and Control Act concerning applicability of requirements implemented through the SIP.
RCRA Land Disposal Restrictions (LDRs)	40 CFR Part 268	No	No	RCRA LDRs are not applicable because the materials in issue have been identified as extraction or beneficiation wastes that are specifically exempted from the definition of a hazardous waste. Not relevant and appropriate, see Superfund LDR Guide #7.

SUMMARY OF POTENTIAL FEDERAL AND STATE CHEMICAL-SPECIFIC ARARS (Continued)

Standard, Requirement, Criteria, or Limitation	Citation	Potentially Applicable	Potentially Relevant and Appropriate	Description
STATE OF COLORADO				
Colorado Air Pollution Prevention and Control Act	5 CCR 1001-14 5 CCR 1001-10 Part C (I) &(II) Regulation 8	Yes	---	Pursuant to the Colorado Air Pollution Prevention and Control Act applicants for construction permits are required to evaluate whether the proposed source will exceed NAAQS. Applicants are also required to evaluate whether the proposed activities would cause the Colorado ambient standard for TSP to be exceeded. Construction activities associated with proposed removal action in OU6 will be limited to generation of fugitive dust emissions. Colorado regulates fugitive emissions through Regulation No. 1. Compliance with applicable provisions of the Colorado air quality requirements will be achieved by adhering to a fugitive emissions control plan prepared in accordance with Regulation No. 1. Regulation 8 sets emission limits for lead and hydrogen sulfide. Applicants are required to evaluate whether the proposed activities would result in the Regulation 8 lead standard being exceeded. The proposed removal action in OU6 is not projected to exceed the emission levels for lead or hydrogen sulfide, although some lead emissions may occur. Compliance with Regulation 8 will be achieved by adhering to a fugitive emissions control plan prepared in accordance with Regulation No. 1.

SUMMARY OF POTENTIAL FEDERAL AND STATE LOCATION-SPECIFIC ARARS

Standard, Requirement Criteria, or Limitation	Citation	Potentially Applicable	Potentially Relevant and Appropriate	Description
FEDERAL				
Endangered Species Act	16 USC § 1531 et seq. 50 CFR §§ 200 and 402	No	No	Provides protection for threatened and endangered species and their habitats. However, site-specific studies did not document the presence of threatened or endangered species. If threatened or endangered species are encountered during remedial activities in OU6, then requirements of Act would be applicable.
Fish and Wildlife Coordination Act	16 USC § 661 et seq. 40 CFR § 6.302	No	No	Requires coordination with federal and state agencies to provide protection of fish and wildlife in water resource development programs; regulates actions that impound, divert, control, or modify any body of water. However, proposed removal action activities in OU6 will not affect fish or wildlife. If it appears that remedial activities may impact wildlife resources, EPA will coordinate with both the U.S. Fish and Wildlife Service and the Colorado Department of Natural Resources.
Wilderness Act	16 USC 1311, 16 USC 668 50 CFR 53, 50 CFR 27	No	No	Limits activities within areas designated as wilderness areas or National Wildlife Refuge Systems.
Executive Order No. 11988 Floodplain Management	40 CFR § 6.302 & Appendix A	Yes	---	Pertains to floodplain management and construction and impoundments in such areas.
Executive Order No. 11990 Protection of Wetlands	40 CFR § 6.302(a) and Appendix A	Yes	---	Minimizes adverse impacts on areas designated as wetlands.
Section 404, Clean Water Act (CWA)	33 USC 1251 et seq. 33 CFR Part 330	Yes	---	Regulates discharge of dredged or fill materials into waters of the United States. Substantive requirements of portions of Nationwide Permit No. 38 (General and Specific Conditions) are applicable to OU6 remedial activities conducted within waters of the United States.

SUMMARY OF POTENTIAL FEDERAL AND STATE LOCATION-SPECIFIC ARARS (Continued)

Standard, Requirement Criteria, or Limitation	Citation	Potentially Applicable	Potentially Relevant and Appropriate	Description
The Historic and Archaeological Data Preservation Act of 1974	16 USC 469 40 CFR § 6.301(c)	Yes	---	Establishes procedures to preserve historical and archeological data that might be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity program. A cultural resource survey was completed in OU6 to identify historic properties which may be affected by removal activity.
National Historic Preservation Act (NHPA)	16 USC § 470 et seq. 40 CFR § 6.301(b) 36 CFR Part 63, Part 65, Part 800	Yes	---	Expands historic preservation programs; requires preservation of resources included in or eligible for listing on the National Register for Historic Places.
Executive Order 11593 Protection and Enhancement of the Cultural Environment	16 USC § 470	Yes	---	Directs federal agencies to institute procedures to ensure programs contribute to the preservation and enhancement of non-federally owned historic resources. Consultation with the Advisory Council on Historic Preservation is required if removal activities should threaten cultural resources.
Historic Sites Act of 1935	16 USC § 461-467	No	No	Preserves for public use historic sites, buildings, and objects of natural significance.
The Archeological Resources Protection Act of 1979	16 USC §§ 470aa-47011	No	Yes	Requires a permit for any excavation or removal of archeological resources from public lands or Indian lands. Maybe relevant and appropriate if archeological resources are encountered during removal action activity.
Resource Conservation and Recovery Act (RCRA), Subtitle D	40 CFR Part 257, Subpart A, § 257.3-1 Floodplains, paragraph (a)	Yes	---	Provides general classification criteria for solid waste disposal facilities pertaining to floodplains.
STATE OF COLORADO				
Nongame, Endangered or Threatened Species Act	CRS §§ 33-2-101 to 108	No	No	Standards for regulation of nongame wildlife and threatened and endangered species. Site-specific studies did not document the presence of threatened or endangered species. If threatened or endangered species are encountered during remedial activities in OU6, then requirements of Act will be applicable.

SUMMARY OF POTENTIAL FEDERAL AND STATE LOCATION-SPECIFIC ARARS (Continued)

Standard, Requirement Criteria, or Limitation	Citation	Potentially Applicable	Potentially Relevant and Appropriate	Description
Colorado Register of Historic Places	CRS §§ 24-80.1-101 to 108	No	No	Authorizes the State Historical Society to nominate properties for inclusion on the State Register of Historic Places. Applicable only if removal action activities impact an area listed on the Register.
Colorado Historical, Prehistorical, and Archaeological Resources Act	CRS §§ 24-80-401 to 410 1301 to 1305	No	Yes	Concerns historical, prehistorical, and archaeological resources; applies only to areas owned by the State or its political subdivisions. May be relevant and appropriate if removal action impacts an archaeological site.
Colorado Species of Special Concern and Species of Undetermined Status	Colorado Division of Wildlife Administrative Directive E-1, 1985, modified	No	No	Protects species listed on the Colorado Division of Wildlife generated list. Urges coordination with the Division of Wildlife if wildlife species are to be impacted. No evidence of species of special concern have been identified at this site.
Colorado Natural Areas	Colorado Revised Statutes, Title 33 Article 33, Section 104	No	No	Maintains a list of plant species of "special concern." Although not protected by State statue, coordination with Division of Parks and Outdoor Recreation is recommended if activities will impact listed species.
Colorado Solid Waste Disposal Sites and Facilities Act,	6 CCR 1007-2 6 CCR 1007-2, Part I	No	No	Establishes regulations for solid waste management facilities, including location standards. Proposed removal action in OU6 will not establish a solid waste management facility.

SUMMARY OF POTENTIAL FEDERAL AND STATE ACTION-SPECIFIC ARARS

Standard, Requirement Criteria, or Limitation	Citation	Potentially Applicable	Potentially Relevant and Appropriate	Description
FEDERAL				
Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act of 1976 (RCRA)	40 CFR Part 257, Subpart A: § 257.3-1 Floodplains, paragraph (a); § 257.3-7 Air, paragraph (b)	Yes	---	Selected portions of Part 257 pertaining to floodplains and air are applicable. These provisions establish criteria for classification of solid waste disposal facilities and practices.
Hazardous Materials Transportation Act	49 USC § 1801-1813 49 CFR 107, 171-177	No	No	Regulates transportation of hazardous materials. Proposed removal action in OU6 will be conducted on private property and will not entail off-site transportation of hazardous materials.
STATE OF COLORADO				
Colorado Solid Waste Disposal Sites and Facilities Act	6 CCR 1007-2	No	No	Establishes standards for licensing, locating, constructing and operating solid waste facilities. Proposed removal action in OU6 will not involve establishment of a solid waste disposal facility.
Colorado Water Quality Control Act, Storm Water Discharge Regulations	5 CCR 1002-2	Yes	---	Establishes requirements for storm water discharges (except portions relating to Site-wide Surface and Groundwater). Substantive requirements for storm water discharges associated with construction activities are applicable.
Colorado Mined Land Reclamation Act	CRS 34-32-101 to 125 Rule 3 of Mineral Rules and Regulations	No	Yes	Regulates all aspects of land use for mining, including the location of mining operations and related reclamation activities and other environmental and socio-economic impacts. Substantive requirements of selected portions of Rule 3 regarding Reclamation Measures, Water - General Requirements (except portions relating to Side-wide Surface and Ground Water), Wildlife, and Revegetation are potentially relevant and appropriate.

SUMMARY OF POTENTIAL FEDERAL AND STATE ACTION-SPECIFIC ARARS (Continued)

Standard, Requirement Criteria, or Limitation	Citation	Potentially Applicable	Potentially Relevant and Appropriate	Description
Colorado Air Pollution Prevention and Control Act	5 CCR 1001-3; Sections III.D.1.b,c,d. Sections III.D.2.b,c,e,f,g. Regulation 1	Yes	---	Regulation No. 1 provisions concerning fugitive emissions for construction activities, storage and stockpiling activities, haul roads, haul trucks, and tailing ponds are applicable (5 CCR 1001-3; Sections III.D.2.b,c,e,f,g.). Construction activities in OU6 will be conducted in accordance with a fugitive emissions control plan.
Colorado Noise Abatement Act	CRS §§ 25-12-101 to 108	Yes	---	Establishes maximum permissible noise levels for particular time periods and land use related to construction projects.
Regulations on the Collection of Aquatic Life	2 CCR 406-8, Ch. 13, Article III, Sec. 1316	No	No	Requirements governing the collection of wildlife for scientific purposes. Removal action activities within OU6 will not include biological monitoring.
Colorado Hazardous Waste Regulations	6 CCR 1007-3, Part 264: Section 264.301, (g), (h), (i), and (j); Section 264.310, (a)(1) through (a)(4); Section 264.310, (b)(1) and (b)(5)	No	Yes	These specific provisions of the hazardous waste regulations may be relevant and appropriate for conducting removal actions in OU6. Specific provisions of Section 264.301 concern run-on control, run-off control, management of run-on and run-off control systems, and wind dispersal. Specific provisions of Section 264.310 concern placement of a cover to minimize infiltration, minimize maintenance, promote drainage and minimize erosion, and accommodate settling.
Colorado Air Pollution Prevention and Control Act	5 CCR 1001-4 Regulation 2 Odors	Yes	---	Applicable only if removal action activities cause objectionable odors. Removal action in OU6 is not expected to produce odors.
Colorado Air Pollution Prevention and Control Act	5 CCR 1001-5 Regulation 3 APENs	Yes	---	Substantive provisions of APENs will be met.

APPENDIX B

Breakdown of Cost Estimates

CALIFORNIA GULCH OU6

ALTERNATIVE S1
SEDIMENT REMOVAL

				FACTOR		
Mobilization/Site Preparation	LS	1	$6,408.12		$6,408.12	**$6,408.12**
Sediment Removal						
SHG Sediment Removal	BCY	15,600	$2.50	1.10	$42,900.00	
SHG Load & Haul to Disposal Facility (10 mile)	CY	14,000	$3.11	1.10	$47,894.00	
Starr Ditch Sediment Removal	BCY	2,000	$2.50	1.10	$5,500.00	
Starr Ditch Load & Haul to Disposal Facility (10 m	CY	2,300	$3.11	1.10	$7,868.30	
Remove Chain Link Fence	LF	3,000	$3.00		$9,000.00	
Subtotal						**$113,162.30**
Sediment Removal Confirmation Sampling	EA.	20	$500.00		$10,000.00	**$10,000.00**
Air Monitoring	LS	1	$5,000.00		$5,000.00	**$5,000.00**
			CAPITAL COSTS SUBTOTAL			**$134,570.42**
Operations and Maintenance Items						
SHG Sediment Removal	BCY	3,120	$2.50	1.10	$8,580.00	
SHG Load & Haul to Disposal Facility (10 mile)	CY	2,800	$3.11	1.10	$9,578.80	
Starr Ditch Sediment Removal	BCY	400	$2.50	1.10	$1,100.00	
Starr Ditch Load & Haul to Disposal Facility (10 m	CY	460	$3.11	1.10	$1,573.66	
5-Year Site Reviews	EA./5 Yr.	0.20	$78,000.00		$15,600.00	
Stormwater Monitoring	LS	1	$4,160.00		$4,160.00	
Subtotal						**$40,592.46**
		OPERATIONS AND MAINTENANCE SUBTOTAL				**$40,592.46**
Note:						
H.W. Factor = Hazardous Waste Factor of 10% applied for work conducted in modified Level "C" conditions.						
LS - Lump Sum	CY - Cubic Yard (Assuming 15% expansion)					
LF - Linear Feet	BCY - Bank Cubic Yard					
Yr - Year	EA -Each					

CALIFORNIA GULCH OU6

ALTERNATIVE S2
CONSOLIDATION INTO SINGLE REPOSITORY WITH CAPPING

ITEM	UNIT	QUANTITY	UNIT COST	H.W. FACTOR	SUBTOTAL	TOTAL COST
Mobilization/Site Preparation	L.S.	1	$249,432.22		$249,432.22	**$249,432.22**
Strip Repository Area	AC.	10	$1,500.00		$15,000.00	**$15,000.00**
Waste Rock Piles Excavation and Consolidation	B.C.Y.	604,550	$5.00	1.10	$3,325,025.00	**$3,325,025.00**
Excavation Confirmation Sampling	EA.	100	$500.00		$50,000.00	**$50,000.00**
Geomembrane (with Geotextile) installed	S.F.	435,600	$0.97		$422,532.00	**$422,532.00**
Rockfill cap material						
Excavate/Haul rockfill	C.Y.	96,100	$5.50		$528,550.00	
Place rockfill	C.Y.	96,100	$1.75		$168,175.00	
Subtotal						**$696,725.00**
White porphyry/dolomite veneer						
Excavate/Haul white porphyry/dolomite fill	C.Y.	16,100	$5.50		$88,550.00	
Place white porphyry/dolomite fill	C.Y.	16,100	$2.00		$32,200.00	
Subtotal						**$120,750.00**
Hydromulch Revegetation	S.Y.	279,000	$0.30		$83,700.00	**$83,700.00**
Perimeter Ditch around Repository	L.F.	2500	$5.00	1.10	$13,750.00	**$13,750.00**
Cap Mine Shafts	EA	36	$5,000.00	1.10	$198,000.00	**$198,000.00**
Sediment Removal						
SHG Sediment Removal	BCY	15,600	$2.50	1.10	$42,900.00	
SHG Load & Haul to Disposal Facility (10 mile)	CY	14,000	$3.11	1.10	$47,894.00	
Starr Ditch Sediment Removal	BCY	2,000	$2.50	1.10	$5,500.00	
Starr Ditch Load & Haul to Disposal Facility (10 mile)	CY	2,300	$3.11	1.10	$7,868.30	
Remove Chain Link Fence	LF	3,000	$3.00		$9,000.00	
Subtotal						**$113,162.30**
Sediment Removal Confirmation Sampling	EA.	20	$500.00		$10,000.00	**$10,000.00**
Dust Control	L.S.	1	$25,000.00		$25,000.00	**$25,000.00**
Air Monitoring	L.S.	1	$60,000.00		$60,000.00	**$60,000.00**
			CAPITAL COSTS SUBTOTAL			**$5,383,076.52**
Operations and Maintenance Items						
SHG Sediment Removal	BCY	1,560	$2.50	1.10	$4,290.00	
SHG Load & Haul to Disposal Facility (10 mile)	CY	1,400	$3.11	1.10	$4,789.40	
Starr Ditch Sediment Removal	BCY	200	$2.50	1.10	$550.00	
Starr Ditch Load & Haul to Disposal Facility (10 mile)	CY	230	$3.11	1.10	$786.83	
Cap Maintenance/Repair	LS	1	$7,203.57		$7,203.57	
5-Year Site Reviews	EA./5 Yr.	0.20	$78,000.00		$15,600.00	
Quarterly Inspection	EA.	4	$500.00		$2,000.00	
Stormwater Monitoring	LS	1	$4,160.00		$4,160.00	
Subtotal						**$39,379.80**
		OPERATIONS AND MAINTENANCE SUBTOTAL				**$39,379.80**
Note:						
H.W. Factor = Hazardous Waste Factor of 10% applied for work conducted in modified Level "C" conditions.						
LS - Lump Sum	CY - Cubic Yard (Assuming 15% expansion)					
LF - Linear Feet	BCY - Bank Cubic Yard					
Yr - Year	EA - Each					
Ac - Acre	SF - Square Feet					

CALIFORNIA GULCH OU6

ALTERNATIVE S3
CONSOLIDATION INTO MULTIPLE PILES WITH CAPPING

ITEM	UNIT	QUANTITY	UNIT COST	H.W. FACTOR	SUBTOTAL	TOTAL COST
Mobilization/Site Preparation	L.S.	1	$225,911.85		$225,911.85	**$225,911.85**
Waste Rock Piles Excavation and Consolidation	B.C.Y.	325,500	$3.50	1.10	$1,253,175.00	**$1,253,175.00**
Excavation Confirmation Sampling	EA.	70	$500.00		$35,000.00	**$35,000.00**
Geomembrane (with Geotextile) installed	S.F.	750,600	$0.97		$728,082.00	**$728,082.00**
Rockfill cap material						
Excavate/Haul rockfill (includes haul road maintenance)	C.Y.	165,600	$5.50		$910,800.00	
Place rockfill	C.Y.	165,600	$1.75		$289,800.00	
Subtotal						**$1,200,600.00**
White porphyry/dolomite veneer						
Excavate/Haul white porphyry and dolomite fill	C.Y.	27,800	$5.50		$152,900.00	
Place white porphyry and dolomite fill	C.Y.	27,800	$2.00		$55,600.00	
Subtotal						**$208,500.00**
Hydromulch Revegetation	S.Y.	115,000	$0.30		$34,500.00	**$34,500.00**
Perimeter Ditches around Waste Rock Piles	L.F.	5,850	$5.00	1.10	$32,175.00	**$32,175.00**
Reconstruction of Cribbing	S.F.	8,150	$15.00	1.10	$134,475.00	**$134,475.00**
Moat Construction at Pyrenees	L.F.	1,600	$10.00	1.10	$17,600.00	**$17,600.00**
Cap Mine Shafts	EA	36	$5,000.00	1.10	$198,000.00	**$198,000.00**
Sediment Removal						
SHG Sediment Removal	BCY	15,600	$2.50	1.10	$42,900.00	
SHG Load & Haul to Disposal Facility (10 mile)	CY	14,000	$3.11	1.10	$47,894.00	
Starr Ditch Sediment Removal	BCY	2,000	$2.50	1.10	$5,500.00	
Starr Ditch Load & Haul to Disposal Facility (10 mile)	CY	2,300	$3.11	1.10	$7,868.30	
Remove Chain Link Fence	LF	3,000	$3.00		$9,000.00	
Subtotal						**$113,162.30**
Sediment Removal Confirmation Sampling	EA.	20	$500.00		$10,000.00	**$10,000.00**
Solidification/Stabilization Treatment Study	L.S.	1	$65,000.00		$65,000.00	**$65,000.00**
Solidification of Historic Waste Rock Piles (RAM/Greenback)						
Cut Pile Face for Solidification	B.C.Y.	11,520	$3.00	1.10	$38,016.00	
Solidify Waste Material (allowing for expansion)	C.Y.	12,672	$35.00	1.10	$487,872.00	
Place and Compact Solidified Material (allowing for expansi	C.Y.	13,248	$2.00	1.10	$29,145.60	
Construct Drainage Ditches around the Historic Piles	L.F.	2,900	$5.00	1.10	$15,950.00	
Subtotal						**$532,967.60**
Air Monitoring	L.S.	1	$45,000.00		$45,000.00	**$45,000.00**
Dust Control	L.S.	1	$25,000.00		$25,000.00	**$25,000.00**
			CAPITAL COSTS SUBTOTAL			**$4,859,148.75**
Operations and Maintenance Items						
SHG Sediment Removal	BCY	1,560	$2.50	1.10	$4,290.00	
SHG Load & Haul to Disposal Facility (10 mile)	CY	1,400	$3.11	1.10	$4,789.40	
Starr Ditch Sediment Removal	BCY	200	$2.50	1.10	$550.00	
Starr Ditch Load & Haul to Disposal Facility (10 mile)	CY	230	$3.11	1.10	$786.83	
Cap Maintenance/Repair	LS	1	$13,373.28		$13,373.28	
5-Year Site Reviews	EA./5 Yr.	0.20	$78,000.00		$15,600.00	
Quarterly Inspection	EA.	4	$500.00		$2,000.00	
Stormwater Monitoring	LS	1	$4,160.00		$4,160.00	
Subtotal						**$45,549.51**
		OPERATIONS AND MAINTENANCE SUBTOTAL				**$45,549.51**
Note:						
H.W. Factor = Hazardous Waste Factor of 10% applied for work conducted in modified Level "C" conditions.						
LS - Lump Sum	CY - Cubic Yard (Assuming 15% expansion)					
LF - Linear Feet	BCY - Bank Cubic Yard					
Yr - Year	EA - Each					
Ac - Acre	SF - Square Feet					

CALIFORNIA GULCH OU6

ALTERNATIVE S4
CONSOLIDATION INTO MULTIPLE PILES WITH SOLIDIFICATION

ITEM	UNIT	QUANTITY	UNIT COST	H.W. FACTOR	SUBTOTAL	TOTAL COST
Mobilization/Site Preparation	L.S.	1	$313,207.43		$313,207.43	**$313,207.43**
Waste Rock Piles Excavation and Consolidation	B.C.Y.	325,500	$3.50	1.10	$1,253,175.00	**$1,253,175.00**
Excavation Confirmation Sampling	EA.	70	$500.00		$35,000.00	**$35,000.00**
Solidification of Waste Rock Piles						
Solidify Waste Material (allowing for expansion)	C.Y.	87,570	$35.00	1.10	$3,371,445.00	
Place and Compact Solidified Material (allowing for expansi	C.Y.	95,910	$2.00	1.10	$211,002.00	
Subtotal						**$3,582,447.00**
Hydromulch Revegetation	S.Y.	115,000	$0.30		$34,500.00	**$34,500.00**
Perimeter Ditches around Waste Rock Piles	L.F.	5,850	$5.00	1.10	$32,175.00	**$32,175.00**
Reconstruction of Cribbing	S.F.	8,150	$15.00	1.10	$134,475.00	**$134,475.00**
Cap Mine Shafts	EA	36	$5,000.00	1.10	$198,000.00	**$198,000.00**
Sediment Removal						
SHG Sediment Removal	BCY	15,600	$2.50	1.10	$42,900.00	
SHG Load & Haul to Disposal Facility (10 mile)	CY	14,000	$3.11	1.10	$47,894.00	
Starr Ditch Sediment Removal	BCY	2,000	$2.50	1.10	$5,500.00	
Starr Ditch Load & Haul to Disposal Facility (10 mile)	CY	2,300	$3.11	1.10	$7,868.30	
Remove Chain Link Fence	LF	3,000	$3.00		$9,000.00	
Subtotal						**$113,162.30**
Sediment Removal Confirmation Sampling	EA.	20	$500.00		$10,000.00	**$10,000.00**
Solidification/Stabilization Treatment Study	L.S.	1	$65,000.00		$65,000.00	**$65,000.00**
Solidification of Historic Waste Rock Piles (Pyrenees/RAM/Greenback)						
Cut Pile Face for Solidification	B.C.Y.	18,464	$3.00	1.10	$60,931.20	
Solidify Waste Material (allowing for expansion)	C.Y.	20,310	$35.00	1.10	$781,950.40	
Place and Compact Solidified Material (allowing for expansi	C.Y.	21,234	$2.00	1.10	$46,713.92	
Construct Drainage Ditches around the Historic Piles	L.F.	4,100	$5.00	1.10	$22,550.00	
Subtotal						**$851,214.32**
Air Monitoring	L.S.	1	$45,000.00		$45,000.00	**$45,000.00**
Dust Control	L.S.	1	$25,000.00		$25,000.00	**$25,000.00**
			CAPITAL COSTS SUBTOTAL			**$6,692,356.05**
Operations and Maintenance Items						
SHG Sediment Removal	BCY	1,560	$2.50	1.10	$4,290.00	
SHG Load & Haul to Disposal Facility (10 mile)	CY	1,400	$3.11	1.10	$4,789.40	
Starr Ditch Sediment Removal	BCY	200	$2.50	1.10	$550.00	
Starr Ditch Load & Haul to Disposal Facility (10 mile)	CY	230	$3.11	1.10	$786.83	
Cap Maintenance/Repair	LS	1	$9,742.98		$9,742.98	
5-Year Site Reviews	EA./5 Yr.	0.20	$78,000.00		$15,600.00	
Quarterly Inspection	EA.	4	$500.00		$2,000.00	
Stormwater Monitoring	LS	1	$4,160.00		$4,160.00	
Subtotal						**$41,919.21**
		OPERATIONS AND MAINTENANCE SUBTOTAL				**$41,919.21**
Note:						
H.W. Factor = Hazardous Waste Factor of 10% applied for work conducted in modified Level "C" conditions.						
LS - Lump Sum	CY - Cubic Yard (Assuming 15% expansion)					
LF - Linear Feet	BCY - Bank Cubic Yard					
Yr - Year	EA - Each					
Ac - Acre	SF - Square Feet					

CALIFORNIA GULCH OU6

ALTERNATIVE W1
REHABILITATION OF THE STRAY HORSE GULCH CHANNEL

ITEM	UNIT	QUANTITY	UNIT COST	H.W.	SUBTOTAL	TOTAL COST
				FACTOR		
Mobilization/Site Preparation	L.S.	1	$17,228		$17,227.80	**$17,227.80**
Rehabilitate SHG Channel - Adelaide to Hamms						
Non-woven, needle punch geotextile (200 # grab tensile str	S.Y.	18,900	$2.50		$47,250.00	
Geomembrane over geotextile	S.Y.	8,000	$8.00		$64,000.00	
Riprap D50=8", quarry 0.5 mile	C.Y.	6,450	$24.00		$154,800.00	
Bedding for riprap D50=3"	C.Y.	2,800	$20.00		$56,000.00	
36" CMP , flared inlet, earthwork	L.F.	60	$52.00	1.10	$3,432.00	
36" CMP , flared inlet, earthwork	L.F.	100	$52.00	1.10	$5,720.00	
36" CMP , flared inlet, earthwork	L.F.	40	$52.00	1.10	$2,288.00	
42" CMP , flared inlet, earthwork	L.F.	40	$64.00	1.10	$2,816.00	
Standard Guardrail	L.F.	550	$15.00		$8,250.00	
Subtotal						**$344,556.00**
			CAPITAL COSTS SUBTOTAL			**$361,783.80**
SHG Channel Annual Maintenance	LS	1	$3,445.56		$3,445.56	
5-Year Site Reviews (Included in Source Control Alternative	EA/5 Yr	0.20	$0.00		$0.00	
SHG/Starr Ditch Sediment Removal (Included in Source C	LS	1.00	$0.00		$0.00	
Stormwater Monitoring (Included in Source Control Alternat	LS	1.00	$0.00		$0.00	
		OPERATIONS AND MAINTENANCE SUBTOTAL				**$3,445.56**
H.W. Factor = Hazardous Waste Factor of 10% applied for work conducted in modified Level "C" conditions.						
LS - Lump Sum	CY - Cubic Yard		SHG - Stray Horse Gulch			
LF - Linear Feet	EA -Each		CMP - Corrugated Metal Pipe			
SY - Square Yard	Yr - Year					

CALIFORNIA GULCH OU6

ALTERNATIVE W2
DETENTION OF SURFACE WATERS WITHIN STRAY HORSE GULCH

ITEM	UNIT	QUANTITY	UNIT COST	H.W. FACTOR	SUBTOTAL	TOTAL COST
Mobilization/Site Preparation	L.S.	1	$34,440		$34,440.00	$34,440.00
Detention Basin						
Excavation for Sediment Pond	C.Y.	27,000	$2.50	1.10	$74,250.00	
Excavation for Wolftone-pond Ditch	C.Y.	520	$2.50	1.10	$1,430.00	
Furnish and Install Zone 1 (0.5 mile from borrow area)	C.Y.	1,650	$3.50	1.10	$6,352.50	
Furnish and Install Zone 2 (0.5 mile from borrow area)	C.Y.	1,450	$3.50	1.10	$5,582.50	
Furnish and Install Sand Filter Material (processed)	C.Y.	640	$3.50	1.10	$2,464.00	
Riprap D50=8" on d/s dam face and inlet	C.Y.	1,640	$24.00		$39,360.00	
Riprap for Wolftone ditch (D50=4")	C.Y.	480	$24.00		$11,520.00	
Grout for riprap on dam face	C.Y.	390	$230.00		$89,700.00	
Soil-cement (aggregate borrow area 0.5 mile)	C.Y.	2,670	$20.00		$53,400.00	
Geomembrane under pond invert	S.Y.	2,060	$8.00		$16,480.00	
Dewatering	LS	1	$30,000.00	1.10	$33,000.00	
18" HDPE Pipe	L.F.	100	$90.00		$9,000.00	
36" RCP vertically	L.F.	5	$66.00		$330.00	
Structural Concrete	C.Y.	5	$215.00		$1,075.00	
Rebar	LBS.	600	$0.50		$300.00	
Confirmation Sampling of Excavation	EA.	10	$500.00		$5,000.00	
Subtotal						$349,244.00
Rehabilitate SHG Channel - Adelaide to Hamms						
Non-woven, needle punch geotextile	S.Y.	18,900	$2.50		$47,250.00	
Geomembrane over geotextile	S.Y.	8,000	$8.00		$64,000.00	
Riprap D50=8", quarry 0.5 mile	C.Y.	6,450	$24.00		$154,800.00	
Bedding for riprap D50=3"	C.Y.	2,800	$20.00		$56,000.00	
36" CMP , flared inlet, earthwork	L.F.	60	$52.00	1.10	$3,432.00	
36" CMP , flared inlet, earthwork	L.F.	100	$52.00	1.10	$5,720.00	
36" CMP , flared inlet, earthwork	L.F.	40	$52.00	1.10	$2,288.00	
42" CMP , flared inlet, earthwork	L.F.	40	$64.00	1.10	$2,816.00	
Standard Guardrail	L.F.	550	$15.00		$8,250.00	
Subtotal						$344,556.00
Air Monitoring	L.S.	1	$5,000.00		$5,000.00	$5,000.00
			CAPITAL COSTS SUBTOTAL			$733,240.00
Operations and Maintenance Items						
SHG Channel Annual Maintenance	LS	1	$3,445.56		$3,445.56	
Muck Sediment from Retention Structure	Day	4	$1,550.00	1.10	$5,115.00	
Maintenance of Detention Basin	LS	1	$10,327.32		$10,327.32	
Replacement of Basin Liners (Every 10 years)	LS	0.10	$50,000.00		$5,000.00	
SHG/Starr Ditch Sediment Removal (Included in Source C	LS	1.00	$0.00		$0.00	
Quarterly Inspection	EA	4.00	$250.00		$1,000.00	
5-Year Site Reviews (Included in Source Control Alternativ	EA/5 Yr	0.20	$0.00		$0.00	
Stormwater Monitoring (Included in Source Control Alternat	LS	1.00	$0.00		$0.00	
		OPERATIONS AND MAINTENANCE SUBTOTAL				$24,887.88
Note:						
H.W. Factor = Hazardous Waste Factor of 10% applied for work conducted in modified Level "C" conditions.						
LS - Lump Sum	CY - Cubic Yard		LBS - Pounds			
LF - Linear Feet	EA -Each		SHG - Stray Horse Gulch			
SY - Square Yard	Yr - Year		CMP - Corrugated Metal Pipe			
RCP - Reinforced Concrete Pipe	HDPE - High-Density Polyethylene					

CALIFORNIA GULCH OU6

ALTERNATIVE W3
DIVERSION OF SURFACE WATERS VIA GRAHAM PARK

ITEM	UNIT	QUANTITY	UNIT COST	H.W. FACTOR	SUBTOTAL	TOTAL COST
Mobilization/Site Preparation	L.S.	1	$71,291.33		$71,291.33	$71,291.33
Land Requisitions	L.S.	1	$100,000.00		$100,000.00	$100,000.00
Detention Basin						
Excavation for Sediment Pond	C.Y.	27,000	$2.50	1.10	$74,250.00	
Excavation for Wolftone-pond Ditch	C.Y.	520	$2.50	1.10	$1,430.00	
Furnish and Install Zone 1 (0.5 mile from borrow area)	C.Y.	969	$3.50	1.10	$3,728.92	
Furnish and Install Zone 2 (0.5 mile from borrow area)	C.Y.	851	$3.50	1.10	$3,276.93	
Furnish and Install Sand Filter Material (processed)	C.Y.	376	$3.50	1.10	$1,446.37	
Riprap D50=8" on d/s dam face and inlet	C.Y.	963	$24.00		$23,104.32	
Riprap for Wolftone ditch (D50=4")	C.Y.	282	$24.00		$6,762.24	
Grout for riprap on dam face	C.Y.	229	$230.00		$52,653.90	
Soil-cement (aggregate borrow area 0.5 mile)	C.Y.	1,567	$20.00		$31,345.80	
Geomembrane under pond invert	S.Y.	1,209	$8.00		$9,673.76	
Dewatering	LS	1	$25,000.00	1.10	$27,500.00	
18" HDPE Pipe	L.F.	100	$90.00		$9,000.00	
36" RCP vertically	L.F.	5	$66.00		$330.00	
Structural Concrete	C.Y.	5	$215.00		$1,075.00	
Rebar	LBS.	600	$0.50		$300.00	
Confirmation Sampling of Excavation	EA.	10	$500.00		$5,000.00	
Subtotal						$250,877.23
Rehabilitate SHG Channel - Adelaide to Hamms						
Non-woven, needle punch geotextile	S.Y.	11,094	$2.50		$27,735.75	
Geomembrane over geotextile	S.Y.	4,696	$8.00		$37,568.00	
Riprap D50=8", quarry 0.5 mile	C.Y.	3,786	$24.00		$90,867.60	
Bedding for riprap D50=3"	C.Y.	1,644	$20.00		$32,872.00	
36" CMP , flared inlet, earthwork	L.F.	60	$52.00	1.10	$3,432.00	
36" CMP , flared inlet, earthwork	L.F.	100	$52.00	1.10	$5,720.00	
36" CMP , flared inlet, earthwork	L.F.	40	$52.00	1.10	$2,288.00	
42" CMP , flared inlet, earthwork	L.F.	40	$64.00	1.10	$2,816.00	
Standard Guardrail	L.F.	550	$15.00		$8,250.00	
Subtotal						$211,549.35
Diversion of Channel to California Gulch						
Construct Diversion Structures below Adelaide	L.S.	1	$37,000.00	1.10	$40,700.00	
Construct Conveyance Pipeline from diversion	L.F.	12,000	$58.00	1.10	$765,600.00	
above to California Gulch (30" Diameter HDPE)						
Install 30" Culvert beneath Roadway by Pipe Jacking	L.F.	50	$330.00	1.10	$18,150.00	
Repair Existing Road	S.Y.	3,500	$10.00	1.10	$38,500.00	
Energy Dissipator at Outlet	S.Y.	10	$45.00		$450.00	
Subtotal						$863,400.00
Air Monitoring	L.S.	1	$5,000.00		$5,000.00	$5,000.00
			CAPITAL COSTS SUBTOTAL			**$1,502,117.91**
Operations and Maintenance Items						
Maintain Diversion and Pipeline to California Gulch	LS	1	$25,902.00		$25,902.00	
SHG Channel Annual Maintenance	LS	1	$2,115.49		$2,115.49	
Muck Sediment from Retention Structure	Day	4	$1,550.00	1.10	$6,820.00	
Maintenance of Detention Basin	LS	1	$7,376.32		$7,376.32	
Replacement of Basin Liners (Every 10 years)	LS	0.10	$50,000.00		$5,000.00	
SHG/Starr Ditch Sediment Removal (Included in Source C	LS	1.00	$0.00		$0.00	
Quarterly Inspection	EA	4.00	$300.00		$1,200.00	
5-Year Site Reviews (Included in Source Control Alternative	EA/5 Yr	0.20	$0.00		$0.00	
Stormwater Monitoring (Included in Source Control Alternat	LS	1.00	$0.00		$0.00	
		OPERATIONS AND MAINTENANCE SUBTOTAL				**$48,413.81**
H.W. Factor = Hazardous Waste Factor of 10% applied for work conducted in modified Level "C" conditions.						
LS - Lump Sum	CY - Cubic Yard		LBS - Pounds			
LF - Linear Feet	EA -Each		SHG - Stray Horse Gulch			
SY - Square Yard	Yr - Year		CMP - Corrugated Metal Pipe			
RCP - Reinforced Concrete Pipe	HDPE - High-Density Polyethylene					

CALIFORNIA GULCH OU6

ALTERNATIVE W4
DIVERSION OF SURFACE WATERS TO LEADVILLE MINE DRAINAGE TUNNEL

ITEM	UNIT	QUANTITY	UNIT COST	H.W. FACTOR	SUBTOTAL	TOTAL COST
Mobilization/Site Preparation	L.S.	1	$130,246.48		$130,246.48	$130,246.48
Land Requisitions	L.S.	1	$100,000.00		$100,000.00	$100,000.00
Detention Basin						
Excavation for Sediment Pond	C.Y.	27,000	$2.50	1.10	$74,250.00	
Excavation for Wolftone-pond Ditch	C.Y.	520	$2.50	1.10	$1,430.00	
Furnish and Install Zone 1 (0.5 mile from borrow area)	C.Y.	969	$3.50	1.10	$3,728.92	
Furnish and Install Zone 2 (0.5 mile from borrow area)	C.Y.	851	$3.50	1.10	$3,276.93	
Furnish and Install Sand Filter Material (processed)	C.Y.	376	$3.50	1.10	$1,446.37	
Riprap D50=8" on d/s dam face and inlet	C.Y.	963	$24.00		$23,104.32	
Riprap for Wolftone ditch (D50=4")	C.Y.	282	$24.00		$6,762.24	
Grout for riprap on dam face	C.Y.	229	$230.00		$52,653.90	
Soil-cement (aggregate borrow area 0.5 mile)	C.Y.	1,567	$20.00		$31,345.80	
Geomembrane under pond invert	S.Y.	1,209	$8.00		$9,673.76	
Dewatering	LS	1	$25,000.00	1.10	$27,500.00	
18" HDPE Pipe	L.F.	100	$90.00		$9,000.00	
36" RCP vertically	L.F.	5	$66.00		$330.00	
Structural Concrete	C.Y.	5	$215.00		$1,075.00	
Rebar	LBS.	600	$0.50		$300.00	
Confirmation Sampling of Excavation	EA.	10	$500.00		$5,000.00	
Subtotal						$250,877.23
Catch Basin						
Excavation for Sediment Pond	C.Y.	8,910	$2.50	1.10	$24,502.50	
Furnish and Install Zone 1 (0.5 mile from borrow area)	C.Y.	545	$3.50	1.10	$2,096.33	
Furnish and Install Zone 2 (0.5 mile from borrow area)	C.Y.	479	$3.50	1.10	$1,842.23	
Furnish and Install Sand Filter Material (processed)	C.Y.	211	$3.50	1.10	$813.12	
Riprap D50=8" on d/s dam face and inlet	C.Y.	541	$24.00		$12,988.80	
Grout for riprap on dam face	C.Y.	129	$230.00		$29,670.00	
Soil-cement (aggregate borrow area 0.5 mile)	S.Y.	881	$20.00		$17,620.00	
Geomembrane under pond invert	S.Y.	680	$8.00		$5,440.00	
Dewatering	LS	1	$20,000.00	1.10	$22,000.00	
18" HDPE Pipe	L.F.	100	$90.00		$9,000.00	
36" RCP vertically	L.F.	5	$66.00		$330.00	
Structural Concrete	C.Y.	5	$215.00		$1,075.00	
Rebar	LBS.	600	$0.50		$300.00	
Construct New Pumping Station (1 cfs capacity)	L.S.	1	$4,000.00		$4,000.00	
Subtotal						$131,677.97
Pipeline - Catch Basin to Detention Basin	L.F.	1,200	$30.00	1.10	$39,600.00	$39,600.00
Pipe-lined Borehole - Detention Basin to Emmet Shaft						
24" Directional Drilled Bore Hole	L.F.	400	$225.00	1.10	$99,000.00	
Muck Removal	C.Y.	50	$75.00	1.10	$4,125.00	
24" Liner Piping Installation	L.F.	400	$150.00	1.10	$66,000.00	
18" Carrier Piping Installation	L.F.	400	$260.00	1.10	$114,400.00	
Grout Annulus	C.F.	550	$8.00	1.10	$4,840.00	
Subtotal						$288,365.00
Emmet Shaft Rehabilitation	L.F.	500	$740.00	1.10	$407,000.00	
Furnish/Install Control Drop Structure	L.F.	390	$740.00	1.10	$317,460.00	
Subtotal						$724,460.00
Rehabilitate SHG Channel - Adelaide to Hamms						
Non-woven, needle punch geotextile	S.Y.	11,094	$2.50		$27,735.75	
Geomembrane over geotextile	S.Y.	4,696	$8.00		$37,568.00	
Riprap D50=8", quarry 0.5 mile	C.Y.	3,786	$24.00		$90,867.60	
Bedding for riprap D50=3"	C.Y.	1,644	$20.00		$32,872.00	
36" CMP , flared inlet, earthwork	L.F.	60	$52.00	1.10	$3,432.00	
36" CMP , flared inlet, earthwork	L.F.	100	$52.00	1.10	$5,720.00	
36" CMP , flared inlet, earthwork	L.F.	40	$52.00	1.10	$2,288.00	
42" CMP , flared inlet, earthwork	L.F.	40	$64.00	1.10	$2,816.00	
Standard Guardrail	L.F.	550	$15.00		$8,250.00	
Subtotal						$211,549.35

CALIFORNIA GULCH OU6

ALTERNATIVE W4
DIVERSION OF SURFACE WATERS TO LEADVILLE MINE DRAINAGE TUNNEL

Diversion of Channel to California Gulch						
Construct Diversion Structures below Adelaide	L.S.	1	$37,000.00	1.10	$40,700.00	
Construct Conveyance Pipeline from diversion	L.F.	12,000	$58.00	1.10	$765,600.00	
above to California Gulch (30" Diameter HDPE)						
Install 30" Culvert beneath Roadway by Pipe Jacking	L.F.	50	$330.00	1.10	$18,150.00	
Repair Existing Road	S.Y.	3,500	$10.00	1.10	$38,500.00	
Energy Dissipator at Outlet	S.Y.	10	$45.00		$450.00	
Subtotal						**$863,400.00**
Air Monitoring	L.S.	1	$5,000.00		$5,000.00	**$5,000.00**
			CAPITAL COSTS SUBTOTAL			**$2,745,176.03**
Operations and Maintenance Items						
Muck Sediment from Retention Structures	Day	12	$1,550.00	1.10	$20,460.00	
Maintain Diversion and Pipeline to California Gulch	LS	1	$25,902.00		$25,902.00	
SHG Channel Annual Maintenance	LS	1	$2,115.49		$2,115.49	
Maintenance of Basins	LS	1	$11,326.66		$11,326.66	
Replacement of Basin Liners (Every 10 years)	L.S.	0.10	$72,000.00		$7,200.00	
Maintenance of Emmett Shaft	LS	1	$30,384.75		$30,384.75	
Add'l O&M Costs incurred at LMDT Treat. Plant	LS	1	$140,000.00		$140,000.00	
5-Year Site Reviews (Assuming no Source Control)	EA/5 Yr	0.20	$78,000.00		$15,600.00	
Quarterly Inspection	EA	4.00	$300.00		$1,200.00	
Pumping Station O&M	LS	1	$5,910.00		$5,910.00	
Stormwater Monitoring (Included in LMDTTP)	LS	1.00	$0.00		$0.00	
		OPERATIONS AND MAINTENANCE SUBTOTAL				**$260,098.90**
H.W. Factor = Hazardous Waste Factor of 10% applied for work conducted in modified Level "C" conditions.						
LS - Lump Sum	CY - Cubic Yard		LBS - Pounds			
LF - Linear Feet	EA -Each		SHG - Stray Horse Gulch			
SY - Square Yard	Yr - Year		CMP - Corrugated Metal Pipe			
RCP - Reinforced Concrete Pipe	HDPE - High-Density Polyethylene					
LMDT - Leadville Mine Drainage Tunnel	LMDTTP - Leadville Mine Drainage Tunnel Treatment Plant					

CALIFORNIA GULCH OU6

ALTERNATIVE W5
TREATMENT OF SURFACE WATERS WITHIN STRAY HORSE GULCH

ITEM	UNIT	QUANTITY	UNIT COST	H.W. FACTOR	SUBTOTAL	TOTAL COST
Mobilization/Site Preparation	L.S.	1	$256,812.63		$256,812.63	$256,812.63
Land Requisitions	L.S.	1	$100,000.00		$100,000.00	$100,000.00
Detention Basin						
Excavation for Sediment Pond	C.Y.	27,000	$2.50	1.10	$74,250.00	
Excavation for Wolftone-pond Ditch	C.Y.	520	$2.50	1.10	$1,430.00	
Furnish and Install Zone 1 (0.5 mile from borrow area)	C.Y.	969	$3.50	1.10	$3,728.92	
Furnish and Install Zone 2 (0.5 mile from borrow area)	C.Y.	851	$3.50	1.10	$3,276.93	
Furnish and Install Sand Filter Material (processed)	C.Y.	376	$3.50	1.10	$1,446.37	
Riprap D50=8" on d/s dam face and inlet	C.Y.	963	$24.00		$23,104.32	
Riprap for Wolftone ditch (D50=4")	C.Y.	282	$24.00		$6,762.24	
Grout for riprap on dam face	C.Y.	229	$230.00		$52,653.90	
Soil-cement (aggregate borrow area 0.5 mile)	C.Y.	1,567	$20.00		$31,345.80	
Geomembrane under pond invert	S.Y.	1,209	$8.00		$9,673.76	
Dewatering	LS	1	$25,000.00	1.10	$27,500.00	
18" HDPE Pipe	L.F.	100	$90.00		$9,000.00	
36" RCP vertically	L.F.	5	$66.00		$330.00	
Structural Concrete	C.Y.	5	$215.00		$1,075.00	
Rebar	LBS.	600	$0.50		$300.00	
Confirmation Sampling of Excavation	EA.	10	$500.00		$5,000.00	
Subtotal						$250,877.23
Pipeline - Detention Basin to Treatment Plant	L.F.	1,200	$30.00	1.10	$39,600.00	$39,600.00
Catch Basin						
Excavation for Sediment Pond	C.Y.	8,910	$2.50	1.10	$24,502.50	
Furnish and Install Zone 1 (0.5 mile from borrow area)	C.Y.	545	$3.50	1.10	$2,096.33	
Furnish and Install Zone 2 (0.5 mile from borrow area)	C.Y.	479	$3.50	1.10	$1,842.23	
Furnish and Install Sand Filter Material (processed)	C.Y.	211	$3.50	1.10	$813.12	
Riprap D50=8" on d/s dam face and inlet	C.Y.	541	$24.00		$12,988.80	
Grout for riprap on dam face	C.Y.	129	$230.00		$29,670.00	
Soil-cement (aggregate borrow area 0.5 mile)	S.Y.	881	$20.00		$17,620.00	
Geomembrane under pond invert	S.Y.	680	$8.00		$5,440.00	
Dewatering	LS	1	$20,000.00	1.10	$22,000.00	
18" HDPE Pipe	L.F.	100	$90.00		$9,000.00	
36" RCP vertically	L.F.	5	$66.00		$330.00	
Structural Concrete	C.Y.	5	$215.00		$1,075.00	
Rebar	LBS.	600	$0.50		$300.00	
Construct New Pumping Station (1 cfs capacity)	L.S.	1	$4,000.00		$4,000.00	
Subtotal						$131,677.97
Pipeline - Catch Basin to Treatment System	L.F.	500	$30.00	1.10	$16,500.00	$16,500.00
Construct New Wastewater Treatment System						
Treatment System (See Attached Spreadsheet)	EA.	1	$3,041,648.00		$3,041,648.00	
Treatment Plant Building	EA.	1	$486,000.00		$486,000.00	
Subtotal						$3,527,648.00
Rehabilitate SHG Channel - Adelaide to Hamms						
Non-woven, needle punch geotextile	S.Y.	11,094	$2.50		$27,735.75	
Geomembrane over geotextile	S.Y.	4,696	$8.00		$37,568.00	
Riprap D50=8", quarry 0.5 mile	C.Y.	3,786	$24.00		$90,867.60	
Bedding for riprap D50=3"	C.Y.	1,644	$20.00		$32,872.00	
36" CMP , flared inlet, earthwork	L.F.	60	$52.00	1.10	$3,432.00	
36" CMP , flared inlet, earthwork	L.F.	100	$52.00	1.10	$5,720.00	
36" CMP , flared inlet, earthwork	L.F.	40	$52.00	1.10	$2,288.00	
42" CMP , flared inlet, earthwork	L.F.	40	$64.00	1.10	$2,816.00	
Standard Guardrail	L.F.	550	$15.00		$8,250.00	
Subtotal						$211,549.35
Diversion of Channel to California Gulch						
Construct Diversion Structures below Adelaide	L.S.	1	$37,000.00	1.10	$40,700.00	
Construct Conveyance Pipeline from diversion	L.F.	12,000	$58.00	1.10	$765,600.00	
above to California Gulch (30" Diameter HDPE)						
Install 30" Culvert beneath Roadway by Pipe Jacking	L.F.	50	$330.00	1.10	$18,150.00	
Repair Existing Road	S.Y.	3,500	$10.00	1.10	$38,500.00	
Energy Dissipator at Outlet	S.Y.	10	$45.00		$450.00	
Subtotal						$863,400.00
Air Monitoring	L.S.	1	$5,000.00		$5,000.00	$5,000.00
			CAPITAL COSTS SUBTOTAL			$5,403,065.18

CALIFORNIA GULCH OU6

ALTERNATIVE W5
TREATMENT OF SURFACE WATERS WITHIN STRAY HORSE GULCH

Operations and Maintenance Items						
Muck Sediment from Retention Structures	Day	12	$1,550.00	1.10	$20,460.00	
Maintain Diversion and Pipeline to California Gulch	LS	1	$25,902.00		$25,902.00	
SHG Channel Annual Maintenance	LS	1	$2,115.49		$2,115.49	
Maintenance of Basins	LS	1	$11,326.66		$11,326.66	
Replacement of Basin Liners (Every 10 years)	L.S.	0.10	$72,000.00		$7,200.00	
Treatment Plant O&M (See Attached Spreadsheet)	LS	1	$1,133,663.00		$1,133,663.00	
5-Year Site Reviews (Assuming no Source Control)	EA/5 Yr	0.20	$78,000.00		$15,600.00	
Quarterly Inspection	EA	4.00	$300.00		$1,200.00	
Pumping Station O&M	LS	1	$5,910.00		$5,910.00	
Stormwater Monitoring (Included in Treatment Plant)	LS	1.00	$0.00		$0.00	
		OPERATIONS AND MAINTENANCE SUBTOTAL				**$1,223,377.15**
H.W. Factor = Hazardous Waste Factor of 10% applied for work conducted in modified Level "C" conditions.						
LS - Lump Sum	CY - Cubic Yard		LBS - Pounds			
LF - Linear Feet	EA -Each		SHG - Stray Horse Gulch			
SY - Square Yard	Yr - Year		CMP - Corrugated Metal Pipe			
RCP - Reinforced Concrete Pipe	HDPE - High-Density Polyethylene					

CALIFORNIA GULCH OU6
ALTERNATIVE W5 WATER TREATMENT PLANT (1800 GPM)
Chemical Precipitation

ITEM	QTY	UNIT	UNIT MH	MHRS	RATE	LABOR	UMAT	MAT'L	UEQP	EQUIP	USUB	SUB	TOTAL	SUBTOTAL
Water Treatment														
Clarifier (incline plates)	2	EA	0	0	$0.00	$0	$0.00	$0	$100,500	$201,000	$0.00	$0	$201,000	
Precip./Coag./Flocc. Tanks	4	EA	0	0	$0.00	$0	$0.00	$0	$27,000	$108,000	$0.00	$0	$108,000	
Mixer	6	EA	0	0	$0.00	$0	$0.00	$0	$2,000	$12,000	$0.00	$0	$12,000	
Thickener Tank	2	EA	0	0	$0.00	$0	$0.00	$0	$14,000	$28,000	$0.00	$0	$28,000	
Centrifugal Pumps	4	EA	0	0	$0.00	$638	$0.00	$2,610	$0	$12	$0.00	$0	$13,040	
Metering Pumps	8	EA	0	0	$0.00	$0	$0.00	$0	$1,700	$13,600	$0.00	$0	$13,600	
Backwash Pumps	1	EA	0	0	$0.00	$784	$0.00	$8,119	$0	$74	$0.00	$0	$8,977	
Sediment Pump	2	EA	0	0	$0.00	$384	$0.00	$12,368	$0	$83	$0.00	$0	$25,670	
Air Compressors	3	EA	0	0	$0.00	$849	$0.00	$11,775	$0	$19	$0.00	$0	$12,643	
Sludge Filter Press	3	EA	0	0	$0.00	$0	$0.00	$0	$270,000	$810,000	$0.00	$0	$810,000	
Sand Filter Unit	2	EA	0	0	$0.00	$1,929	$0.00	$143,467	$0	$44	$0.00	$0	$290,880	
Backwash Holding Tank	1	EA	0	0	$0.00	$29,352	$0.00	$55,739	$0	$8,953	$0.00	$0	$94,044	
Acid Addition Tanks	2	EA	0	0	$0.00	$369	$0.00	$9,970	$0	$7	$0.00	$0	$20,692	
Caustic Addition Tanks	2	EA	0	0	$0.00	$0	$0.00	$0	$4,000	$8,000	$0.00	$0	$8,000	
Chemical Addition Tanks (FeS, polymer)	6	EA	0	0	$0.00	$0	$0.00	$0	$620	$3,720	$0.00	$0	$3,720	
Effluent Tank	1	EA	0	0	$0.00	$38,872	$0.00	$86,574	$0	$11,857	$0.00	$0	$137,303	
SUBTOTAL														$1,787,569
Piping	10%	of Subtotal	0	0	$0.00	$0	$0.00	$0	$0.00	$0.00	$0	$178,757	$178,757	
Electrical	10%	of Subtotal	0	0	$0.00	$0	$0.00	$0	$0.00	$0.00	$0	$178,757	$178,757	
Freight	5%	of Subtotal	0	0	$0.00	$0	$0.00	$0	$0.00	$0.00	$0	$89,378	$89,378	
Installation	20%	of Subtotal	0	0	$0.00	$0	$0.00	$0	$0.00	$0.00	$0	$357,514	$357,514	
Instrumentation	20%	of Subtotal	0	0	$0.00	$0	$0.00	$0	$0.00	$0.00	$0	$357,514	$357,514	
SUBTOTAL	1	LS		0		$73,177		$330,622		$1,205,369		$1,161,920	$2,949,489	
SALES TAX	6%	LS		0		$0		$19,837		$72,322		$0	$92,159	
TOTAL				0		$73,177		$350,459		$1,277,691		$1,161,920	$3,041,648	

QTY - Quantity
Unit MH - Units of Man Hours
MHR - QTY * Unit MH

EA - Each
UMAT - Unit Price per Material
MAT'L - QTY * UMAT

LS - Lump Sum
UEQP - Unit Price per Equipment
EQUIP - QTY * UEQP

USUB - Unit Price per Subcontractor
SUB - QTY * USUB

CALIFORNIA GULCH OU6
ALTERNATIVE W5 WATER TREATMENT PLANT (1800 GPM)
Chemical Precipitation

Annual O&M Cost

ITEM	QTY	UNIT	UNITMH	MHRS	RATE	LABOR	UMAT	MATL	UEQP	EQUIP	USUB	SUB	TOTAL
Waste Disposal													
Filter Cake	9,880	CY	0	0	$0.00	$0	$0.00	$0	$0.00	$0.00	$0	$0	$0
Stabilization Agent	19,760	GAL	0	0	$0.00	$0	$17.00	$335,920	$0.00	$0.00	$0	$0	$335,920
Characterization	4	EA	0	0	$0.00	$0	$0.00	$0	$0.00	$0.00	$500	$2,000	$2,000
Waste Transportation	4,491	MI	0	0	$0.00	$0	$0.00	$0	$0.00	$0.00	$4	$17,964	$17,964
Pump Replacement													
Centrifugal (every 3 yrs)	4	EA	0	0	$0.00	$638	$0.00	$2,610	$0	$12	$0.00	$0	$4,347
Metering (every 2 yrs)	8	EA	0	0	$0.00	$0	$0.00	$0	$1,700	$13,600	$0.00	$0	$6,800
Backwash (every 3 yrs)	1	EA	0	0	$0.00	$784	$0.00	$8,119	$0	$74	$0.00	$0	$2,992
Sediment (every 3 yrs)	2	EA	0	0	$0.00	$384	$0.00	$12,368	$0	$83	$0.00	$0	$8,557
Air Compressor (every 3 yrs)	3	EA	0	0	$0.00	$849	$0.00	$11,775	$0	$19	$0.00	$0	$12,643
Chemicals													
Acid	254	TON	0	0	$0.00	$0	$90.00	$22,860	$0.00	$0.00	$0	$0	$22,860
Polymer	4,600	LB	0	0	$0.00	$0	$2.00	$9,200	$0.00	$0.00	$0	$0	$9,200
Ferrous Sulfate	46	LB	0	0	$0.00	$0	$0.78	$36	$0.00	$0.00	$0	$0	$36
Sodium Hydrosulfide	46	LB	0	0	$0.00	$0	$0.85	$39	$0.00	$0.00	$0	$0	$39
Caustic Soda	1,036	TON	0	0	$0.00	$0	$430.00	$445,480	$0.00	$0.00	$0	$0	$445,480
Performance Monitoring													
Sample Analysis	100	EA	0	0	$0.00	$0	$0.00	$0	$0.00	$0.00	$496	$49,600	$49,600
Electricity													
Power Usage	471,102	KWH	0	0	$0.00	$0	$0.08	$37,688	$0.00	$0.00	$0	$0	$37,688
Operating Labor													
Operator	3,408	HR	1	3,408	$25.00	$85,200	$0.00	$0	$0.00	$0.00	$0	$0	$85,200
Supervisor	511	HR	1	511	$35.00	$17,885	$0.00	$0	$0.00	$0.00	$0	$0	$17,885
Maintenance Labor													
Laborer	341	HR	1	341	$30.00	$10,230	$30.00	$10,230	$0.00	$0.00	$0	$0	$20,460
SUBTOTAL	1	LS		3,408		$87,855		$886,095		$13,788		$69,564	$1,079,670
SALES TAX	6.00%	LS		0		$0		$53,166		$827		$0	$53,993
TOTAL				3,408		$87,855		$939,261		$14,615		$69,564	$1,133,663

QTY - Quantity
CY - Cubic Yard
Unit MH - Units of Man Hours
MHR - QTY * Unit MH
EA - Each
GAL - Gallon
UMAT - Unit Price per Material
MATL - QTY * UMAT
LS - Lump Sum
MI - Mile
UEQP - Unit Price per Equipment
EQUIP - QTY * UEQP
LB - Pound
KWH - Kilowatt Hour
USUB - Unit Price per Subcontractor
SUB - QTY * USUB

APPENDIX C

Preliminary Technical Memorandum on Solidification/Stabilization Treatability

Draft - Treatability Study

In-Situ Stabilization of Mine Waste Rock Piles

California Gulch Superfund Site
Operational Unit 6
Leadville, Colorado

U.S. Bureau of Reclamation
Technical Service Center
Denver, Colorado
May 21, 1997

I. Background

The U.S. Bureau of Reclamation has been contracted by the U.S. Environmental Protection Agency , Region 8 to investigate and design corrective actions at the California Gulch Superfund Site, Operational Unit 6, Leadville, CO. This encompasses the cleanup and/or solidification/stabilization of numerous mine tailings and mine waste rock piles throughout the Leadville area.

The objective of this treatability study is to evaluate the feasibility of in-situ stabilization and solidification of selected mine waste rock piles in Operable Unit 6 (OU6), thereby reducing/eliminating existing metal-laden acid rock drainage (ARD) and preserving the appearance of the mine waste piles for historic purposes. In addition, successful field demonstration of the proposed in-situ solidification of steeply-sloped sulfide-bearing mine waste rock piles would enhance the variety of remediation alternatives available to Reclamation (and others) for current and future mine sites.

The mine waste rock piles have been exposed to weathering for over 50 years and contribute to the ARD through oxidative dissolution of metal sulfides, releasing large concentrations of acid, toxic metals, and total dissolved/suspended solids. Onsite stabilization/solidification of these materials will try to cover these piles with an impermeable barrier to prevent infiltration of moisture from snowmelt and rainfall and/or to neutralize the acid-bearing minerals, or both. Three waste rock piles have been selected for possible in-situ solidification: (1) Pyrenees, (2) RAM, and (3) Greenback. These piles were chosen because the city of Leadville and Lake County, Colorado wanted them preserved for historical and tourism purposes and left untreated, the piles will represent a significant ARD source once other remedial action in OU-6 has been completed.

The three mine waste rock piles are sized as follows:

Mine Pile	Surface Area (yd^2)	Mine Waste Volume (yd^3)
Pyrenees	15,300	60,500
Greenback - east (SH-H)	21,800	42,500
Greenback - west (SH-I)	2,100	1,500
RAM (SH-J)	24,100	23,700

Note that the Surface Area is the area of the footprint of the of mine waste in and around the mine pile, not just of the pile itself. In the case of the RAM, the area around the large remnant pile is much larger than the area of the remnant pile. In the cases of the Pyrenees and the two Greenback piles, the two areas do not differ significantly.

One primary aesthetic criterion of this solidification/stabilization program is to maintain the historic configuration of the waste rock piles. This includes maintaining the original shape, slopes, texture, and colors of the piles. Additional design criteria include reducing/eliminating infiltration of moisture into the piles to minimize/prevent ARD reactions from continuing, minimizing long-term treatment costs of ARD, and minimizing maintenance costs for the site.

II. Conclusions - Physical Properties

A. Addition of 25 percent cement by mass of dry soil is recommended to meet Reclamation soil cement criteria for compressive strength, wetting-drying durability, and freezing-thawing durability. The recommended minimum compressive strength for this cement content is about 1000 lb/in^2 at 28 days, and is higher than standard soil cement.

B. The cement plus fly ash combination, KB proprietary additive, and TB proprietary additives did not meet the Reclamation criteria for soil cement.

C. Mixtures that did not meet the required compressive strength criterion at 7 days also did not meet the freezing-thawing criterion.

D. Mechanical shear mixing, such as a pugmill mixing is recommended for mixing soil cement.

E. Additional exposure testing may be beneficial to compare soil cement durability testing with standard concrete durability testing.

F. The permeability of soil cement tested ranges from 5x10-8 to 3x10-9 cm/s, and is comparable to cementitious materials of this strength level.

G. Soil cement mixtures are suitable for use in other slope protection applications at the project site, such as detention ponds.

H. All stabilized/solidified soils tested pass TCLP test requirements, and would not be classified by EPA/RCRA as hazardous waste, based on toxicity.

III. Review of Treatment Options

A number of potential stabilization/solidification options were identified and reviewed in light of the project objectives:

1. No work at this site; waste rock piles will remain as is and ARD will be collected, monitored, and treated in a long-term treatment program.

2. Complete removal of the waste piles, followed by neutralization of the waste materials and rebuilding the piles to the original configuration and staining to restore the color.

3. Surficial treatment of the waste piles with materials to reduce infiltration of moisture.

4. Covering of the waste piles with a geomembrane, followed by a surficial covering of similar waste rock-like materials.

5. Covering the waste piles with a pneumatically applied layer of protective concrete colored or stained to recreate the original colors ("thin-shell" protective covering).

6. Removing surficial mine waste rock, stabilizing this material, and re-introducing the stabilized waste rock to the original configuration using soil cement / roller-compacted concrete (RCC) construction methods, followed by coloring or staining to the original colors ("thick-shell solidification").

7. Covering the waste piles with a water-repellant cover by using borrowed non-reactive (sulfide-free) materials and soil cement / RCC construction methods, followed by coloring or staining to the original colors ("thick-shell covering").

Preserving the mine waste rock piles as in Option No. 1 will retain the historic integrity of the site, but will require long-term monitoring and treatment of ARD. Pile removal, neutralization, and replacement (Option No. 2) will provide long-term benefits by potentially eliminating ARD to acceptable long-term compliance levels. This is likely to be the most conservative and most expensive option, requiring removing the piles, adding amendments to neutralize the waste materials, and recreating the shape, texture, and coloring of the piles.

In-situ surface solidification (Option No. 3) would include introduction of a stabilizer and roto-tilling it into the top 1 foot of the pile surface. However, there are numerous concerns with such in-situ solidification. First, it is doubtful that standard construction equipment could work effectively on these pile slopes, which are as steep as 1:1 (H:V). Second, the relatively thin shell material is likely to experience severe cracking, followed by water infiltration through these cracks. If water gets behind the shell, there is the possibility of ARD generation, frost heave, freeze-thaw cracking, slope instability, and differential settlement problems.

The combination of shallow injection and surface tilling of amendments was also considered. There is experience with lime injection for coal waste piles. A combination of injection and tilling would create a thicker, more stable mass which could address pile slope stability concerns. Although thicker than in-situ solidification by option 3, the thicker shell may still be insufficient to prevent all cracking and eliminating all generation of long-term ARD. Furthermore, shallow injection is an uncontrolled fracturing process, which may not uniformly penetrate the waste rock. Other concepts and materials included for consideration were sodium silicate spray or injection, lime injection, and use of fly ashes and cement kiln dusts.

Covering the waste piles with a geomembrane followed by a soil/rock cover (Option No. 4) would likely be the most effective method of reducing infiltration, at least initially. The long-term performance of the geomembrane would depend on the thickness and durability of the geomembrane and the cover material. This concept may not be feasible to construct with the desired steep side slopes of the current mine waste rock piles. Covering with a thin shell of pneumatically applied "shotcrete" (Option No. 5) would initially be effective. However, there are again concerns for long-term durability of a rigid, thin cover shell subject to settlement, frost heave, shrinkage cracking, and freeze-thaw on or beneath the cover.

As a result of long-term durability and stability concerns regarding thin-shell solidification techniques, we are currently considering the use of more conventional soil cement and RCC solidification (Option Nos. 6 and 7), which would be placed in horizontal lifts, compacted around the perimeter of the piles. Reclamation has over 40 years of experience with construction of soil cement facings on many dams. These dam facings have been performing well after more than 20 years of service under severe conditions and are expected to provide even longer operating life. The standard soil cement dam facing is put down in horizontal lifts which are 8 to 12 ft wide, 6 to 8 inches thick on relatively flat slopes, such as 3:1 (H:V). Soil cement production rates are typically 1,000 to 3,000 yd^3 per day. These facings have withstood severe wave and ice action by reservoirs. Our general design criteria is for the soil to be silty sand (SM) or poorly-graded sand (SP-SM) with cement contents ranging from 8 to 12 percent. It is our experience with dams that the soil cement be compacted to about 95 percent of the maximum Proctor dry density. The lifts are compacted at optimum moisture content conditions, and bonding is assured by placement of a cement mortar layer between lifts. For the OU6 in-situ solidification application, this construction technique would produce a thick, stabilized shell which should have an operating life of better that 50 years under Leadville's environmental conditions, which are less severe than the wave and freeze/thaw actions experienced by reservoir materials. Some maintenance or rehabilitation of the soil cement shell may be required at about that point in its life for continued operation.

RCC techniques are similar to soil cement, but use larger aggregate sizes and often have higher design performance requirements. RCC production rates are usually the same as for soil cement, about 1,000 to 3,000 yd^3 per day using continuous mixing plants. About 15,000 yd^3 of RCC were recently placed in less than three weeks in a spillway plunge pool constructed at Ochoco Dam. This RCC was placed in 10 ft wide, 1 ft thick layers against both rock and embankments on 0.8:1 and 1:1 (H:V) slopes, respectively. RCC techniques have been used as dam facing overtopping protection at a number of dams around the world, including at Goose Lake Dam, near Breckenridge, CO. The Goose Lake Dam facing was constructed in about five days. Both soil cement and RCC facings could experience long-term shrinkage cracking. However, the width and frequency of cracking can be anticipated and corrected by either post-cracking grout injection or, sealing. In addition, the exterior surface of these piles can be finished to an appearance similar to the existing piles.

Option 6 stabilization/solidification will use waste rock from the three piles to make the soil cement or RCC for the shells. The suitability of using this waste rock will depend on the geochemical weathering potential of the rock and the rock's ability to provide acceptable construction strengths and durability, particularly when compared to using non-reactive materials such as low-sulfide glacial debris/moraine and dolomite rocks, (Option No. 7). Therefore, it will be necessary to thoroughly characterize the waste rock for likely field durability and to determine whether increases in cementitious materials may be required due to possible large, fine-grained size fractions in the waste rock. Reclamation has many operating field applications with long-term service life history under more severe saturated freeze-thaw conditions. A thick shell facing for these waste rock piles would not likely experience the saturated freeze-thaw and wave-pounding conditions of an upstream dam facing.

Waste Pile color (and texture) preservation has also been discussed. If mixed in place, a thin shell may not necessarily provide acceptable long-term color preservation. Very likely, artificial coloring either through additives to cement, external staining and finishing, or both additives and external staining and finishing may be necessary. Steep, shotcreted slopes have been sculptured and stained to simulate natural soil and rock formations. The design will consider methods of adding color to the stabilized materials and how to finish slopes and apply external coloring, if necessary.

Based on the evaluation of the proposed treatment options, construction requirements, long-term durability and stability, and historic preservation criteria, the "thick-shell" approach (options 6 and 7) to solidification/stabilization with soil cement or RCC was favored. The treatability study was developed to fully evaluate these options through a laboratory testing program to characterize the waste rock materials and evaluate the effectiveness of cement addition to mine waste rock materials to form a structurally viable soil cement or RCC for capping the waste rock piles.

IV. Treatability Study - Purpose and Scope

The treatability study and laboratory testing program was designed to quantify the likelihood that a cementitious thick-shell cover over the reactive sulfide-rich waste rock of the Pyrenees, RAM, and Greenback piles of OU6 will be sufficiently impermeable to completely and permanently reduce the acid rock drainage currently generated by these piles to a compliance level that meets strength and durability criteria for the site and satisfies the historical and aesthetic criteria desired by the City of Leadville and Lake County, Colorado.

For the purpose of this investigation the waste rock materials are referred to as "soil" and the solidification/stabilization techniques are referred to as "soil cement" techniques. Samples of soils were obtained from the Pyrenees and RAM waste piles. These samples were further designated as PY (Pyrenees)-1, PY-2, RAM1, and RAM2 with the RAM pile separated into to samples due to the differing gradation and color appearance in the RAM pile. The Greenback rock pile was not sample because of it's similar composition to the Pyrenees materials.

Chemical and mineralogical testing were performed to characterize the soils before and after stabilization. Physical testing was also performed to determine the properties of the soils before stabilization and performance of the soil cement after stabilization. The physical properties testing program also provided design data for proposed detention structures scheduled for construction in the summer of 1997. After determining in situ density, moisture content, physical properties, and geochemical characteristics of the soils; soil cement proportioning, mixing, and testing procedures were used determine the percent of various additives required to neutralize the acid generating potential of the soil and meet strength and durability criteria necessary to function as an armoring for this site.

Four additives were investigated for the soil cement mixture proportioning and testing program:

1. Type V cement,
2. Type V cement plus and equal amount of Class C pozzolan (fly ash),
3. proprietary additive "KB," and
4. proprietary additive "TB."

Additive dosage levels were initially selected at 10 and 20 percent by dry mass of soil, based on previous experience with soil cement and the grading of in situ materials. The dosage was increased to 20 and 30 percent additive due to low compressive strength and durability in trial mixes at the 10 percent level. Some additives were discontinued during the test program due to obvious poor performance at the 10 and 20 percent dosages.

Limited chemical testing was performed on representative samples of mixtures using the three soils and four additives. Additional chemical and durability testing was performed on mixtures which met the minimum strength and durability criteria for soil cement.

V. Field Sampling

In early November, 1996, project personnel collected representative rock samples from four locations at OU6 - two sites on the RAM pile and two on the Pyrenees pile. After removing the top-most layers with a backhoe samples were hand-collected and placed into burlap bags for transfer to the Reclamation Technical Service Center. Approximately 400 pounds of rock was collected from each location on RAM and Pyrenees. The four samples were assigned the following index codes as follows:

RAM-1	66H-665
RAM-2	66H-666
PYR-1	66H-667
PYR-2	66H-668

VI. Initial Geotechnical and Geochemical Assessments

A. Geochemical Characterization of Native and Stabilized OU-6 Mining Waste Rock

In this study, "geochemical characterization" was defined as the laboratory determination of chemical composition and the tendency of waste rock or stabilized waste rock mixtures to undergo weathering reactions in the field. The weathering reactions of greatest interest were oxidation of sulfide minerals to produce acidic sulfate waters called acid-rock drainage (ARD). Geochemical reactivity can be estimated in two ways. First, the intrinsic reactivity to oxidation and the distribution (i.e. lithology) of primary rock minerals in test rocks provide a first-order assessment of ARD formation potential. Second, the relative geochemical reactivity for native and stabilized OU-6 rock specimens was determined by standard laboratory chemical tests. Both approaches were employed in this study.

1. Test Procedures

Representative subsamples of the four waste rock samples from OU-6 (RAM-1, RAM-2, PYR-1, PYR-2) were tested for initial geotechnical and geochemical assessment. First, the chemical composition of each sub-sample was determined by the Denver Federal Center U.S. Geological Survey (USGS) Chemistry Laboratory using a standard USGS method that employs a borate fusion-$HClO_4$ digestion and inductively-coupled plasma - atomic emission spectrometry (ICP-

AES). These data were compared with the TSC staff petrographic evaluation of the four samples, which included x-ray diffractrometry (XRD) identification of abundant minerals.

Second, Core Laboratories, Aurora, CO, was contracted to perform the following standard tests to estimate the potential of the four samples to form ARD:

(1) Acid-Base Accounting[1] according to EPA Publication No. EPA-600/2-78-054, "Field and Laboratory Methods Applicable to Overburdens and Minesoils."

(2) Total S and Acid Potential (AP) according to ASTM D4239-85C, "Test Method for Sulfur in the Analysis Sample of Coal and Coke using High Temperature Tube Furnace Combustion Methods" LECO combustion

(3) Sulfur Forms: ASTM D2492-90, "Forms of Sulfur in Coal" acid extractions for pyritic and sulfate sulfur

Third, both Reclamation and Core Laboratories performed the following standard tests to estimate the amount toxic metals leached by pH 5 and near-neutral pH ground waters :

(1) Toxic Characteristic Leaching Procedure (TCLP): 1992, EPA Method 1311

(2) Shake Extraction of Solid Waste with Water: 1986, ASTM D3987-85

(3) Acid Digestion for Total Metals: 1986, SW-846 Method 3010

(4) Analyses of Metals by ICP-AES: 1992, EPA SW-846 Method 6010A

(5) Analysis of Mercury by Cold Vapor AAS: 1994, SW-846 Method 7470A

Fourth, Reclamation staff used a standard soil science method[2] "Saturated Paste, Mixed (8A)" to determine the pH for porewater in saturation equilibrium with native and treated OU-6 waste rock specimens:

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[1] Sobek, et al., 1978, Field and Laboratory Methods Applicable to Overburdens and Minesoils, EPA Publication No. EPA-600/2-78-054

[2] "Miscellaneous Saturated Paste, Mixed (8A)", 1996, Soil Survey Laboratory Methods Manual, U.S. Department of Agriculture, Soil Survey Investigations Report No. 42.

2. Results and Conclusions

Table 2 shows the total elemental composition of the four samples. In addition to high levels of Al, Ca, K, and Mg, there were weight percent levels of Fe and Pb. One sample, RAM-2, contained 2.3 % Mn and 3.2 % Zn.

Table 3 summarizes the Acid-Base Accounting, TCLP, and ASTM D3987 water leaching of the four field samples. While the samples all had significant amounts of quartz and sulfide weathering products (jarosite, gypsum), they differed in their relative amounts of acid-producing minerals (e.g. pyrite, galena) and acid-neutralizing minerals (e.g. calcite, dolomite).

The ratio of Acid Neutralization Potential to Acid Potential (ANP/AP) provides a quantitative measure of the ability of the rock to neutralize acidic water (ANP) versus the acid-producing ability of the rock (AP). Generally, an ANP/AP ≥ 3 means that the rock formation will not produce ARD while an ANP/AP ≤ 1 means that ARD production is likely. ANP/AP ratios between 1 and 3 mean that ARD production would depend on site conditions and could vary. As revealed in Table 3, RAM-1, PYR-1 and PYR-2 would all be expected to generate ARD when exposed to oxygenated water conditions. Only RAM-2, with a reasonably high ANP/AP ratio (2.37) and significant ANP (178 tons $CaCO_3$ per kiloton), would not be expected to generate ARD over time. Note that the D3987 leachate final pH for RAM-2 was 6.1, while the other samples had pH values near 3. Lastly, TCLP testing revealed leachate Pb concentrations from 16 to 35 ppm, well above the MCL of 5 ppm. The only other concentration above MCLs was the 1.84 ppm Cd concentration for RAM-2. Although not a TCLP metal, Zn concentrations were also quite high, especially the 387 ppm value measured for RAM-2 leachate.

Table 4 summarizes the TCLP testing for RAM-1, RAM-2, and combined Pyrenees specimens treated with the stabilization/solidification amendments. The table 3 TCLP results for untreated samples is included for comparison. The names for the treated specimens describe the rock sample used and the treatment applied as follows:

* First letter and number = rock code P = combined PYR R1 = RAM-1 R2 = RAM-2	for P10C - 6, P = combined Pyrenees
* Next two numbers = % amendment code	for P10C - 6, 10 = 10%
* Next letters = treatment amendment code C = cement K = KB (proprietary additive) T = TB CF = 50 percent cement plus 50 percent coal fly ash (by mass of additive)	for P10C - 6, C = cement
* Last numbers = individual specimen	for P10C - 6, 6 = specimen 6

The data in table 4 reveals that all 10-20% amended rock samples passed the TCLP test. In particular, the high untreated TCLP extract concentrations for Cd, Pb, Mn, and Zn were substantially reduced. Table 5 presents the TCLP analytical quality control data for the table 4 results. Extraction of the Environmental Resource Associates TCLP standard reference material No. 544 produced satisfactory recoveries between 79% and 122%. The high recovery for Ba can be partially explained by a 0.6-0.8 mg/L blank in the extraction blanks, most likely during the filtration step. There was also a 0.5 - 0.7 mg/L zinc blank. Lastly, duplicate sample extractions produced very good results for the few measurable metals results. Please note for sample R120C that the high relative percent differences for Mn and Zn duplicate extractions are based on concentrations near the detection limits.

Table 6 summarizes the soil paste pH values for a number of the treated samples. Since all the amendments used in this study contained large amounts of alkaline components, the paste solution pH values were expected to be very basic. The pH values were typically between 10.5 and 11.

VII. Physical Properties Testing Program Features and Test Procedures

The physical properties testing program features included the following:

1. In situ density and moisture content and physical properties testing and classification of the soils
2. Mixture proportioning and physical properties testing of soil cement
3. Petrographic examination and chemical analysis of materials and stabilized soil cement.

A. Test Procedures

In situ density tests were performed according to ASTM D 1556, " Density and Unit Weight of Soil in Place by Sand Cone Method." Physical properties tests were performed on soils sampled from the Pyrenees and RAM waste piles included gradation, atterberg limits, specific gravity, compaction characteristics, and unified soils classification. Test methods included ASTM D 422 "Partical-Size Analysis of Soils," ASTM D 4318 "Liquid Limit, Plastic Limit, and Plasticity Index of Soils," ASTM D 854 "Specific Gravity of Soils," and ASTM D 2487 "Classification of Soils for Engineering Purposes," respectively. Maximum density and optimum moisture content of the minus 4.75 mm (No. 4) fraction of the three density samples (Pyrenees, RAM1, and RAM2) were performed according to ASTM D 1557 "Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lb/ft3 (2,700 kN-m/m3))." Gradation, in situ density, and compaction characteristics of the three soils are given in figures 1 through 3. The theoretical maximum density and optimum moisture content of the total sample were determined for each soil and used as the target values for the soil cement mixtures. The RAM samples were classified into two separate samples (RAM1 and RAM2) based on gradation and soil classification. The Pyrenees soil is classifies as silty, clayey gravel with sand. The RAM1 and RAM2 soils are classified as clayey sand with gravel and silty gravel with sand, respectively.

The gradations of the three soils sampled are given in figures 4 through 6. For the Pyrenees sample oversize rocks larger than the 37.5 mm (3/4 in) size fraction were crushed so they passed the 37.5 mm screen and remixed to form a composite sample for the soil cement mixtures. The gradation of the Pyrenees minus 37.5 mm composite soil sample is given in figure 7.

Soil cement mixture proportions used either of four additives: cement, cement plus an equal quantity of pozzolan (fly ash), and two proprietary additives. Cement met the requirements for ASTM C 150, Type V (sulfate resisting) cement and was obtained from a local Denver Supplier. Pozzolan met the requirements of ASTM C 618 for Class C pozzolan. It is a fly ash was obtained from a local supplier from the Comanche power plant, near Denver, Colorado. The two proprietary additives were not identified by the manufacturer. Manufacturers Safety Data Sheets

(MSDS) identified the materials generically as calcium oxide and silica and silica components. Petrographic examination of the additives indicated they were similar and like fly ash. The manufacturer did not recommend optimum dosage levels for the proprietary additives and they were tested at similar dosages as the cementitious mixtures. Not all additives were tested with all soils due to lack of sufficient soil samples and obvious poor performance early on in the testing program.

Soil cement mixture proportioning and test specimen preparation were performed according to ASTM D 558 "Moisture-Density Relations of Soil-Cement Mixtures." Fresh soil cement tests included compacted density, moisture content by oven drying, and temperature. Three fresh soil cement density tests were performed using three different moisture contents to determine the maximum density and optimum moisture content of each soil type. Four 4.5 in (114 mm) diameter by 4 in (100 mm) high test specimens and twelve 2.8 in (71 mm) diameter by 6 in (150 mm) high specimens were made for durability and compressive strength testing, respectively. Two of the 4.5 by 4 in specimens were tested for wet-dry durability according to ASTM D 559 "Wetting and Drying Compacted Soil-Cement Mixtures." The remaining two were tested for freeze-thaw durability according to ASTM D 560 Freezing and Thawing Compacted Soil-Cement Mixtures." Compressive Strength specimens were in accordance with ASTM D 1632 "Making and Curing Soil-Cement Compression and Flexure Test Specimens in the Laboratory." Three 2.8 by 6 in specimens were tested for compressive strength at 7 days age and three were tested at 28 days age according to ASTM D 1633 "Compressive Strength of Molded Soil-Cement Cylinders." Some remaining specimens were tested for permeability according to ASTM D 5084 "Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter." Other remaining specimens will be used in additional durability testing (concrete freeze-thaw, sulfate resistance, 100 percent humidity exposure, and outdoor exposure), if necessary.

B. Soil Cement Mixture Proportions

Soil cement mixture proportions were based on Reclamation and industry experiences for embankment dam slope protection. Strength criteria for durable soil cement are a minimum compressive strength of 600 lb/in2 (4,100 kPa) at 7 days and 875 lb/in2 (6,000 kPa) at 28 days. Durability criteria are no more than 6 percent accumulated mass loss (by dry mass of sample) after 12 cycles of wetting and drying and no more than 8 percent accumulated mass loss (by dry mass of sample) after 12 cycles of freezing and thawing. Mixtures meeting the minimum compressive strength requirements normally also meet the durability requirements.

C. Additive Dosage Levels

Typically, the cement content of soil cement for dam facing slope protection ranges from about 8 to 12 percent by dry mass of soil. However, these mixtures normally use silty sands or soils classified as SP or SM materials. The Leadville materials were classified as silty and clayey gravel with sand, GC-GM (Pyrenees); clayey sand with gravel, SC (RAM1); and silty gravel with sand, GM (RAM2). Reclamation soil cement experience using clayey soils is limited. But the presence of clay normally increases the required cement content for a given strength level due to a higher water demand by the fines. Cement (or other additive) contents were originally tested at 10 and 20 percent additive by dry mass of soil. However, after the first round of tests the dosage was increased to 20 and 30 percent additive by dry mass of soil in order to meet the minimum strength and durability criteria. This change was made after numerous specimens failed to meet the minimum compressive strength at 7 days age.

D. Soil Cement Mixing and Making and Curing Test Specimens

Samples were initially hand mixed. However this mixing was not effective in breaking up clay balls and coarse particles segregated during mixing and making specimens. A mechanical "Hobart" mixer was used for most 20 and 30 percent additive mixtures. This shear type mixing greatly reduced clay balls and segregation.

Test specimens were cured at 100 percent relative humidity room until testing. Some mixtures expanded and cracked in the saturated environment and were clearly not considered durable for this application. These were later dropped from the test program. Wet dry and freeze-thaw durability tests were normally tested after 7 days age. Some durability tests were delayed until 28 days due to initially lower compressive strengths at 7 days in the anticipation that better results would be obtained at later ages. Specimens remained in the 100 percent humidity until testing.

E. Determination of Optimum Moisture Content and Maximum Dry Density

The procedure for determining the required density and moisture content of the soil cement using hand mixing and the Pyrenees soil were as follows:

1. First, a five point compaction curve was determined for the Pyrenees soil cement mixture with 10 percent cement.
2. The optimum moisture content and maximum dry density were determined from a plot of the moisture-density curve and compared to the theoretical values determined for the Pyrenees soil obtained with the plus No. 4 size fraction moisture-density relations.
3. Durability test specimens were cast at the optimum moisture content. Compressive strength test specimens were cast at the optimum moisture content and compacted to 95 percent of the maximum dry density. (Typical soil cement specifications require compaction to a minimum of 95 percent of the maximum dry density.)
4. A three point compaction curve was determined for the Pyrenees soil using 20 percent cement. The optimum moisture content and maximum dry density were again compared to the theoretical values.

5. Because there was close agreement between the soil cement values at 10 and 20 percent cement and theoretical soils values, the remaining additive formulations used the same optimum moisture content for casting durability and strength specimens.

Due to low compressive strengths at 7 days and poor initial durability performance, the following changes were made to the mixing and casting procedures:

1. Mixing was changed from hand to mechanical mixing using a Hobart type paddle mixer.
2. A three point compaction curve was used to determine the optimum moisture content and maximum dry density for the RAM1 and RAM2 soil cement mixtures using 20 percent cement.
3. Durability specimens were cast similarly to previous methods and compressive strength test specimens were cast at 98 percent of the maximum dry density (or to refusal in the test apparatus).
4. Test specimens for the remaining additive formulations were cast at the optimum moisture content based on the 20 percent soil cement mixture.

F. Physical Properties Test Results

1. Moisture vs. Density

Moisture versus density plots for the test program are given in figures 8 through 20. Included with each plot is the moisture versus wet and dry density compaction curve for the soil cement and the wet and dry densities of the four durability test specimens for each additive formulation. For example; figure 8 gives the moisture-wet and dry density relationships for the 10 percent cement and Pyrenees soil cement formulation and the four individual wet and dry density test results for the 10 percent cement durability specimens. Figure 16 gives the moisture-wet and dry density relationship for the 20 percent cement RAM1 soil cement formulation and the four individual wet and dry density test results for the 30 percent cement RAM1 durability specimens for comparison purposes.

Differences in the sample moisture content and density versus the compaction curve theoretical values can result from differences in conditioned soil moisture content and from hydration with cement during oven drying. Some additives had considerably different densities than cement and the soil cement density may change due to different material specific gravity. The TB mixture also had apparent hydration or "flash setting" of the additive during mixing. The moisture content had to be increased to compensate for the moisture lost during this hydration process. The TB additive flash setting had about a 28 degree C (50 degree F) temperature rise during mixing which could also have contributed to moisture loss.

2. Compressive Strength

Reclamation strength criteria for soil cement are a minimum 7 day strength of 600 lb/in2 and 875 lb/in2 at 28 days. The compressive strength development with age of soil cement mixtures is similar to conventional concrete. The 7 day compressive strength of concrete with Type V cement is normally about 2/3 of the 28 day strength. Mixtures with 50 percent pozzolan would normally be expected to be between 1/3 and 2/3 of the 28-day compressive strength, depending on the reactivity with cement.

Compressive strength of soil cement mixtures are summarized in table 6 and figures 21 through 25.

a. Effect of Mixing Procedure

The 7 and 28-day compressive strengths of hand-mixed Pyrenees soil cement were all low, regardless of additive. None of the mixtures met the minimum Reclamation 7 and 28 day strength criteria for durable soil cement. Rock pockets and clay balls were found in all test specimens and greatly reduced strength. This indicates surficial tilling of the soil with cement (or other additive) would not be effective as a surface treatment method.

The compressive strength increased after switching to mechanical mixing and increasing compaction requirements for test cylinders. The compressive strength more than doubled at both 7 and 28 days age for the 20 percent cement, Pyrenees mixture. This mixture also had a decrease in compressive strength between 7 and 28 days, which may indicate uncemented clay fines in the specimens.

b. Effect of Cement Content - Pyrenees, RAM1, and RAM2 Soil Cement

Increasing the cement content of the soil cement mixtures increased the compressive strength. For the mechanical mixing, the 28 day compressive strength ranged from 930 lb/in^2 for the 20 percent cement, Pyrenees mixture to 2420 lb/in^2 for the 30 percent cement, RAM2 mixture. For hand mixing, the 20 percent cement Pyrenees mixture was about double the 10 percent cement mixture.

The strength efficiency can be expressed in terms of strength per unit of cement added or lb/in^2 per percent of cement. The strength efficiency of a typical 4000 psi, 6-sack (564 lb/yd^3 cement) concrete mixture would be about 220 lb/in^2 per percent or cement added. The strength efficiency ranges from about 50 lb/in^2 per percent cement for the 20 percent cement mixtures to about 70 lb/in^2 per percent cement for the 30 percent cement mixtures. The RAM2 mixtures had the highest compressive strength and strength efficiency, followed by the RAM1 mixtures, and Pyrenees mixtures. Although the 20 percent cement mixture met the minimum strength criteria for soil cement, there was a strength loss with the Pyrenees soil. To avoid potential strength loss and other construction related variables, the recommended cement additive level is 25 percent by dry mass of soil.

c. Effect of Additive Type

Cement was the only additive to meet compressive strength criteria at 7 and 28 days age at the 20 percent dosage level. The 20 percent cement plus fly ash mixture only reached about one-half the minimum strength criteria at either 7 or 28 days. Neither of the two proprietary additives (KB or TB) had any significant strength at 7 or 28 days. Some of the cement/fly ash, TB, and KB mixtures also had strength loss between 7 and 28 days. These test specimens also had significant cracking and some gel exuding from the cracks. It appears either some part of the additive was expanding, or the mixtures had insufficient strength to prevent the clay fines from swelling in the 100 percent humidity environment. The low strength and cracking were also associated with poor durability performance.

3. Wetting-Drying and Freezing-Thawing Durability Results

The Results of durability tests are summarized in table 6. Reclamation criterion for durability is no more than 6 percent accumulated mass loss after 12 cycles of wetting-drying and no more than 8 percent accumulated loss after 12 cycles of freezing-thawing. Tests were initially performed using Pyrenees soils mixed with the cement, cement plus fly ash, and KB additives. Other soils and additives were added to the testing as it progressed. The first set of mixtures were tested regardless of compressive strength. As more results became available, durability tests were only performed on those mixtures that met the required 7 day compressive strength and had a better chance of passing. Some of the latter tests were delayed until 28 days in the hope that better results would be obtained.

Specimens from the Pyrenees soil cement mixtures were tested at 7 days age. The first mixtures used 10 and 20 percent additive and were all hand-mixed. None of these mixtures met the minimum compressive strength criteria at 7 days. The durability test results were poor and no mixtures met the criterion for freezing-thawing resistance. The cement and cement plus fly ash mixtures met the wetting-drying criterion. The KB mixtures did not meet either the wetting-drying or freezing-thawing criteria. None of the 10 percent additive mixtures completed the required 12 cycles of freezing-thawing.

After the mixing procedures were changed to mechanical mixing, both the compressive strength and durability increased significantly for all three soil types using 20 or 30 percent cement. The 20 percent KB, soil cement mixture was retested and again failed to meet either the strength or the durability criteria. The cement plus fly ash and TB mixtures were not tested for durability after failing to meet the required 7 or 28 day compressive strength.

All three soil cement mixtures with either 20 or 30 percent cement meet the criteria for both wetting-drying and freezing-thawing durability. All mixtures had less than 1 percent accumulated mass loss in wetting-drying and less than 2 percent in freezing-thawing. Based on the results of strength and durability testing, it appears that mixtures that have sufficient compressive strength also meet the durability criteria.

Additional tests will be run to compare the soil cement freezing-thawing durability test to the concrete freezing-thawing test. However, the concrete freeze-thaw durability test is a much more severe test than the corresponding soil cement test and specimens probably will not meet the criterion for durable concrete. Field exposure tests may also be conducted at the project site in Leadville to obtain additional data.

4. Permeability of Soil Cement

The permeability of soil cement specimens P30C (Pyrenees - 30 percent cement) and R130C (RAM1 - 30 percent cement) were tested using the flow-pump permeability test procedure. This procedure is normally used for soils and soil-cement-bentonite mixtures. A 70 mm (2.7 in) long section was cut from the center of one compression cylinder and had a diameter of 72 mm (2.8 in). The lateral confining pressure was 1,170 kPa (170 lb/in^2) and the back pressure was 760 kPa (110 lb/in^2), for an effective confining pressure of kPa 410 (60 lb/in^2). The results of permeability testing on mixtures P30C and R130C are given in figures 26 and 27, respectively. The coefficient of permeability of the two tests average $2.8x10^{-8}$ cm/s, and is near the limitation of the test procedure. Typical mass concretes range from $8x10^{-10}$ to $35x10^{-10}$ cm/s[3].

G. Petrographic Examination

Petrographic examination was performed on materials to provide descriptions, mineralogical compositions, and observations on the two proprietary additives and on soil cement test specimens for documentation. Four samples from the test pit sampling program, Pyrenees 1, Pyrenees 2, RAM1, and RAM2 were examined megascopically, microscopically, by X-ray diffraction, by scanning electron microscope, and by physical and chemical tests. The results of this examination are reported by Hurcomb in Earth Sciences and Research Laboratory Referral No. 8340-97-??, included in appendix A.

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[3] Neville, A.M., Properties of Concrete, Third Edition, Pitman Publishing Limited, London, England, 1981, p. 438.

Table 1. Elemental Composition of Field Samples from OU6, Treatability Study, In-Situ Stabilization of Mine Waste Rock Piles, California Gulch Superfund Site, Operational Unit 6, Leadville, Colorado (ND = not detected)

Element	Units	Ram-1 66H-665	Ram-2 66H-666	Pyrenees-1 66H-667	Pyrenees-2 66H-668
Al	wt. %	2.9	2.1	3.6	3.2
Ca	wt. %	0.19	7.3	2.3	1.4
Fe	wt. %	2.0	14.0	18.0	12.0
K	wt. %	1.8	0.88	1.7	1.2
Mg	wt %	0.15	1.4	0.78	0.20
Na	wt %	0.29	0.05	0.03	0.01
P	wt. %	0.02	0.04	0.03	0.05
Ti	wt. %	0.05	0.03	0.06	0.11
Pb	wt %	0.35	1.9	1.1	0.42
Zn	wt %	0.10	3.2	0.17	0.52
Mn	mg/kg	63	23,000	430	180
Ag	mg/kg	16	63	270	210
As	mg/kg	20	160	160	130
Au	mg/kg	ND	ND	ND	ND
Ba	mg/kg	320	68	84	69
Be	mg/kg	ND	ND	ND	ND
Bi	mg/kg	ND	14	160	120
Cd	mg/kg	8	240	15	170
Ce	mg/kg	40	20	25	36
Co	mg/kg	ND	6	4	4
Cr	mg/kg	5	11	6	19
Cu	mg/kg	52	180	350	260
Eu	mg/kg	ND	ND	ND	ND
Ga	mg/kg	8	22	11	11
Ho	mg/kg	ND	ND	ND	ND
La	mg/kg	23	10	13	17
Li	mg/kg	4	5	4	14
Mo	mg/kg	ND	ND	ND	ND
Nb	mg/kg	6	ND	7	6
Nd	mg/kg	14	4	8	13
Ni	mg/kg	ND	4	ND	3
Sc	mg/kg	ND	3	3	3
Sn	mg/kg	ND	ND	ND	ND

Sr	mg/kg	46	82	110	310
Ta	mg/kg	ND	ND	ND	ND
Th	mg/kg	9	ND	ND	6
V	mg/kg	9	17	14	23
Y	mg/kg	4	7	6	7
Yb	mg/kg	ND	ND	ND	ND

Table 2. Geochemical Data for Field Samples from OU6, Treatability Study, In-Situ Stabilization of Mine Waste Rock Piles, California Gulch Superfund Site, Operational Unit 6, Leadville, Colorado

	Ram-1 66H-665	Ram-2 66H-666	Pyrenees-1 66H-667	Pyrenees-2 66H-668	Duplicate
Acid-Base Acct.	J-8797	J-8798	J-8799	J-8800	J-88A
ANP	24	178	<0.1	<0.1	<0.1
AP (totS - SO4 S)	26.3	74.7	305	273	241
ANP/AP	0.91	2.37	0.005	<0.001	<0.001
Total S (wt %)	0.95	5.99	11.6	10.5	9.07
SO4 S (wt %)	0.11	3.6	1.85	1.76	1.35
FeS2 S (wt %)	0.47	1.27	17.2	10.8	11.6
Other S (wt %)	0.37	1.12	<0.01	<0.01	<0.01
TCLP (ppm)					
As (limit 5.0)	<0.05	<0.05	<0.05	<0.05	<0.05
Ba (100)	0.11	0.02	0.03	0.05	0.05
Cd (1.0)	0.027	1.84	0.019	0.057	0.058
Cr (5.0)	<0.01	0.02	<0.01	<0.01	<0.01
Co	<0.03	<0.03	<0.03	<0.03	<0.03
Cu	<0.01	0.11	<0.01	0.02	0.02
Fe	0.21	<0.03	3.67	5.18	6.27
Pb (5.0)	27.9	35	22.9	16.3	16
Mn	1.04	50.3	2.93	3.1	3.25
Hg (0.2)	<0.002	<0.002	<0.002	<0.002	<0.002
Mo	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	<0.04	<0.04	<0.04	<0.04	<0.04
Se (1.0)	<0.1	<0.1	<0.1	<0.1	<0.1
Ag (5.0)	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	4.35	387	2.06	7.21	6.82
ASTM D3987 (ppm)					
Final pH	3.22	6.09	2.77	2.77	2.77
As	<0.05	<0.05	<0.05	<0.05	<0.05
Ba	0.01	0.02	<0.01	0.01	0.01
Cd	0.026	1.15	0.027	0.071	0.073
Cr	<0.01	<0.01	<0.01	<0.01	<0.01
Co	<0.03	<0.03	<0.03	<0.03	<0.03
Cu	0.1	<0.01	0.39	0.47	0.52
Fe	1.99	<0.03	105	130	131
Pb	4.98	1.46	2.83	1.81	2.1
Mn	0.87	33.5	3.83	3.58	3.66
Hg	<0.002	<0.002	<0.002	<0.002	<0.002
Mo	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	<0.04	<0.04	<0.04	<0.04	<0.04
Se	<0.1	<0.1	<0.1	<0.1	<0.1
Ag	<0.01	<0.01	<0.01	0.01	0.02

Zn	4.67	150	3.25	8.4	8.3

Table 3. Chemical Analyses of TCLP ExtractsTreatability Study, In-Situ Stabilization of Mine Waste Rock Piles, California Gulch Superfund Site, Operational Unit 6, Leadville, Colorado (units = mg/L)

Description	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Fe	Mn	Zn
TCLP MCL (1)	5.0	100	1.0	5.0	5.0	0.2	1.0	5.0	NA(2)	NA	NA
Untreated Specimens											
Ram-1	ND(3)	0.11	0.03	ND	**7.9**	ND	ND	ND	0.21	1.04	4.35
Ram-2	ND	0.02	**1.84**	ND	**35**	ND	ND	ND	ND	50.3	387
Pyrenees-1	ND	0.03	0.02	ND	**22.9**	ND	ND	ND	3.67	2.93	2.06
Pyrenees-2	ND	0.05	0.06	ND	**16.3**	ND	ND	ND	6.27	3.10	7.21
Treated Specimens											
P10C - 6	ND	0.13	ND	ND	ND	ND	ND	ND	0.01	0.02	0.06
P10K-C	ND	0.12	0.01	ND	0.51	ND	ND	ND	0.02	2.02	1.15
R120C	ND	0.35	ND	ND	0.07	NP(4)	0.11	ND	0.01	0.02	0.02
R120C dup	ND	0.37	ND	ND	0.06	NP	0.11	ND	0.01	0.04	0.01
P20C	ND	0.30	0.01	ND	0.10	NP	0.13	0.01	0.01	2.60	0.19
R120C-1	ND	0.32	ND	0.04	0.34	ND	ND	ND	0.01	ND	0.12
R220C-1	ND	0.25	ND	ND	0.06	ND	ND	ND	0.02	ND	0.14
R220T-2	ND	0.28	0.01	ND	0.08	ND	0.12	ND	0.02	0.26	0.17
P20C	ND	0.18	ND	ND	0.05	ND	ND	ND	0.01	ND	0.10
P20C - 5	ND	0.18	ND	ND	0.04	ND	ND	ND	0.01	ND	0.14
P20CF - 5	ND	0.15	ND	ND	ND	ND	ND	ND	0.01	ND	0.14
P20CF - 5 dup	ND	ND	ND	ND	ND	ND	0.10	ND	0.01	ND	0.15
R120CFC C-2	ND	0.44	ND	ND	ND	ND	ND	ND	0.01	ND	0.07

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R220CF - 2	ND	0.24	ND	ND	ND	ND	0.10	ND	0.02	ND	0.06
R120T C-2	ND	1.86	ND	ND	ND	ND	ND	ND	0.01	ND	0.07
R120T C-2 dup	ND	1.58	ND	ND	ND	ND	ND	ND	0.01	ND	0.08

(1) MCL = maximum contaminant level, i.e. concentrations above MCL result in a “hazardous” waste classification
(2) NA = not applicable, i.e. metal not covered under TCLP test method
(3) ND = not detected
(4) NP = not performed
All metals analyzed by Inductively-Coupled Plasma - Atomic Emission Spectrometry (ICP-AES), except Hg by cold-vapor AAS
TCLP for ""Untreated"" samples was performed by Core Labs, Denver, CO

Table 4. Analytical Quality Control for TCLP Extract Analyses, Treatability Study, In-Situ Stabilization of Mine Waste Rock Piles, California Gulch Superfund Site, Operational Unit 6, Leadville, Colorado (units = mg/L)

Description	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Fe	Mn	Zn
ERA SRM No. 544											
Certified Values	1.93	11.8	1.48	1.16	1.63	0.0329	0.664	0.818	NA(1)	NA	5.52
TCLP Result	1.52	14.4	1.36	0.86	1.28	NP(2)	0.68	0.86	NA	NA	5.01
Recoveries (%)	79	122	92	74	79	NP	102	105	NA	NA	91
TCLP Extraction Blanks											
J-9008 Blank	ND(3)	0.58	ND	ND	ND	NP	ND	ND	0.06	0.01	0.72
J-9009 Blank	ND	0.59	ND	ND	ND	NP	ND	ND	0.06	0.01	0.72
J-9136 Extract Fluid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
J-9137 Blank	ND	0.67	ND	ND	ND	ND	ND	ND	0.03	ND	0.72
J-9138 Blank	ND	0.80	ND	ND	ND	ND	ND	ND	0.02	ND	0.51
Duplicate Extractions (relative percent difference)											
R120C	ND	5.5	ND	ND	15	ND	0.0	ND	0.0	67	67
P20CF - 5	ND	ND	ND	ND	ND	ND	ND	ND	0.0	ND	6.9
R120T C-2	ND	16	ND	ND	ND	ND	ND	ND	0.0	ND	13

(1) NA = Not applicable
(2) NP = Not performed
(3) ND = Not detected
All metals analyzed by Inductively-Coupled Plasma - Atomic Emission Spectrometry (ICP-AES), except Hg by cold-vapor AAS

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Table 5. Soil Paste pH of Stabilized OU6 Rock Specimens, Treatability Study, In-Situ Stabilization of Mine Waste Rock Piles, California Gulch Superfund Site, Operational Unit 6, Leadville, Colorado

Sample I.D.	Description	Paste pH
P10C #6	Pyrenees + 10% Portland[1] Sample #6	10.5
P10K-C	Pyrenees + 10% KB	9.8
P20C	Pyrenees + 20% Portland	12.0
P20C #5	Pyrenees + 20% Portland Sample #5	10.9
P220C #1	2nd Run Pyrenees + 20% Portland Sample #1	11.0
R120C #1	RAM-1 + 20% Portland Sample #1	11.1
R120C #2	RAM-1 + 20% Portland V Sample #2	11.0
P20CF #5	Pyrenees + 10% Portland + 10% Fly ash Sample #5	10.5
R220CF #2	RAM-2 + 10% Portland + 10% Fly ash Sample #2	10.6
R120CFC #2	RAM-1 + 10% Portland + 10% Fly ash Sample #2	10.8
R120T #2	RAM-1 + 20% TB Sample #2	11.3
R220T #2	RAM-2 + 20% TB Sample #2	11.1

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Table 6. Soil Cement Physical Properties Testing - Compressive Strength, Freezing-Thawing, and Wetting-Drying Durability - Leadville Mine Waste Solidification/Stabilization Program

Waste Rock Stockpile	Additive	Mixing Method	Average Compressive Strength - (lb/in^2) 1/		Freeze/Thaw - Wet /Dry Durability Cycles to Failure 2/	Freeze/Thaw - Wet/Dry Mass Loss (percent) 2/	Comments
(Mix Date)			7 day	28 day			
Pyrenees (1/28/97)	10% Cement	Hand	175	215	12 WD 6 FT 7 FT	1.3 19.3 (F) 3/ 55.1 (F)	
Pyrenees (1/29/97)	10% Cement/ Fly ash	Hand	140	95	12 WD 4 FT 4 FT	2.0 33.7 (F) 14.5 (F)	
Pyrenees (2/6/97)	10% KB	Hand	40	0 (F)	12 WD 5 WD 1 FT 1 FT	50.1 (F) 5.0 (F) (F) (F)	Specimens failed during handling and testing due to low strength.
Pyrenees (1/29/97)	20% Cement	Hand	330	400	12 WD 12 FT 12 FT	0.6 10.5 (F) 11.0 (F)	

1/ Average of three specimens
2/ Reclamation criteria - not to exceed 6 percent accumulated mass loss in wetting-drying or 8 percent accumulated mass loss in freezing-thawing after 12 cycles
3/ (F) - specimen failed during testing or handling

Waste Rock Stockpile	Additive	Mixing Method	Average Compressive Strength - (lb/in^2) 1/		Freeze/Thaw - Wet /Dry Durability Cycles to Failure 2/	Freeze/Thaw - Wet/Dry Mass Loss (percent) 2/	Comments
(Mix Date)			7 day	28 day			
Pyrenees (1/30/97)	20% Cement / Fly ash	Hand	275	275	12 WD 12FT 12 FT	0.9 31(F) 37.3 (F)	
Pyrenees (3/18/97)	20% Cement	Mechanical	1130	930	12 WD 12 WD 12 FT 12 FT	0.3 0.9 2.0 1.1	
Pyrenees (3/18/97)	20 % KB	Mechanical	100	75	10 WD 9 WD 5 FT 7 FT	37.9 (F) 25.3 (F) 58.9 (F) 71.6 (F)	
RAM 1 (2/14/97)	20% Cement	Mechanical	755	935	12 WD 12 WD 12 FT 12 FT	0.9 0.7 1.1 1.6	
RAM 1 (2/17/97)	20% Cement/ Fly ash	Mechanical	245	450	Not Tested	Not Tested	

1/ Average of three specimens
2/ Reclamation criteria - not to exceed 6 percent accumulated mass loss in wetting-drying or 8 percent accumulated mass loss in freezing-thawing after 12 cycles
3/ (F) - specimen failed during testing or handling

Waste Rock Stockpile	Additive	Mixing Method	Average Compressive Strength - (lb/in²) 1/		Freeze/Thaw - Wet /Dry Durability Cycles to Failure 2/	Freeze/Thaw - Wet/Dry Mass Loss (percent) 2/	Comments
(Mix Date)			7 day	28 day			
RAM 1 (2/17/97)	20% TB	Mechanical	70	180	Not Tested	Not Tested	
RAM 2 (2/18/97)	20% Cement	Mechanical	1080	1230	12 WD 12 WD 12 FT 12 FT	0.7 0.4 0.7 1.4	Durability tested at 28 days
RAM 2 (2/20/97)	20% Cement/ Fly ash	Mechanical	305	230	Not Tested	Not Tested	
RAM 2	20% TB	Mechanical	165	85	Not Tested	Not Tested	
Pyrenees	30% Cement	Mechanical	1240	1820	12 WD 12 WD 12 FT 12 FT	0.3 0.3 0.5 0.8	Durability tested at 28 days
RAM 1 (2/21/97)	30% Cement	Mechanical	1230	2030	12 WD 12 WD 12 FT 12 FT	0.3 0.5 0.7 0.4	Durability tested at 28 days

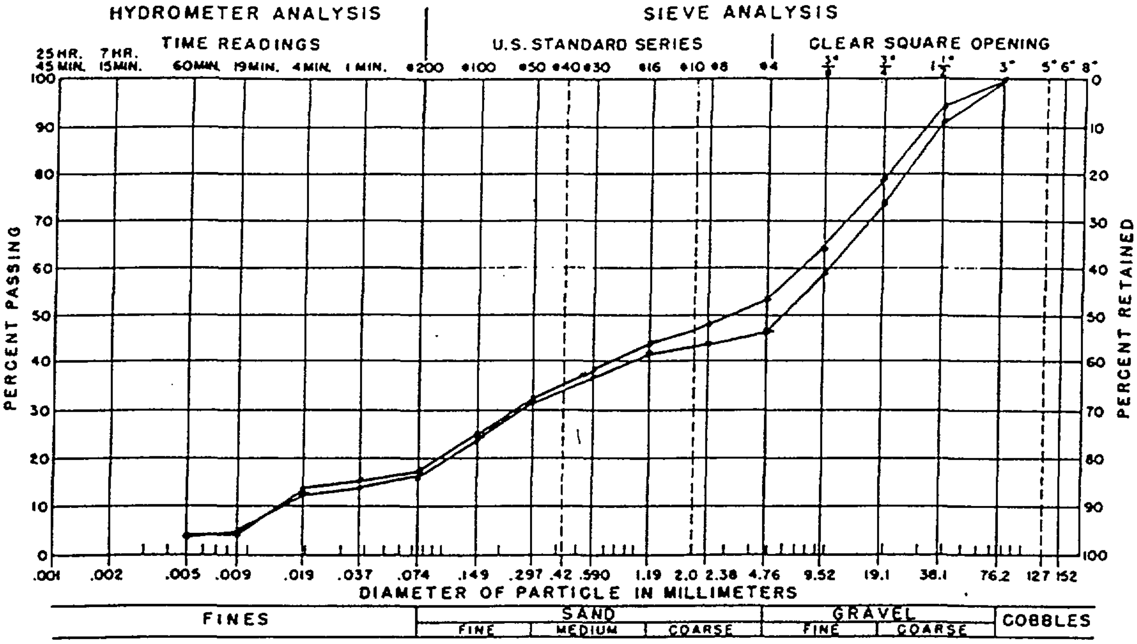
1/ Average of three specimens
2/ Reclamation criteria - not to exceed 6 percent accumulated mass loss in wetting-drying or 8 percent accumulated mass loss in freezing-thawing after 12 cycles
3/ (F) - specimen failed during testing or handling

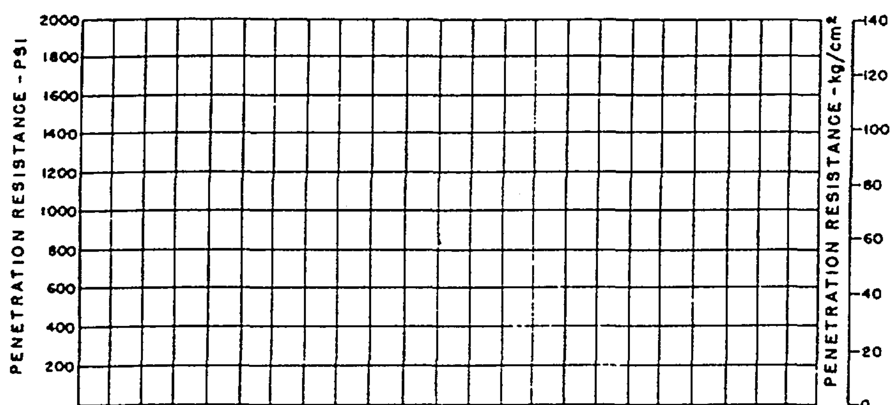
Waste Rock Stockpile	Additive	Mixing Method	Average Compressive Strength - (lb/in^2) 1/		Freeze/Thaw - Wet /Dry Durability Cycles to Failure 2/	Freeze/Thaw - Wet/Dry Mass Loss (percent) 2/	Comments
(Mix Date)			7 day	28 day			
RAM 2	30% Cement	Mechanical	1785	2420	12 WD 12 WD 12 FT 12 FT	0.2 0.2 0.5 0.5	Durability tested at 28 days

1/ Average of three specimens
2/ Reclamation criteria - not to exceed 6 percent accumulated mass loss in wetting-drying or 8 percent accumulated mass loss in freezing-thawing after 12 cycles
3/ (F) - specimen failed during testing or handling

7-1565 (8-70)
Bureau of Reclamation

PHYSICAL PROPERTIES SUMMARY PLOT (Compaction)





CLASSIFICATION SYMBOL GC-GM

GRADATION SUMMARY

GRAVEL	47-53 %
SAND	36-31 %
FINES	18-16 %

ATTERBERG LIMITS

LIQUID LIMIT	26-25 %
PLASTICITY INDEX	7-8
SHRINKAGE LIMIT	%

SPECIFIC GRAVITY

MINUS NO. 4	3.45-3.34
PLUS NO. 4	
BULK	2.33-2.34
APPARENT	
ABSORPTION	3.8-7.3 %

COMPACTION

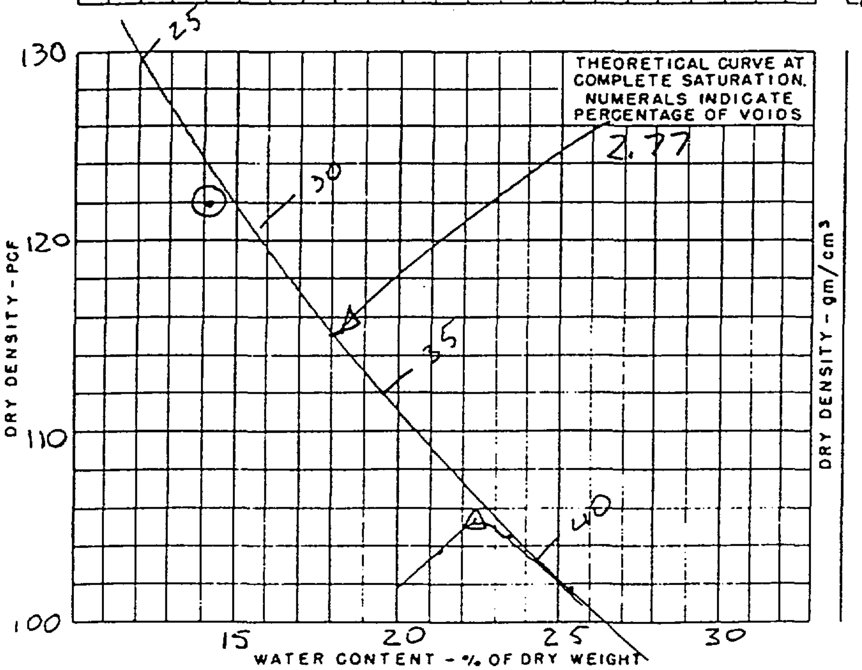
% LARGER THAN TESTED 41-57
MAX. DRY DENSITY 129.2 PCF
(______ gm/cm²)
OPTIMUM WATER CONT. 22.3 %
PENETRATION RESISTANCE ______ PSI
(______ kg/cm²)

PERMEABILITY SETTLEMENT

PLACEMENT CONDITION ______
COEF. OF PERMEABILITY ______ FT/YR.
(______ cm/sec)
SETTLEMENT UNDER
______ PSI LOAD ______ %
(______ kg/cm²)

NOTES:

γ_D MAX TOTAL = 121.9
w OPT TOTAL = 14.1
γ_D INPLACE TOT = 98
w INPLACE TOT = 13.5
Gs AVG = 2.77



COMPACTION - PENETRATION RESISTANCE CURVES

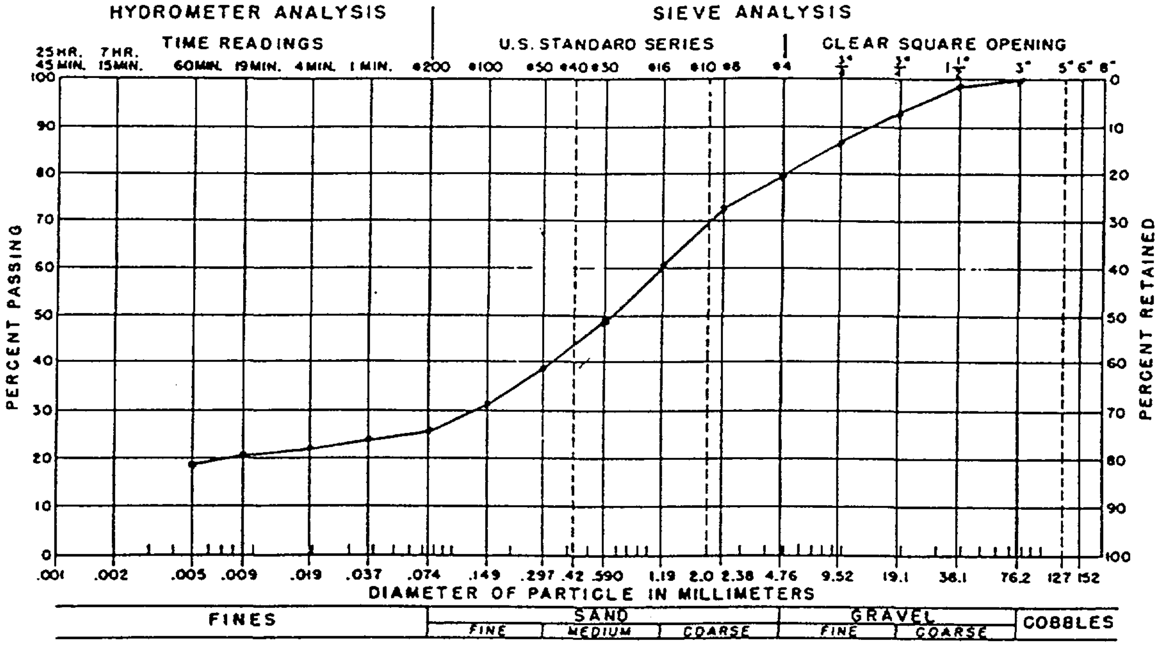
Fig 1

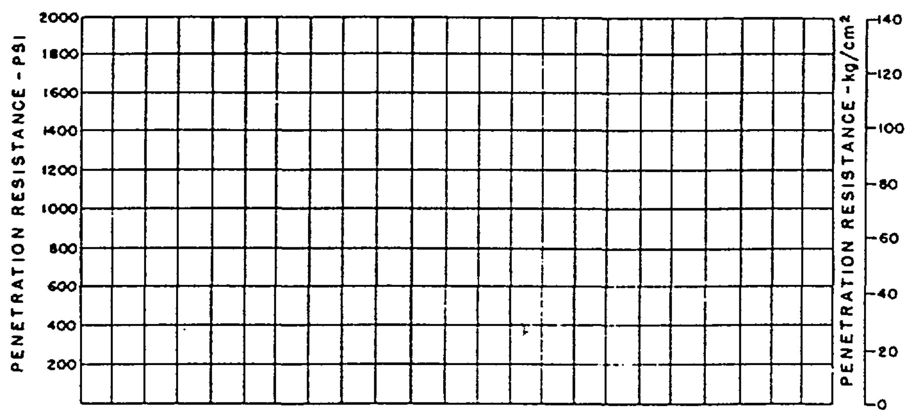
SAMPLE NO. 66H-667, 668 HOLE NO. PYR 1 & 2 DEPTH 0-3 FT
COMBINED

GPO 839-525

7-1565 (8-70)
Bureau of Reclamation

PHYSICAL PROPERTIES SUMMARY PLOT (Compaction)





CLASSIFICATION SYMBOL SC

GRADATION SUMMARY

GRAVEL	21 %
SAND	53 %
FINES	26 %

ATTERBERG LIMITS

LIQUID LIMIT	43 %
PLASTICITY INDEX	24
SHRINKAGE LIMIT	%

SPECIFIC GRAVITY

MINUS NO. 4	2.71
PLUS NO. 4	
BULK	2.37
APPARENT	
ABSORPTION	3.2 %

COMPACTION

% LARGER THAN TESTED	15.6
-#4 MAX. DRY DENSITY	113.2 PCF (gm/cm²)
OPTIMUM WATER CONT.	14.2 %
PENETRATION RESISTANCE	PSI (kg/cm²)

PERMEABILITY SETTLEMENT

PLACEMENT CONDITION ______

COEF. OF PERMEABILITY ______ FT/YR. (______ cm/sec)

SETTLEMENT UNDER ______ PSI LOAD ______ % (______ kg/cm²)

NOTES:

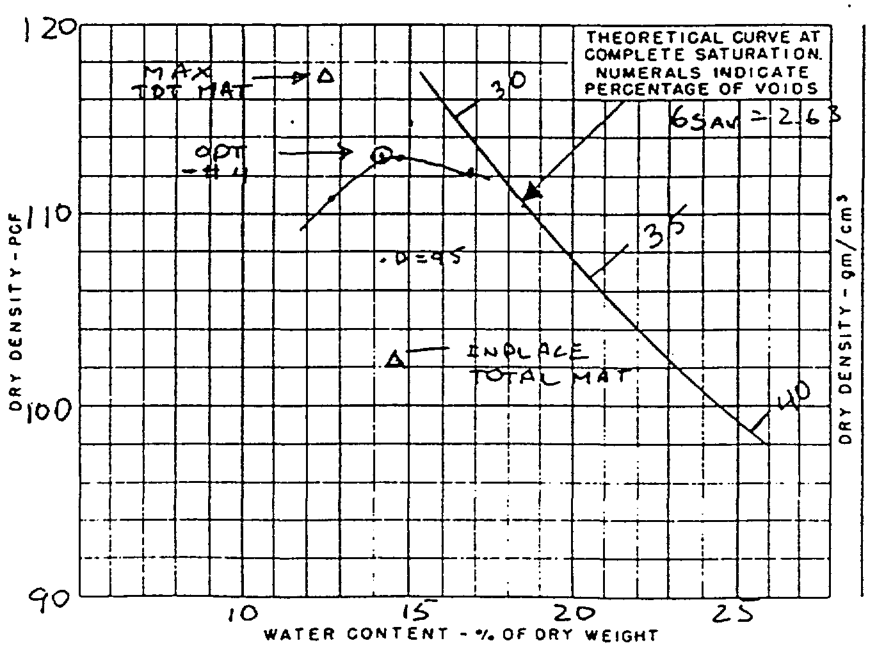
γ_{D} MAX TOTAL = 112.5

W OPT TOTAL = 12.5

γ_{D} INPLACE TOT =

W INPLACE TOT =

Gs AVG = 2.63



COMPACTION - PENETRATION RESISTANCE CURVES

Fig 7

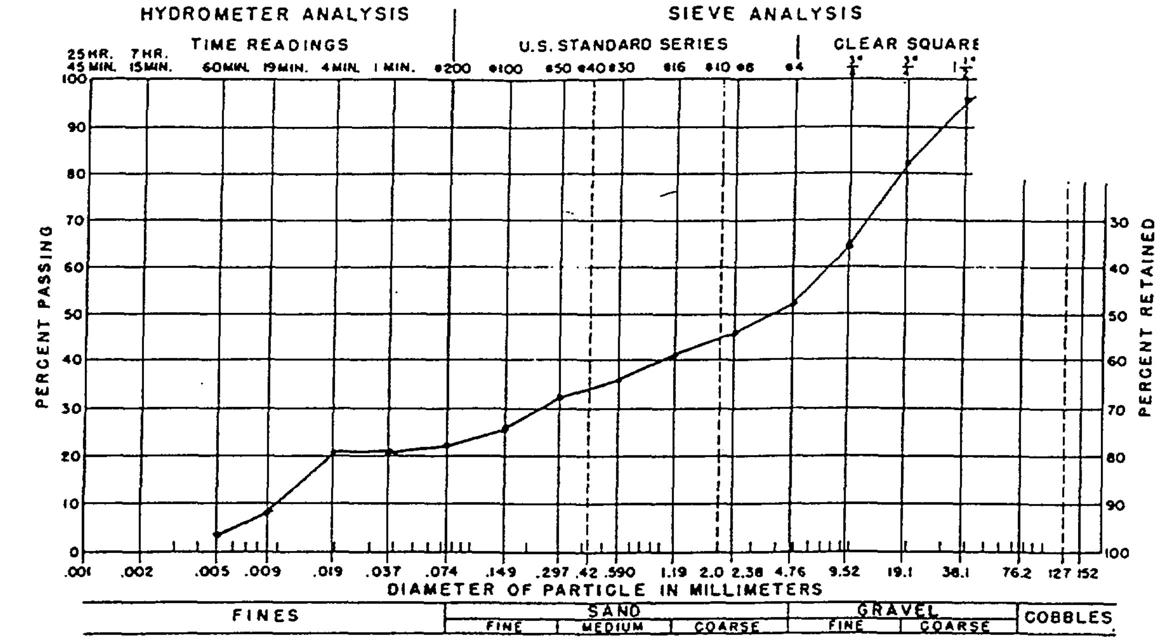
SAMPLE NO. 66H-665 HOLE NO. RAM-1 DEPTH 0-3 FT

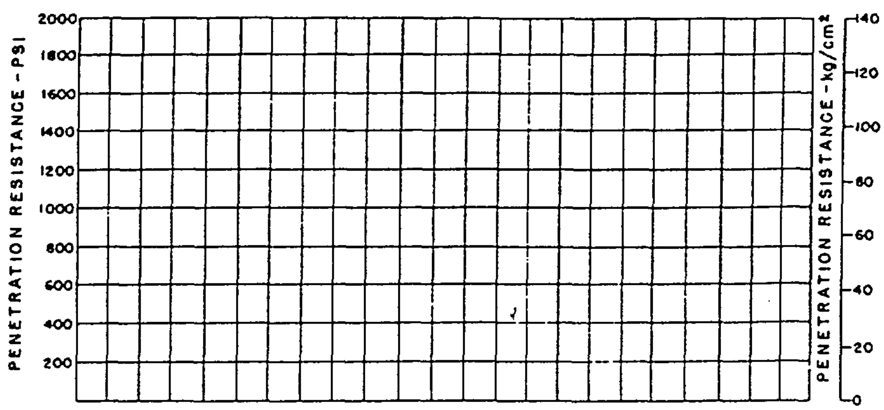
GPO 839-525

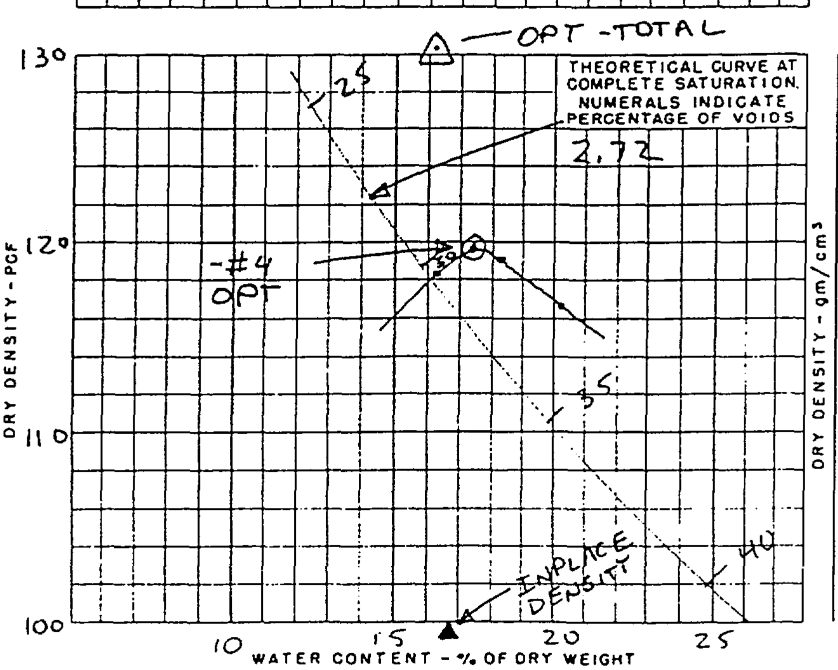
7-1545 (8-70)
Bureau of Reclamation

PHYSICAL PROPERTIES SUMMARY PLOT (Compaction)

Fig 3







COMPACTION - PENETRATION RESISTANCE CURVES

CLASSIFICATION SYMBOL 6M

GRADATION SUMMARY
- GRAVEL 48 %
- SAND 30 %
- FINES 22 %

ATTERBERG LIMITS
- LIQUID LIMIT 34 %
- PLASTICITY INDEX 6
- SHRINKAGE LIMIT ____ %

SPECIFIC GRAVITY
- MINUS NO. 4 3.25
- PLUS NO. 4
- BULK 2.33
- APPARENT
- ABSORPTION 15.0 %

COMPACTION
- % LARGER THAN TESTED 49
- MAX. DRY DENSITY 119.5 PCF (____ gm/cm²)
- OPTIMUM WATER CONT. 17.2 %
- PENETRATION RESISTANCE ____ PSI (____ kg/cm²)

PERMEABILITY SETTLEMENT
- PLACEMENT CONDITION ____
- COEF. OF PERMEABILITY ____ FT/YR. (____ cm/sec)
- SETTLEMENT UNDER ____ PSI LOAD ____ % (____ kg/cm²)

NOTES:

$\gamma_{d\,max}$ ~~TOTAL~~ = 130.9
W_{OPT} TOTAL = 16.1

γ_D INPLACE TOT = 99.3
W INPLACE TOT = 16.7

Gs TOT = 2.72

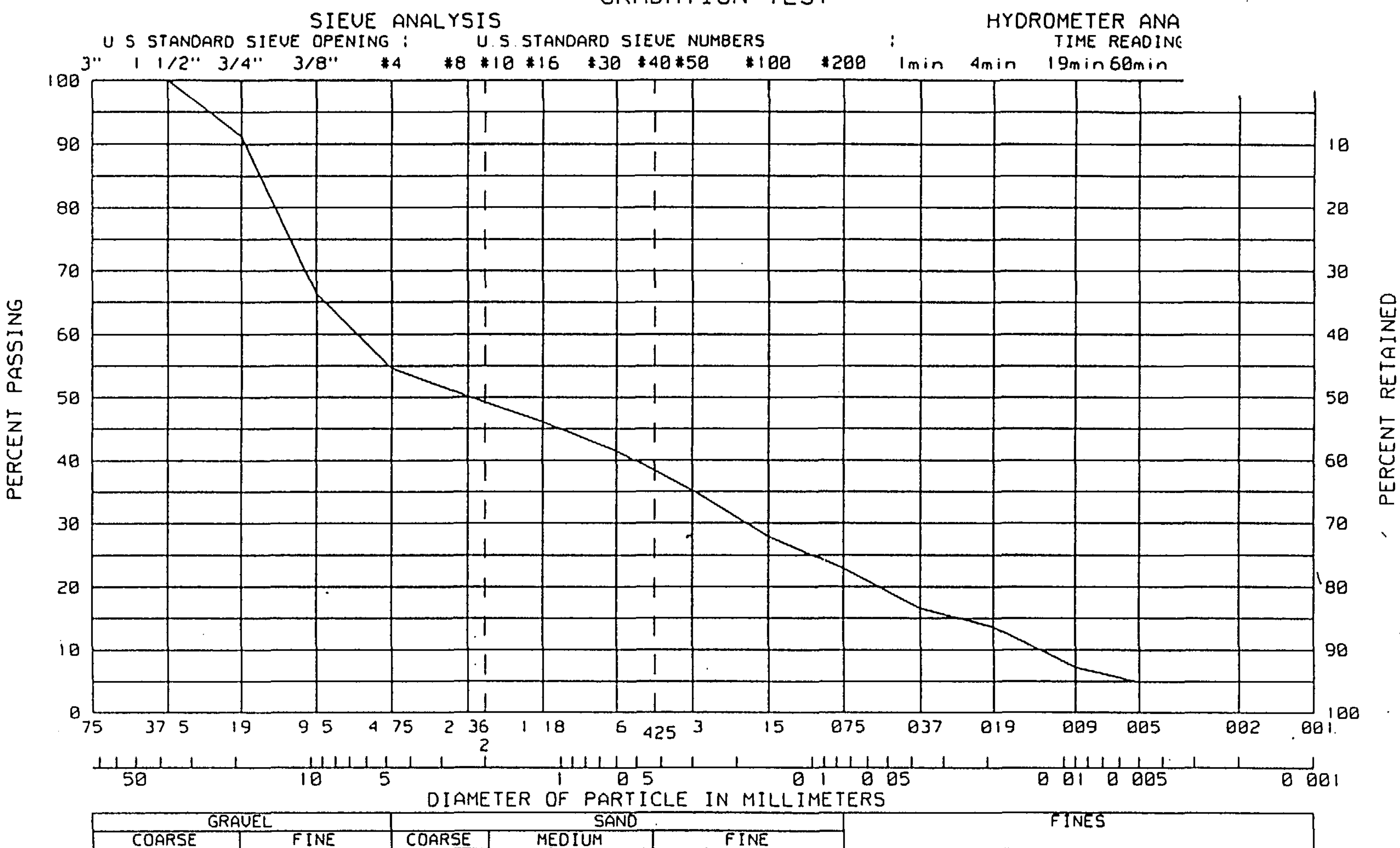
SAMPLE NO. 66H-666 HOLE NO. RAM 2 DEPTH 0 - 3 FT (____ m)

GPO 839-525

Figure

Figure 1.

GRADATION TEST



PHYSICAL PROPERTIES SUMMARY

FEATURE PILE STABILIZATION
DRILL HOLE OU-6
SAMPLE NUMBER PYRENE 1&2

PROJECT LEADVILLE EPA
DEPTH feet

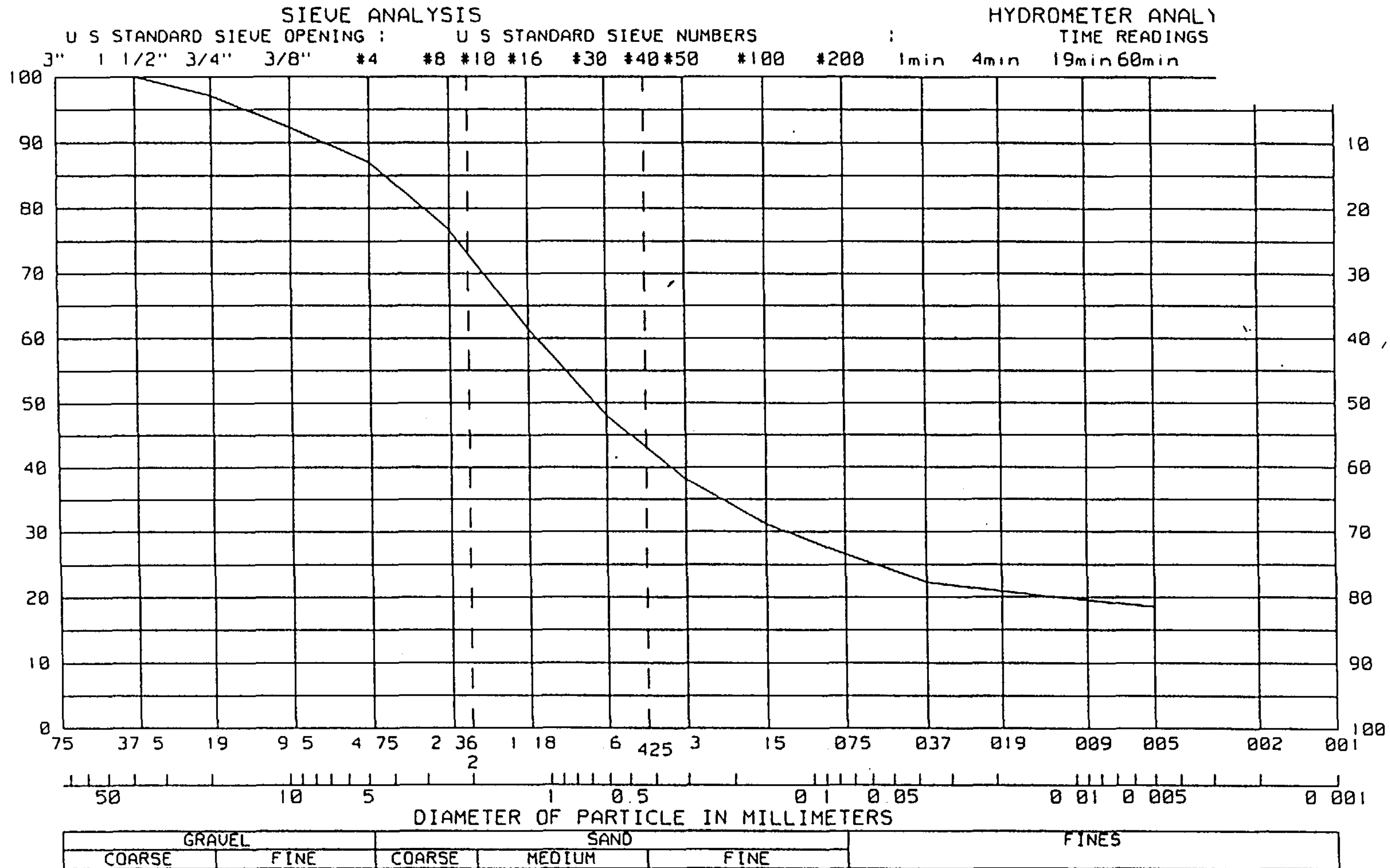
ATTERBERG LIMITS NO TEST PERFORMED
SPECIFIC GRAVITY NO TEST PERFORMED
GRADATION

Percent Gravel 45 4 Percent Sand 31 7 Percent Fines 22 9
D60 (mm): 6.541 D50 (mm): 2.282 D30: .183 D10 (mm) 012
Coefficient of Curvature Cc: .41 Coefficient of Uniformity Cu 524 10

PREPARED BY_______________ CHECKED BY_______________ FIGURE_________

Fig. 5

GRADATION TEST



PHYSICAL PROPERTIES SUMMARY

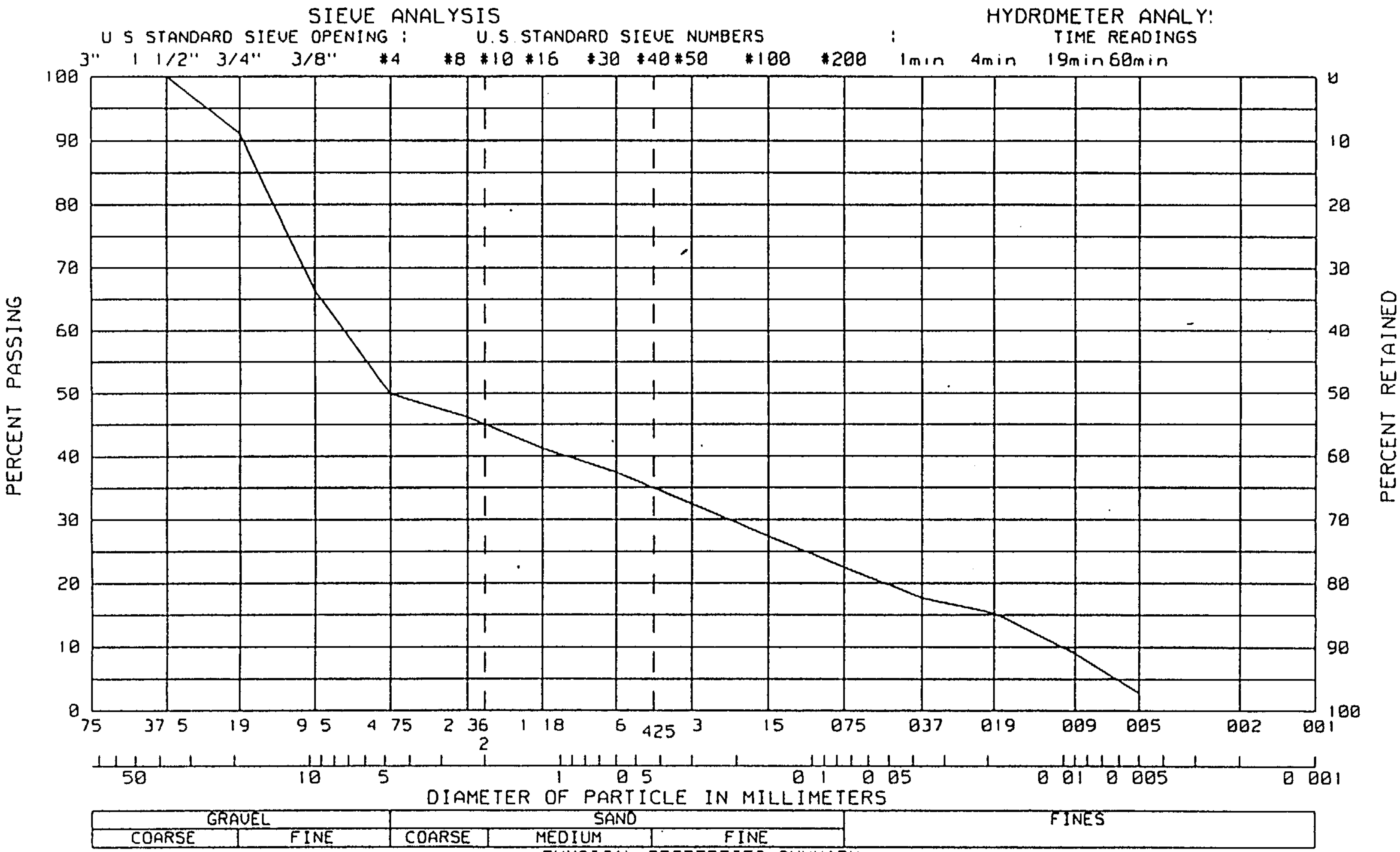
FEATURE PILE STABILIZATION PROJECT LEADVILLE EPA
DRILL HOLE OU-6 DEPTH feet
SAMPLE NUMBER RAM 1

ATTERBERG LIMITS NO TEST PERFORMED
SPECIFIC GRAVITY NO TEST PERFORMED
GRADATION Percent Gravel 13.0 Percent Sand: 60.4 Percent Fines 26 6

PREPARED BY_______________ CHECKED BY_______________ FIGURE_________

Fig 4

GRADATION TEST



PHYSICAL PROPERTIES SUMMARY

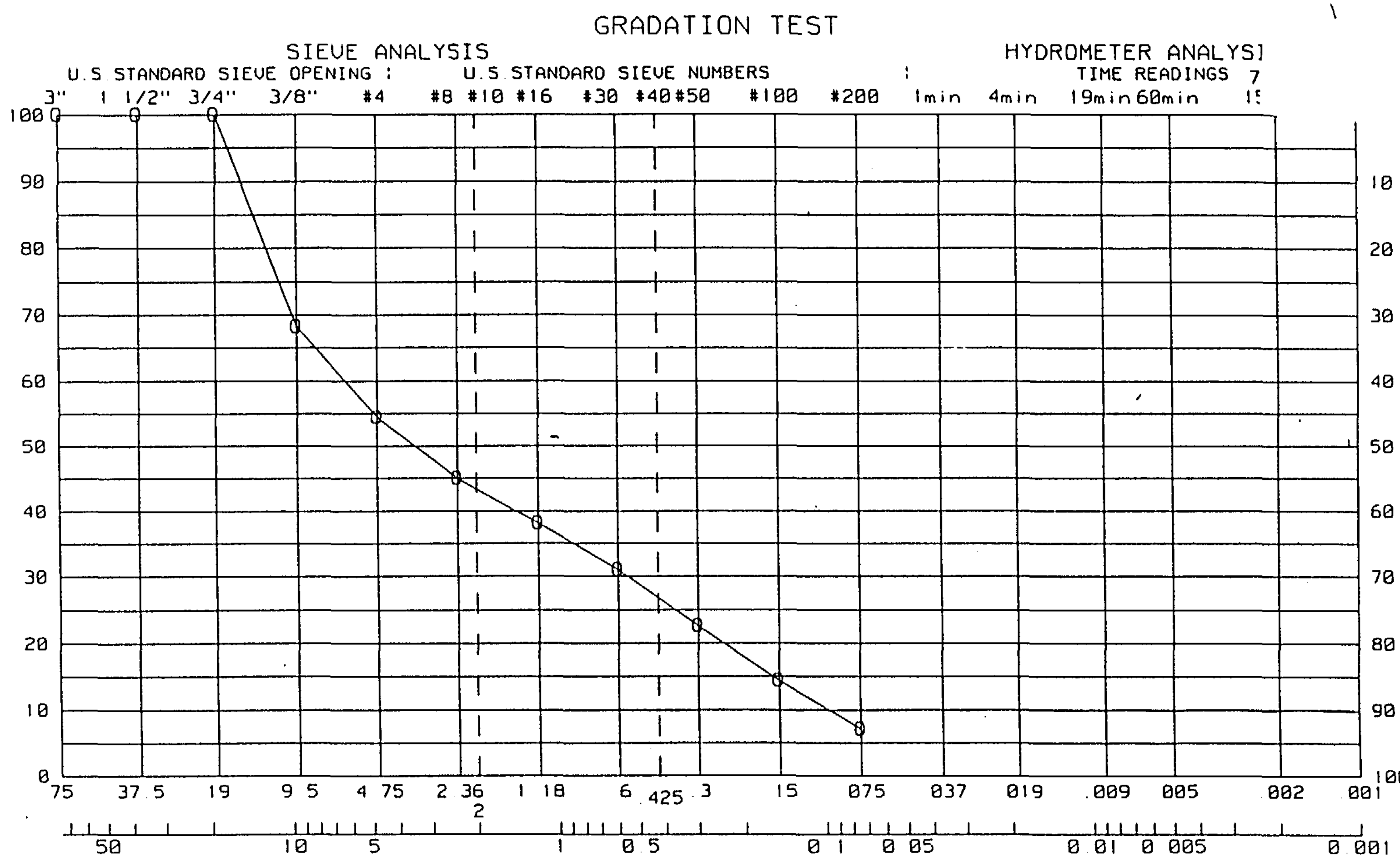
FEATURE PILE STABILIZATION PROJECT LEADVILLE EPA
DRILL HOLE OU-6 DEPTH feet
SAMPLE NUMBER RAM 2

ATTERBERG LIMITS: NO TEST PERFORMED
SPECIFIC GRAVITY NO TEST PERFORMED
GRADATION Percent Gravel 50 1 Percent Sand: 27 4 Percent Fines 22 5
D60 (mm): 7 260 D50 (mm): 4 770 D30: 214 D10 (mm) 010
Coefficient of Curvature Cc: 62 Coefficient of Uniformity Cu 716 49

PREPARED BY______________ CHECKED BY______________ FIGURE_________

Fig 7

GRADATION TEST



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

PHYSICAL PROPERTIES SUMMARY

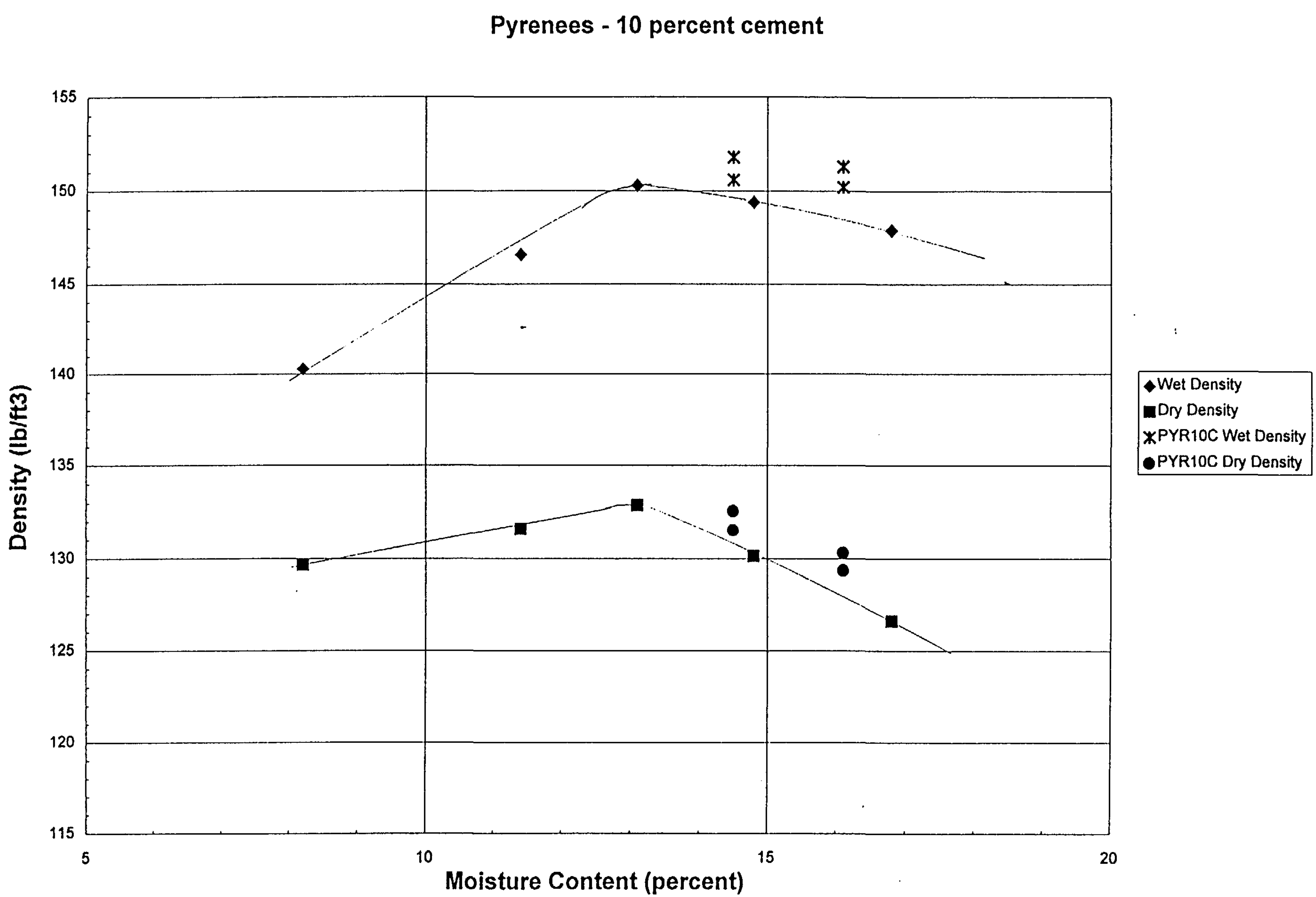
FEATURE: PILE STABILIZATION
DRILL HOLE: TP-96-14
SAMPLE NUMBER: PYR 1&2
NOTES: -3/4/ COMPOSITE

PROJECT: LEADVILLE EPA
DEPTH: 0.0-3.0 feet

ATTERBERG LIMITS: NO TEST PERFORMED
SPECIFIC GRAVITY: NO TEST PERFORMED
GRADATION:
Percent Gravel: 45.6 Percent Sand: 47.3 Percent Fines: 7.1
D60 (mm): 6.293 D50 (mm): 3.424 D30: .552 D10 (mm): .099
Coefficient of Curvature Cc: .49 Coefficient of Uniformity Cu:. 63.71

PREPARED BY [signature] CHECKED BY _______________ FIGURE _________

Fig (8)-12



Pyrenees - 10 percent cement
Density (lb/ft3)
155
150
145
140
135
130
125
120
115
5
10
15
20
Moisture Content (percent)
Wet Density
Dry Density
PYR10C Wet Density
PYR10C Dry Density

Fig 9

Pyrenees - 20 percent cement

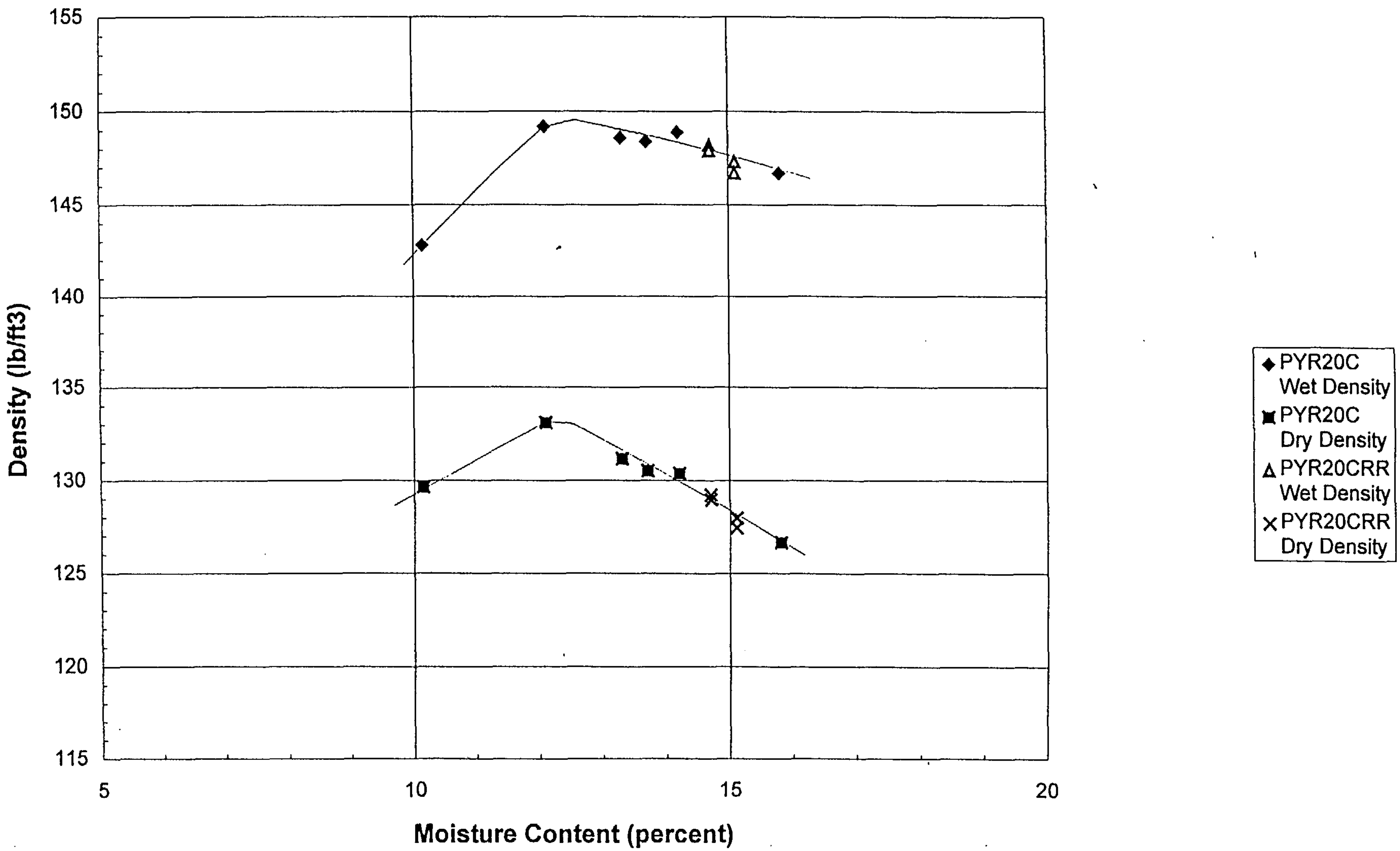
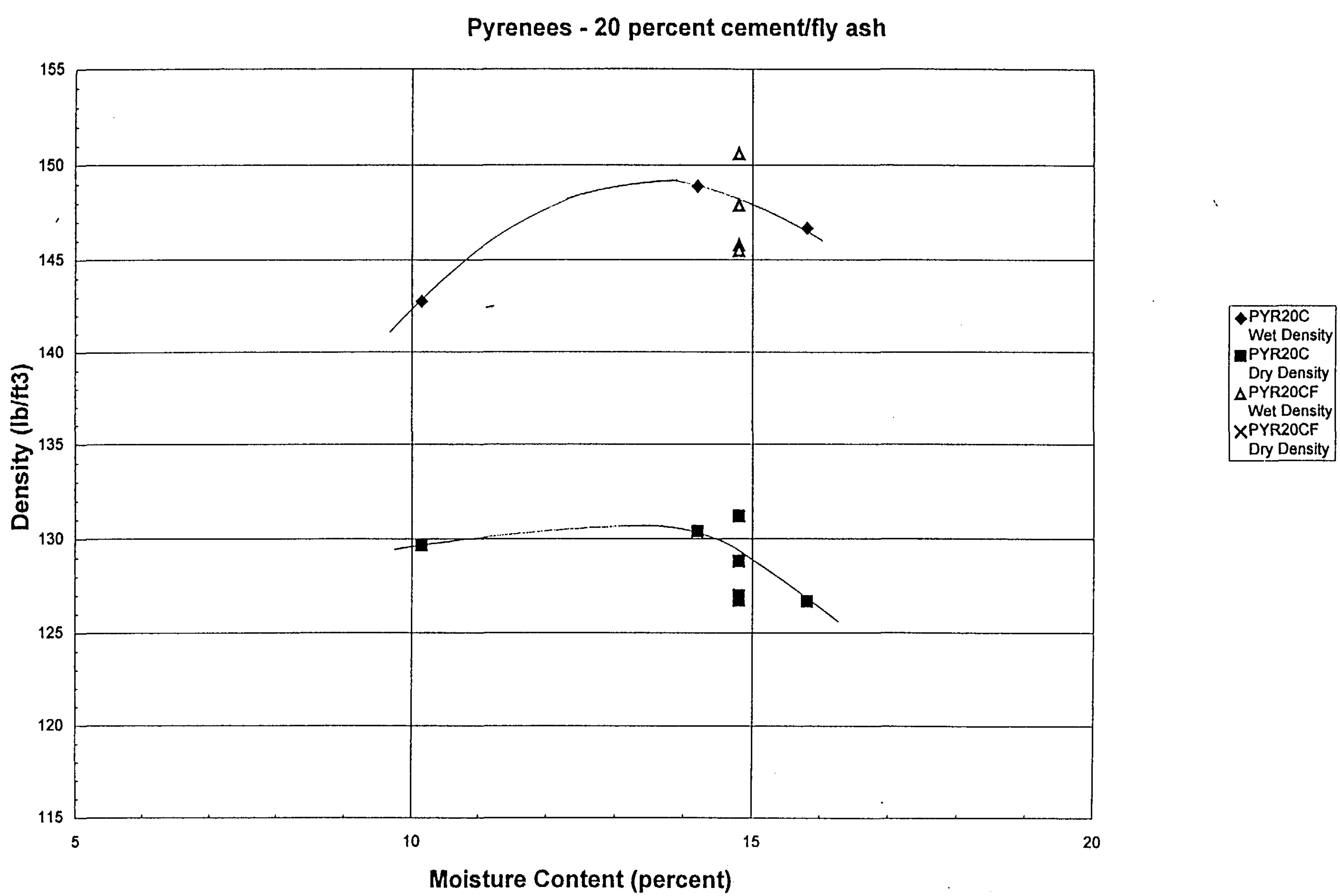
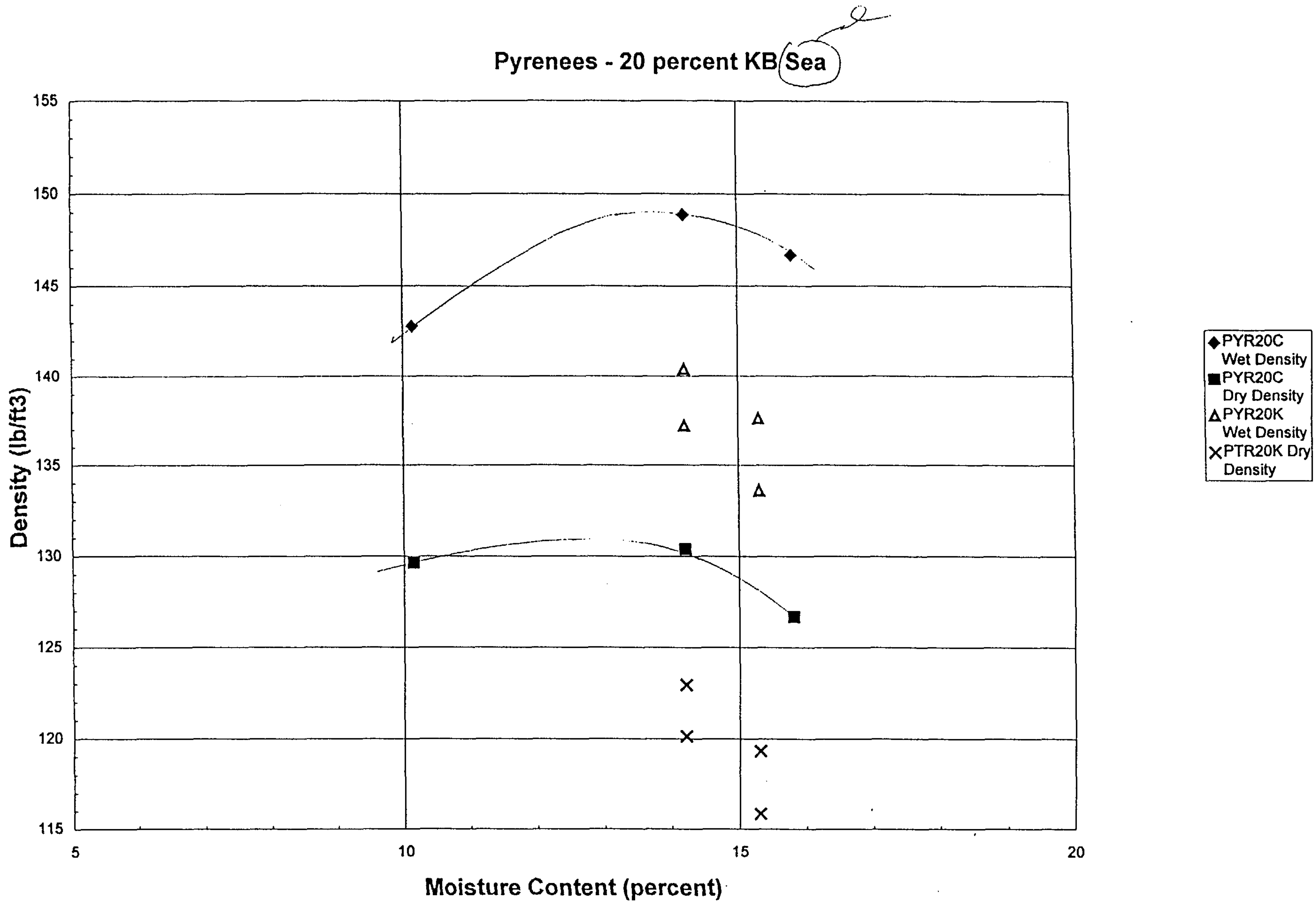


Fig 10



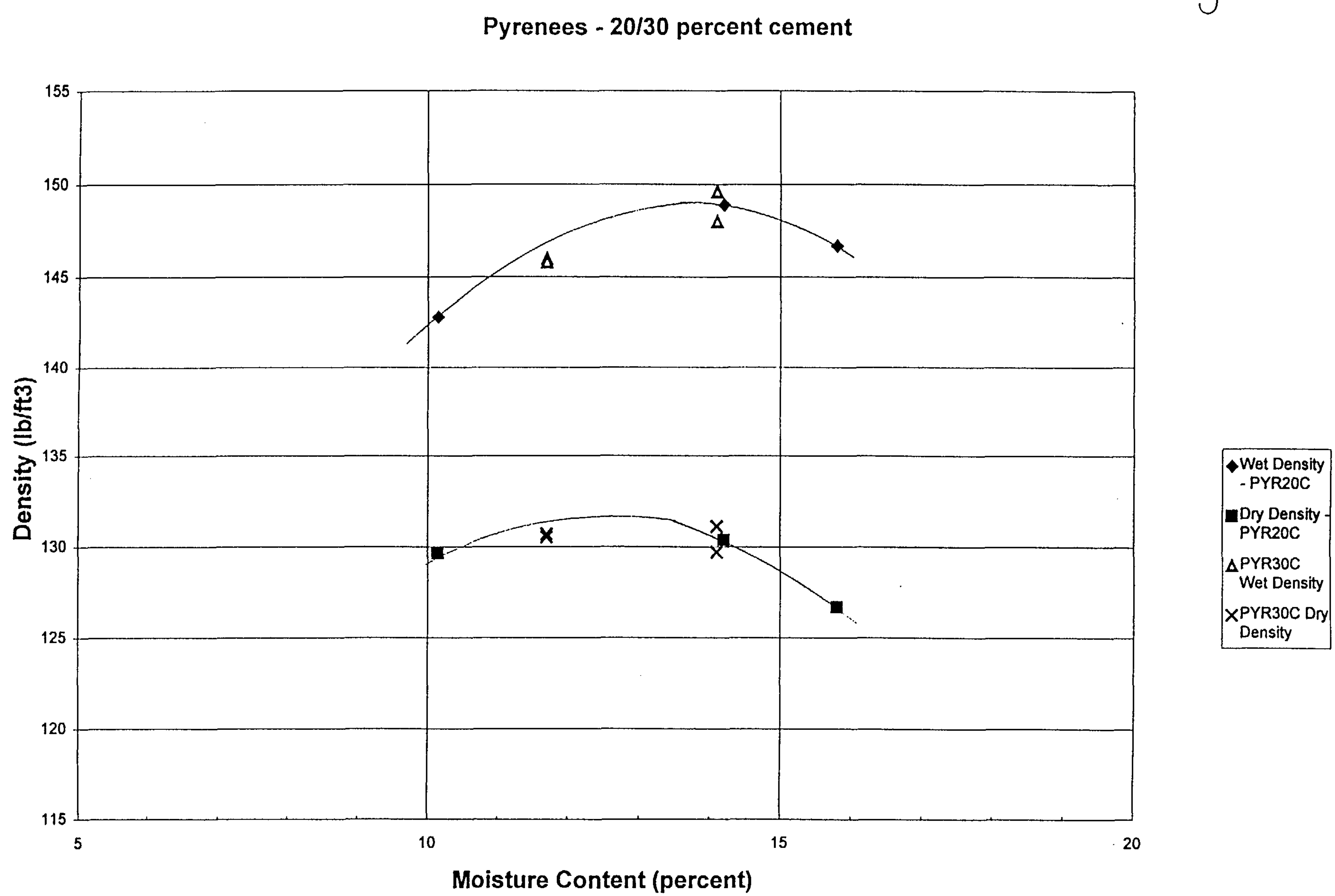
Pyrenees - 20 percent cement/fly ash
Density (lb/ft3)
155
150
145
140
135
130
125
120
115
5
10
15
20
Moisture Content (percent)
PYR20C Wet Density
PYR20C Dry Density
PYR20CF Wet Density
PYR20CF Dry Density

Fig 11



Pyrenees - 20 percent KB Sea
Density (lb/ft3)
155
150
145
140
135
130
125
120
115
5
10
15
20
Moisture Content (percent)
PYR20C Wet Density
PYR20C Dry Density
PYR20K Wet Density
PTR20K Dry Density

Fig 12



Pyrenees - 20/30 percent cement
Density (lb/ft3)
155
150
145
140
135
130
125
120
115
5
10
15
20
Moisture Content (percent)
Wet Density - PYR20C
Dry Density - PYR20C
PYR30C Wet Density
PYR30C Dry Density

Fig (13)-16

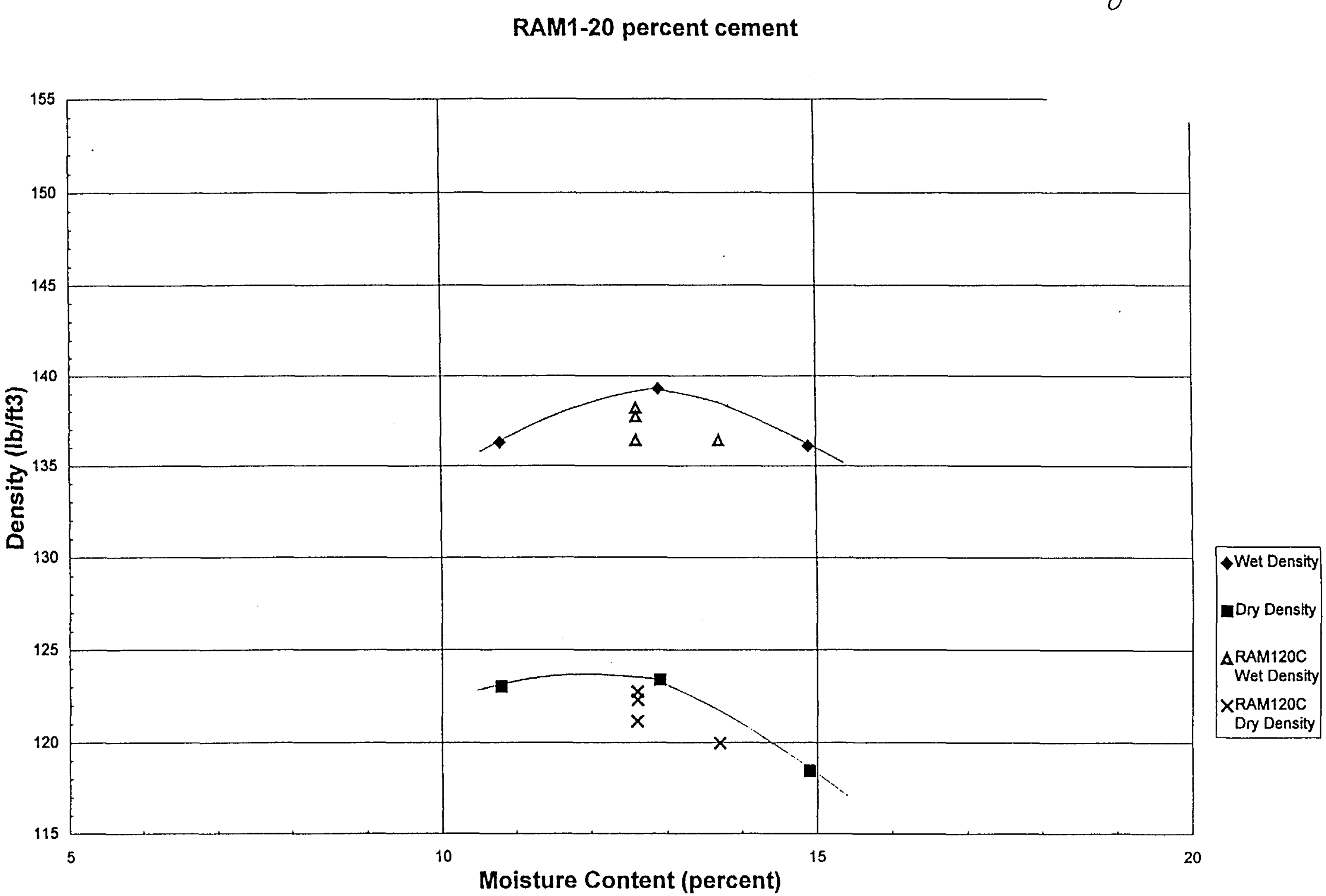

RAM1-20 percent cement
Density (lb/ft3)
155
150
145
140
135
130
125
120
115
Moisture Content (percent)
5
10
15
20
Wet Density
Dry Density
RAM120C Wet Density
RAM120C Dry Density

Fig 14

RAM1 - 20 percent cement/fly ash

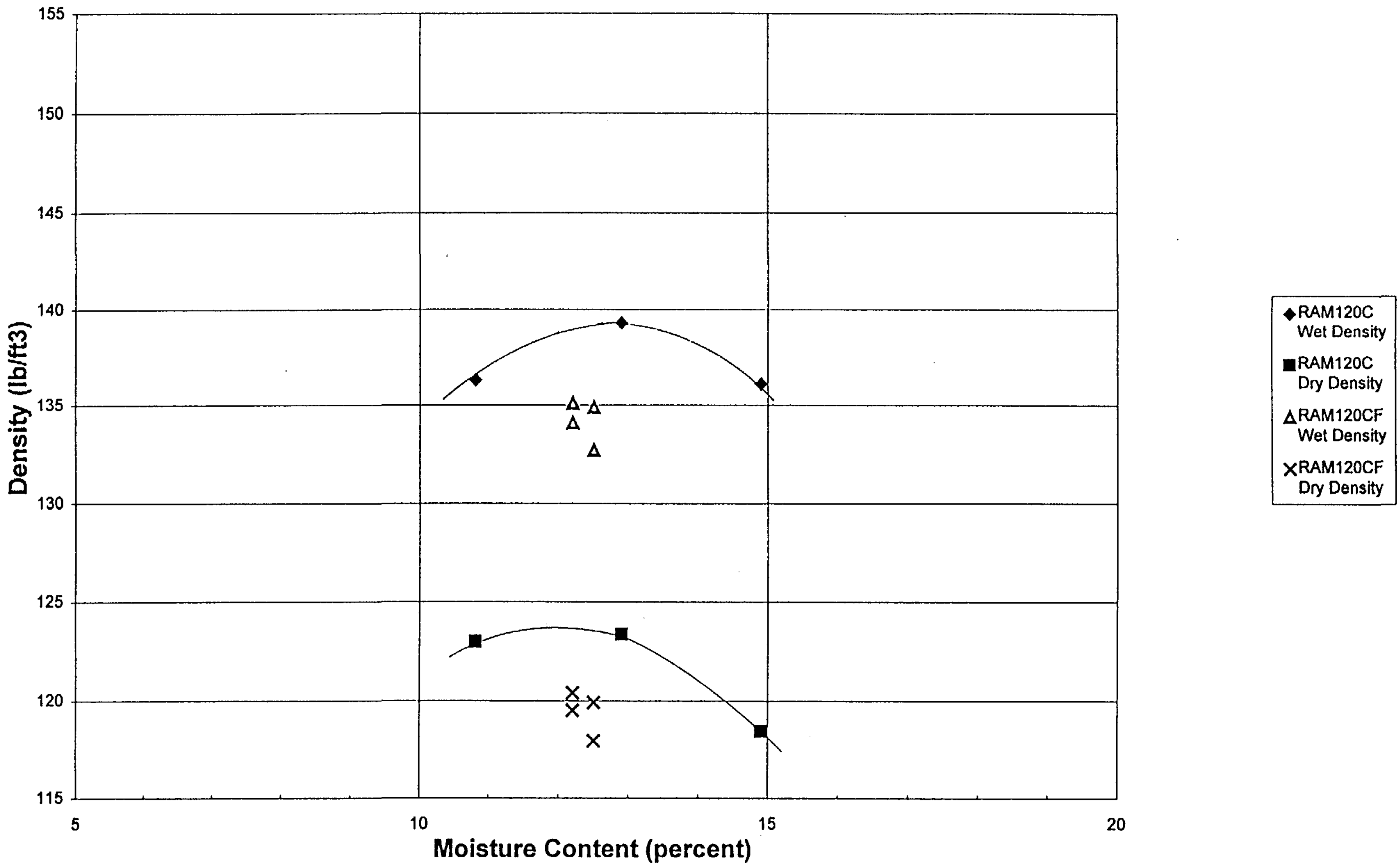


Fig 15

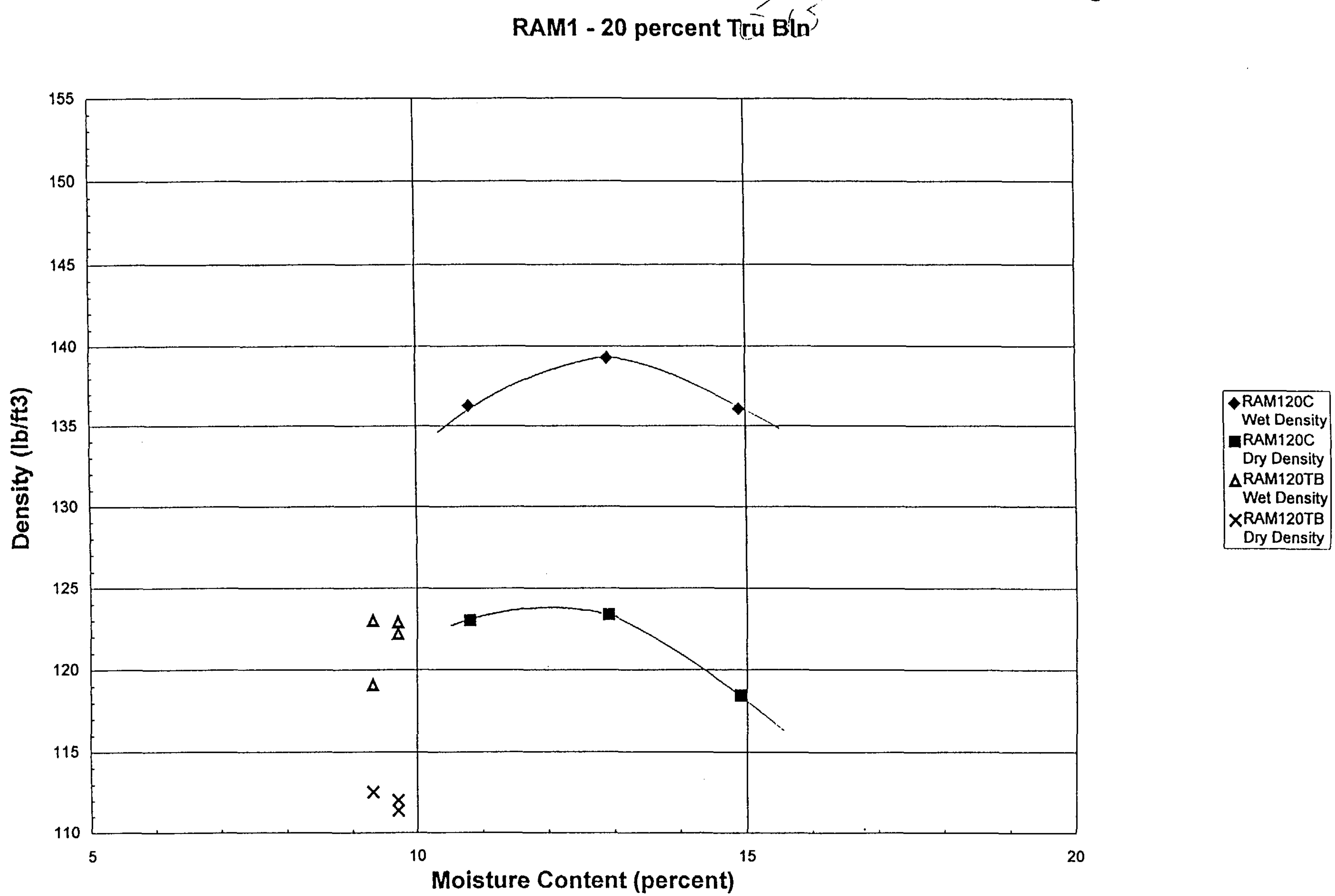

RAM1 - 20 percent Tru Bln
Density (lb/ft3)
155
150
145
140
135
130
125
120
115
110
5
10
15
20
Moisture Content (percent)
RAM120C Wet Density
RAM120C Dry Density
RAM120TB Wet Density
RAM120TB Dry Density

Fig 1k

RAM1 - 30 percent cement

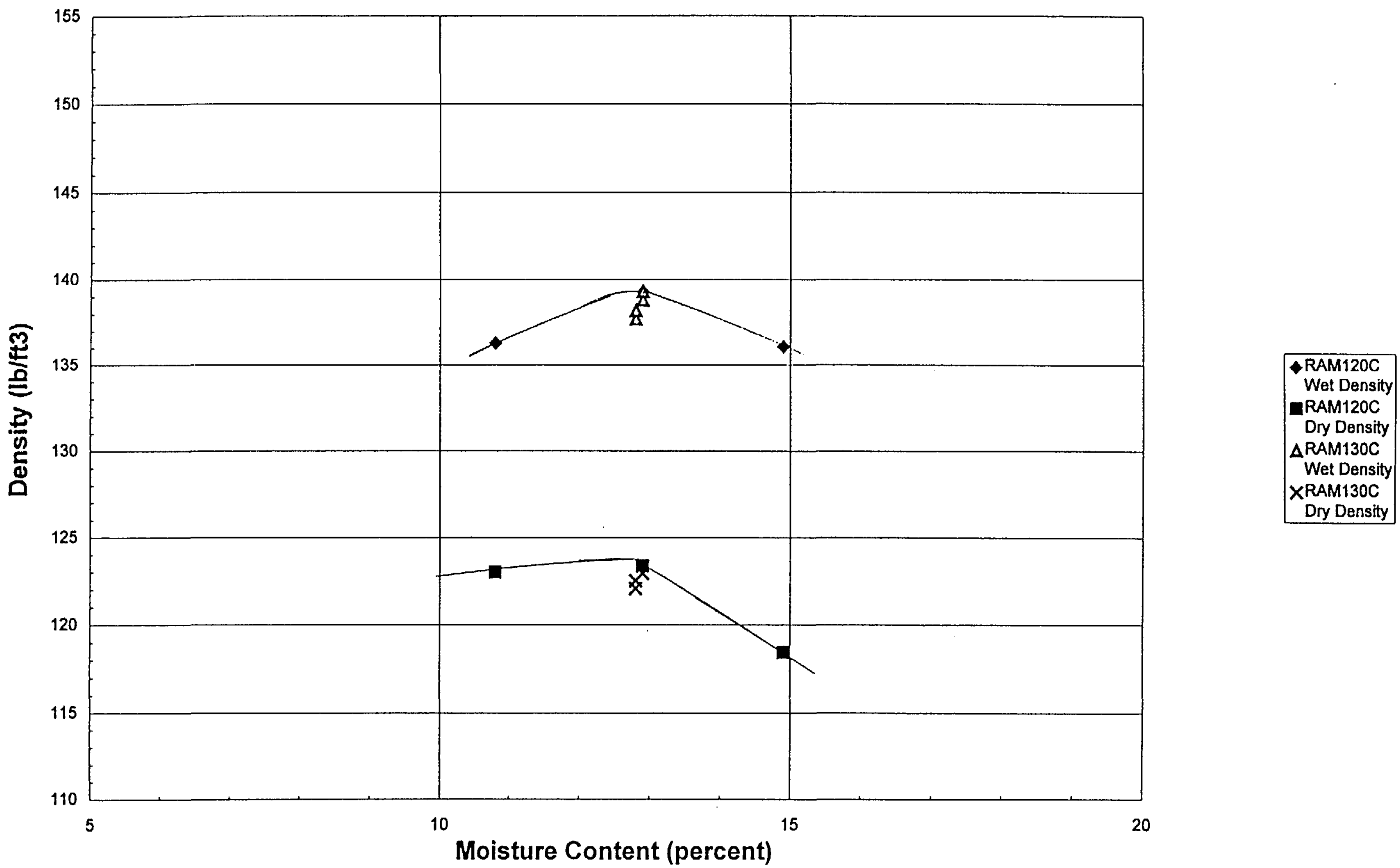


Fig (7)-2d

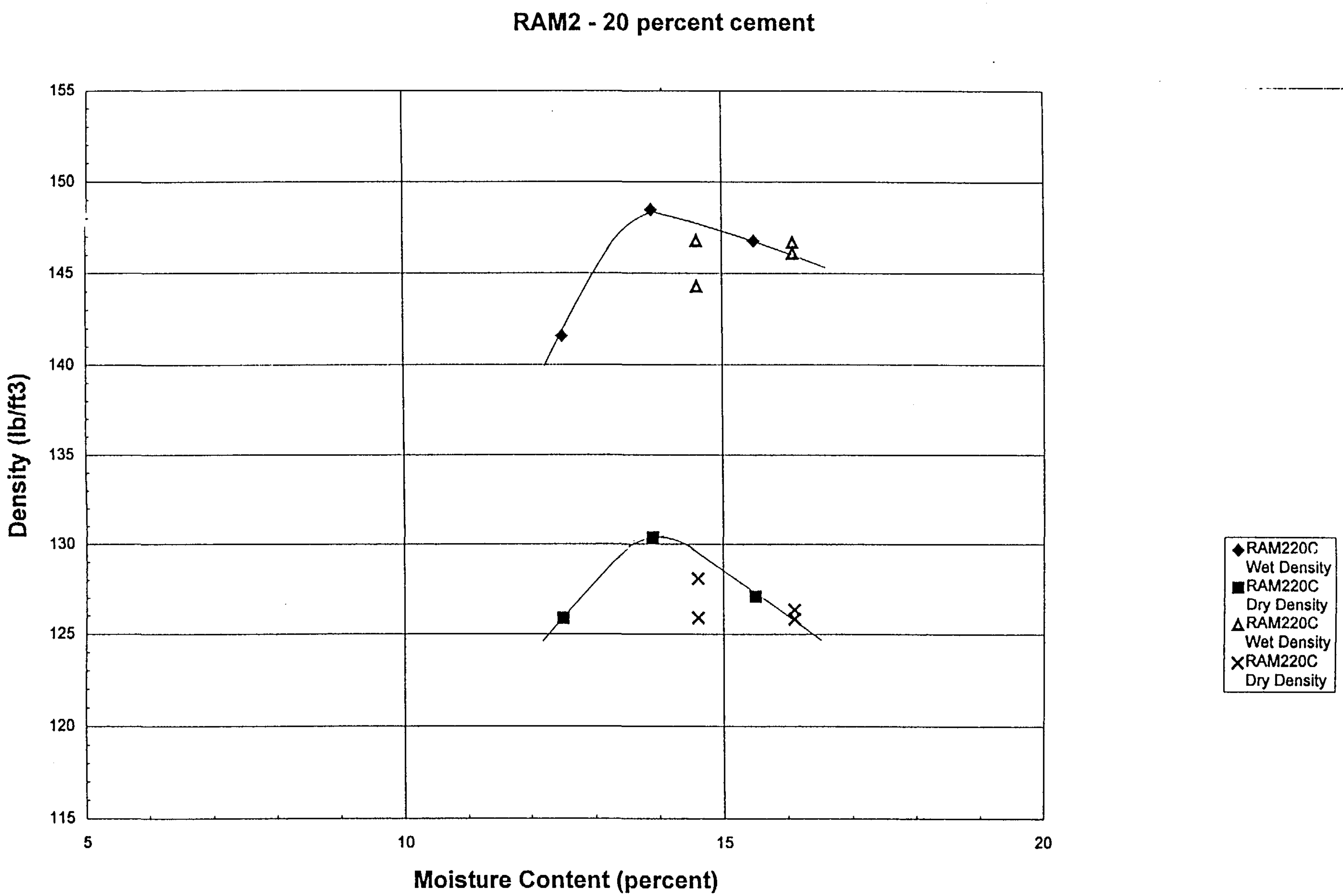
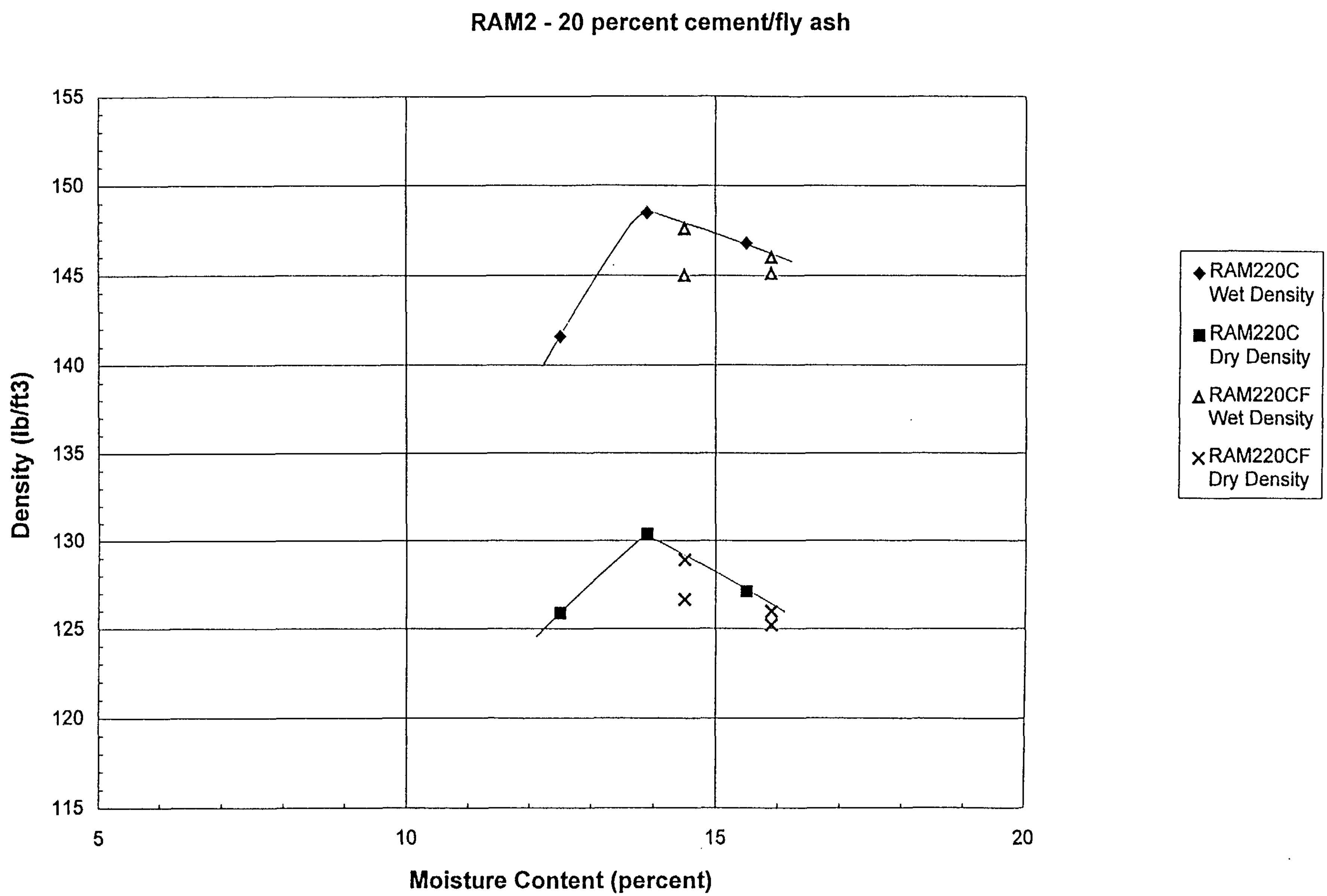

RAM2 - 20 percent cement
Density (lb/ft3)
155
150
145
140
135
130
125
120
115
5
10
15
20
Moisture Content (percent)
RAM220C Wet Density
RAM220C Dry Density
RAM220C Wet Density
RAM220C Dry Density

Fig 18



RAM2 - 20 percent cement/fly ash
Density (lb/ft3)
155
150
145
140
135
130
125
120
115
5
10
15
20
Moisture Content (percent)
RAM220C Wet Density
RAM220C Dry Density
RAM220CF Wet Density
RAM220CF Dry Density

Fig 19

RAM2 - 20 percent Tru Bin

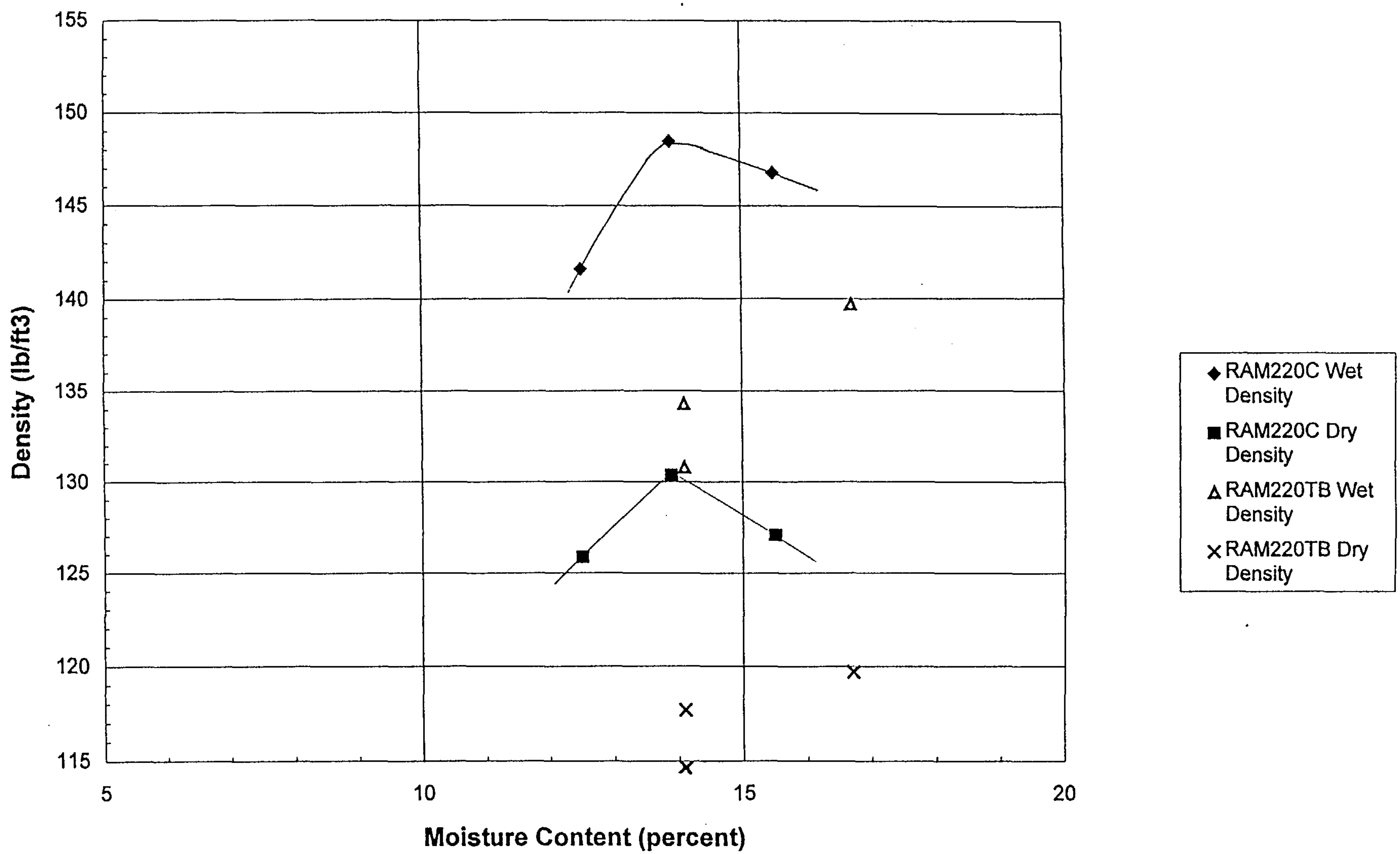


Fig 20

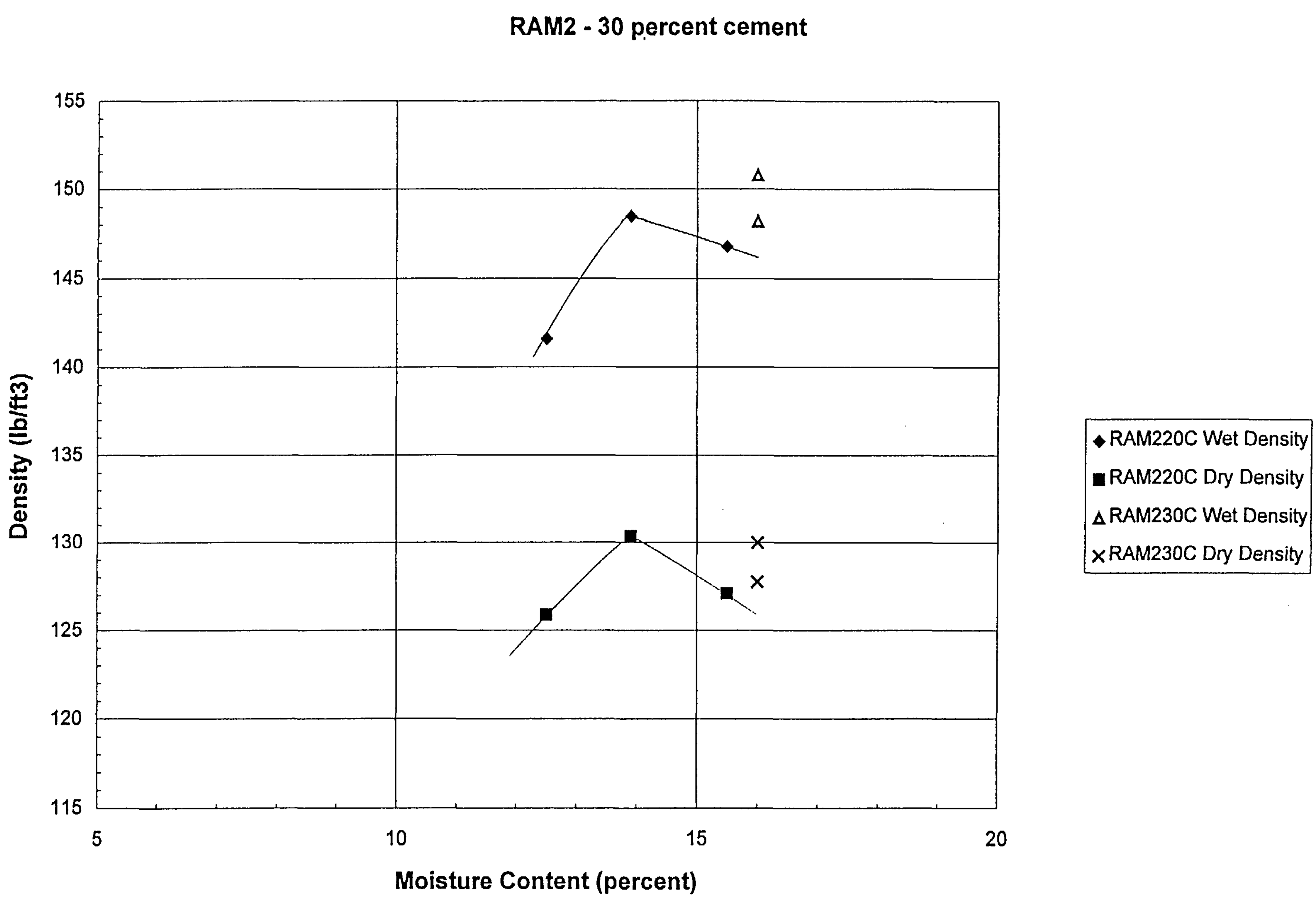

RAM2 - 30 percent cement
155
150
145
140
135
130
125
120
115
Density (lb/ft3)
5
10
15
20
Moisture Content (percent)
RAM220C Wet Density
RAM220C Dry Density
RAM230C Wet Density
RAM230C Dry Density

Fig 21

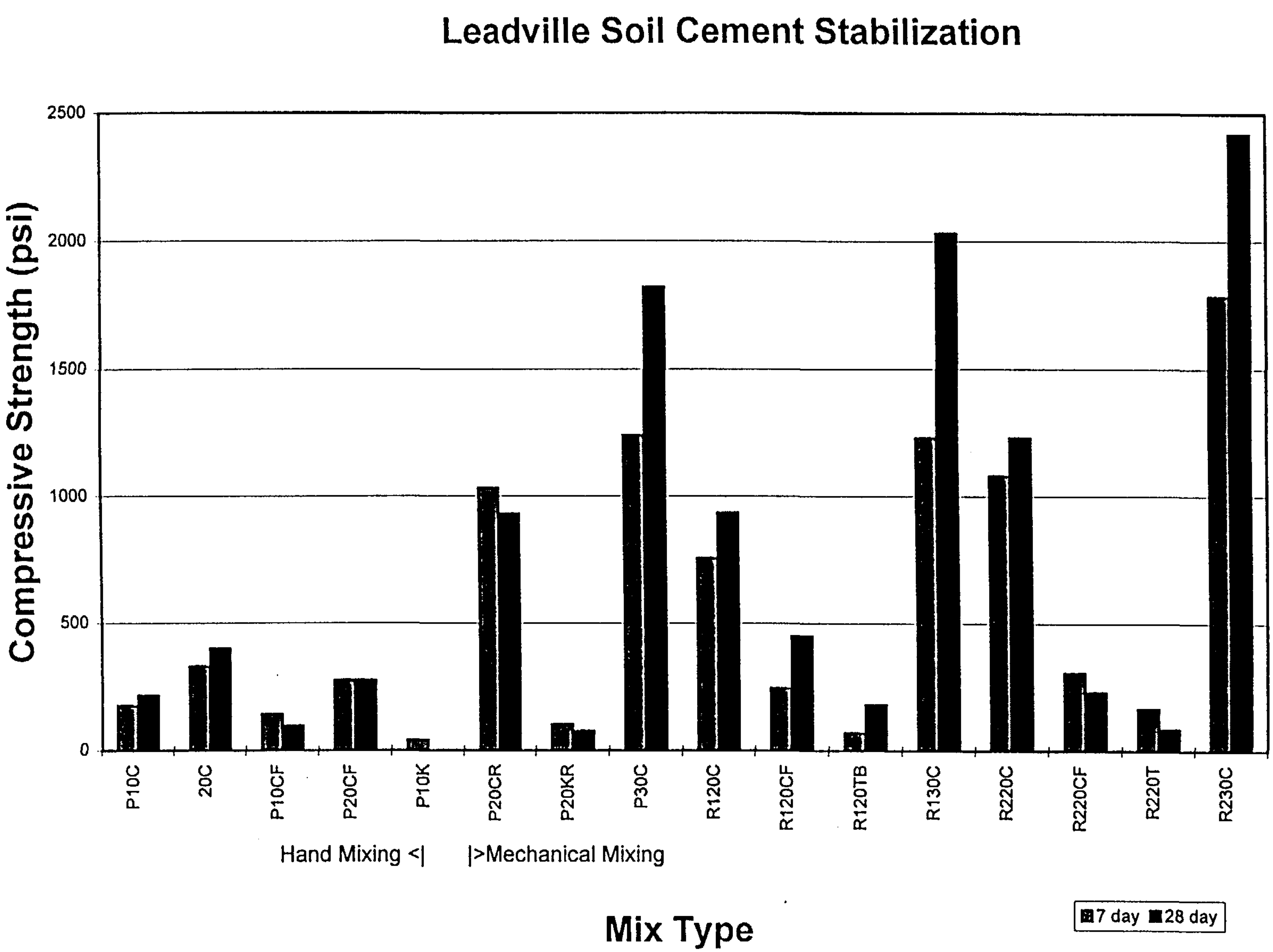

Leadville Soil Cement Stabilization
Compressive Strength (psi)
2500
2000
1500
1000
500
0
P10C
20C
P10CF
P20CF
P10K
P20CR
P20KR
P30C
R120C
R120CF
R120TB
R130C
R220C
R220CF
R220T
R230C
Hand Mixing <|
|>Mechanical Mixing
Mix Type
7 day
28 day

Fig 22
Effect of Cement Pyrenees
RAM 1
RAM 2

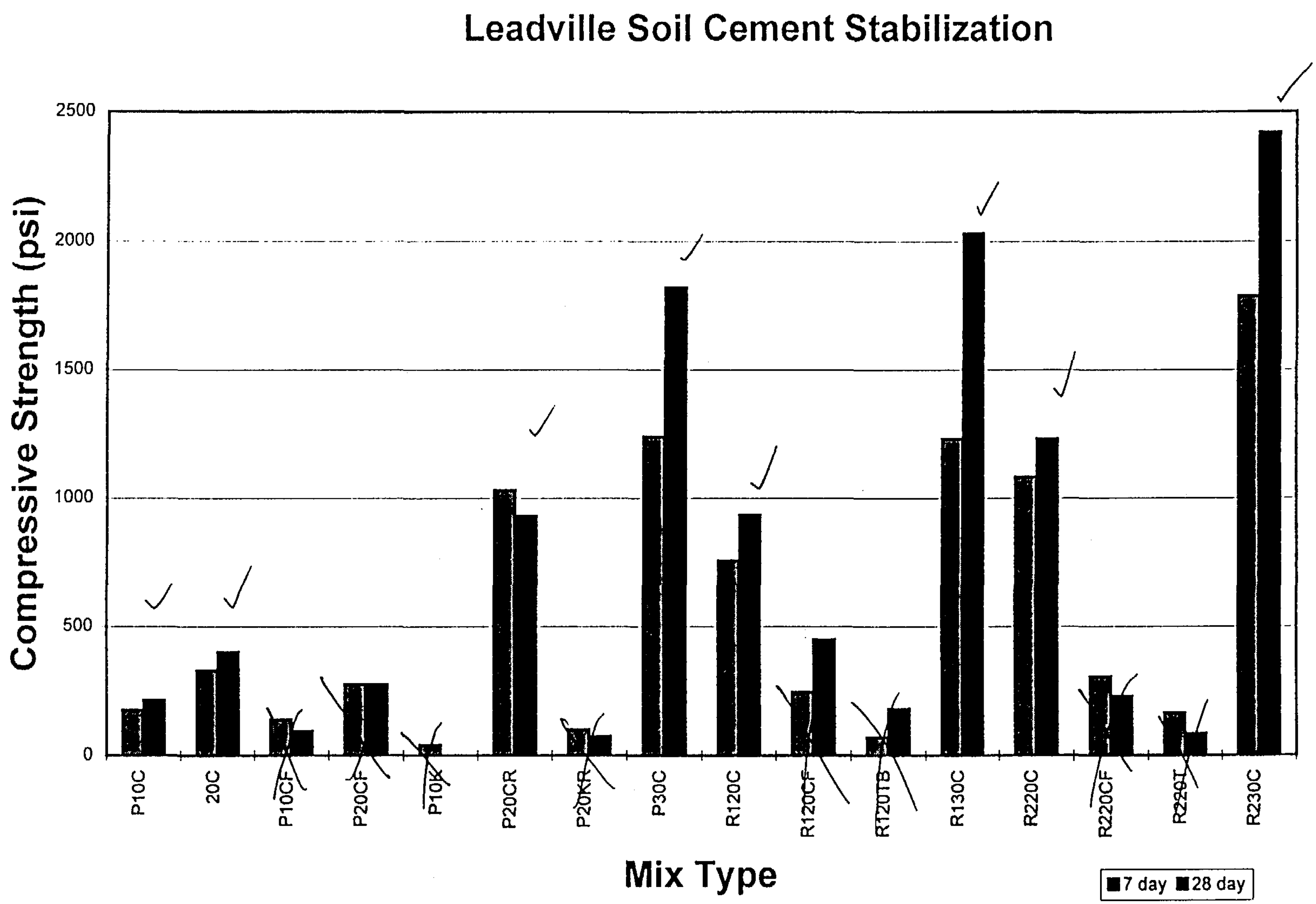
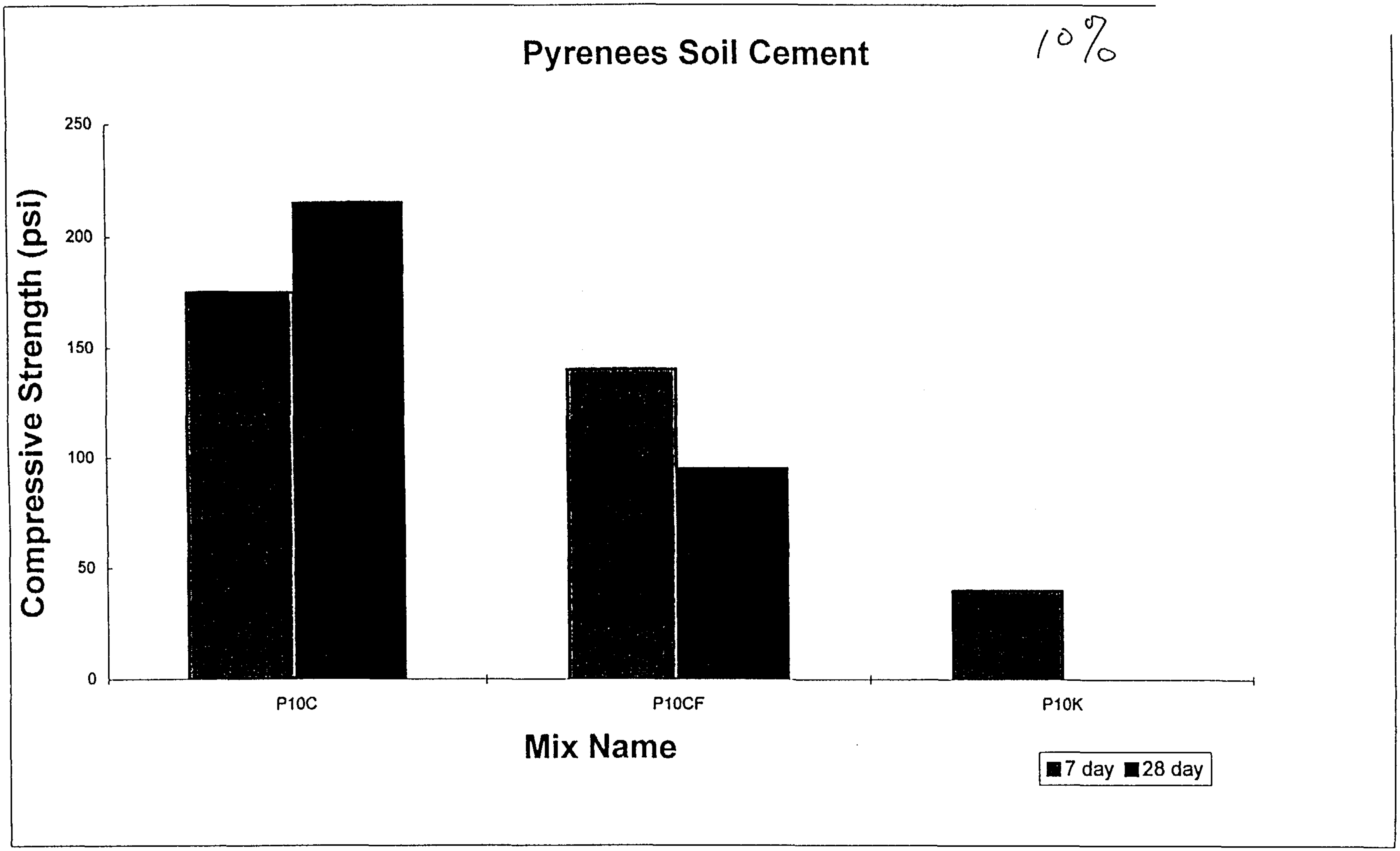


Fig 23


Pyrenees Soil Cement
10%
Compressive Strength (psi)
250
200
150
100
50
0
P10C
P10CF
P10K
Mix Name
7 day
28 day

Leadville Soil Cement - 20 percent additive

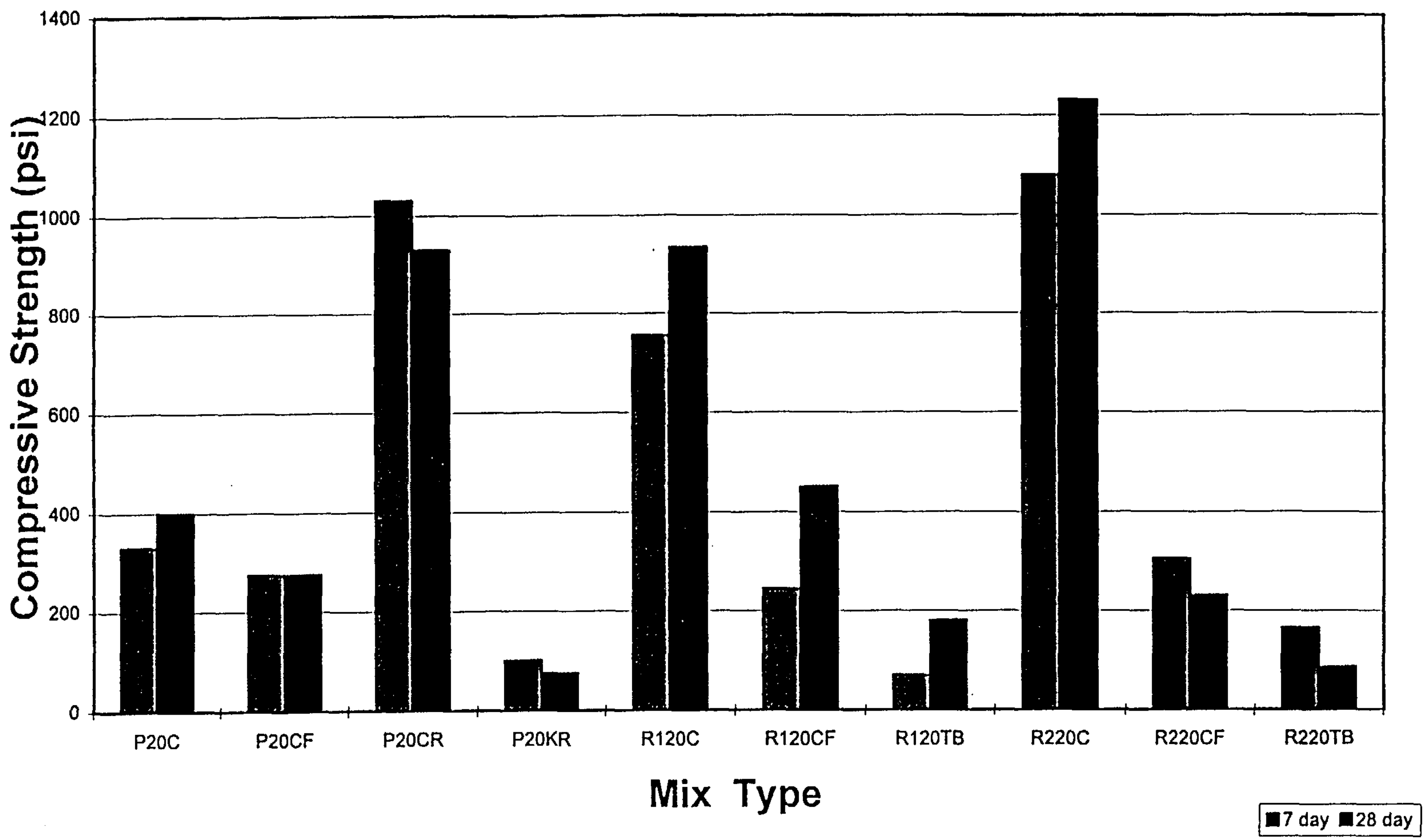
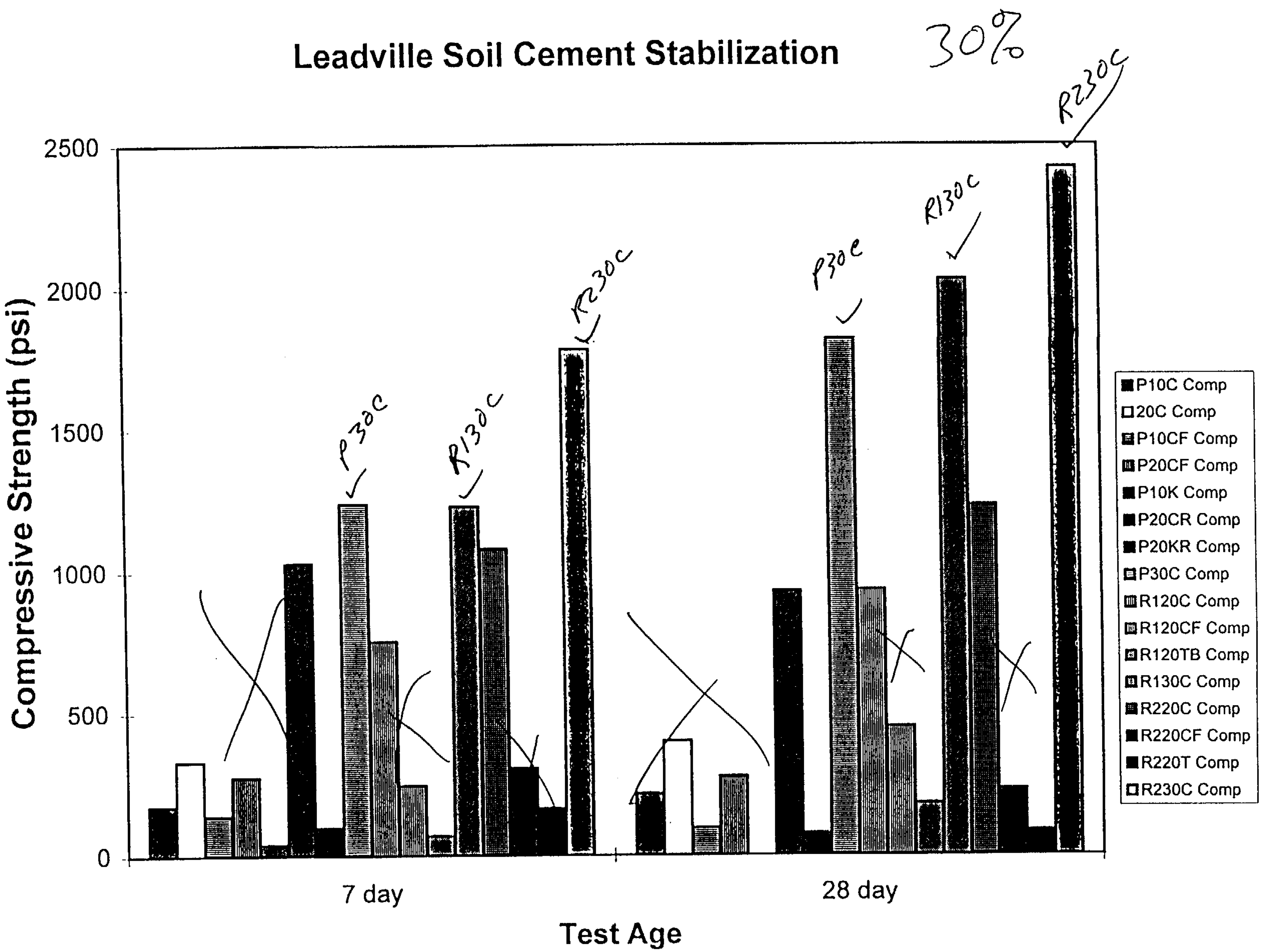
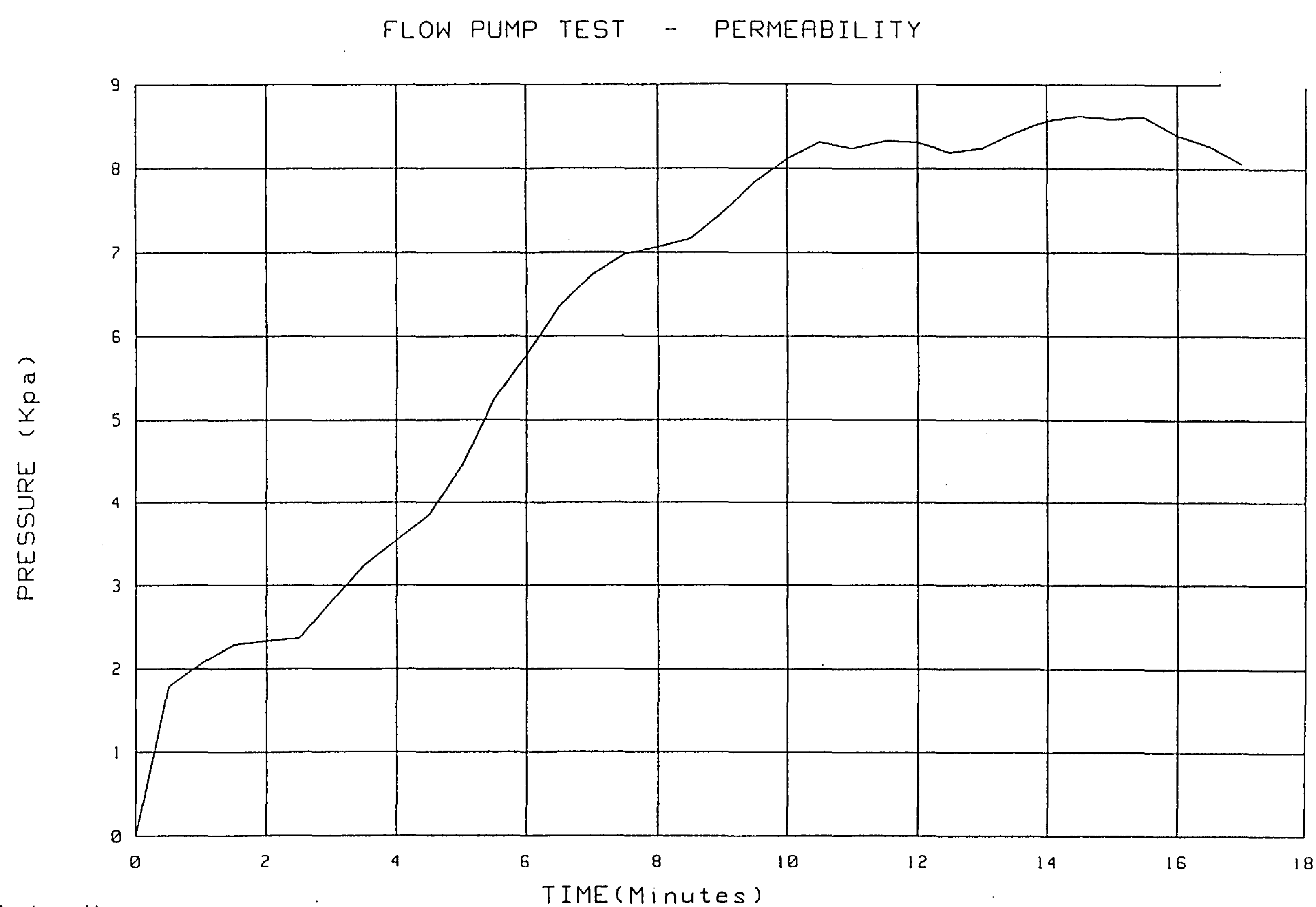


Fig 28



Leadville Soil Cement Stabilization
30%
Compressive Strength (psi)
2500
2000
1500
1000
500
0
7 day
28 day
Test Age
P30C
R130C
R230C
P30C
R130C
R230C
P10C Comp
20C Comp
P10CF Comp
P20CF Comp
P10K Comp
P20CR Comp
P20KR Comp
P30C Comp
R120C Comp
R120CF Comp
R120TB Comp
R130C Comp
R220C Comp
R220CF Comp
R220T Comp
R230C Comp

Fig. 26

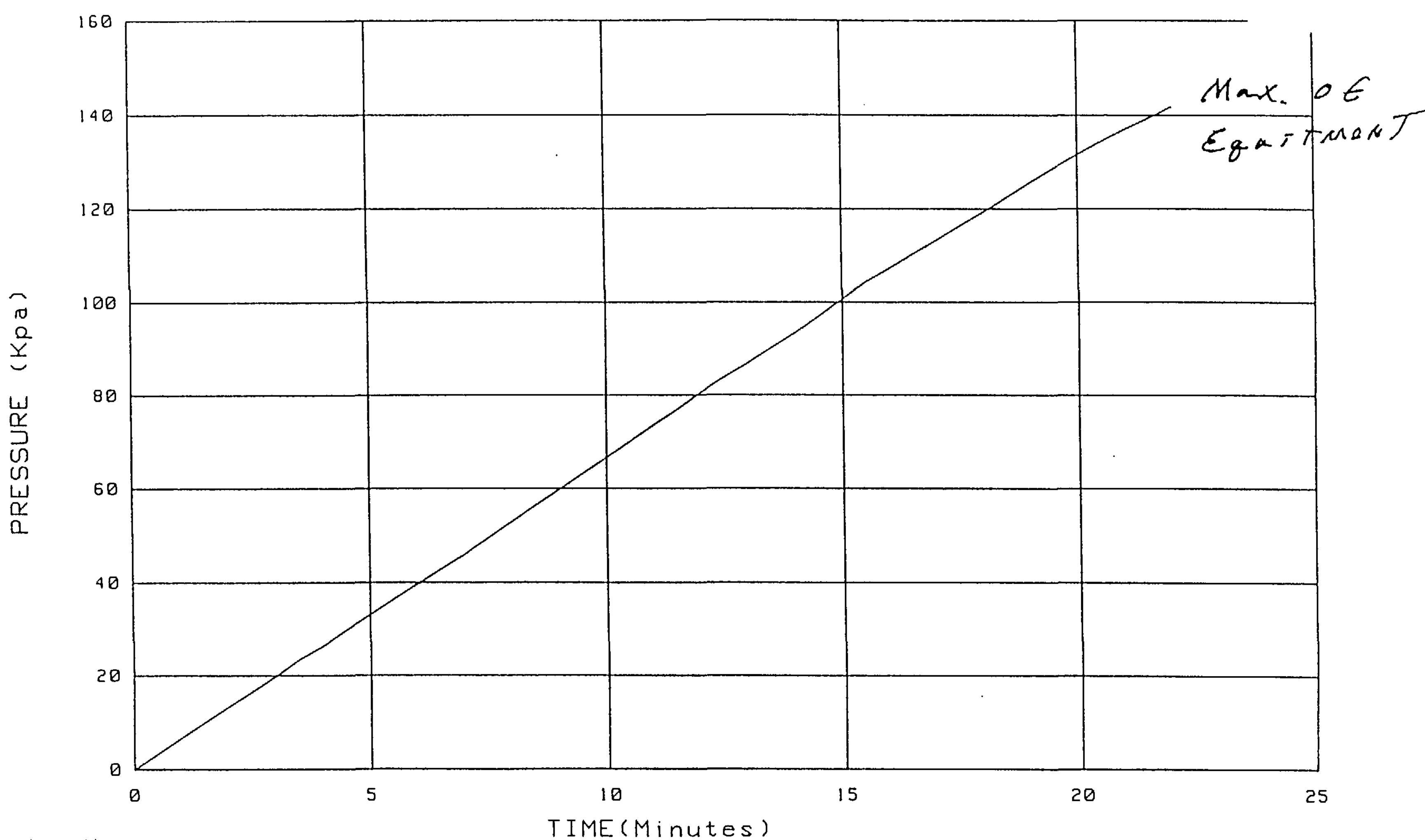


Index No.
Sample No. R130C
Specimen No. 1
Height(cm) 7.064 Diameter(cm) 7.151 Mass(gm) 624.9
Lateral Pressure 170.0 lbf/in^2
Back Pressure 110.0 lbf/in^2 Flow Rate 2.694E-5 cm^3/s

Coeff. of Perm. 5.39E-08 cm/s
Gradient 12.447

Fig 27

FLOW PUMP TEST - PERMEABILITY



Index No.
Sample No. P30C
Specimen No. 1
Height(cm) 6.826 Diameter(cm) 7.155 Mass(gm) 640.7
Lateral Pressure 170.0 lbf/in^2
Back Pressure 110.0 lbf/in^2 Flow Rate 2.694E-5 cm^3/s

Coeff. of Perm. 3.16E-09 cm/s
Gradient 211.768

APPENDIX D

Stability Analysis of Mine Wasterock Piles Proposed for Removal Action

Stability Analysis of Proposed Mine Wasterock Piles
Stray Horse Gulch - Operable Unit 6
California Gulch Superfund Site

The Removal Action design work performed for EPA Region VIII by the Bureau of Reclamation, Geotechnical Engineering Group 1 (D-8311), Technical Service Center, U.S. Department of the Interior, included an evaluation of the slope stability of the seven wasterock piles to be constructed in the vicinity of Stray Horse Gulch in Operable Unit 6. The stability analyses were performed on a pile cross-section representative of all of the mine wasterock piles to be constructed. The pile slope design was required to achieve the geotechnical stability performance criteria identified in the Work Area Management Plan (WAMP). The WAMP required a minimum static factor of safety of 1.5 and a minimum pseudo-static factor of safety of 1.2.

Material Properties

The wasterock piles to be constructed contain three materials. The major component is wasterock produced by underground mine excavations that was deposited on the surface in the form of the existing "mine waste dumps." The mine wasterock is a variable mixture of rock and soil. The interior wasterock in the proposed piles will then be covered with an impervious composite geomembrane, which will then be covered with a layer of dolomite rockfill to stabilize the pile side-slopes and to protect the geomembrane from attack by the sun's ultra-violet (UV) radiation. Selected piles will also have a thin surface veneer of different colored wasterock (white porphyry and mixed white porphyry and dolomite) to present a more varied appearance around the proposed historic mining district..

Some of the existing mine wasterock piles were drilled and sampled during the Remedial Investigation/Feasibility Study work performed by Woodward-Clyde Consultants (WCC). Samples were obtained from various Stray Horse Gulch mine piles and were tested for geotechnical engineering properties, such as grain size and shear strength. The mine wasterock piles drilled, sampled, and tested included in the Humbolt, New Mikado, Old Mikado, RAM, and Maid of Erin. The data from WCC's report was used to model the strength of the wasterock material. The shear strength (internal angle of friction) of the dumped mine wasterock varied from about 31 to 35 degrees. Since the mine wasterock material being consolidated into the piles will be compacted by four passes of a heavy vibratory tamping roller, an assumed wasterock shear strength of 35 degrees and zero cohesion was judged to be an appropriate, conservative assumption. Note that the geomembrane will maintain the pile's wastrock in a dry state, eliminating the strength-reducing affect of soil moisture or water pressure.

Sack samples of the dolomite rockfill material in the Sherman Mine Pile were obtained and gradation analyses were performed on the samples. The shear strength of the dolomite rockfill was then estimated for use in the stability analysis, based on Reclamation's experience with testing similar materials and on similar data from other sources. Since the dolomite rockfill being placed to form the outer pile slopes will be compacted by four passes of the same heavy vibratory tamping roller, an assumed dolomite rockfill shear strength of 45 degrees and zero cohesion was judged to be an appropriate, conservative assumption. The veneer rockfill layer is not a factor in the slope's stability, but it was included and assigned a shear strength of 45 degrees like the dolomite rockfill.

Material and design information from various vendors of composite geomembrane materials was examined and material shear strength data were reviewed. Laboratory shear strength testing of geomembranes and composite geomembranes has been performed by Reclamation and these data were compared to the vendor-supplied information. Good agreement between the two material data sources was found, with interface shear strengths as high as 45 degrees being noted for composite geomembrane materials. Based on the information reviewed, an assumed composite geomembrane shear strength of 30 degrees was judged to be an appropriate, conservative assumption.

Engineering Properties

Based upon the material data described and presented above, the following material shear strengths were selected as being appropriate for use in the stability analyses:

Material	Internal Angle of Friction (Φ')
Mine wasterock	35 degrees
Composite geomembrane	30 degrees
Dolomite rockfill	45 degrees
Veneer rockfill	45 degrees

Note that the mine wasterock material should have some cohesion; however, the cohesion component of the material's shear strength was ignored in the stability analysis as a conservative assumption.

Pile Slope Design

The pile slope geomembrane reduces surface water contamination by isolating the mine wasterock from precipitation and runoff. The pile slope design will also preserve the "historic" appearance of the proposed mining district along Stray Horse Gulch, with the steep pile slopes replicating the old mine dumps sloping at the material's "angle of repose."

The pile design calls for the composite geomembrane to be placed on the 1:1 (horizontal to vertical) outer slope of the mine wasterock zone, to then be covered by a dolomite rockfill zone placed on a 1.5:1 (H:V) outer slope. The outer dolomite rockfill zone is eight feet wide at the top of the slope, widening down the slope. The foundation area beyond the perimeter of the inner mine wasterock zone will be excavated down to form a horizontal surface located at or below the pre-mining ground surface to provide a firm and level foundation for the dolomite rockfill zone. The top and horizonal bench surfaces of the piles are covered with a two-foot-thick layer of dolomite rockfill. In order to present a more varied mine pile appearance and texture, several mine wasterock piles will have a one-foot-thick veneer of white porphyry rockfill or mixed white porphyry and dolomite rockfill covering the dolomite rockfill.

Stability Analyses

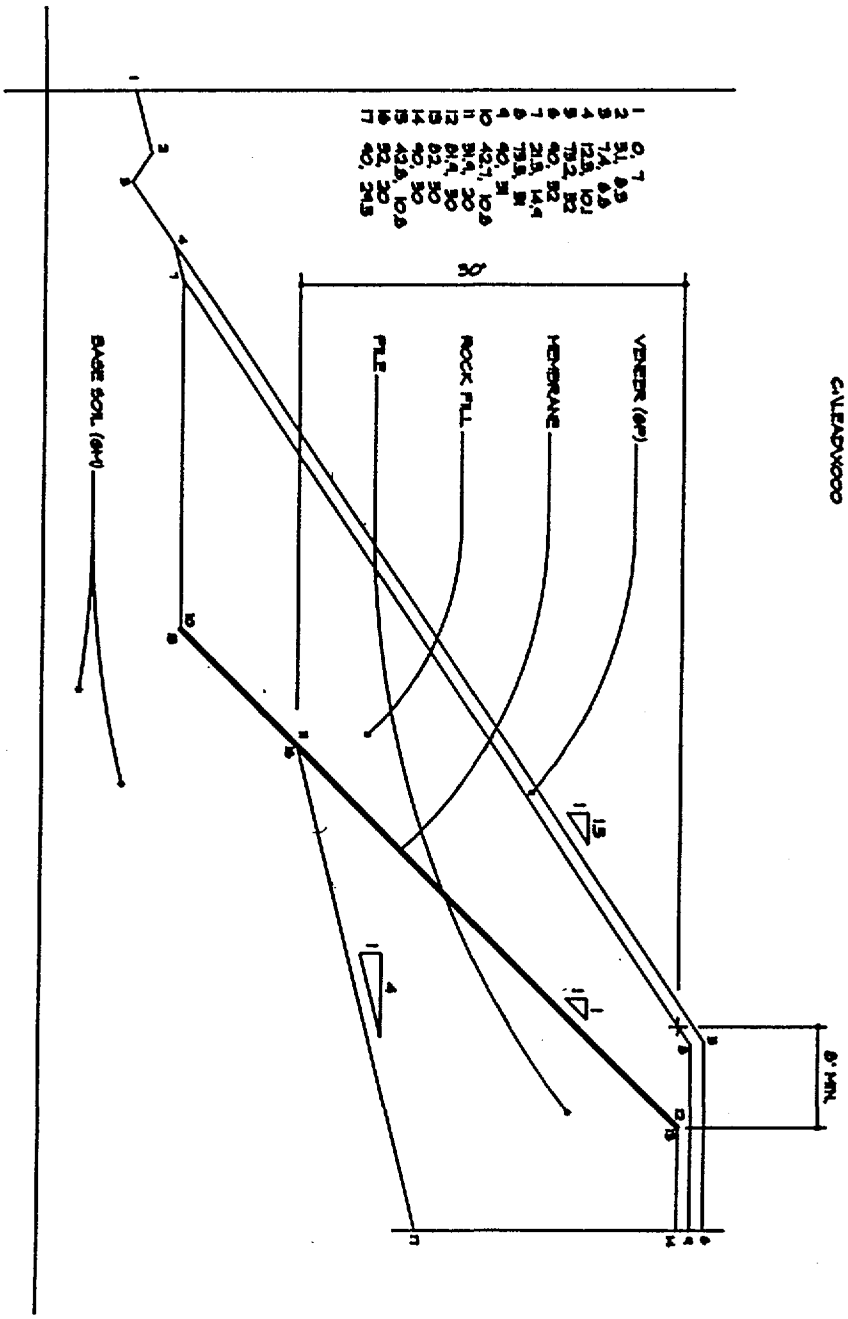
The mine wasterock pile stability analyses were performed using the computer program "SLOPE/W" which was developed by Geo-Slope International Ltd. of

Calgary, Alberta, Canada. The material properties and standard pile-slope geometry were input into the program. Stability computations were performed for both circular failure and plane/wedge failure surfaces. Spencer's method was used for the circular failure analysis. Performance of the circular analysis ensures that a slope failure through the interior of the pile has been properly evaluated. Plane/wedge slope-failure geometries were identified and analyzed to ensure that failure along the composite geomembrane interface has been properly evaluated. The trapezoidal-shaped outer dolomite rockfill zone was assumed for this analysis. A parallelogram-shaped outer rockfill zone was also evaluated during the design, but it did not produce an adequate slope stability. In addition to static analysis, a pseudo-static stability analysis was also performed to evaluate the effects of earthquake forces upon the piles. However, central Colorado and the Leadville area are not generally considered to be highly seismic like coastal California.

For the conditions anticipated for the Stray Horse Gulch area mine wasterock piles, a minimum static factor of safety of 1.5 was achieved for all static-stability failure scenarios. Slope failure along the composite geomembrane surface was identified as the critical failure surface. As a sensitivity check on the shear strength assumed for the composite geomembrane, the interface strength was reduced from 30 degrees to 25 degrees. The pile slope was still stable under this weaker condition, calculating a factor of safety of 1.15.

The pseudo-static factor of safety analysis assumed a 0.2g coefficient of horizontal earthquake loading. The factor of safety was reduced by 0.25, decreasing from the static condition at 1.5 to the pseudo-static 1.25, which satisfies the WAMP requirement of a 1.2 factor of safety.
Note that most earthquake-induced slope or embankment dam failures involve saturated soil materials. The mine wasterock material in the Stray Horse Gulch piles will be dry due to the geomembrane's isolation effect, thereby avoiding "normal" earthquake effects.

@PJL ENTER LANGUAGE = HP-GL/2



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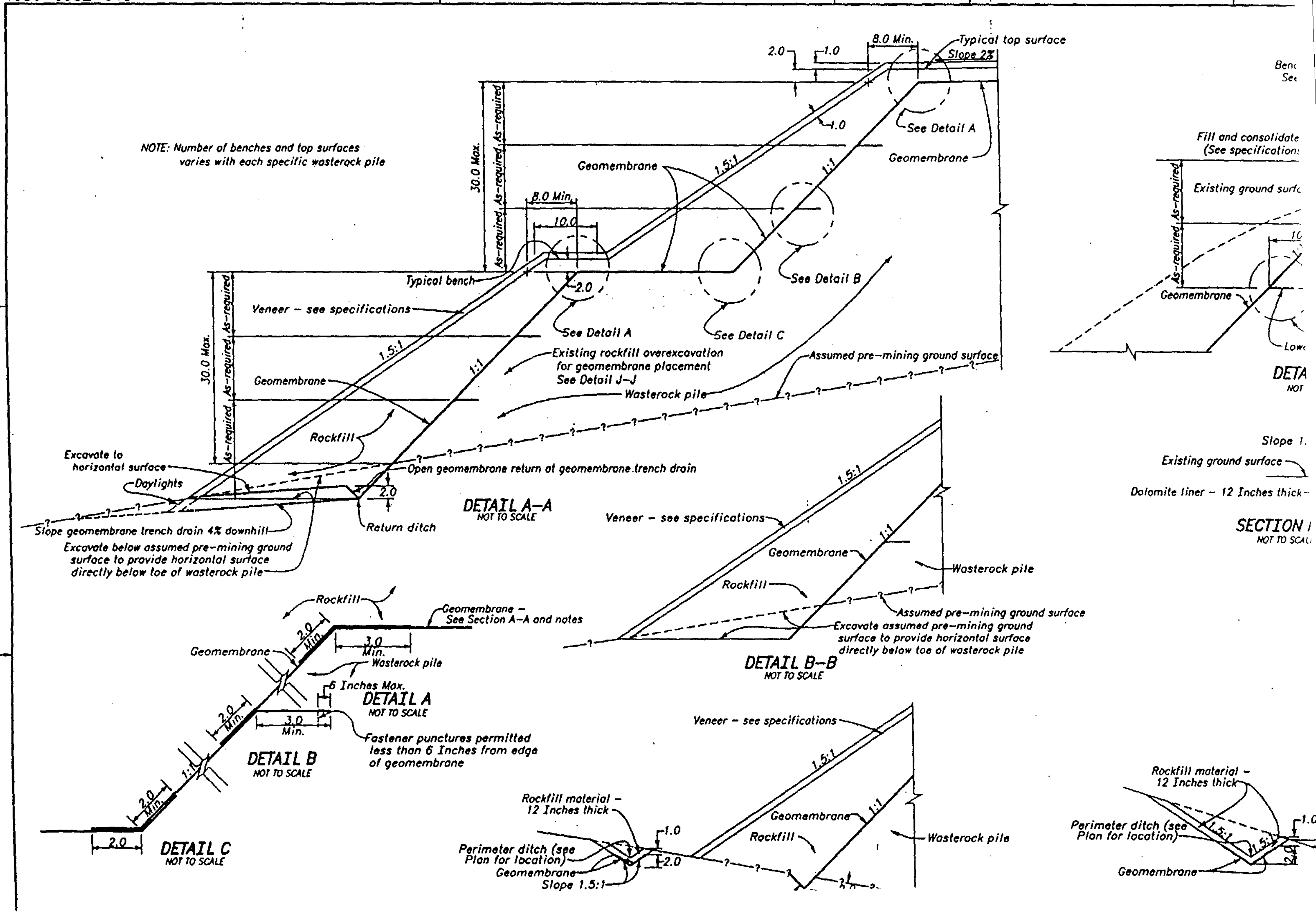

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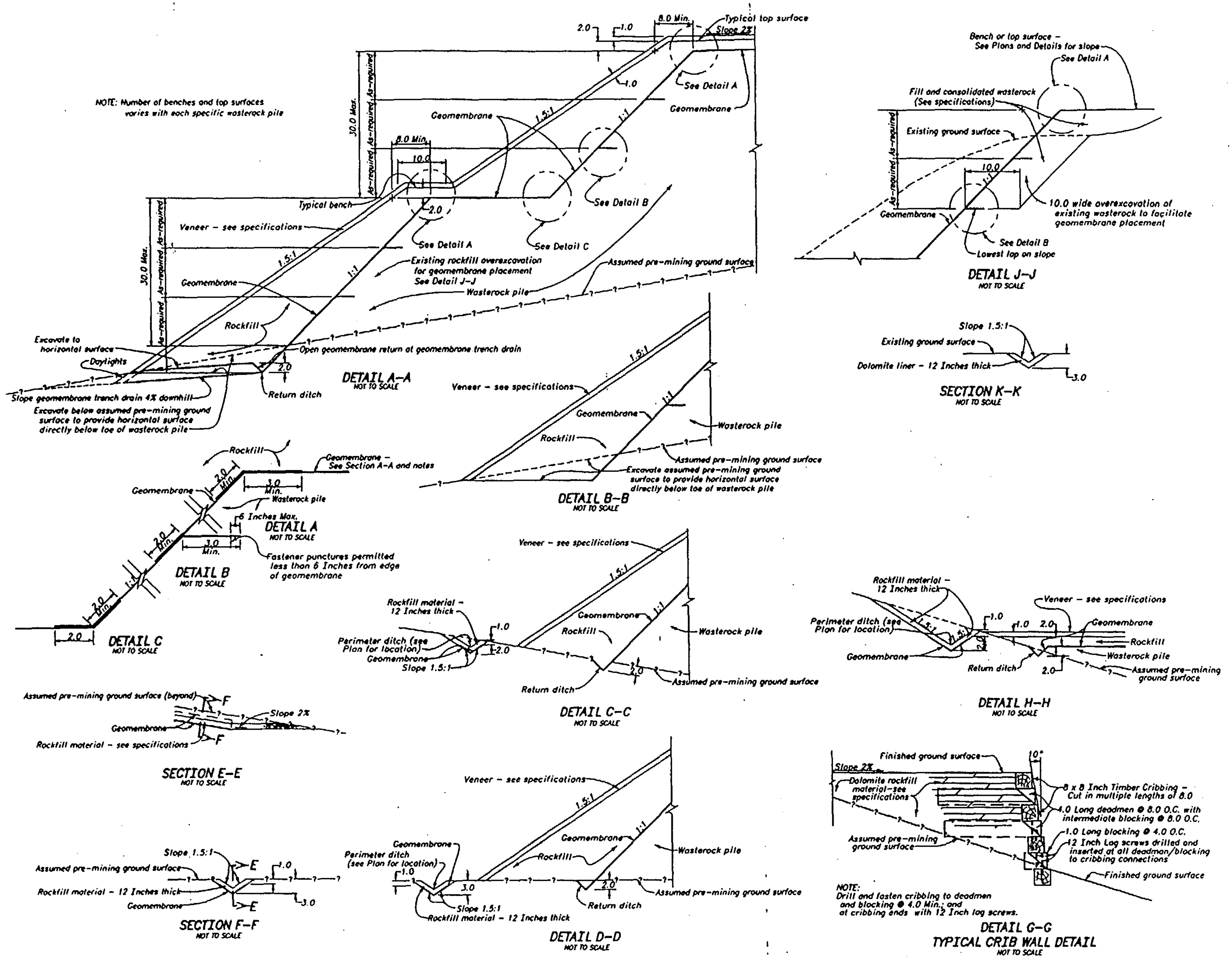


NOTES

1. Rockfill shall be dolomite obtained … Pile. Veneer shall be either white … or a 50-50% mix of dolomite and … specifications for additional rockfil… and wasterock pile applicability.
2. Wasterock top and bench surfaces sh… geomembrane, seamed as required … specifications. Geomembrane laps o… surfaces (see Details A and C) and … determined by the widths of geome… furnished by the factory.
3. Number and location of geomembran… required shall be determined by the … sheets/panels furnished by the fact…
4. All dimensions are in feet, unless ot…

ALWAYS THINK …

UNITED STATES
DEPARTMENT OF THE INTE…
BUREAU OF RECLAMATI…
CALIFORNIA GULCH NPL SITE - L…
OPERABLE UNIT 6 REMOVA…
STRAY HORSE …
TYPICAL SECTIONS AN…

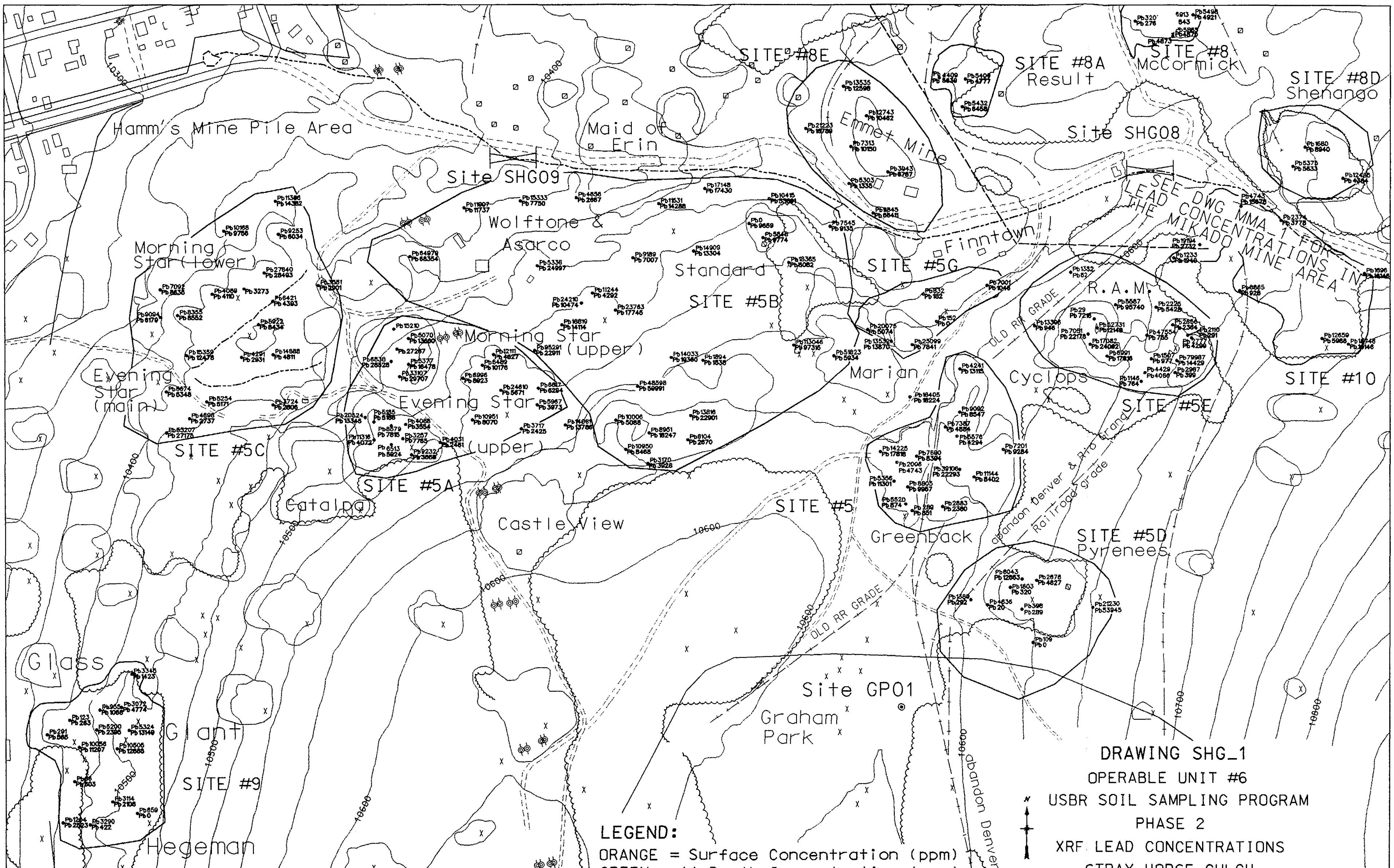
DESIGNED … CHECKED …
DRAWN …
APPROVED …
CADD SYSTEM AutoCAD
DENVER, COLORADO
3 - 1997

APPENDIX E

U.S. Bureau of Reclamation Soil Sampling Program Data Maps for Stray Horse Gulch

Color Map(s)

The following maps contain color that does not appear in the scanned images. To view the actual images please contact the Superfund Record Center at (303) 312-6473.



LEGEND:

ORANGE = Surface Concentration (ppm)

GREEN = At Depth Concentration (ppm)

DRAWING SHG_1

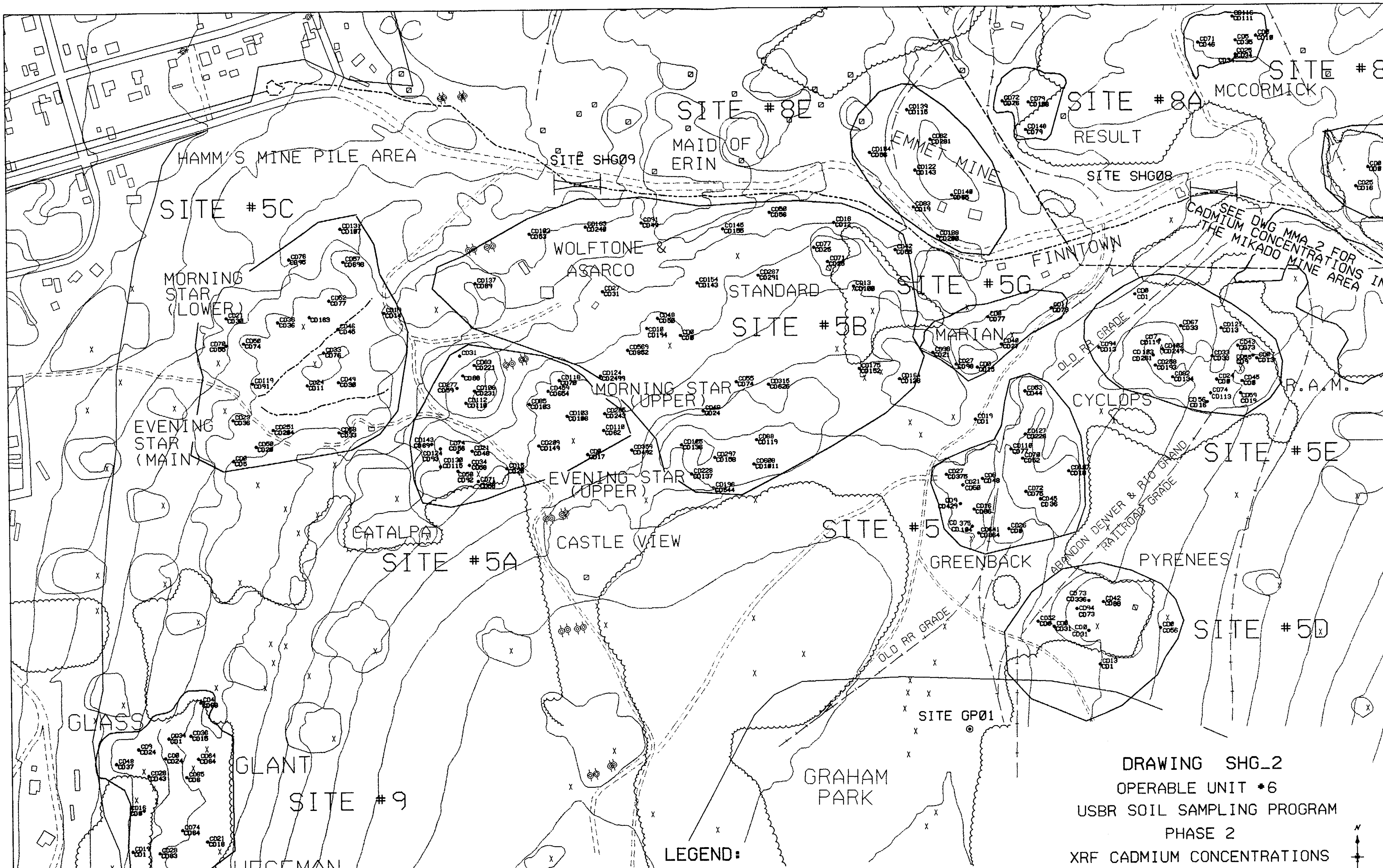
OPERABLE UNIT #6

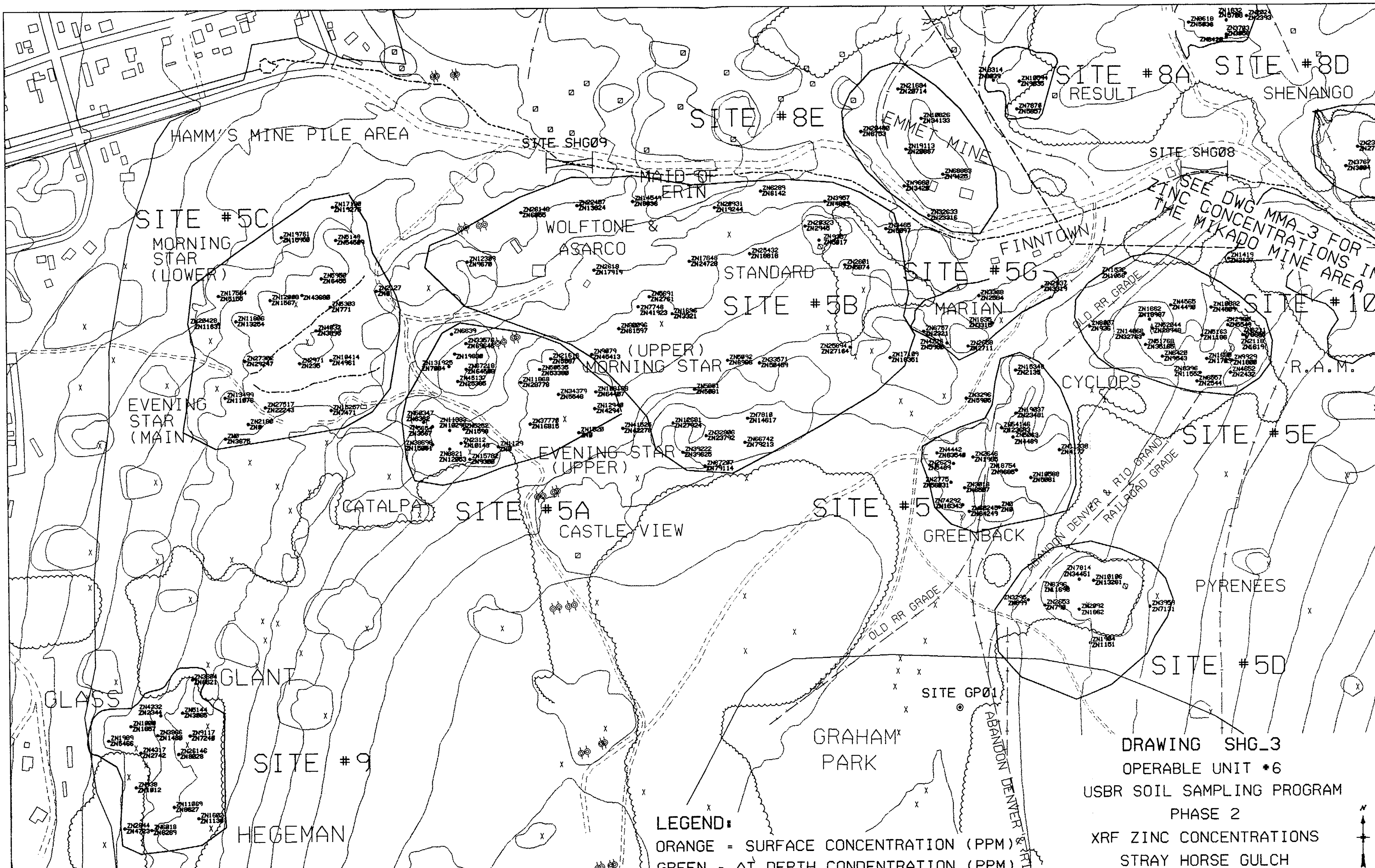
USBR SOIL SAMPLING PROGRAM

PHASE 2

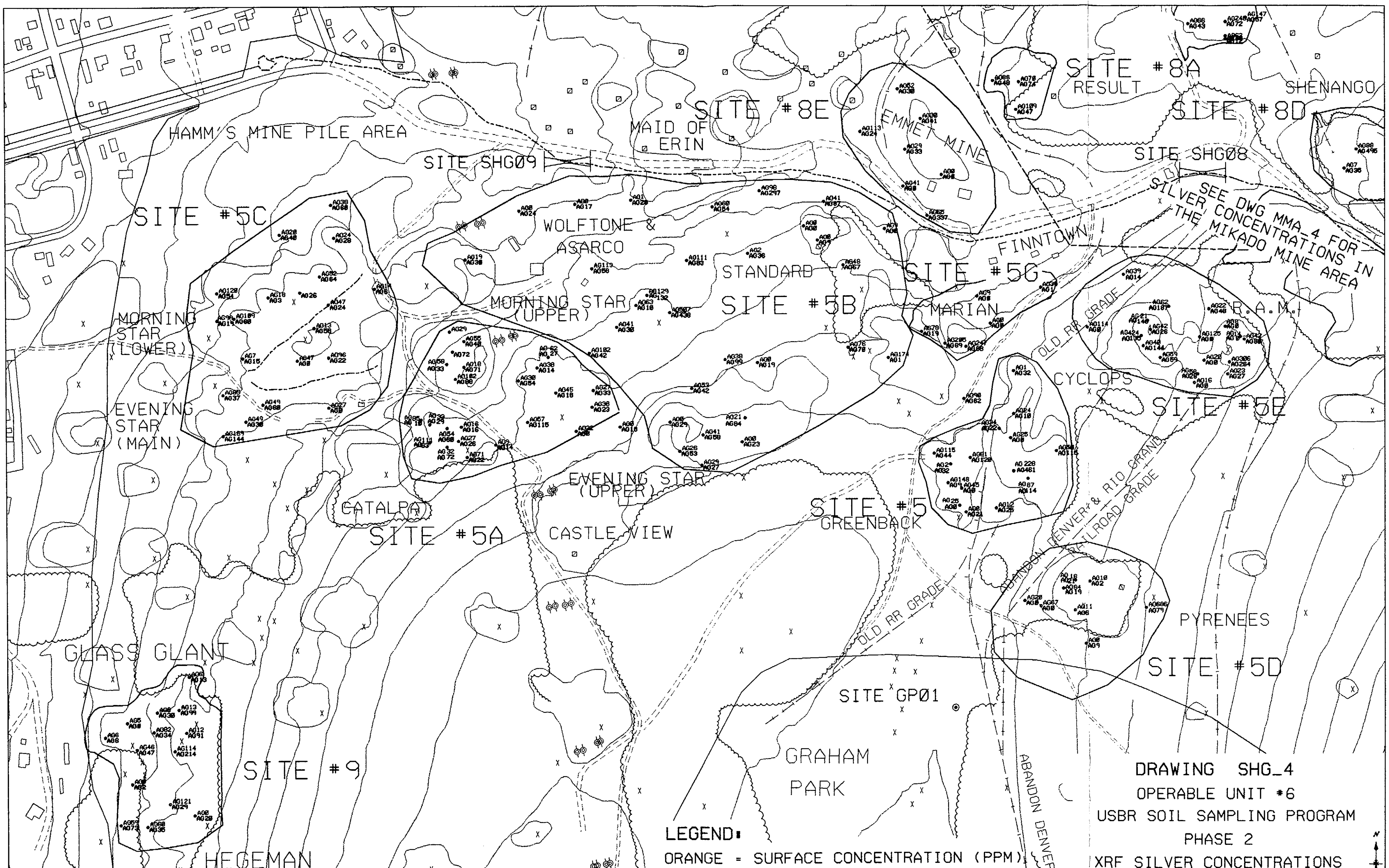
XRF LEAD CONCENTRATIONS

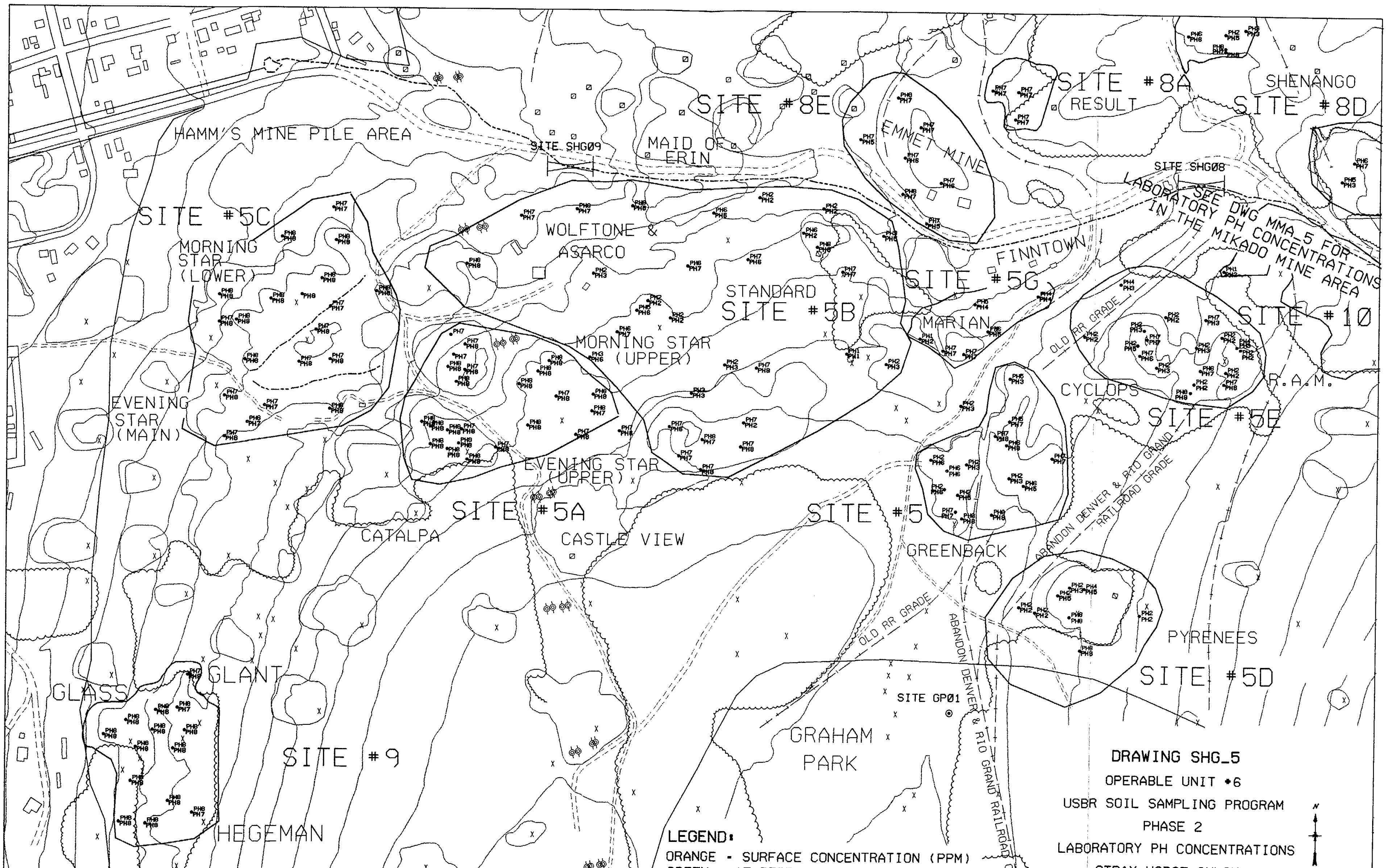
STRAY HORSE GULCH


SITE #8
MCCORMICK
SITE #8A
RESULT
SITE SHG08
SITE #8E
MAID OF
ERIN
SITE SHG09
HAMM'S MINE PILE AREA
SITE #5C
EMMET MINE
SEE DWG MMA_2 FOR
CADMIUM CONCENTRATIONS IN
THE MIKADO MINE AREA
FINNTOWN
SITE #5G
WOLFTONE &
ASARCO
STANDARD
SITE #5B
MARIAN
MORNING
STAR
(LOWER)
EVENING
STAR
(MAIN)
MORNING STAR
(UPPER)
EVENING STAR
(UPPER)
OLD RR GRADE
CYCLOPS
R.A.M.
SITE #5E
CATALPA
CASTLE VIEW
SITE #5A
SITE #5
GREENBACK
ABANDON DENVER & RIO GRAND
RAILROAD GRADE
PYRENEES
SITE #5D
OLD RR GRADE
SITE GP01
GLASS
GLANT
SITE #9
HEGEMAN
GRAHAM
PARK
LEGEND:
DRAWING SHG_2
OPERABLE UNIT #6
USBR SOIL SAMPLING PROGRAM
PHASE 2
XRF CADMIUM CONCENTRATIONS
N



HAMM'S MINE PILE AREA
SITE SHG09
SITE #8E
EMMET MINE
SITE #8A
RESULT
SITE #8D
SHENANGO
SITE SHG08
SEE DWG MMA_3 FOR ZINC CONCENTRATIONS IN THE MIKADO MINE AREA
MAID OF ERIN
SITE #5C
MORNING STAR (LOWER)
WOLFTONE & ASARCO
STANDARD
FINNTOWN
SITE #5G
MARIAN
SITE #5B
SITE #10
OLD RR GRADE
(UPPER) MORNING STAR
R.A.M.
CYCLOPS
EVENING STAR (MAIN)
EVENING STAR (UPPER)
SITE #5E
ABANDON DENVER & RIO GRAND RAILROAD GRADE
CATALPA
SITE #5A
CASTLE VIEW
SITE #5
GREENBACK
PYRENEES
SITE #5D
GLANT
GLASS
SITE GP01
GRAHAM PARK
ABANDON DENVER & RIO
SITE #9
HEGEMAN
LEGEND:
ORANGE = SURFACE CONCENTRATION (PPM)
GREEN = AT DEPTH CONDENTRATION (PPM)
DRAWING SHG_3
OPERABLE UNIT #6
USBR SOIL SAMPLING PROGRAM
PHASE 2
XRF ZINC CONCENTRATIONS
STRAY HORSE GULCH
N


SITE #8A
RESULT
SHENANGO
SITE #8D
SITE #8E
MAID OF
ERIN
EMMET MINE
SITE SHG08
SEE DWG MMA_4 FOR
SILVER CONCENTRATIONS IN
THE MIKADO MINE AREA
HAMM'S MINE PILE AREA
SITE SHG09
SITE #5C
WOLFTONE &
ASARCO
STANDARD
SITE #5B
FINNTOWN
SITE #5G
MARIAN
R.A.M.
OLD RR GRADE
MORNING STAR
(UPPER)
MORNING
STAR
(LOWER)
EVENING
STAR
(MAIN)
CYCLOPS
SITE #5E
EVENING STAR
(UPPER)
CATALPA
SITE #5A
CASTLE VIEW
SITE #5
GREENBACK
ABANDON DENVER & RIO GRAND
RAILROAD GRADE
PYRENEES
SITE #5D
GLASS GLANT
SITE #9
SITE GP01
GRAHAM
PARK
ABANDON DENVER
HEGEMAN
LEGEND:
ORANGE = SURFACE CONCENTRATION (PPM)
DRAWING SHG_4
OPERABLE UNIT #6
USBR SOIL SAMPLING PROGRAM
PHASE 2
XRF SILVER CONCENTRATIONS


HAMM'S MINE PILE AREA
SITE SHG09
MAID OF ERIN
SITE #8E
EMMET MINE
SITE #8A
RESULT
SHENANGO
SITE #8D
SITE SHG08
SEE DWG MMA_5 FOR LABORATORY PH CONCENTRATIONS IN THE MIKADO MINE AREA
SITE #5C
MORNING STAR (LOWER)
WOLFTONE & ASARCO
STANDARD
SITE #5B
FINNTOWN
SITE #5G
MARIAN
SITE #10
OLD RR GRADE
MORNING STAR (UPPER)
EVENING STAR (MAIN)
EVENING STAR (UPPER)
CYCLOPS
R.A.M.
SITE #5E
SITE #5A
CATALPA
CASTLE VIEW
SITE #5
GREENBACK
ABANDON DENVER & RIO GRAND RAILROAD GRADE
PYRENEES
SITE #5D
GLASS
GLANT
SITE #9
HEGEMAN
SITE GP01
GRAHAM PARK
ABANDON DENVER & RIO GRAND RAILROAD
LEGEND:
ORANGE - SURFACE CONCENTRATION (PPM)
DRAWING SHG_5
OPERABLE UNIT #6
USBR SOIL SAMPLING PROGRAM
PHASE 2
LABORATORY PH CONCENTRATIONS
N