Final Volume 2

Focused Feasibility Study Crystal Mine OU5 Jefferson County, Montana

Prepared for

U.S. Environmental Protection Agency
Region 8, Helena, Montana

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Executive Summary

This feasibility study (FS) report for the Crystal Mine Site OU5 (the Site) of the Basin Mining Area NPL site was prepared by CH2M HILL on behalf of the U. S. Environmental Protection Agency (EPA). The FS addresses human health and environment risks identified in the 2013 Focused Remedial Investigation prepared for EPA by CH2M HILL.

EPA has determined that Interim Records of Decision (RODs) are needed to address the acidic mine drainage from both the Bullion (OU6) and Crystal Mine sites located within the Basin Watershed Operable Unit (OU2). In accordance with Agency guidance, these interim RODs will be protective of human health and the environment in the short term and are intended to provide adequate protection until a final ROD for the Basin Watershed is signed. Therefore, the actions resulting from this FS are not intended to address fully the statutory mandate for permanence and treatment to the maximum extent practicable, yet they are intended to support those statutory mandates.

Potential Applicable or Relevant and Appropriate Requirements (ARARs) will be addressed in detail as part of the Basin Watershed OU2 ROD. The Crystal Mine OU5 cleanup will be an interim remedial action where compliance with groundwater and surface water ARARs is concerned. EPA doesn't expect that this action will result in final compliance with surface and ground water ARARs at the Basin Mining District NPL Site. For now, EPA is invoking the interim action waiver as provided in 40 CFR § 300.430(f)(1)(ii)(C)(*1*) with respect to all water quality ARARs at OU5. It should be noted that EPA expects all other ARARs for the Crystal Mine OU5 action to be complied with during or at completion of the action, as appropriate.

Remediation alternatives were developed. Potentially applicable technologies were identified and screened to obtain a set of technologies feasible for use in achieving the PRAOs and PRGs. Retained technologies were assembled into remediation alternatives that cover a range of possible response actions. The alternatives were then screened based on effectiveness, implementability, and cost, to eliminate alternatives that were impractical, infeasible, or have high costs relative to other alternatives without being more effective.

A number of remediation elements (common elements) were used in multiple alternatives. To streamline the FS, the common elements were evaluated independently and then applied to each alternative. The common elements retained for all alternatives were as follows:

Surface water runoff controls. Several approaches were evaluated through a treatability study for managing groundwater recharge and surface water associated with the wetlands above the mine workings

- Surface water best management practices will be applied to snowmelt and storm-generated overland flow to prevent waste mobilization and accelerated erosion.
- **Stream bank reconstruction.** The Uncle Sam Gulch Creek channel, adjacent to the Site, will be reconstructed.
- **Removal of ponds and buildings.** Two man-made ponds contain contaminated sediments, and they sit on top of waste rock that requires remediation. Old mine buildings also sit on waste rock that requires remediation.

The following alternatives, coupled with the common elements, were retained for remediation of the Site:

- **Alternative 1—No Further Action**
- **Waste Rock Treatment Alternatives**
  - **Alternative WR-1**—capping of waste rock
  - **Alternative WR-2**—removal and disposal of waste rock at existing local offsite repository
  - **Alternative WR-3**—removal and disposal of waste rock at a repository to be constructed onsite
- **Groundwater Treatment Alternatives**

- **Alternative GW-1**—blocking of acid mine drainage (AMD) by tunnel sealing (plugging) through re-opened tunnels.
- **Alternative GW-2**—blocking of AMD by tunnel sealing (plugging) through grouting from the surface.
- **Alternative GW-3**—installing bulkhead to control of AMD flow followed by active treatment (represented by a high-density sludge treatment plant).
- **Alternative GW-4**—installing bulkhead, followed by semi-active treatment, (lime injection with settling ponds).
- **Alternative GW-5**—install bulkhead followed by passive treatment, control of AMD and pH adjustment and sulfate reducing bioreactor (SRBR).
- **Alternative GW-6**—Passive Treatment, pH adjustment and SRBR, aeration, settlement, and wetland polishing.

The proposed remedial alternatives were evaluated using criteria established in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR 300.430):

- Overall Protection of Human Health and the Environment
- Compliance with ARARs
- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, and Volume through Treatment
- Short-Term Effectiveness
- Implementability
- Cost

Table ES-1 presents a summary comparison of the alternatives evaluated against the listed criteria.

In summary, Alternative 1 would not change existing conditions and would not offer protection of human health or the environment. Each of the three waste rock alternatives and each of the five groundwater alternatives would offer enhanced protection of human health and the environment through interruption of contaminants of concern (COC) pathways, or treatment of AMD discharge. None of the alternatives address both AMD and waste rock together, and therefore, none are completely protective of human health and environment on their own. Therefore, a phased remedial approach incorporating both a waste rock and a groundwater option would be needed to fully meet human health and environmental protection goals.

This FS will be used to select a preferred alternative for remediating the Site. The preferred alternative will then be presented in a Proposed Plan (PP) that will be subject to public comment. The PP will briefly summarize the results of the remedial investigation (RI) and FS, and allow the State of Montana and the general public an opportunity to provide comments for EPA to consider prior to finalizing a remedial approach in a Record of Decision. EPA will hold a public meeting to explain the RI/FS and remedial alternatives considered, and hear concerns from community members and interested stakeholders. A Responsiveness Summary will be prepared by EPA for all written and verbal comments provided on the PP, prior to finalizing a ROD. Once the ROD is issued, EPA will move forward with Remedial Design planning and development. Finally, EPA will proceed with implementing a Remedial Action at the site in accordance with the ROD.

TABLE ES-1
Comparison of Remediation Alternatives

	1—No Further Action	WR-1—Waste Rock Capping	WR-2—Excavate and Local Disposal	WR-3—Excavate and Dispose Onsite	GW-1—Mine Plugging Through Reopened Mine Adit	GW-2—Mine Plugging Through Borings from the Surface	GW-3—Active Treatment of AMD	GW-4—Semi-Active Treatment of AMD (Quicklime Injection System)	GW-5—Semi-Passive Treatment of AMD (SRBR)	GW-6—Semi-Passive Treatment of AMD (SRBR, Aeration Systems, Oxidation/Settling Ponds, Wetlands, and Discharge)
Overall Protection of Human Health and the Environment	Not protective of human health and the environment.	Protective of human health and environment by reducing contact with contaminated soils. However, these soils still remain beneath covers over large areas of OU5 and could pose future risk if caps are compromised. Thus, not as protective as excavation and disposal alternatives. Does not address AMD.	Protective of human health and the environment but does not address AMD. Long-term protection is more effective because contaminated soils are taken to an offsite local repository. However, short-term risk to community is high because of waste haul traffic on community roads.	Protective of human health and the environment but does not address AMD. Proper design and construction of onsite repository needed to ensure long-term protectiveness. Low short-term risk to community because no offsite waste haul traffic on community roads.	Potentially protective of human health and the environment for AMD, but does not address waste rock and contaminated soils. High degree of uncertainty for long-term protection because of potential plug failure and potential for AMD to seep out through fractures to multiple surface expressions.	Potentially protective of human health and the environment for AMD, but does not address waste rock and contaminated soils. High degree of uncertainty for long-term protection because of potential plug failure and potential for AMD to seep out through fractures to multiple surface expressions.	Protective of human health and the environment for AMD, but does not address waste rock and contaminated soils. Long-term protectiveness is more certain than with mine plugging alternatives because of less uncertainty and use of proven technology.	Less protective than active treatment because AMD is not as thoroughly and consistently treated. Does not address protection from waste rock and contaminated soils.	Considered less reliable and effective than active and semi-active treatment GW-3, 4). Less protective of the environment than active treatment because process is more prone to upset and temperamental results, if design doesn't properly account for discharge chemistry, climatic influences, and maintenance. Does not address protection from waste rock and contaminated soils.	Considered less reliable and effective than active and semi-active treatment (GW-3, 4). Less protective of the environment than active treatment because process is more prone to upset and temperamental results, if design doesn't properly account for discharge chemistry, climatic influences, and maintenance. However, still provides significant improvement in water quality from AMD water. Does not address protection from waste rock and contaminated soils.
Compliance with ARARs	Does not meet water quality standards.	Surface and Groundwater ARARs are waived for OU5; however, implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2.	Surface and Groundwater ARARs are waived for OU5; however, implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2.	Surface and Groundwater ARARs are waived for OU5; however, implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2.	Surface and Groundwater ARARs are waived for OU5; however, implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2.	Surface and Groundwater ARARs are waived for OU5; however, implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2.	Surface and Groundwater ARARs are waived for OU5; however, implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2.	Surface and Groundwater ARARs are waived for OU5; however, implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2.	Surface and Groundwater ARARs are waived for OU5; however, implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2.	Surface and Groundwater ARARs are waived for OU5; however, implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2.
Long-Term Effectiveness and Permanence	Does not address PRGs, not effective in long term.	Effectiveness highly dependent on proper construction and subject to long-term deterioration of cap resulting from weathering. Not as protective as excavation and disposal alternatives, and not permanent.	Effective long-term solution dependent on complete removal of contaminated materials. Effective long-term solution with proper construction and removal. More permanent that WR-3 because contaminated soils are permanently removed from the Site.	More effective than capping, dependent on complete removal of contaminated materials. Effective long-term solution with proper repository construction and complete removal of contaminated materials.	Highly uncertain long-term effectiveness and permanence dependent on proper construction and on actual condition of bedrock. Very difficult to confirm through plugging. Potential for plug failure or for development of new paths of AMD leakage through fractures to surface expressions.	Highly uncertain long-term effectiveness and permanence; dependent on proper construction and on unknown fracture conditions of bedrock. Less effective than GW-1 because of construction difficulty. Almost impossible to confirm competent seal from plug. Potential for plug failure or for development of new paths of AMD leakage through fractures to surface expressions.	Expected to consistently meet water quality standards for adit discharge water. More reliable than mine plugging. Dependent on proper and continuous long-term operation and maintenance. Permanent road to the Site would need to be constructed and daily traffic on community roads to the Site would increase risk to community.	Expected to frequently meet water quality standards for adit discharge water. More reliable than mine plugging. Highly dependent on proper construction and long-term maintenance. Almost daily traffic on community roads to the Site would increase risk to community.	Expected to frequently meet water quality standards for adit discharge water. More reliable than mine plugging. Highly dependent on proper construction and less frequent long-term maintenance. Fewer trips to the Site for O&M and lower traffic risk to community.	Expected to frequently meet water quality standards for adit discharge water. More reliable than mine plugging Highly dependent on proper construction and infrequent long-term maintenance. Infrequent trips to the Site for O&M mean minimal traffic risk to community.

TABLE ES-1
Comparison of Remediation Alternatives

	1—No Further Action	WR-1—Waste Rock Capping	WR-2—Excavate and Local Disposal	WR-3—Excavate and Dispose Onsite	GW-1—Mine Plugging Through Reopened Mine Adit	GW-2—Mine Plugging Through Borings from the Surface	GW-3—Active Treatment of AMD	GW-4—Semi-Active Treatment of AMD (Quicklime Injection System)	GW-5—Semi-Passive Treatment of AMD (SRBR)	GW-6—Semi-Passive Treatment of AMD (SRBR, Aeration Systems, Oxidation/Settling Ponds, Wetlands, and Discharge)
Short-Term Effectiveness	Does not create short-term construction risks.	Short-term construction risks typical of earthmoving projects, but less than WR-2 or WR-3 because of less disturbance of contaminated soils and waste rock. Risks would be mitigated through use of PPE. No risk to community since all work would occur within the Site.	Increases short-term construction risks resulting from disturbance of large areas of contaminated soils and longer duration of construction. Added short-term risk resulting from exposures during loading of trucks. Highest short-term risk to community since haul trucks would use community roads to haul wastes to local but offsite repository. This increases traffic safety risks as well as risks from potential exposure to spilled contaminated soils.	Increases short-term construction risks resulting from disturbance of large areas of contaminated soils and longer duration of construction. Added short-term risk resulting from exposures during loading of trucks. Lower risk to community than WR-2 because haul trucks stay onsite.	Short-term construction risks are high because of confined space entry underground, which requires strict adherence to MSHA regulations, typical of tunneling projects.	No confined space entry risks but additional risks from use of explosives and larger drill rigs.	Short-term construction risk typical of light industrial building and transport of equipment and materials to the Site.	Similar type of construction risk to GW-3 but for two years. Treatment not fully effective in first year of operation.	Similar type of construction risk to GW-3 but for two years (anticipate two construction seasons because of location and climate. Treatment not fully effective in first year of operation.	Similar type of construction risk to GW-5, anticipating potential two year construction period to accommodate short construction season. Treatment not fully effective in first year of operation. Wetland construction and initial functionality may reduce short-term effectiveness.
Reduction in Toxicity, Mobility, Volume through Treatment	No treatment provided.	No treatment but capping of waste rock is expected to reduce mobility. Toxicity unchanged.	No treatment but removal of waste rock would reduce mobility, and volume of onsite contaminants. Toxicity remains unchanged.	No treatment but removal to properly designed onsite repository would reduce mobility. Volume would not be reduced Toxicity remains unchanged.	Flooding mine workings, reduces/eliminates acid generation and mobility of metals, reduces toxicity (treatment); ideally reduces the volume of contaminants; Toxicity and volume of AMD could be eliminated if plug is 100% effective. However, effective seal is difficult to achieve by plugging and mine water can be transmitted by fractures in the bedrock.	Flooding mine workings, reduces/eliminates acid generation and mobility of metals, reduces toxicity (treatment); ideally reduces the volume of contaminants; Toxicity and volume of AMD could be eliminated if plug is 100% effective. However, effective seal is difficult to achieve by plugging and mine water can be transmitted by fractures in the bedrock.	Effectively treats AMD. Most efficient alternative, expected to provide 99 percent reduction in volume, efficiently removes toxicity through treatment.	Treats AMD, expected to provide 85 to 95 percent reduction in volume. Less efficient than GW-3 at removing toxicity through treatment.	Treats AMD, expected to provide up to 90+ percent reduction in volume and mitigating toxicity.	Treats AMD, expected to provide up to 90 + percent reduction in volume and mitigating toxicity.
Implementability	Does not require implementation.	Readily implemented.	Readily implemented, waste rock removal more difficult than capping because of increase in construction steps. Offsite disposal of large volumes of contaminated soils requires coordination with trucks and public use of community roads, probable maintenance of community roads, plus coordination with offsite disposal facility.	Readily implemented, waste rock removal more difficult than capping because of increase in construction steps. Less problems with implementability than WR-2 because haul trucks and waste stay onsite.	Readily implemented but requires specialized mining techniques.	Less readily implemented than GW-1 because of underground work performed remotely.	Implementability similar to wastewater plant construction, but readily done with experienced construction personnel. Would require development of power source and onsite buildings for operators.	Similar to GW-3 with specialized construction personnel.	Similar to GW-3 with specialized construction personnel. May need permission from USFS for placement of treatment system elements on USFS property.	Similar to GW-3 with specialized construction personnel. May need permission from USFS for placement of treatment system elements on USFS property.
Cost (NPV. 30 year life, 5% discount rate)	**$231,000**	**$4,801,000**	**$7,571,000**	**$5,160,000**	**$7,698,000**	**$12,228,000**	**$7,655,000**	**$4,996,000**	**$4,349,000**	**$3,740,000**

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Acronyms and Abbreviations

AMD	acid mine drainage
amsl	above mean sea level
ARARs	Applicable or Relevant and Appropriate Requirements
ARD	acid rock drainage
ATV	all-terrain vehicle
BERA	baseline ecological risk assessment
CDM	CDM Federal Programs Corporation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMC	criterion maximum concentration
COC	contaminant (chemical) of concern
COI	contaminant (chemical) of interest
COPC	contaminant (chemical) of potential concern
ELCR	excess lifetime cancer risks
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
FS	feasibility study
GRA	general response action
HDPE	high-density polyethylene
HDS	high-density sludge
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
LOAEL	lowest observed adverse effect level
MBMG	Montana Bureau of Mines and Geology
MCLs	maximum contaminant levels
MDEQ	Montana Department of Environmental Quality
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAEL	no observed adverse effect level
NPV	net present value
NRWQC	National Recommended Water Quality Criteria
PEF	particulate emissions factor
PP	proposed plan
PRAOs	Preliminary Remedial Action Objectives
PRG	preliminary remediation goal
PVC	polyvinyl chloride

RA	risk assessment
RI	remedial investigation
RME	reasonable maximum exposure
ROD	record of decision
RTI	Renewable Technologies, Inc.
SME	Society for Mining, Metallurgy, and Exploration, Inc.
SRBR	sulfate reducing bioreactor
TCRA	Time Critical Removal Action
TSS	total suspended solids
USFS	U.S. Forest Service
USG	Uncle Sam Gulch
USGS	U.S. Geological Survey
yd^3	cubic yard

SECTION 1

1. Introduction

This document presents the feasibility study (FS) for the Crystal Mine Site OU5 (the Site) located within the Basin Watershed OU2. The FS portion (Volume 2) of the remedial investigation (RI)/FS process provides a structured means to identify, develop, and evaluate remedial alternatives designed to eliminate, prevent, reduce, or control human health and/or environmental risks identified during the RI, and otherwise contribute to compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), including Applicable or Relevant and Appropriate Requirements (ARARs) compliance (see 40 CFR 300, 430 (a) (l) and (e) (3)(i) and (e)(9)(iii)(A)). This document has been prepared in accordance with requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (U.S. Environmental Protection Agency [EPA], 1990), EPA guidance (1988) and the *Crystal Mine Site Statement of Work* (CH2M HILL, 2010).

EPA has determined that Interim Records Of Decision (RODs) are needed to address the acidic mine drainage from both the Bullion (OU6) and Crystal (OU5) Mine sites located within the Basin Watershed Operable Unit (OU2). In accordance with Agency guidance, these interim RODs will be protective of human health and the environment in the short term and are intended to provide adequate protection until a final ROD for the Basin Watershed is signed. Therefore, the actions resulting from this focused FS are not intended to address fully the statutory mandate for permanence and treatment to the maximum extent practicable, yet they will support those statutory mandates.

1.1 Purpose and Organization of Report

The primary purpose of the FS is to "...ensure that appropriate remedial alternatives are developed and evaluated such that relevant information concerning the remedial action options can be presented to a decision-maker and an appropriate remedy selected" (EPA, 1995). Based on the descriptions and evaluations of alternatives presented in this report, and on the entire administrative record, a comprehensive Site alternative will be selected by EPA to address contaminants of concern (COCs) characterized in the RI Report.

The organization of this report generally follows the suggested FS report format presented in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988).

Section 1 presents site description and historic information, outlines the conceptual site model, summarizes the nature and extent of contamination at the Site, and the findings of the human health and ecological risk assessment (RA). Section 2 presents the remedial action objectives, ARARs, general response actions, and identification, screening, and development of technology types, process options, and initial alternatives. Section 3 presents the delineation, description, and screening of initial alternatives. Screening is based on EPA-accepted criteria of effectiveness, implementability, and cost. Section 4 presents the detailed analysis of alternatives process, including the criteria for individual evaluation of alternatives, and the collective comparative analysis of alternatives against NCP's seven threshold, balancing, and modifying criteria. Evaluation against the final two NCP criteria, state and community acceptance, will be completed by EPA after the public comment period.

Additional supporting information for FS text discussions is presented in report appendices. The information found in each appendix is as follows:

- **Appendix A.** *Treatability Study: Preliminary Activities—Piezometer Installation and Groundwater Hydrogeology*, *Crystal Mine Wetland Area*; and *2012 Installation, Sampling, and Testing of Ground Water Monitoring Wells – Crystal Mine OU5 Basin, Montana*.
- **Appendix B.** Applicable or Relevant and Appropriate Requirements.
- **Appendix C.** Alternative and Common Element Cost Estimates.
- **Appendix D.** Crystal Mine—Adit Discharge Design Flow Rate Memorandum.

1.2 Background Information

Mining within the Basin Mining District began in the mid-to-late 1800s and continued sporadically into the 1960s. The early placer mining activities concentrated on Basin and Cataract Creeks. Lode mining followed in the 1870s with the Eva May, Crystal, Uncle Sam, Hattie Ferguson, Bullion, and the Hope/Katie Mines (CDM, 2005b). Miners sought gold, silver, and copper from local mines and eventually developed mineral processing facilities within the watershed. The town of Basin, located at the mouth of Basin Creek, was settled in 1880. Mining was most active in the 1890s and the early 1900s. Subsurface mining continued into the 1970s when the Crystal Mine ended production. The final shipment of ore occurred in the mid-1980s. The majority of the minerals were mined prior to 1920 (CDM, 2005b).

1.2.1 Site Location and Description

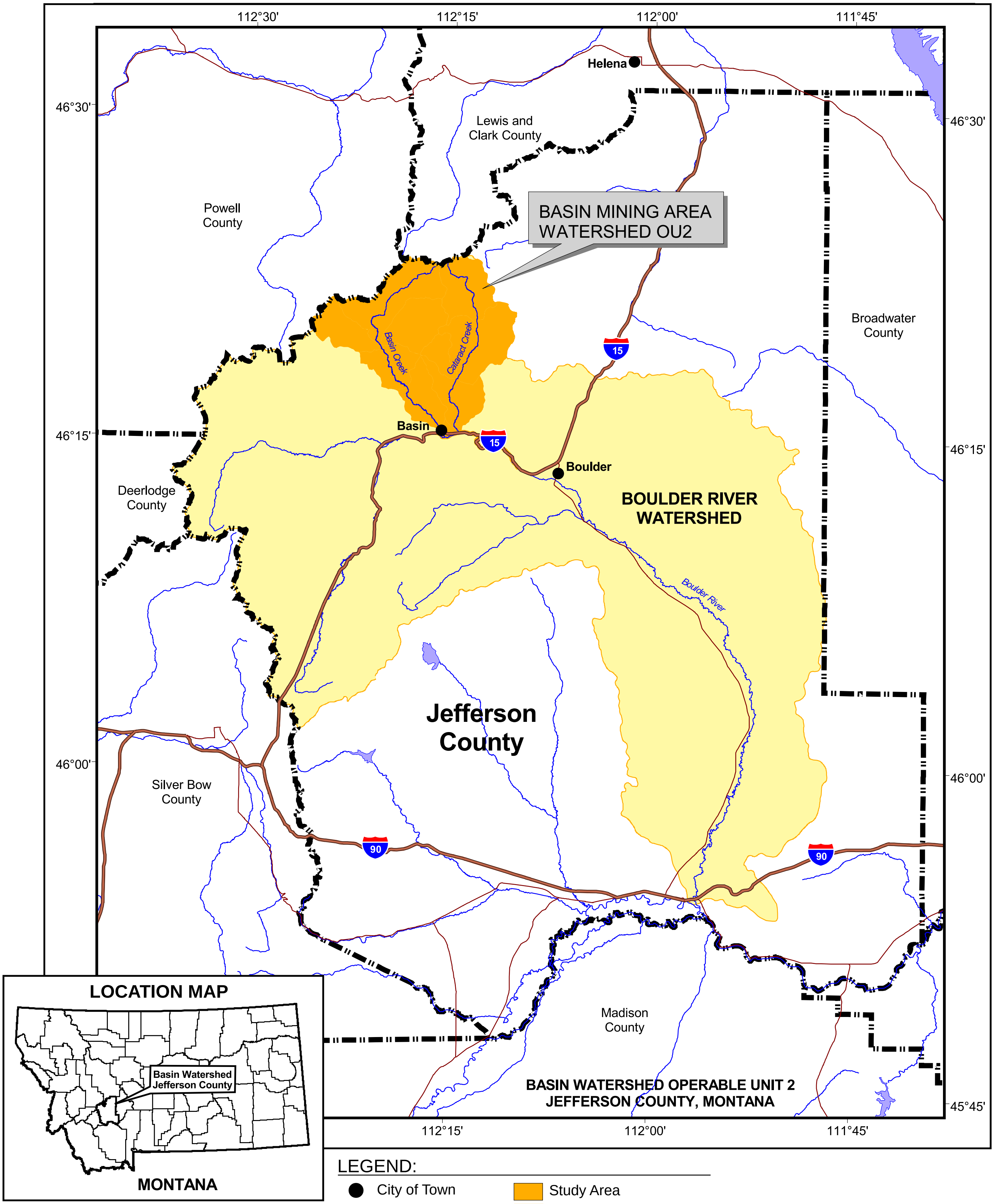
1.2.1.1 General

The Site, also called Operable Unit Number 05 (OU5) of the Basin Creek Watershed, is located on private (mineral patents) lands north of the town of Basin in Jefferson County, Montana. The Basin Watershed is located in the Northern Rocky Physiographic Province, a mountainous region with elevations ranging from nearly 5400 feet above mean sea level (amsl) at the town of Basin to 8752 feet amsl at Jack Mountain, the highest peak. The watershed is divided into two major drainages. The western portion is drained by Basin Creek, and the eastern portion is drained by Cataract Creek (see Figure 1-1).

The Site is located in the Cataract Creek Watershed, in the headwaters of Uncle Sam Gulch (USG) tributary. The Site is remote, and resides at an elevation of between 7600 feet and 8100 feet amsl on the northeast flank of Jack Mountain in Sections 18, 19, and 20 of T7N, R5W of the Montana-Principle Meridian. The watershed landforms consist of predominantly steep slopes and narrow valleys. The watershed is primarily evergreen forest dominated by lodgepole pine, Douglas fir, spruce, aspen and common juniper (CDM, 2005b). A variety of small trees, shrubs, and grasses are found in scattered open areas and along stream banks.

Access throughout the watershed is limited to existing, unpaved, secondary roads maintained by the U.S. Forest Service (USFS). The roads are snow-covered and typically impassible from late fall to early spring (USDA NRCS, 2009) (see Photograph 1-1).

PHOTOGRAPH 1-1. **Crystal Mine Site Lower Portal, March 2011**



LEGEND:

- City of Town
- River or Creek
- Interstate Hightway
- Highway
- Study Area
- Boulder River Watershed
- County Line

North

0 4 8 Miles

Source: Draft RI for Basin Watershed OU2 (CDM 2005b)

FIGURE 1-1
SITE LOCATION
Crystal Mine Feasibility Study

CH2MHILL

ES030911032705BOI Fig1-1_BasinMiningDistrict_v1.ai

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The surface expression of the Site covers approximately 22 disturbed acres, including an east-west trending linear trench feature located on a subbasin drainage divide (at 8100 feet amsl). The east end of the trenched area intercepts an incised subdrainage (Uncle Sam Gulch) that is oriented north-south and drains to the south. The slope below the east end of the trench is steep and covered with waste rock. The exposed surface features of the Site form an inverted “L” shape and consist of a lined and backfilled 800- to 1,000-foot-long trench, numerous waste rock piles, twin ore bins, five historic out buildings, a visible portal (elevation 7640 feet amsl) leading to lower underground workings, remnants of an old trestle, several ore chutes, and two lined ponds built over a waste rock dump. The two settling ponds (see Photograph 1-2) were constructed on top of the original adit-discharge drainage pond during a 1994 pilot treatment study (see Figure 1-2). Acid mine drainage (AMD) from the lower adit is presently directed into the ponds. USG Creek skirts the eastern edge of the waste rock dumps and the Site.

PHOTOGRAPH 1-2. **Settling Ponds Constructed in the Mammoth Dump**

1.2.1.2 Cultural Resource Inventory

In August 2011, EPA contracted with Renewable Technologies, Inc. (RTI) to perform an updated cultural resource inventory of the Site. RTI performed the original inventory in 1998 (historic entity 24JF1567). Because it was more than 10 years old, the Montana State Historic Preservation Office requested that the Site be re-inventoried to note any changes that might have occurred and reconsidered for site eligibility in light of the 2003 guidance.

When the site was first examined in 1998, the surface area associated with the mine covered portions of three mining claims—the Mammoth, Vermillion, and Sparkling Water. These claims and others, including the Crystal, St. Lawrence, Jack, and Commerce, together comprise the Crystal group. RTI’s investigation noted that the remains at the Crystal Mine reflect basically two different periods of operations: (1) significant initial production at the turn of the twentieth century; and (2) operations during the late 1920s and 1930s when the Bullock family leased and mined the property for a number of years. Twenty-six features were observed at the site, including residences and a variety of mining-related buildings and structures in two distinct clusters (Rossillon and Haynes, 1999).

At the time of its original examination, RTI determined that the Crystal Mine was eligible for listing in the National Register of Historic Places. As one of the larger producers in the Basin/Cataract Mining District and involving a good and intact complement of industrial and residential features, 24JF1567 was found to be eligible under Criteria A and C. Additionally, it seemed possible that it might also be eligible under Criterion D, should buried household artifacts be present in good numbers. No subsurface testing was conducted at the time.

On August 6, 2011, RTI historic archaeologist Mitzi Rossillon revisited the Crystal Mine. She examined all of the previously recorded features, comparing their current condition with that reported previously. Repeat photographs were taken. In one instance, a feature not found in 1998 was recorded. Because the site has changed very little from its earlier appearance, RTI elected not to remap the site, and the site form amendment simply mentions the newly recorded shaft and the removal of some modern equipment. The final report begins with a historic context for the entire Basin/Cataract Mining District, includes a focused history for the Crystal Mine, and contains descriptions of all observed features at the Site. It concludes with a detailed discussion of National Register of Historic Places evaluation methodology and a statement specific to the Crystal Mine. Its National Register evaluation of 1998 still stands. A complete copy of the inventory is presented as a reference to the RI report (2013).

1.2.2 Surface Water Hydrology

In the Crystal Mine subbasin, USG Creek surface water flow regimes mimic seasonal patterns common for the entire watershed. Surface water high flows typically coincide with snowmelt runoff in late spring and low flows in the late summer through the winter.

As a major tributary, the USG drainage enters Cataract Creek which flows into the Boulder River near the town of Basin, Montana. The Montana beneficial use classification for Cataract Creek is B-1. This classification states that the water quality of the stream must be sufficient to support (1) recreational activities such as bathing and swimming; (2) growth and propagation of salmonid fishes and associated aquatic life and other wildlife; (3) waterfowl and furbearers; (4) agricultural and industrial water supply; and (5) drinking and culinary purposes (after conventional treatment). The USG tributary is not officially classified by the state, but by virtue of its flow contribution it plays a significant role in whether Cataract Creek achieves its water quality criteria for achieving B1 classification. Its importance as a degrading influence is noted in the draft total daily maximum loading requirements proposed by the Montana Department of Environmental Quality (MDEQ) (MDEQ, 2012b).

1.2.3 Site History—Previous Investigations

Interest in the Basin Mining district (including the Crystal Mine), its legacy of hard rock mining, and the impacts on local aquatic resources extends back to 1975 with flow and water quality studies initiated by the USFS, US Geological Survey (USGS) and the Montana Bureau of Mines and Geology (MBMG). Several studies documented water quality in the Boulder River, Basin Creek, and Cataract Creek. Major tributaries to Cataract Creek (including USG Creek) were bracketed by the sampling in 1991 and 1992. Sampling performed on USG Creek from the Crystal Mine concluded that the water flowing down USG was degraded more significantly by the Crystal Mine than by any other influence down to its confluence with Cataract Creek (Martin, 1992; Reclamation, 2002).

From May to September 1993, an effort to identify abandoned and inactive hard rock mine sites causing severe environmental degradation to surface water and groundwater was initiated by state and federal land management stewards. Montana Department of State Lands (Abandoned Mine Land Reclamation Bureau) coordinated an effort to prioritize these sites with respect to exposure pathways, and the severity and extent of their contamination (based onsite visits and media sampling). The results of this inventory survey effort are described in the State's "Red Book" published in 1994 (Pioneer Technical Services Inc. and Thomas, Dean and Hoskins, Inc.). Out of 270 mine sites inventoried for environmental threats and hazards, the Crystal Mine ranked 20. In 1995, the MBMG and the USFS completed an abandoned mine inventory of the Deerlodge National Forest lands, which included Cataract Creek, Uncle Sam Gulch, and the Crystal Mine (MBMG, 1995). They identified 51 abandoned or inactive mine sites within the Cataract Creek drainage, of which 27 were sampled, including the Crystal Mine. Five surface water samples were collected during the field investigation: (1) the spring above the Crystal Mine; (2) USG Creek below the Site; (3) USG Creek above the confluence with Cataract Creek; and (4) Cataract Creek both above and below the confluence with USG Creek. Metals-related degradation of water quality from the Site down to the confluence with Cataract Creek was documented. Adverse impacts to vegetation were also noted.

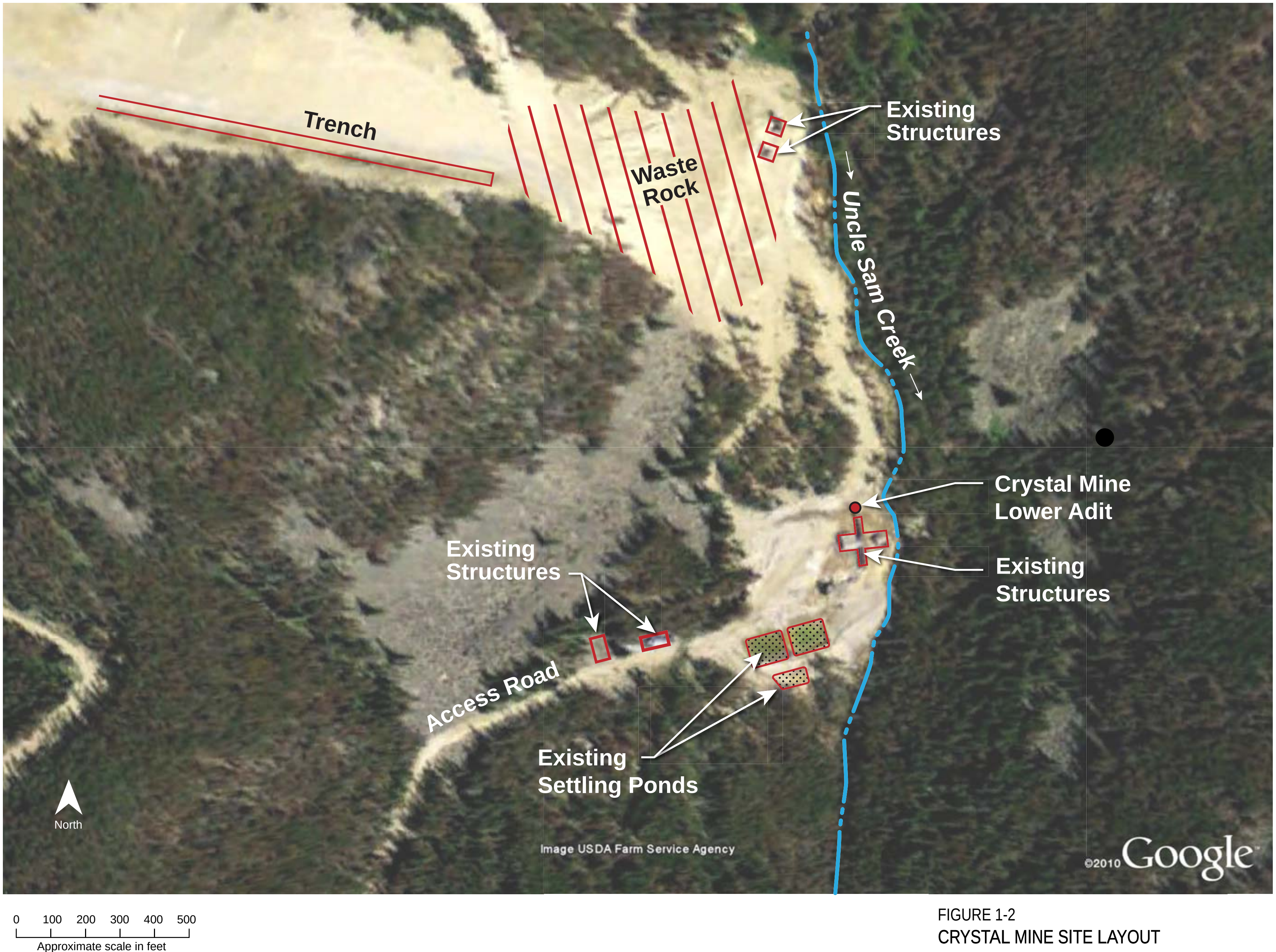

FIGURE 1-2
CRYSTAL MINE SITE LAYOUT
Crystal Mine Feasibility Study

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In 1994, MSE Technology Applications, Inc. (MSE) initiated a treatment study on the discharge from the Crystal Mine lower adit. Through an interagency agreement, the EPA and U.S. Department of Energy administered the study. Effluent draining from the lower adit of the Crystal Mine was piped to an Aqua-Fix® system. The system utilized a flywheel to inject quicklime (calcium oxide) into the mine adit discharge, where it was allowed to mix prior to being discharged into one of two primary settling ponds. Effluent from the secondary settling pond was discharged directly into USG Creek. Although this treatment effort was only partially successful, it provided a 2-year evaluation period where water quality data were collected (on a weekly basis) to characterize the dissolved metals content of the mine influenced discharge. The effluent data consistently exceeded (often by several orders of magnitude) water quality benchmarks considered protective of human and ecological receptors (MSE, 1998).

In 1996 the USGS initiated a 5-year study of the impacts of mining and issues related to AMD on Upper Boulder River Basin. This area included the Basin Mining District and the Cataract Creek Watershed. The study collected data on surface water quality and flow characteristics, impacts to soil and sediment, acid-neutralizing potential of bedrock and mine waste, leaching potential of mine wastes, and geophysical surveys of mine sites in Basin Creek and Cataract Creek Watersheds. The USGS focused their investigations on priority mine sites, including the Crystal Mine in the Cataract Creek Watershed. In their compendium of studies (USGS, 2004), several studies concluded that the Crystal Mine and its adit discharge is the major source of metal loading to USG Creek and "….contribute acidic, metal-rich water to the receiving streams. Colloidal metal laden material from the Crystal Mine source was described as one of two mine adit discharges likely to have the most impact on aquatic health of the Boulder River Watershed."

In 2001, EPA authorized an RI/FS of the Basin Watershed OU2 in which the Crystal Mine was included. Remedial field investigation sampling data were used to define and explain the nature and the extent of the contamination in the Cataract Creek drainage. The RI/FS was published in 2005 and concluded that water quality degradation in Cataract Creek during low-flow months was predominantly attributable to the tributaries—in particular, Uncle Sam Gulch Creek. The Crystal Mine was identified as the primary contributor of COC concentrations in USG Creek. Discharge from the lower adit was sampled during the 2001 RI field investigation. The results exceeded both ecological and human health benchmarks for arsenic, cadmium, copper, lead, and zinc (CDM, 2005b).

Also in 2001, a Time Critical Removal Action (TCRA) for the Crystal "trench area" was initiated. The objective of the TCRA was to reduce the collection of snow melt and precipitation in the "trenched" surface feature caused by previous mining. The collection of precipitation in this feature was thought to contribute to the recharge of the Crystal Mine underground workings and production of AMD. The TCRA consisted of placement of a liner and back filling the trench. It was completed in 2002 and appeared to help reduce the rate of AMD discharge from the lower adit. This work was also performed in anticipation of future remedial work to capture and treat the remaining AMD.

In 2009, EPA completed a draft engineering evaluation/cost analysis (CH2M HILL, 2009) for additional cleanup work at the Crystal and Bullion Mines. However, in 2010, EPA decided instead to develop focused RI/FS reports and Interim RODs for both the Bullion and Crystal Mine sites. Sampling and remedial investigation activities were performed at the Crystal in 2010 through 2012.

1.2.4 Conceptual Site Model

A conceptual site model (CSM) was prepared for the Site to help identify potential sources of metals and arsenic, and probable pathways of movement of these contaminants from source material into soils, groundwater, and surface water (see Figures 1-3 and 1-4). The CSM was developed from existing data (previous sampling and Basin Watershed OU2 RI) and information obtained from RI field activities performed in 2010 through 2012. The Site consists of: (1) a lined and back-filled surface trench; (2) two adits and portals (upper portal is collapsed and covered); (3) several waste rock dumps (typically near adit portal locations); (4) ore bins and other mine support structures; and (5) two lined settling ponds (25,000-gallon capacity each). Each of these five key aspects of the CSM are described in Sections 1.2.4.1 through 1.2.4.5.

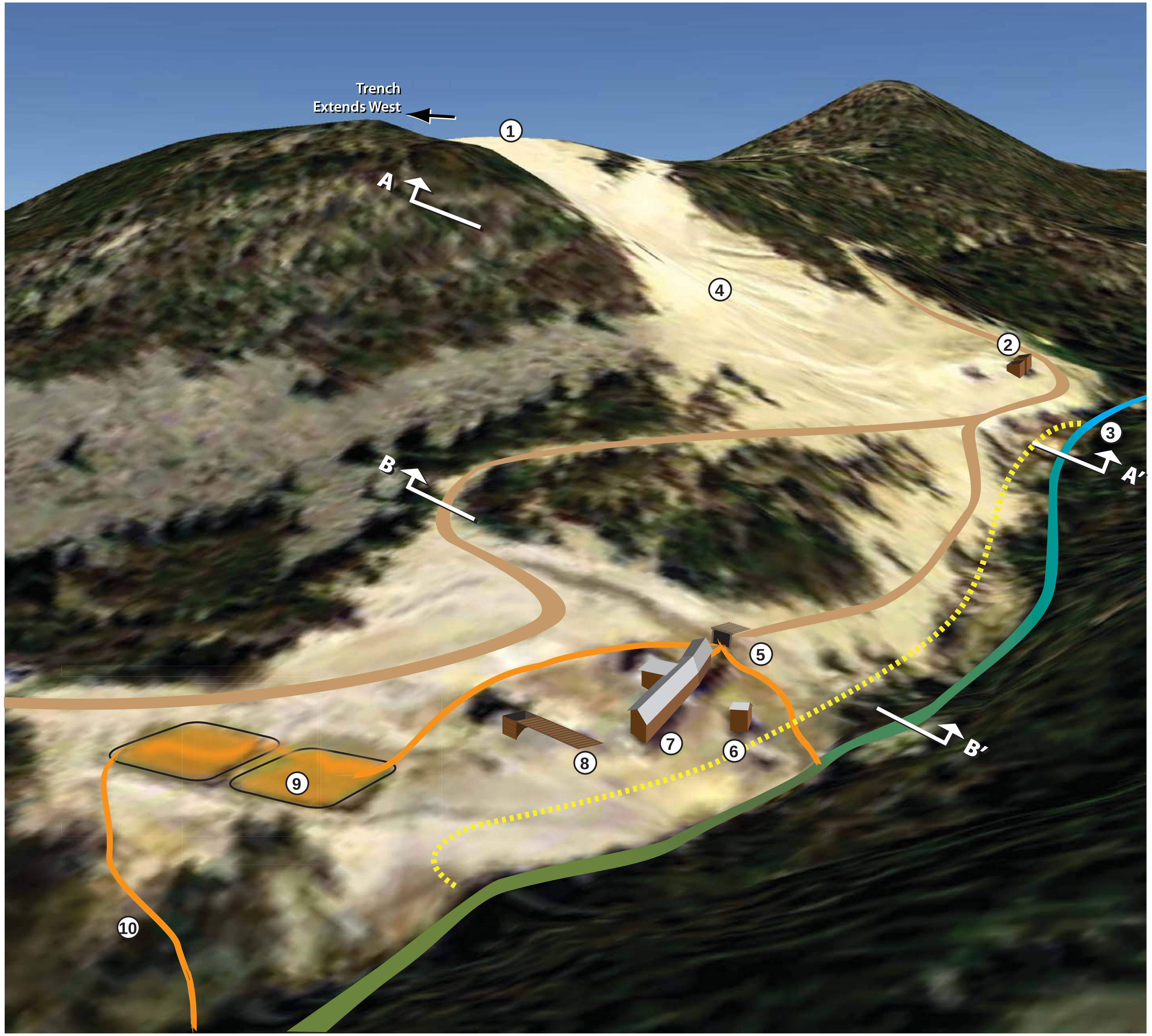
1.2.4.1 Mining Waste Rock

Waste rock dumps are commonly located near an adit or shaft from which the rock is removed (see Figure 1-5). These dumps consist of a variety of rock fragment sizes depending on the method of extraction, and the integrity and friability of the host rock. Three waste rock dumps were identified at the Site, and one road was constructed from the waste material. The dumps show signs of extensive erosion, are unvegetated, and because of their sulfide and mineralized origin are likely to generate an acidic leachate when exposed to oxygen, water, and bacteria.

1.2.4.2 Acid Mine Drainage/Acid Rock Drainage

When sulfide-bearing rock is exposed to oxygen and water, the sulfide minerals undergo an oxidation reaction resulting in the creation of sulfuric acid. This reaction occurs in underground workings as well as in waste rock and tailings. When the volume of acidic leachate exceeds the natural buffering (acid neutralizing) capacity of the host rock, AMD/acid rock drainage (ARD) occurs and can result in the dissolution of metals into surface and groundwater. Evidence of AMD/ARD can be seen in iron oxide staining (orange precipitate) commonly associated with groundwater from adit discharge or seeps and from surface water runoff from waste rock dumps, both of which are present at the Site (see Photograph 1-3).

PHOTOGRAPH 1-3. **Iron Oxide Staining Representative of AMD**



North

Note

(1) Site Feature (See Figure 1-3a)

Legend

Mine Adit Discharge

Creek Water Impacted by Mine

FIGURE 1-3
CRYSTAL MINE CONCEPTUAL SITE PLAN
Crystal Mine Feasibility Study

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① Crystal Mine Trench
(Lined and Filled in 2002 TERA)

⑤ Lower Adit Portal
(Note: Acid Mine Drainage)

⑨ Old Settling Ponds on
Mammoth Dump

② Twin Ore Bins Dump

⑥ Waste Rock Dump Erosion
into Creek

⑩ Dying Trees from Acid Mine
Drainage

③ Uncle Sam Gulch Creek
(Note: Proximity to Waste Rock)

⑦ Mine Support Structures on
Mammoth Dump

④ Crystal Dump
(Note: Erosion Rills)

⑧ Ore Loading Trestle on
Mammoth Dump

FIGURE 1-3a
CRYSTAL MINE CONCEPTUAL
SITE PLAN
Crystal Mine Feasibility Study

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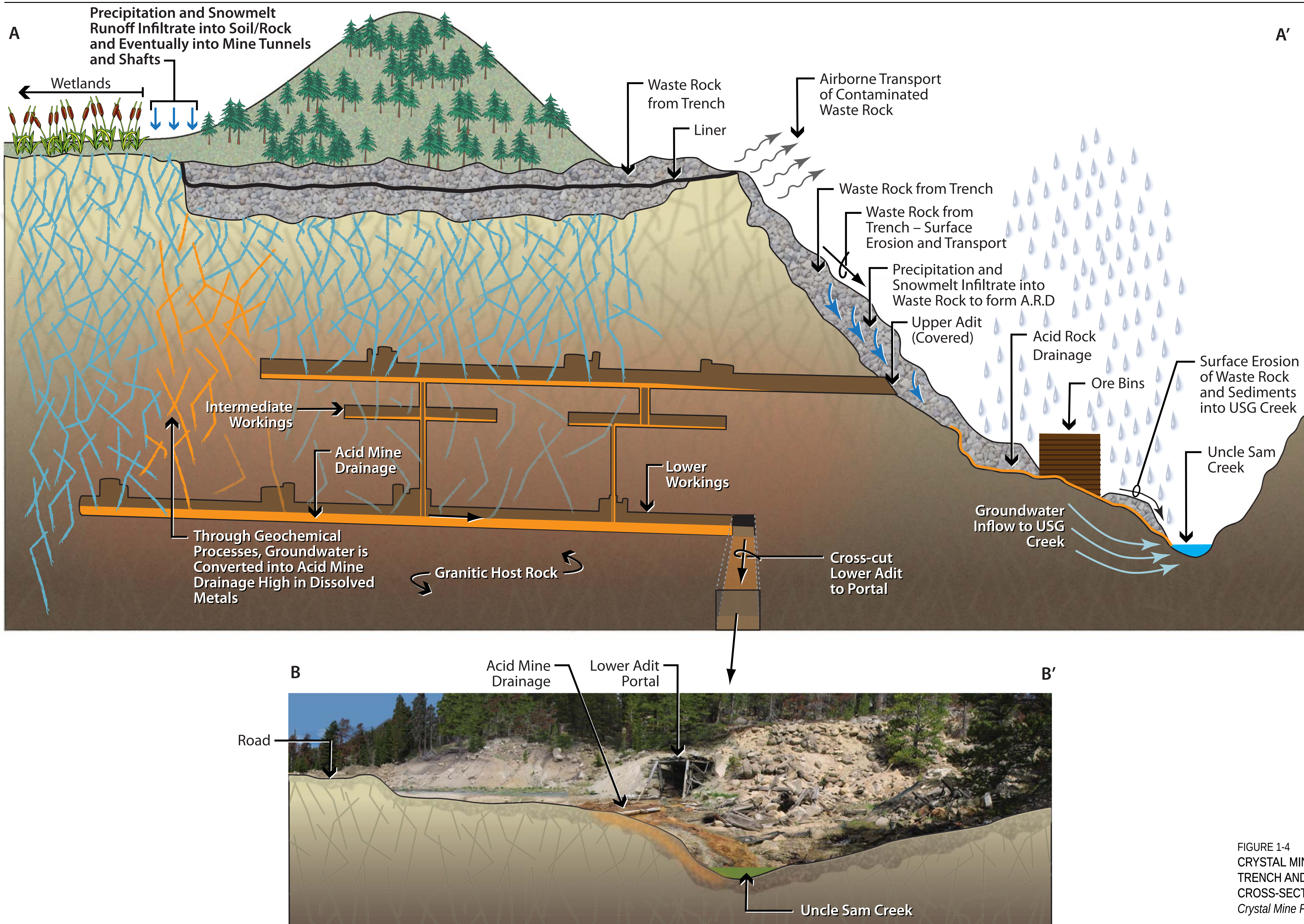

FIGURE 1-4
CRYSTAL MINE SITE PLAN
TRENCH AND DUMP
CROSS-SECTION
Crystal Mine Feasibility Study

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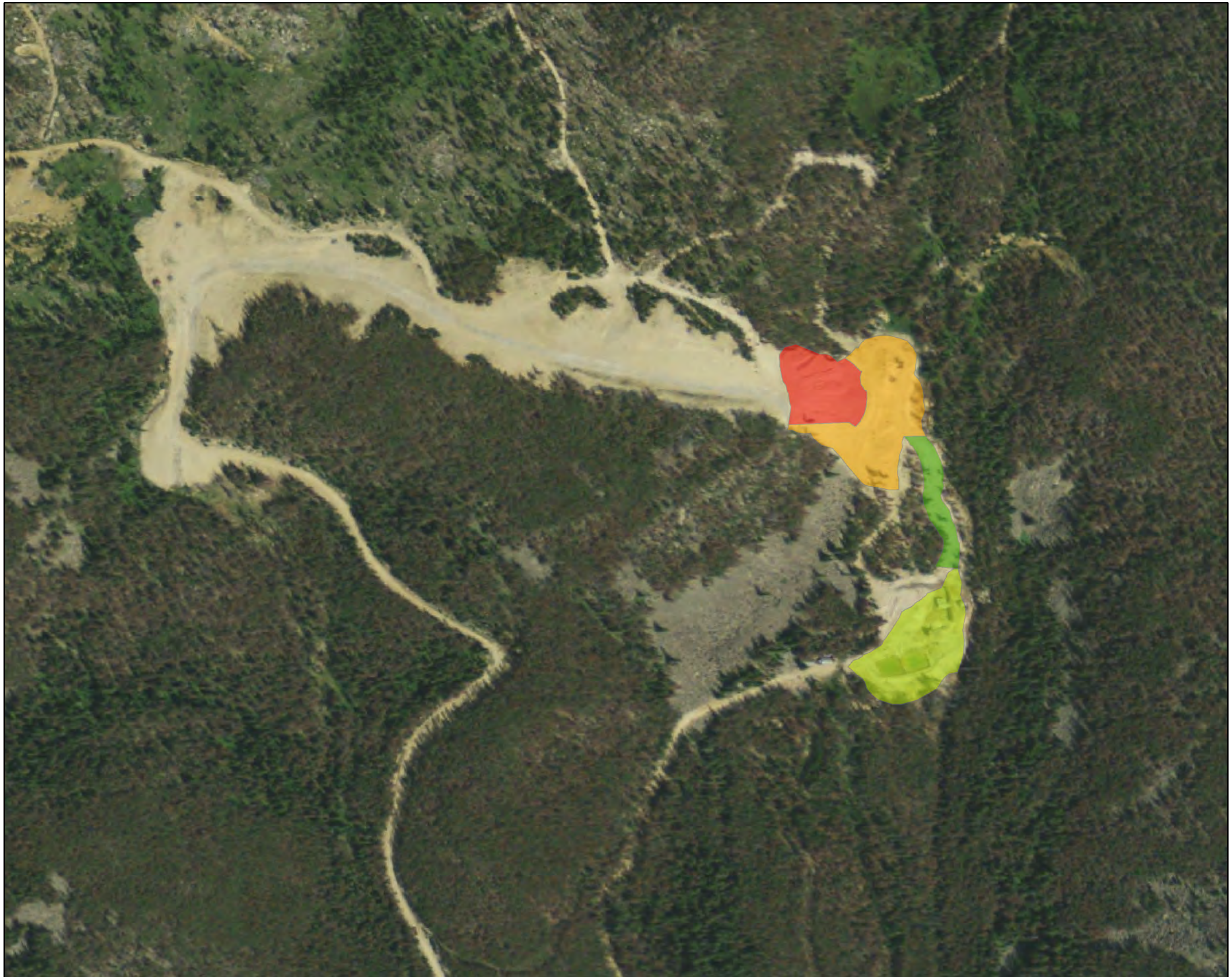

VICINITY MAP

LEGEND

Waste Dump

- Mammoth Road
- Mammoth Dump
- Twin Ore Bin Dump
- Crystal Dump

Notes:
1. Area of interest subject to change.
2. 2009 NAIP Orthophoto.

N

0 250 500
Feet

FIGURE 1-5
Mine Waste Dumps
Crystal Mine OU5 Feasibility Study

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1.2.4.3 Contaminated Surface Water

Surface water quality can be degraded by stormwater runoff carrying contaminants released from mine waste material, or by adit discharge water flowing directly into surface water. Concentration of contaminants is highly dependent on chemical release mechanisms, stream flow, and water chemistry. Degradation of surface water quality can be more severe during low-flow stream conditions, if the release of contaminants into the stream, from an adit for instance, remains constant. Storm events or spring runoff can erode waste rock dump material into nearby streams where sediment load and contaminant dissolution contribute to surface water quality degradation. The Site adversely affects USG Creek water quality through both of these mechanisms.

1.2.4.4 Contaminated Groundwater

Groundwater can become contaminated through a number of physical processes. Surface water can infiltrate and migrate into underground mine workings and become degraded through interaction with contaminant bearing host rock. Contaminated water can then migrate into adjacent bedrock aquifers and, discharge as base flow into local creeks, or flow through interconnected mine working and surface as an adit discharge or seep a significant contaminant migration pathway at the Site (see Figure 1-3). Because of its high elevation, steep slopes, and shallow soils, contaminants also migrate to shallow groundwater by snow melt or precipitation infiltrating down through waste rock to the soil-bedrock interface. The shallow groundwater is connected, particularly during storm events and spring runoff, to USG Creek.

1.2.4.5 Stream Sediments

Contaminated stream sediments are often the result of direct erosion of contaminated waste rock and soils into the stream or contaminated sediment-laden runoff co-mingling with the stream. Stream sediments can also become contaminated by the precipitation of COCs onto stream bed load and sediment in reaches where AMD/ARD intercepts the stream. Historic and current sampling of USG Creek has demonstrated that the Site is a source of contaminated sediment within USG (CDM, 2005b; CH2M HILL, 2012).

1.2.5 Summary of RI Findings

The nature and extent of contamination at the Site as presented by historic results was verified by the findings of the RI, as discussed in Sections 1.2.5.1 through 1.2.5.7.

1.2.5.1 Surface Water

Field sampling of surface water was performed at five stations associated with USG Creek (including the lower adit discharge) and five springs/seeps inventoried in the vicinity of the Site. Springs located upgradient of the mine in Uncle Sam Gulch (Spring-1, Spring-2, and Spring-3) exhibited acceptable water quality. However, Spring-3 did show the influence of mineralization with elevated aluminum, cadmium, copper, and lead. Spring-4 and Spring-5 are topographically downgradient of the disturbed mine area and show more of a mineralized signature with COC concentrations slightly elevated.

Water quality in USG Creek above the confluence with the lower adit discharge is significantly better than what was recorded from stations located downstream of the mine (see Figure 1-6). In general, COC concentrations and acidity were greatest in the Crystal Mine adit discharge, followed by water at Station USC-3 located immediately downstream from the confluence of the adit discharge and USG Creek. Arsenic concentrations exceeded human health maximum contaminant levels (MCLs) during sampling conducted by CH2M HILL in 2010 of the adit discharge, Crystal Spring-4, USG Creek Stations 2 and 3, and the USG Creek tributary. Cadmium concentrations exceed human health standards in the adit discharge water and at Station USG-3. The only exceedance of copper occurred in the adit discharge samples, while lead and zinc concentrations consistently exceeded standards in the adit discharge and waters collected at Station USG-3. This pattern of degradation is consistent with previous sampling that demonstrated an adverse impact beyond USG Creek's confluence with Cataract Creek.

1.2.5.2 Groundwater

Groundwater recharge in the vicinity of the Site results from snowmelt and precipitation at topographic highs. Recharge is greatest in areas with higher hydraulic conductivity, such as zones of weathered, fractured rock and old exploratory shafts, raises, pits, and trenches. Groundwater discharge occurs at numerous small springs and seeps in topographic lows and slope breaks, and at geologic contacts with changes in hydraulic conductivity. The lower Crystal Mine adit is a significant point of groundwater discharge contributing to surface water degradation summarized under the preceding surface water discussion (see Photograph 1-4). Based on the adit discharge hydrograph, seasonal fluctuations in adit discharge flows coincide with seasonal variations in precipitation and temperature. Adit discharge flow is high in the spring and early summer and drops off significantly in the late summer, fall, and winter. The seasonal flow pattern is the result of the availability of precipitation falling on surface soils and infiltrating down through bedrock fractures, eventually intercepting the mine workings.

PHOTOGRAPH 1-4. **AMD from Adit Flowing into USG Creek**

Surface water associated with a wetland located northwest of the Site was suspected as a recharge source of water for the underground mine workings and formation of AMD. In an effort to confirm this condition, preliminary activities associated with a treatability study were initiated in late August 2011. Activities consisted of excavating test pits and installing a nest of piezometers to identify depth to bedrock, water bearing zones, and vertical groundwater gradients in the vicinity of the western end of the mine workings. The results highlight a fractured bedrock profile with numerous quartz veins, many of which transmit water at multiple depths. The treatability study data indicated that the water was not simply pooling up at the bedrock/unconsolidated rock interface. The study confirmed the presence of a large groundwater flow component throughout the fractured bedrock profile (0 to 140 feet bgs). The source area for the recharge of this zone appears widespread with groundwater being transmitted in a heterogeneous manner through a fracture dominated system with multiple quartz veins (see treatability study memo in Appendix A).

VICINITY MAP

LEGEND

- Stream Sample Location
- Spring Sample Location
- Digitized\DEM Generated Streams

Notes:
1. Area of interest subject to change.
2. 2009 NAIP Orthophoto.

N

0 250 500
Feet

FIGURE 1-6
Creek and Spring Sampling Locations in Uncle Sam Gulch
Crystal Mine OU5 Feasibility Study

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In 2012, additional remedial investigation field work was performed to identify the origin of source water entering the mine. This work consisted of:

- The installation, sampling, and testing of physical characteristics of two deep monitoring wells (to 300 feet bgs) and one mid-zone well to 150 feet bgs, and
- The performance of a geophysical investigation (Willowstick, LLC, 2012) to identify preferential groundwater flow paths. This investigation confirmed the findings of the previous shallow zone investigation. It further determined that from 150 to 300 feet the bedrock becomes more dense and competent with tighter, less frequent fractures to transmit groundwater.

The results of the 2011 and 2012 investigations showed that to effectively reduce groundwater recharge to the lower, middle or upper workings would require capture and diversion of the water throughout the entire bedrock profile (0 to 300 feet bgs). Such an approach would be very expensive and technically impractical to construct. Water discharging from the lower adit appears to define the baseline groundwater elevation at the Site. No groundwater discharge is currently emanating from the upper adit, which suggests that the groundwater level is below the elevation of the upper workings.

1.2.5.3 Waste Rock and Soils

Samples of waste rock and soils were collected from 40 pits established in accordance with the sampling and analysis plan throughout the Site. Locations of these pits in relation to the mine working are presented in Figures 1-7 and 1-8. Surface (0- to 2-inch depth) materials as well as materials as deep as approximately 216 inches (18 feet) were obtained. Deeper sampling occurred in waste rock dump areas, but samples were not taken below the natural soil layer. Between 55,000 and 60,000 yd^3 (cubic yards) of waste rock reside in four dump locations on the Site. A total of 201 samples were collected for elemental analysis.

Mean and maximum concentrations of the arsenic, cadmium, copper, iron, lead, manganese, nickel, silver, selenium, and zinc far exceed their respective ecological benchmark values. For example, the mean and maximum concentrations of arsenic in surface soils are orders of magnitude greater than the ecological benchmark of 18 milligrams per kilogram (mg/kg). The ecological benchmark for lead of 11 mg/kg is also exceeded in many samples, with mean and maximum concentrations up to two orders of magnitude greater than the benchmark value. Comparisons to human health residential and recreational benchmark values of soil and waste rock COCs in samples collected in 2010 indicate the Site values are far in excess of those considered to be protective of human health. However, background area arsenic levels range from 7.6 to 162 mg/kg, indicating some naturally high arsenic conditions.

Very elevated COC concentrations were found as deep into the soil as 18 feet at one waste dump area. Mean levels of arsenic, throughout the soil profile, are consistently between 1,000 and nearly 5,000 mg/kg, with little variation with depth. Maximum concentrations can be found at any soil depth, which is to be expected for waste dumps where soils from various locations of the mine are mixed. This same pattern of heterogeneity is found for mean levels of lead as a function of soil depth. Concentrations of copper and zinc in the soil profile are also variable, with little pattern in terms of mean concentrations. The concentrations of copper and zinc are generally less than those of arsenic and lead.

Acidity in the soil and waste rock samples was determined by measuring pH. Mean pH levels indicate acidic soil/waste rock throughout the soil profile. Minimum and maximum values ranged from 2.6 to 7.8, with one sample collected from a 6-foot depth having a pH value of 8.1. The source of the acidity in this material is derived from the oxidation of pyrite in the ore body.

Elevated metal concentrations coupled with high acidity (low pH) results in enhanced metal mobility and migration to the environment (surface water, vadose zone, and groundwater), and ecological receptors (vegetation, aquatic biota). Under oxidizing conditions of low pH, cadmium, copper, and zinc are very mobile, while lead is only somewhat mobile (Smith and Huyck, 1999). Under reduced conditions in the absence of hydrogen sulfide and pH greater than 5, cadmium, copper, and zinc are mobile.

1.2.5.4 Stream Sediments

Sediment was sampled during the 2012 RI activities. Sediment enters USG Creek through bank erosion and over land flow. The highest COCs concentrations were detected in the 260-mesh particle size (silt, clay). In Cataract Creek, the highest COC concentrations occurred in sediments originating from USG Creek. Antimony, arsenic, cadmium, copper, lead, manganese, and silver significantly exceeded probable effects benchmarks for benthic macroinvertebrates, and important aquatic ecological and human health benchmarks. USG Creek was the largest source of contaminated sediment to Cataract Creek historically and in the 2001 sampling (CDM, 2005b).

1.2.5.5 Macroinvertebrate Survey

To perform a benthic macroinvertebrate survey, monitoring stations were established at three locations on USG Creek and two locations on Cataract Creek bracketing Uncle Sam Gulch (see Figure 1-9).

Few macroinvertebrates were found in USG Creek or Cataract Creek. A total of 944 organisms, representing 53 taxa, were collected during this survey, despite doubling the area of each sample. Measurable impacts extended downstream into Cataract Creek. A sparse, but relatively diverse macroinvertebrate assemblage was present above the mine (USG-1). Macroinvertebrate density and number of species declined significantly at the Site (USG-2). Downstream from the Site, USG Creek was essentially devoid of life. Only two macroinvertebrates were collected below the Site (USG-3). Macroinvertebrate density and taxa richness were also reduced in Cataract Creek below USG (CC-4) compared to the sampling site approximately 80 meters upstream (CC-5). These data clearly show toxic impacts to macroinvertebrate communities attributable to discharges from the Site.

1.2.5.6 Wetlands

A wetlands inventory of the Site was performed in August 2010. The Site has three distinct wetland areas (north Site, Uncle Sam Gulch, and Lower Seep) consisting of 21.1 acres of jurisdictional wetlands. Jurisdictional wetland acres are those regulated by the U.S. Army Corps of Engineers that meet the three criteria for a wetland (hydric soils, hydrophytic vegetation, and wetland hydrology), and are connected or adjacent to a water of the United States. All jurisdictional wetlands are subject to the “no net loss” requirement of Executive Order 11990, and remedial actions performed at the Site must avoid impacting them.

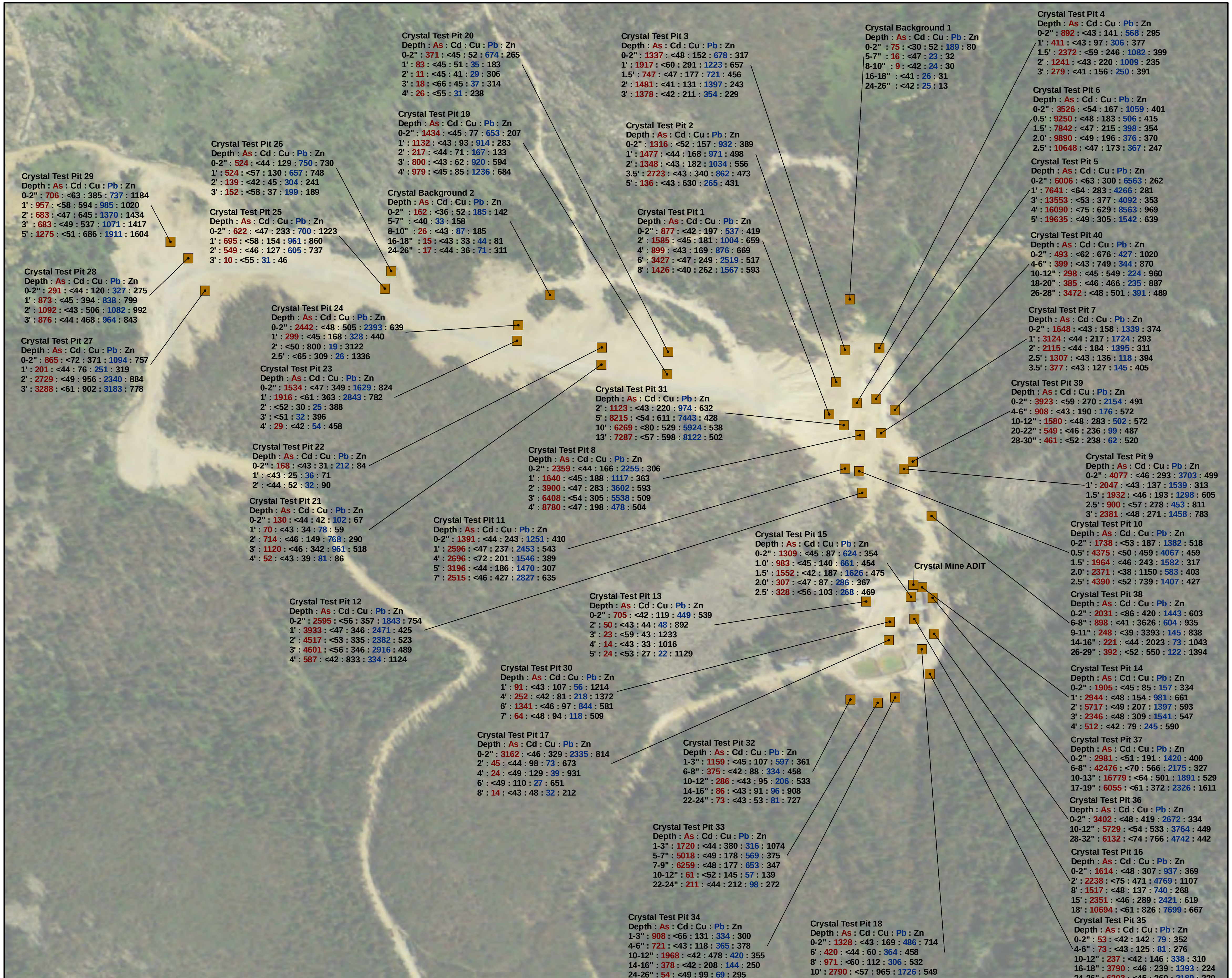
At the USG Creek site, bare ground predominated in the wetland areas mainly because of the collection of mine wastes along the stream. The other two wetland sites were less affected by mine wastes, although the upland area at the Lower Seep wetland clearly showed the downhill movement of mine waste materials through the forest from waste rock piles positioned upslope.

1.2.5.7 Threatened and Endangered Species

A survey of U.S. Fish and Wildlife Service information and Montana Natural Heritage Program data were reviewed to identify potential threatened and endangered species potentially using or living within the vicinity of the Site. Only the following currently listed threatened and endangered species have a realistic potential of being at or near the Site: Canada lynx (2010), and grizzly bear (2013).

1.2.6 Contaminants of Concern

Previous sampling efforts helped identify COCs for the Site. The Site was evaluated as part of the RI/FS for the Basin Watershed OU2 in 2001-2005. As such, contaminants of potential concern (COPCs) were evaluated for the Site through a human health and baseline ecological risk assessment (BERA) for the Basin Watershed OU2 (CDM, 2002). The risk assessment identified the primary COCs that drive the risk to human health and the environment at the Site as: arsenic, cadmium, copper, lead, and zinc (CDM, 2001). Using the previous Basin Watershed OU2 risk assessment findings, site-specific historic investigation findings, and the knowledge that the Site has been inactive since those findings, a list of metals and metalloids



VICINITY MAP

LEGEND

- Test Pit Sample Location

Notes:
1. Analytical values are mg\kg
2. LOD = Level of Detection
3. 2009 NAIP Orthophoto

N

0 250 500
Feet

FIGURE 1-7
Soil Pits with Samples Analyzed by XRF
Crystal Mine OU5 Feasibility Study

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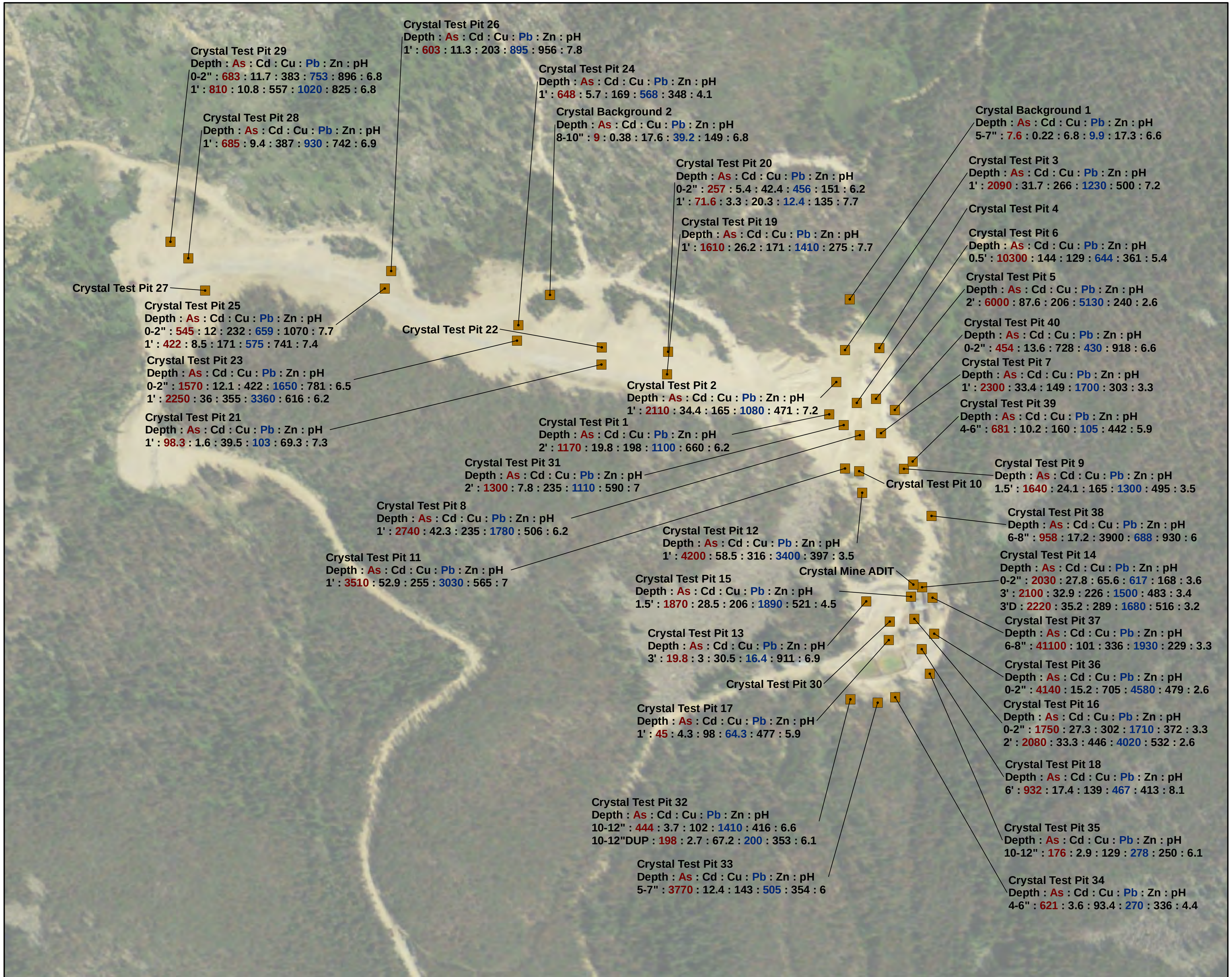

VICINITY MAP

LEGEND

- Test Pit Sample Location

Notes:
1. Analytical values are mg\kg
2. 2009 NAIP Orthophoto

N

0 250 500
Feet

FIGURE 1-8
Soil Pits with Samples Analyzed by Laboratory Methods
Crystal Mine OU5 Feasibility Study

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VICINITY MAP

LEGEND

- Macro-Invertebrate Sampling Location
- NHD Stream
- Mine Claim Boundary

Notes:
1. Area of interest subject to change.
2. 2009 NAIP Orthophoto

N

0 250 500 1,000 1,500 2,000 2,500
Feet

FIGURE 1-9
Benthic Macro-Invertebrate Monitoring Locations
Crystal Mine OU5 Feasibility Study

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(Contaminants of interest [COI]) was developed to evaluate under the focused RI for nature and extent of contamination at the Crystal Mine. Mercury was not included based on historic and current sampling results indicating its presence typically at or below detection levels in samples from the Crystal Mine discharge and USG Creek (CDM 2005b, Tables 7.3-1, 7.4-1, 7.5-1, 7.7-1; USGS, 2011). COIs included: aluminum, antimony, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, thallium, and zinc.

1.2.7 Summary of Human Health and Ecological Risk Assessment

A human health risk assessment (HHRA) and ecological risk assessment (ERA) was conducted at the Site in accordance with applicable EPA and MDEQ guidance. The resulting characterization of potential risk is expected to provide enough information for informed decisions at the Site. The primary decision using the results of the risk assessment is whether the potential human health or ecological risk is high enough to warrant development of remedial alternatives for any areas and to identify COPCs at the Site.

1.2.7.1 Conceptual Exposure Model

A conceptual exposure model is formulated with the use of professional judgment and site-specific information on land use, water use, ecological habitat, contaminant sources, release mechanisms, routes of migration, potential exposure points, potential routes of exposure, and potential receptor groups associated with the Site. This information is used to identify the most plausible current or future human and ecological receptor populations that may contact COCs originating from the Site, that are evaluated during the risk assessment.

Human Receptors. Potential human receptors are as follows:

- Future intermittent workers (for example, road maintenance, environmental sampling, or USFS workers).
- Future adult and adolescent recreational users (for example, hikers, all-terrain vehicle [ATV] riders, or hunters).
- Future excavation workers (for example, trenching activities).

For these potentially exposed populations, the most plausible exposure routes considered for characterizing human health risks include the following:

- Incidental ingestion and dermal contact with surface soil, or inhalation of dust by future intermittent workers and recreational users.
- Incidental ingestion and dermal contact with subsurface soil, or inhalation of dust by future excavation workers.
- Ingestion of surface water by recreational users.

Given the present understanding of current and reasonably anticipated land uses at the Site, the slope of the land, elevation, and unconsolidated material on which to build structure, it is not likely that there will be residents or standard occupational workers at the area of interest in the future. In fact, EPA intends to pursue an institutional control for the Site that will prevent residential development. Therefore, no standard default occupational and hypothetical future residential scenarios are considered in the HHRA. The results from evaluation of the stated scenarios are expected to provide a frame of reference for indicating the potential significance of future land use changes, if any, or identifying the need for land use controls.

Ecological Receptors. Potential ecological receptors are as follows:

- Potential exposure of avian and terrestrial wildlife (primarily birds and mammals) to mine-related contaminants in soil.
- Potential exposure of wildlife to mine-related contaminants in surface water and sediment.
- Potential ingestion of site-related chemicals via uptake in the food chain by higher trophic level terrestrial and avian wildlife.

- Potential exposure of aquatic resources to mine-related contaminants present in shallow groundwater (measured by seep and adit water concentrations) potentially discharging to nearby surface water.
- Potential exposure of vegetated and forested areas to mine-related contaminants present in soil.

Based the exposure assumptions used in the risk assessment (Section 6), the findings are described in the following text.

Human Health

Intermittent Workers

- Cumulative excess lifetime cancer risks (ELCR) estimates are within but do not exceed the EPA target risk range of 1×10^{-6} to 1×10^{-4}, and are below the MDEQ statutory risk level of 1×10^{-5}.
- Hazard index (HI) estimates below the EPA and MDEQ threshold value of 1 are also identified for this exposure scenario.
- These results indicate that there are no unacceptable risks for current and future intermittent workers, under the exposure assumptions used.

Recreational Users (both adult and adolescent)

- **Adult—Exposure to Surface Soil**
  - The cumulative ELCR from all carcinogenic COPCs exceeds EPA's risk management range of 1×10^{-6} to 1×10^{-4} and MDEQ's regulatory target risk of 1×10^{-5} for cumulative risk. The individual ELCR for arsenic was 2×10^{-4} for the reasonable maximum exposure (RME) scenario. The arsenic EPC was 2,256 mg/kg, which is well above MDEQ's default Action Level for Arsenic in Surface Soil (2005) of 40 mg/kg and the measured background concentrations from non-impacted areas of 75 to 162 mg/kg, indicating that risk associated with arsenic is attributable to historic mining operations.
  - The HI for noncancer effects exceeds the EPA and MDEQ regulatory threshold value of 1 with arsenic as the primary contributor (RME Hazard Quotient [HQ]=6).
  - These results indicate that there are unacceptable risks for current and future adult recreational users exposed to soil, under the exposure assumptions used. Arsenic was identified as a COC for human health.
- **Adult—Exposure to Surface Water**
  - The cumulative ELCR from all carcinogenic COPCs is within but does not exceed EPA's risk management range of 1×10^{-6} to 1×10^{-4} and exceeds MDEQ regulatory target risk of 1×10^{-5} for cumulative risk.
  - The HI for noncancer effects below the EPA and MDEQ regulatory threshold value of 1.
  - These results indicate that there are no unacceptable risks for current and future adult recreational users exposed to surface water, under the exposure assumptions used.
- **Adolescent—Exposure to Surface Soil**
  - The cumulative ELCR from all carcinogenic COPCs is within EPA's risk management range of 1×10^{-6} to 1×10^{-4} and above MDEQ regulatory target risk of 1×10^{-5} for cumulative risk. The individual ELCR for arsenic was 6×10^{-5} for the RME scenario. The arsenic EPC was 2,256 mg/kg, which is well above MDEQ's default Action Level for Arsenic in Surface Soil (2005) of 40 mg/kg and the measured background concentrations from non-impacted areas of 75 to 162 mg/kg, indicating that risk associated with arsenic is attributable to historic mining operations.
  - The HI for noncancer effects exceeds the EPA and MDEQ regulatory threshold value of 1 with arsenic as the primary contributor (RME HQ=6).

   - These results indicate that there are unacceptable risks for current and future adolescent recreational users exposed to soil, under the exposure assumptions used. Arsenic was identified as a COC.

- **Adolescent—Exposure to Surface Water**
   - The cumulative ELCR from all carcinogenic COPCs is within but does not exceed EPA's risk management range of 1×10^{-6} to 1×10^{-4} and exceeds MDEQ regulatory target risk of 1×10^{-5} for cumulative risk.
   - The HI for noncancer effects below the EPA and MDEQ regulatory threshold value of 1.
   - These results indicate that there are no unacceptable risks for current and future adolescent recreational users exposed to surface water, under the exposure assumptions used.

Excavation Workers

- The cumulative ELCR from all carcinogenic COPCs is within EPA's risk management range of 1×10^{-6} to 1×10^{-4} and above MDEQ's regulatory target risk of 1×10^{-5} for cumulative risk. The arsenic EPC was 3,685 mg/kg, which is well above MDEQ's default Action Level for Arsenic in Surface Soil (2005) of 40 mg/kg and the measured background concentrations from non-impacted areas of 75 to 162 mg/kg, indicating that risk associated with arsenic is attributable to historic mining operations.
- The HI for noncancer effects is below the EPA and MDEQ regulatory threshold value of 1.
- These results indicate that there are unacceptable risks for hypothetical excavation workers exposed to soil, under the exposure assumptions used. Arsenic and lead were identified as COCs for human health.

Hypothetical Industrial Workers

- The cumulative ELCR from all carcinogenic COPCs is within EPA's risk management range of 1×10^{-6} to 1×10^{-4} and exceeds the MDEQ regulatory target risk of 1×10^{-5} for cumulative risk. The arsenic EPC was 2,256 mg/kg, which is well above the MDEQ's default Action Level for Arsenic in Surface Soil (2005) of 40 mg/kg and the measured background concentrations from non-impacted areas of 75 to 162 mg/kg, indicating that risk associated with arsenic is attributable to historic mining operations.
- The HI for noncancer effects is below the EPA and MDEQ regulatory threshold value of 1.
- These results indicate that there are unacceptable risks for hypothetical industrial workers exposed to soil, under the exposure assumptions used. Arsenic and lead were identified as COCs for human health.

Ecological. The conclusions on risks posed to wildlife and vegetation in upland and riparian areas on and around the Crystal Mine are as follows:

- **Conclusions of Risk Estimation for Plants.** The risk evaluation for plants indicates that measured soil levels of antimony, arsenic, copper, lead, manganese, selenium, and zinc exceed screening toxicity benchmarks, indicating a potential for risk to vegetation.
- **Conclusions of Risk Characterization for Aquatic Resources.** The results of the benchmark comparisons for surface water indicate that cadmium, copper, and zinc significantly exceeded freshwater acute and chronic WQC. To a lesser extent, aluminum and lead concentrations in USG Creek were also measured at levels exceeding freshwater chronic WQC. As indicated in Table 6-4 of the RI, a substantial portion of the concentrations observed downstream of the Site are contributed by high metals concentrations discharging from the mine adit, located upgradient of USG-03 where surface water concentrations are the highest. These exceedances indicate that water quality within USG Creek is not suitable to support aquatic life. Furthermore, historical fish toxicity testing conducted within USG Creek provides empirical evidence in support of this conclusion. Considered collectively, these lines of evidence provide a strong indication that these metals in surface water in USG Creek are at levels that pose significant risk to aquatic resources.

- **Conclusions of Risk Estimation for Sediment Infauna.** The results of the effects benchmark comparisons for sediment indicate that antimony, arsenic, cadmium, lead, manganese, and silver exceed upper effects benchmarks above which adverse effects are expected. These exceedances indicate that sediment quality within USG Creek is not suitable to support sediment infauna. The benthic macroinvertebrate study conducted in 2010 within USG Creek and Cataract Creek provided empirical evidence in support of this conclusion. Furthermore, there appears to be an association between benthic macroinvertebrate impairment and metals concentrations in sediment. Considered collectively, these lines of evidence provided a strong indication that these COPECs in sediment in USG Creek and Cataract Creek near its confluence with USG Creek are at levels that pose significant risk to sediment infauna.
- **Conclusions of Risk Estimation for Mammals and Birds.** The risk evaluation of mammalian and avian wildlife indicates that the combined exposures to measured levels of metals in surface soil, sediment, and water are high enough to pose a significant risk to wildlife should they forage at the Site. The greatest risk to wildlife is from exposure to arsenic, antimony, aluminum, and lead in surface soil and arsenic in sediment, although nine metals (aluminum, antimony, arsenic, cadmium, copper, lead, selenium, silver, and zinc) exceed the EPA and MDEQ threshold value of 1 for at least one endpoint species.

Based on the results of this ERA, the contaminants with the highest potential for ecological exposure are (1) aluminum, antimony, arsenic, cadmium, copper, lead, selenium, silver, and zinc in soil and sediment; and (2) aluminum, cadmium, copper, lead, and zinc in surface water. These were identified as COCs for ecological health.

1.3 Risk Assessment Summary

Based on the findings of the risk assessment (CH2M HILL, 2013), which used a weight-of-evidence approach, multiple lines of evidence support the conclusion that exposure to COPCs in site media pose an unacceptable risk to human health and the environment. Arsenic in soils is identified as the COC of highest potential exposure for human health. The COCs with the highest potential for ecological exposure are (1) antimony, arsenic, cadmium, copper, lead, manganese, and silver in soil and sediment; and (2) cadmium, copper, and zinc in surface water. Therefore, the RI recommended that these contaminants be carried forward to the FS to determine whether remedial alternatives are necessary to address these risks. Other collocated contaminants, not identified in the RI for specific action, will also be addressed by the eventual remedial action selected.

The following media will be considered for remediation in the FS (remediation will not extend much beyond the Mammoth Claim boundary):

- Waste rock/soils associated with the Crystal Dump, Twin Ore Bins Dump, Mammoth Road, Mammoth Dump, and associated USG Creek stream bank areas.
- Groundwater expressed as an adit discharge from the lower workings of the Crystal Mine.

All building debris associated with existing structures will be properly disposed of as part of a remedial option.

- Stream sediment in USG Creek will not be specifically targeted for remedial action. Cleanup of waste rock and contaminated soils from slopes along the reach running adjacent to the east side of the mine, and post cleanup reconstruction of the stream channel will address contributing source materials. Sediment already transported downstream beyond the mine claim boundaries will recover naturally and be disbursed by annual runoff events that occur in this steep drainage. If appropriate, these sediments may be addressed under the Basin Watershed OU2 remedy.

SECTION 2

2. Identification and Screening of Technologies

2.1 Introduction

2.1.1 Remedial Action Objectives

A goal of this focused RI/FS process is to define the nature and extent of contamination at the Site and develop appropriate remedial alternatives for selection as an interim action in accordance with CERCLA criteria. Alternatives must be protective of human health and the environment, contribute to ARARs compliance, and rank highly when evaluated against the following additional seven criteria: (1) long-term effectiveness and permanence; (2) reduction of toxicity, mobility, and volume through treatment; (3) short-term effectiveness; (4) implementability; (5) cost; (6) state acceptance; and (7) community acceptance.

Preliminary remedial action objectives (PRAOs) and preliminary remediation goals (PRGs) for the Crystal Mine are described in the followings sections. The general cleanup objectives and goals identified in this FS are common for cleanup actions at abandoned hard rock mine sites. As site-specific information becomes available during the RI/FS, the PRAOs and PRGs are formulated. Final remedial action objectives and final remediation action goals will be identified in the ROD for this site.

2.1.2 Applicable or Relevant and Appropriate Requirements

Section 121 of CERCLA, the NCP (40 CFR Part 300), and EPA guidance and policy require that interim remedial actions contribute to compliance with ARARs. These requirements are threshold standards that any selected remedy must meet during and upon completion of the remedial action.

A requirement under environmental laws may be either “applicable” or “relevant and appropriate” to a site-specific remedial action, but not both. Identification of ARARs must be done on a site-specific basis, and requirements are further identified as applicable or relevant and appropriate.

Applicable requirements refer to those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations under federal or state law that specifically address hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances found at a CERCLA site. Only those state standards more stringent than federal standards, identified in a timely manner, and applied consistently may be applicable.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements under federal environmental or state environmental citing laws that, while not “applicable” to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a CERCLA site, address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to the particular site. Only those state standards more stringent than federal standards, identified in a timely manner and applied consistently, may be relevant and appropriate.

The NCP identifies three classifications of ARARs: chemical specific, action specific, and location specific. As part of the RI/FS, potential federal and state ARARs are identified. A summary of potential ARARs is provided in Appendix B. Potential chemical-, action-, and location-specific requirements for the Crystal Mine OU5 site are as follows:

- **Chemical-Specific ARARs.** Federal and state health- or risk-based numeric standards that are promulgated for site-specific media. They represent the maximum allowable concentration of a chemical that may remain onsite and still protect against unacceptable risks to human health and the environment. Chemical-specific ARARs exist for surface water and groundwater, but do not exist for waste rock, tailings, soils, or sediments.

- **Action-Specific ARARs.** Technology- or activity-based requirements or limitations on remedial actions taken with respect to hazardous waste. These requirements are triggered by the selection of particular remedial activities.

- **Location-Specific ARARs.** Statutory or regulatory restrictions on the management of hazardous substances or on the conduct of remedial activities in specific locations. Locations of special interest include: flood plains, wetlands, historic and culturally sensitive places, and sensitive ecosystems and habitats.

It should be noted that the scope of this FS is limited to the Site. As previously discussed, the Site is located within the 77-square-mile Basin Watershed Operable Unit. Remedial alternatives retained in the FS were chosen for their ability to mitigate human health and ecological risk associated with media at the Site. Implementation of preferred remedial alternatives will contribute to the overall compliance with ARARs for the Basin Watershed OU2. However, a full assessment of such compliance will be deferred until a ROD for the entire Basin Watershed is prepared.

2.1.3 Preliminary Remedial Action Objectives

PRAOs are media-specific objectives for protecting human health and the environment. They address various chemicals of concern, media of concern, exposure pathways and receptors, current and likely future land and water uses, and preliminary remediation goals. Proposed PRAOs for the Site as defined by EPA include the following:

2.1.3.1 Groundwater

Groundwater is believed to be transmitted through bedrock fractures and into the underground workings. This groundwater then discharges from the lower adit as AMD. This discharge presently intercepts and degrades USG Creek, which is a tributary to Cataract Creek and eventually the Boulder River. Proposed PRAOs for groundwater are:

- Groundwater migrates through the bedrock fractures into the underground mine workings. Methods for diverting source water from the mine workings will be considered, if practical.
- Prevent or control groundwater discharge containing COCs such that surface water standards can be met in Cataract Creek.
- Reduce concentrations of COCs in site groundwater such that state groundwater standards are met for the Basin Watershed OU2, including nondegradation standards.

Formal groundwater quality objectives will be determined by the Basin Watershed OU2 remedy. In the interim, remedial action at the Site will strive to achieve Montana groundwater quality standards to the maximum extent practicable.

2.1.3.2 Surface Water

MDEQ classifies water quality in Cataract Creek as a B1 stream. This classification states that the water quality of the stream must be sufficient to support recreational activities such as bathing and swimming; growth and propagation of salmonid fishes and associated aquatic life and other wildlife; agricultural and industrial water supply; and drinking and culinary purposes (after conventional treatment).

From a human health standpoint, Cataract Creek does not currently meet the requirements for suitable drinking or culinary and food processing use. Cataract Creek appears on MDEQ's 303(d) list for exceedances of water quality standards set for arsenic, copper, lead, mercury, and zinc. Because of these characteristics, the surface water PRAOs proposed for USG Creek are as follows:

- Surface water, in the form of snow melt and precipitation, infiltrates through the bedrock fractures into the underground mine workings. Diversion of potential source water away from the mine workings will be considered, if practical.
- Prevent release of COCs to surface waters that result in unacceptable dermal and incidental risks for visitors and recreationists.
- Prevent release of COCs to surface waters that result in unacceptable risks to terrestrial and aquatic species.

2.1.3.3 Mine Wastes and Soils

The nature and extent of mine waste and impacted soils at the Site are defined by the RI and are significant for a number of COCs. The PRAOs for mine waste and soils are as follows:

- Prevent or reduce human exposure to soils/waste rock contaminated with COCs where incidental ingestion, dust inhalation, or direct contact would pose an unacceptable health risk.
- Prevent or reduce unacceptable risk to ecological systems (including aquatic and terrestrial) from contaminated waste rock/soils containing elevated levels of metals (arsenic, cadmium, copper, lead, and zinc).

2.1.3.4 Stream Sediments

The nature and extent of contaminated sediments in USG Creek is delineated in the RI and represent considerable exposure to ecological receptors. As previously described, stream sediments will not be actively remediated beyond the southern boundary of the Site. Removal of source materials along the mine reach and natural recovery of sediments downstream will be used to mitigate risk to the aquatic environment. The PRAO for sediment in the mine area is as follows:

- Prevent or reduce unacceptable risk to ecological systems (including aquatic and terrestrial) degraded by contaminated sediment containing elevated levels of metals (arsenic, cadmium, copper, lead, and zinc). Prevent further migration of Site-contaminated source materials or discharges in close proximity to the creek.

2.1.4 Preliminary Remediation Goals

PRGs are medium-specific contaminant concentrations that are considered protective of human health and the environment given the possibility of exposures to human or ecological receptors. Contaminant-specific PRGs also consider the available ARARs for the site. The PRGs for human health and the environment are developed for each of the identified COCs using the same exposure assumptions as used in the baseline risk assessment for the Site. The PRGs proposed in this document serve as guidelines. EPA typically considers excess cancer risks below 1E-06 to be small, and risks above 1E-04 to be large enough that some form of remediation is necessary. Acceptable cancer risks generally fall within the range of 1E-04 and 1E-06, although this is evaluated on a case-by-case basis. The 1E-06 risk level is the point of departure for determining remediation goals for alternatives when ARARs are neither available nor sufficiently protective because of the presence of multiple contaminants or multiple pathways of exposure (NCP 300.430(e)(2)(i)(A)(2)), although higher risk levels (for example, the 1E-05 cumulative excess lifetime cancer risk that Montana DEQ uses) may be used on a case-by-case basis. In the case of the Crystal Mine, the HHRA total cancer risk is the sum of the risks by oral and inhalation exposure routes. Subsequent text summarizes proposed remediation goals, by media, based on exposure risks considered by the risk assessment.

Final remediation goals will be selected by EPA after review of available data and information including: final risk assessment documents, anticipated effectiveness of proposed cleanup alternatives, and other remedy selection criteria such as public and State preferences. PRGs proposed for surface water, groundwater, mine wastes, and soils for the Site are presented in the following text.

2.1.4.1 Groundwater

The PRGs for groundwater are based on the MDEQ Circular DEQ-7 (2012a) standards.

- Formal groundwater quality goals will be determined by the Basin Watershed OU2 remedy. In the interim, remedial action at the Site will strive to achieve Montana groundwater quality standards to the maximum extent practicable.

2.1.4.2 Surface Water

PRGs for surface water are based on the State of Montana's water quality standards, defined in MDEQ Circular DEQ-7 (2012). The surface water PRGs are intended to provide for potential surface water use in compliance with State B1 classification at the confluence of USG Creek and Cataract Creek. If human health drinking water standards and aquatic life standards exist for the same contaminant, the more restrictive of the standards will be used as the State's surface water quality cleanup standard. The PRGs for surface water, at a point of compliance located approximately a quarter mile downstream from the discharge of any treatment system, are as follows:

- MCLs or state human health standards for all COCs downstream of the confluence of USG Creek and Cataract Creek.
- Acute and chronic aquatic life criteria for all COCs in surface water downstream of the confluence of USG Creek and Cataract Creek.

Table 2-1 identifies the State of Montana Water Quality Standards for both surface and groundwater. These standards are to be the PRGs for USG Creek downstream of the Site. Table 2-1 also identifies the National Surface Water Quality standards. The State of Montana surface water standards are to be the primary PRGs for USG Creek downstream of the Site. The National Surface Water Quality standards are to be supplementary PRGs to the State of Montana standards.

TABLE 2-1
Montana Water Quality Standards National Surface Water Quality Criteria

	State of Montana Standards [2]				National Recommended Water Quality Criteria—Aquatic Life[3,c]		
	Human Health Standards		Aquatic Life				
Analyte	**Surface Water**	**Groundwater**	**Acute**	**Chronic**	**Acute**	**Chronic**	**EPA Surface Water[1]**
Aluminum	---	---	0.75	0.087	0.75	0.087	0.087
Antimony	0.0056	0.006	---	---	---	---	0.03
Arsenic	0.01	0.01	0.34	0.15	0.34	0.15	0.005
Cadmium	0.005	0.005	0.00052	0.000097	0.0008[a]	0.00012[a]	0.00025
Copper	1.3	1.3	0.00379	0.00285	0.0052[a]	0.0038[a]	0.009
Iron	---	---	---	1	---	---	0.3
Lead	0.015	0.015	0.01398	0.000545	0.021[a]	0.0008[a]	0.0025
Manganese	---	---	---	---	---	---	0.12
Nickel	0.1	0.1	0.145	0.0161	0.20[a]	0.022[a]	0.052
Selenium	0.05	0.05	0.02	0.005	---	0.0050[b]	0.001
Silver	0.1	0.1	0.000374	---	0.0032[a]	---	0.0032
Thallium	0.00024	0.002	---	---	---	---	0.0008
Zinc	2	2	0.037	0.037	0.05[a]	0.05[a]	0.12

Notes:

[1] EPA Freshwater Screen Benchmarks (milligrams per liter [mg/L]) (2012). Available at http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fw/screenbench.htm.

[2] DEQ-7 Montana Numeric Water Quality Standards (MDEQ, 2012a)

[3] Freshwater standards from EPA (2009b), National Recommended Water Quality Criteria (NRWQC) for Priority Pollutants.

[a] The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to the minimum hardness reported in Uncle Sam Gulch of 36.6 mg/l as CaCO3 (Data source: USGS Station 461904112144401 [mouth of Uncle Sam Gulch], 1998 – 2007). Criteria values for other hardness may be calculated from the following:

CMC (dissolved) = exp(mA[ln(hardness)]+bA) (CF), or CCC (dissolved) exp (mC[ln(hardness)] + bC) (CF)

[b] This recommended water quality criterion for selenium is expressed in terms of total recoverable metal in the water column. It is scientifically acceptable to use the conversion factor (0.996 – CMC or 0.922 – CCC) that was used in the GLI (60 FR 15393-15399, March 23, 1995; 40 CFR 132 Appendix A) to convert this to a value that is expressed in terms of dissolved metal.

[c] Metals are stated as dissolved unless otherwise specified.

Units are all reported in mg/L

2.1.4.3 Stream Sediments

The PRGs for COCs in stream sediments in USG Creek adjacent to the Site address potential risks to benthic infaunal communities, and are provided in Table 2-2.

TABLE 2-2
Sediment Preliminary Remediation Goals for Benthic Infauna

Sediment COPEC	Units	Probable Effects Concentrations/Cleanup Screening Levels	Source
Arsenic	mg/kg	33.0	McDonald, et al 2000
Cadmium	mg/kg	5.4	McDonald, et al 2000
Copper	mg/kg	149	McDonald, et al 2000
Lead	mg/kg	128	McDonald, et al 2000
Nickel	mg/kg	48.6	McDonald, et al 2000
Zinc	mg/kg	459	McDonald, et al 2000

These PRGs are derived from probable effects threshold concentrations (PECs) from the sources listed in the table. Sediment PRGs protective of recreational users or wildlife from exposure to site COCs are the same as those provided for soil, presented in the next subsection.

2.1.4.4 Mine Wastes and Soils

The PRGs for mine waste and soils address potential risks to site workers, recreational visitors, and wildlife from exposure to site COCs.

Note: Current and future land use identified during the RI for the Site indicated that residential use is not practical; therefore, children were not assessed as a specific Human Health receptor party. It is expected that adolescents potentially using the site are old enough to accompany adults for recreation using ATVs and hiking. This determination was made by considering the lack of nearby residences and the steep topography, surface obstacles, and remoteness of the site.

Human health PRGs for mine waste, soil, and dust are derived for arsenic—the only COC identified. Details regarding the exposure assumptions for these potentially exposed populations are presented in the RI Report. The approach and equations used for calculating PRGs for arsenic are consistent with EPA guidance in *Risk Assessment Guidance for Superfund—Volume I: Human Health Evaluation Manual* (Part B: Development of Risk-Based Preliminary Remedial Goals) (1991). PRGs are calculated for the range of risks allowed by CERCLA regulations: ELCR = 10^{-6}, 10^{-5}, and 10^{-4}, and HQ = 1. Table 2-3 presents the PRGs derived for arsenic.

TABLE 2-3
Soil Arsenic Preliminary Remediation Goals for Human Health

	Preliminary Remediation Goal for Arsenic (mg/kg)							
	ELCR=1 × 10^{-6}		ELCR=1 × 10^{-5}		ELCR=1 × 10^{-4}		HQ=1	
Exposure Scenario	RME	CTE	RME	CTE	RME	CTE	RME	CTE
Recreational User – Adult (ATV User Scenario)	17	299	167	2.993	1,667	29,933	418	3,866
Recreational User – Adolescent (ATV User Scenario)	48	809	477	8,088	4,773	80,877	393	3,578
Recreational User – Adult (non-ATV; for example, hiker)	119	1,774	1,193	17,744	11,933	177,439	17,999	134,413
Recreational User – Adolescent (non-ATV; for example, hiker)	124	1,845	1,241	18,445	12,412	184,450	4,759	35,403

TABLE 2-3
Soil Arsenic Preliminary Remediation Goals for Human Health

	Preliminary Remediation Goal for Arsenic (mg/kg)							
	ELCR=1 × 10^{-6}		ELCR=1 × 10^{-5}		ELCR=1 × 10^{-4}		HQ=1	
Exposure Scenario	RME	CTE	RME	CTE	RME	CTE	RME	CTE
Excavation Worker	236	3,111	2,357	31,108	23,566	311,076	9,922	19,845
Hypothetical Industrial Worker	48	358	475	3,580	4,754	35,803	7,371	14,160

Notes:
Arsenic Background Range = 7.6 to 162 mg/kg
ELCR = excess lifetime cancer risk
HQ = noncancer hazard quotient

The lowest human health PRGs are for recreational user scenarios that assume ATV riding occurs regularly at the Crystal Mine. The risk from this scenario (described in the RI) is largely driven by exposure through inhalation. During the RI, the particulate emissions factor (PEF) (dust in the air) for ATV users was assumed to be much higher than the standard PEF. A PEF of 8.47 × 10^5 m^3/kg for this scenario was derived for EPA Region 8 (SRC, 2009) was applied for both the RME and CTE scenarios. EPA's default PEF of 1.36 × 10^9 m^3/kg was used for all other exposure scenarios. To account for potential land use restrictions or remedial designs that would significantly reduce or prevent ATV use, PRGs were calculated for recreational users using EPA's default PEF. These levels are intended to be protective of recreationalists that are not regularly using ATVs at the Crystal Mine (for example, hikers).

Ecological PRGs for mine waste, soil, and dust are derived for aluminum, antimony, arsenic, cadmium, copper, lead, selenium, silver, and zinc, which were the COCs identified (Table 2-4). PRGs are developed for the wildlife species determined to be most sensitive to each COC, as documented in the BERA of the RI Report, and represent toxicity levels ranging from the no observed adverse effect level (NOAEL) to the lowest observed adverse effect level (LOAEL). Since some of the toxicity-based PRGs listed are within the range of natural levels in soil, the background levels for each of the COCs are also provided in Table 2-4.

TABLE 2-4
Soil/Sediment Preliminary Remediation Goals for Wildlife

COPEC	Endpoint Species	NOAEL-based PRG (mg/kg)	LOAEL-based PRG (mg/kg)	Soil Background (mg/kg)	Other
Aluminum	Deer mouse	64	640	4,430 to 17,900	pH > 5.5
Antimony	Deer mouse	0.7	7.1	0.38U to 0.4	
Arsenic	Deer mouse	71	120	7.6 to 162	
Cadmium	Dusky flycatcher	0.7	1.3	0.22 to 0.38	
Copper	Dusky flycatcher	31	36	6.8 to 52	
Lead	Dusky flycatcher	13	17	9.9 to 189	
Selenium	Deer mouse	1.1	1.1	0.58U to 0.98	
Silver	Dusky flycatcher	4.0	40	0.38U	
Zinc	Dusky flycatcher	34	35	17.3 to 311	

2.2 Identification and Screening of General Response Actions, Technology Types and Process Options

The first step to developing remedial alternatives, following or concurrent with the development of remedial action objectives, requires the identification of likely response scenarios. Using the terminology that is laid out in the EPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988), these are called general response actions (GRAs). GRAs are media-specific measures that may satisfy the remedial action objectives alone or in combination.

During the development of alternatives, an initial determination is made of areas or volumes of media to which a GRA might be applied. Defining areas or volumes of media should include consideration of acceptable exposure levels and potential exposure routes, as well as site conditions and nature and extent of contamination. To account for interaction between media, response actions for areas or volumes of media are later refined after site-wide alternatives are defined and considered.

Potential treatment, resource recovery, and containment technologies that will accomplish these measures are proposed subsequent to the identification of GRAs.

> "In this step, the universe of potentially applicable technology types and process options is reduced by evaluating the options with respect to technical implementability." (EPA, 1988)

Following the identification and screening of remedial technologies, representative process options are selected to represent the remedial technology through alternative development and analyses. Process options, on a medium-specific basis and relative to specific GRAs, are screened using effectiveness, implementability, and cost.

At this stage in the development of alternatives, remedial technologies and process options may still be retained that would not necessarily meet effectiveness requirements for all media, the full site, or as standalone technologies (EPA, 1988).

2.2.1 General Response Actions

The media to be addressed at the Crystal Mine includes surface water, groundwater (adit discharge), and waste rock/soil. Division of the media of interest into these categories is based upon engineering and materials-handling considerations to make review and analyses of technologies consistent.

The following GRAs have been selected for consideration for the Site:

- **No Further Action.** Required by the NCP as a baseline comparison to other actions.
- **Institutional Controls.** Institutional controls are legal and physical restrictions intended to control or prevent present or future use and access to source areas. Institutional controls are supplemental actions, not a true alternative.
- **Monitoring.** Site monitoring (short-term and long-term) is usually a requirement of all remedies to assess the success and protectiveness of the remedy. Monitoring is a supplemental action, not a true alternative.
- **Natural Recovery.** Natural recovery refers to the use of natural processes for site cleanup. These processes include a variety of naturally occurring physical, chemical, and biological processes that can mitigate the risk of contaminants of concern.
- **In-Place Stabilization.** In-place stabilization consists of physical application of commercial products and/or natural materials to prevent migration of contaminants.
- **Containment.** Containment is a GRA used to prevent exposure to contaminated material, to control migration of constituents, and to prevent direct contact. Containment is a physical means of collecting and controlling contaminated media including soil, groundwater, and surface water.
- **Groundwater Source Control.** Upgradient groundwater management to control potential recharge to the underground mine workings. Groundwater source control is a supplemental method that, if successful, would reduce the volume of water entering the mine, interacting with sulfide minerals, bacteria, and air to produce an acidic discharge. This is not a standalone alternative.
- **Surface Water Runoff Controls.** Surface water management involves controlling surface water run-on or run-off at the Site. Surface water runoff control is a supplemental action that will help other alternatives become more successful. This is not a standalone alternative.
- **Removal/Transport/Disposal and Reclamation.** A complete or partial removal of source material (waste rock, waste soils, and the wetlands) from the Site to an approved offsite repository, and reclaim the affected area (if needed).
- **Treatment.** Treatment technologies involve the physical, chemical, or biological measures applied to source materials or contaminated media that reduce toxicity, mobility, and/or volume of contaminants present.

2.2.2 Identification of General Response Action Technologies

In this section, GRA technologies are described in more detail for use in developing remedial alternatives for groundwater, surface water, and waste rock/soils.

2.2.2.1 No Further Action

Sources are left in their existing condition with no attempt to control or cleanup planned. AMD will continue to flow out of the lower adit and contaminate USG Creek. For instance, the exposed waste rock and soil piles will continue to remain devoid of vegetation, allowing for erosion and downstream migration of contaminated waste rock and soil in surface waters and stream sediments. In compliance with the NCP, the No Further Action must be retained as an alternative for consideration as the baseline against which other alternatives are compared.

2.2.2.2 Institutional Controls

Institutional controls are non-engineered instruments, such as administrative and legal controls, that help minimize the potential for human exposure to contamination and/or protect the integrity of the remedy. Institutional controls are generally used when contamination is first discovered, when remedies are ongoing, and when residual contamination remains onsite at a level that does not allow for unrestricted use and unlimited exposure after cleanup.

Examples of institutional controls include: providing an alternative water supply to prevent the use of a contaminated water source, and land use restrictions to preclude access (fencing). Institutional controls are not intended to substitute for viable engineering solutions. EPA will implement institutional controls with the existing landowner to prevent future residential development and surface and groundwater water use, preserve the integrity of the remedy when constructed, and provide access to facilitate operation and maintenance.

"The National Oil and Hazardous Substances Pollution Contingency Plan emphasizes that institutional controls, such as water use restrictions, are meant to supplement engineering controls during all phases of cleanup and may be a necessary component of the completed remedy. The NCP also cautions against the use of institutional controls as the sole remedy unless active response measures are determined to be impracticable." (EPA, 2000)

Institutional controls are considered supplemental to alternatives and will not be evaluated as a true alternative.

2.2.2.3 Monitoring

Site monitoring is usually a requirement of all remedies:

- Short-term monitoring is conducted to ensure that potential risks to human health and the environment are controlled while a site remedy is implemented.
- Long-term monitoring is conducted to measure the effectiveness of the remedy and thereby ensure that the remedy continues to be protective of human health and the environment. Long-term monitoring would include periodic inspection as necessary to determine maintenance needs.
- A monitoring plan would be developed for the selected remedial action.
- Site monitoring is considered a supplemental action to all alternatives and will not be evaluated as a true alternative.

2.2.2.4 Natural Recovery

Natural recovery refers to the use of naturally occurring processes that act together to reduce risk posed by the contaminants. Natural recovery of COCs includes a variety of physical, chemical, and biological processes that occur naturally such as dilution, sorption, and dispersion. Evaluation and assessment of the success of this activity requires long-term monitoring and is typically applied to waters. At the Site it would apply to the fate of AMD and ARD. Natural recovery processes result in reduction of toxicity, mobility, and/or volume of COCs. Natural recovery will be evaluated as an alternative.

2.2.2.5 In-Place Stabilization

In-place stabilization refers to the physical application of commercial products and/or natural materials to prevent migration of contaminants (for instance, in-situ treatment of soils with lime to increase soil pH or organic matter to increase soil water retention). In-place stabilization may apply to waste rock and soil piles located at the Site. Application of this action will be limited by the course nature, location, and size of the waste rock and proximity to the creek. In-place stabilization will be evaluated as an alternative.

Onsite disposal of contaminated waste rock/soil, which consists of building a lined repository to encapsulate wastes, may incorporate a waste stabilization treatment. During disposal, wastes may be amended with lime to mitigate low pH and potential production of ARD should the wastes be exposed to moisture within the repository or to facilitate implementation and function of an evapotranspiration cap. This response action is supplementary, and will be evaluated as part of other alternatives.

2.2.2.6 Containment—Capping

Containment by capping existing contaminated mine waste onsite is a GRA used to prevent exposure to contaminated material, control migration of constituents, and prevent direct contact. Containment is a physical means of collecting and controlling contaminated media. Capping is a proven and effective technology for providing reliable long-term containment and preventing or minimizing offsite migration of

COCs. Caps may be constructed of a variety of natural and synthetic materials. Caps may consist of a single layer or be a composite of several layers including a synthetic flexible membrane layer or clay and other soil layers. Capping provides containment in three primary ways:

- Creates a physical barrier to prevent humans, animals, and vegetation from coming into contact with contaminated materials.
- Prevents erosion of soil by surface water runoff and wind.
- A low permeability cap or vegetated soil cover reduces infiltration through waste, thereby decreasing the potential for migration of COCs from waste into groundwater and surface water.

Capping may be an appropriate technology for waste rock dumps, terraced slopes, and particularly along the banks of USG Creek (approximately 33 acres). Capping will be evaluated as an alternative.

2.2.2.7 Groundwater Source Control

Groundwater source control is interception and management of groundwater upgradient of an area of concern. This activity involves an engineered application of subsurface drains or wells with the specific purpose of intercepting/removing the water to prevent its movement into or through an area for concern. This response action is supplementary to all groundwater treatment remedial alternatives and will not be evaluated as a standalone alternative.

2.2.2.8 Surface Water Controls

Surface water management involves an engineered application to control surface water run-on or run-off at the Site for the purpose of mitigating a site condition. Surface water controls is a supplementary remedial action to all remedial alternatives and will not be evaluated as a stand-alone alternative.

2.2.2.9 Removal/Transport/Disposal and Reclamation

Remove/transport/disposal and reclamation consists of a complete or partial removal of source material (waste rock, and waste soils) including transport to and disposal at an onsite location, and reclamation of the affected area. The four waste rock dumps identified by the RI (approximately 60,000 to 70,000 yd^3) are targets for this action. Road improvement, final site grading, and reclamation with cover soil (12 to 18 inches), USFS-approved seed mix, shrubs and trees are integral to this action. Removal/transport/ disposal and reclamation will be evaluated as an alternative.

2.2.2.10 Treatment

Numerous technologies (physical, chemical, and biological) exist to treat AMD. All potential treatments would include collection of AMD discharging from the lower adit of the Crystal Mine. Potential treatment technologies to mitigate AMD include the following:

- **Active Treatment** employing a treatment plant to implement a standard technology for treating AMD (such as high-density sludge [HDS]).
- **Semi-Active Treatment**, which uses injection of quick lime to treat AMD.
- **Semi-Passive Treatment**, which consists of a series of ponds to treat AMD through pH adjustment, sulfate reduction, and clarification. Several variations of this treatment approach will be considered.

The final treatment approach may include a combination of two or more treatment strategies. Treatment will be evaluated as an alternative.

2.2.3 Evaluation of Technologies and Selection of Representative Technologies

Table 2-5 presents the seven GRAs listed above with applicable site media, remedial technology, and process options.

In the next section, the list of potentially feasible remedial technologies developed for the Site will be evaluated against the following criteria:

- **Effectiveness.** The likelihood of technology to meet remedial action objectives.
- **Implementability.** Technical and logistical feasibility of applying technology.
- **Cost.** The relative capital and operations and maintenance expenses of a technology.

Technologies retained through this process are assembled into remedial action alternatives by media for the Site in Section 3.

TABLE 2-5
General Response Actions for Surface/Groundwater and Waste Rock/Soils

Media	General Response Action	Technology Group	Process Option	Retained for Evaluation
SW/GW/WR/S	No further action	No further action	Not Applicable	Yes
SW/GW/WR/S	Institutional controls	Access restrictions	Physical barriers and signage	*
SW/GW/WR/S	Monitoring	Monitoring	Short-term	*
			Long-term	*
SW/GW	Natural recovery	Natural treatment	Physical, chemical, and biological process	No
SW/GW	Treatment	Active treatment	Conventional AMD treatment plant	Yes
		Semi-active treatment	Quick lime injection system	Yes
		Semi-passive treatment	Sulfate-reducing bioreactor with aeration and infiltration system	Yes
WR/S	In-place stabilization	Soil cover	Amended soil cover	Yes
		Phytostabilization	Vegetation /cover supplement to waste rock	No
WR/S	Containment	Capping	Liner	Yes
			No Liner	No
WR/S	Removal, transport, dispose, and reconstruction	Removal/reconstruction	Stream bank removal/reconstruction	Yes
		Waste rock disposal	Waste disposal offsite	Yes
			Waste disposal onsite	Yes
GW	Containment	Mine plugging	Construct in-mine plug	Yes
			Construct plug remotely, by drilling from surface only	Yes
GW	Groundwater Source Control	Groundwater diversion	Divert groundwater away from underground mine workings	*
SW	Surface water control	Runoff /surface water diversion	Divert snow melt and storm runoff from mine wastes	*

Notes:
*Supplemental activity, used in conjunction with other alternatives.
GW = groundwater
S = Soils
SW = surface water
WR = waste rock

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3. Development of Initial Alternatives

3.1 Screening of Initial Alternatives

In this section, the GRAs, remedial technologies, and process options retained after initial screening in Section 2.3 are further screened for suitability as remedial alternatives. These alternatives represent viable approaches to remedial action at the Site. As a first step, the actions, technologies, and options retained from Section 2.3 are further screened for use in combinations as remedial alternatives. Then the common elements that would be incorporated into multiple alternatives (except "no further action") are developed. Media-specific remedial alternatives are developed that address the individual media of concern at the Site. Then, the media-specific techniques are assembled into combined-media remedial alternatives. Alternatives developed to span the range of categories defined by the NCP are as follows:

- **No action alternative.** Site remains as is. No remedial action is applied to the Site. Water quality monitoring continues.
- **Waste rock and soils source control actions.** Alternatives in which the possible source of COCs is contained (capped), stabilized (treated in place), or removed and contained. Controlling the source can reduce the potential for direct human exposure or mobilization of COCs through run off.
- **Groundwater response actions.** Remedial alternatives that prevent groundwater from limiting the ability of streams to attain surface water quality standards by utilizing one or more different technologies.
- **Groundwater source control actions.** Alternatives that address the source of potential recharge water into the mine workings, or the conduit for AMD mobility through the mine is blocked. Controlling the water recharge source into the mine workings can reduce the volume of AMD discharging from the lower adit, and its subsequent treatment or the need for long-term management.
- **Surface Water Runoff Controls.** Alternatives that address surface water management involving surface water run-on or run-off at the Site. Surface water runoff control is a supplemental action that will help other alternatives become more successful.
- **Innovative treatment technologies.** Those technologies that offer the potential for (1) comparable or superior performance or implementability; (2) fewer or less adverse impacts than other available approaches; or (3) lower costs for similar levels of performance than demonstrated treatment technologies.

3.2 Common Elements

Remedial actions for this focused FS will not extend much beyond the Mammoth Claim boundary and are likely to include the following common elements:

- Construct surface water controls to collect and convey surface water runoff around and away from remedial features to prevent accelerated erosion.
- Source water control will be limited spatially to activities that can be implemented within the boundaries of the operable unit (mine claims). Source water control alternatives that could be applied outside the OU5 boundaries will be considered for the Basin Watershed OU2 ROD.

  During the RI for this site, source water recharge (groundwater and surface water) into the mine workings was investigated through construction of monitoring well networks, piezometers, test pits, aquifer testing, and geophysical testing. Results of these activities were incorporated into evaluations of potential interception activities (for example, horizontal drilling, new upgradient adit construction with infiltration galleries, slurry cut-off walls, and dewatering through pumping and drainage ditch arrays) with the conclusion being that a majority of the source water intercepts the mine workings through a myriad of interconnected bedrock fractures. The recharge area was determined to be extensive and impracticable to intercept given the prevalence of fractured, mineralized intrusions, and multiple faults and secondary fractures.

EPA and the State of Montana recognize that complete control of source water is not technically practicable in these highly fractured bedrock systems, and long-term treatment will be required to mitigate ongoing adit discharge. Both EPA and the State share the goal of conducting a timely, efficient, and effective remedy. For these reasons, source water control efforts for this interim ROD will be limited to those which are technically practicable to implement, and represent a reasonably expected clear net benefit when compared to cost, as described below:

Phase 1

– Review existing information and confirm extent of mine workings on the existing mine maps. Look for additional information on the extent of the mine workings. Take note of specific mine features not observed during the RI that may have “daylighted” or created a surface expression that would allow water to enter the workings.

– Perform a final site reconnaissance to find, identify, and map “daylighted” mine workings that could potentially act as a conduit for surface water into the mine. Utilize information obtained during the RI process to assist with the reconnaissance.

– Identify strategic locations for drainage ditches to capture and convey snowmelt and rainfall away from areas above the underground workings.

Phase 2

– Design seals for mine features identified in Phase 1.

– Design ditches that quickly and efficiently convey snowmelt and storm runoff away from areas above the underground workings and into adjacent drainages to limit ponding and infiltration.

Phase 3

– Construct surface seals and ditches.

– Continue to monitor lower adit discharge to gage impact on flow.

Phase 4

– Design and construct an appropriate treatment system, using flow rates adjusted after source water control actions have been implemented.

- Remove mining structures constructed on top of waste rock.
- Remove the two existing settling ponds also constructed on waste rock.
- Reconstruct a section of USG Creek impacted by waste soils.
- Implement institutional controls that limit residential use of the site.

Most alternatives share some common elements in their development. To avoid repetition, the common elements are described in this section and then referenced in the various alternatives and included as part of the remedial cost estimate where appropriate in Section 4 and Appendix C. In addition to these likely common elements, EPA will, with State concurrence, establish appropriate institutional controls to address site access for remedial action, residential development, use of water, secure long-term operation of an AMD treatment system, and other relevant issues to protect the remedy.

3.2.1 Surface Water Controls

In the immediate vicinity of the Crystal Mine, groundwater recharge into the workings of the mine appears to be constantly replenished by water from local groundwater moving through the high alpine basin north of the Site. Weathered and competent bedrock transmit water through a matrix of fractures and quartz veins throughout the bedrock profile. A small portion of this water intercepts the workings of the mine, where it acidifies and mobilizes contaminants as it interacts with the exposed mineralized zone. Because of the geologic complexity and large recharge catchment area, using surface water controls to reduce recharge of the local, shallow, water table aquifer and groundwater movement toward the workings of the mine would be impractical. Therefore, surface water control will be applied to more traditional remedial applications where stormwater flows are directed away from waste piles and construction areas to limit contact with contaminated materials and to prevent accelerated erosion in sensitive areas, such as stream banks and steep slopes. Surface water control will also discourage impoundment or pooling of water above known areas with underground workings. This will be accomplished by trenching and berming in critical areas that will be identified during remedial design.

3.2.2 Stream Bank Reconstruction

Mine waste rock impacts approximately 1,000 feet of USG Creek (see Figure 3-1 and Photographs 3-1 and 3-2). All remedial actions would include removal of waste rock along USG Creek and reconstruction of the creek to its approximate elevation and slope. The bottom of the stream would be lined with native rock and large woody debris, with step-pool design features to prevent scouring of the bottom and sides of the newly constructed stream banks. Jute matting and native vegetation would be installed to stabilize the sides of the newly constructed stream to prevent erosion.

A USFS-approved seed mix consisting of weed free grasses and forbs would be planted at all disturbed stream banks. Fallen timbers and rocks would be randomly placed in the newly constructed stream bank to accommodate natural grade, dissipate energy, and match the existing stream bank.

PHOTOGRAPH 3-1. **Waste Rock Impacting USG Creek**

PHOTOGRAPH 3-2. **Waste Rock Impacting USG Creek**

3.2.3 Removal of Ponds and Buildings

Five wood-framed structures are currently located with the mammoth dump at the Site: (1) two load-out ore bin structures below the upper portal, (2) the trestle from the lower adit, and (3) two mine support structures located below the lower adit (see Photograph 3-3). The upper ore bins and trestle sit on waste rock source materials and would be demolished (pending approval from the State Historic Preservation Office prior to demolition) to allow appropriate remediation. Non-recyclable building materials would be disposed of at the Luttrell Repository with the exception of wood debris which may be burned onsite.

Two settling ponds are located on the Site and are also constructed on waste rock (Mammoth Dump). These ponds would be drained, and sludge/sediments, and liners disposed of at the Luttrell Repository or an onsite repository to allow for remediation of underlying waste rock.

PHOTOGRAPH 3-3. **Crystal Mine Structures**

FIGURE 3-1
UNCLE SAM CREEK RECONSTRUCTION
Crystal Mine Feasibility Study

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3.3 Description of Alternatives

GRAs for groundwater and surface water discussed in Section 2.3 are summarized in Table 2-3 along with associated technologies and process options. As shown in Table 3-1, the initial process options are screened for effectiveness, implementability, and cost. Those process options that pass the initial screening are carried forward as elements of alternatives that are described in the sections to follow.

The proposed remedial alternatives and associated common remedial actions, by media, are presented in Table 3-2 and described in subsequent text.

3.3.1 Alternative 1—No Further Action

The No Further Action Alternative would involve no further remedial action or institutional controls at the Site beyond those currently in place or undertaken. This alternative would provide the baseline conditions against which the other remedial action alternatives would be compared. This alternative would include completed and ongoing actions at the Site.

Any ongoing long-term biological and surface water monitoring conducted by the MBMG, the USFS, the State of Montana, and the USGS is assumed to continue in accordance with the existing basin-wide plan under the no further action alternative.

3.3.2 Waste Rock/Soil Media

Areas of exposed waste rock would be removed, including impacted vegetation, or capped as part of any selected remediation action. Where removals intercept stream banks, the banks would be reconstructed as described in Section 3.2.2. Stream banks without impacted soils and with woody vegetation would be slated for no action or for best management practices, and land use management.

3.3.2.1 Alternative WR-1—Waste Rock Capping

The capping alternative would require covering of exposed waste rock with a flexible membrane liner, such as high-density polyethylene (HDPE) and then covering the liner with 24 inches of imported clean fill material. Prior to placing the liner the waste rock would be graded to provide control of surface water runoff, which would reduce erosion problems and eliminate ponding. Existing structures and ponds would also be removed to allow for uniform treatment of the waste rock. Overly steep slopes would most likely require regrading or terracing to allow installation of both liner and cover material.

Four areas of the Site contain waste rock that would need to be covered. The four areas are the Crystal Dump, Twin Ore Bins Dump, the Mammoth Road, and the Mammoth Dump, encompassing a total of approximately 6 acres of waste rock. Capping of the rock would then require a total of approximately 6 acres of liner material and 20,000 yd^3 of imported, clean fill material suitable for revegetation.

3.3.2.2 Alternative WR-2—Excavate and Local Disposal

In an excavate-and-dispose alternative, removals would occur on approximately 6 acres and approximately 59,500 yd^3 of waste rock would be removed.

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TABLE 3-1
Initial Screening of Technologies and Response Actions

General Response Actions	Remedial Technologies	Process Options	Description	Screening Comments
No Further Action	No action	Not applicable	No action	Required by NCP
Institutional Controls	Access restrictions	Physical barriers and signage	Installation of security fencing	Applicable only as temporary measure or as part of other remedial actions
Monitoring	Monitoring	Short-term	Monitor during remedy implementation	Potentially applicable for all WR and GW alternatives
		Long-term	Monitor post-remedy implementation	Potentially applicable for all WR and GW alternatives
Natural Recovery	Natural Treatment	Physical, chemical, biological process	Use natural process for site cleanup	Low cost. Easy to implement. Not effective at achieving PRAOs.
In-place Stabilization	Soil Cover	Amended soil cover	Amended top soil cover over waste rock to allow for revegetation	Moderate cost. Easy to implement. Not effective for achieving PRAOs.
	Phytostabilization	Phytoremediation applied to waste rock	Cover soil, lime, and organic material added to waste rock to neutralize pH and promote revegetation	Moderate cost. Moderate ease of implementation. Not effective because of short growing season, lack of organic materials in waste rock, potential lack of State acceptance
Containment	Mine plugging	Engineered plug in mine	Reopen mine and build plug	Moderate to high cost. Moderate to difficult implementation. Moderate to high effectiveness, but many uncontrollable variables associated with host and mined rock environment. Potentially applicable as a GW alternative.
		Engineered plug remote grouting	Inject concrete slurry through drilled borings to plug	High cost. Moderate to difficult implementation. Effectiveness uncertain. Potentially applicable.
	Waste rock/soil capping	Topsoil with liner	Site grading, line with clay or synthetic, cover with topsoil for revegetation	Moderate to high cost. Moderate to difficult implementation. Moderate effectiveness. Potentially applicable.
Groundwater Source Control	Groundwater Dewatering	Groundwater Diversion	Divert groundwater from reaching the mine workings (extraction wells, subsurface drains, interception adit)	High cost. Construction impracticable, given topography and location of mineralized areas.
Surface Water Control	Runoff Diversion	Runoff/surface water diversion	Divert runoff and overland flow from sensitive waste areas and USG Creek	Potentially applicable to all remedial actions.
		Grading	Site grading to control surface water runoff	Potentially applicable to all WR and GW alternatives.
		Revegetation	Control soil erosion	Potentially applicable to all WR and GW alternatives.

TABLE 3-1
Initial Screening of Technologies and Response Actions

General Response Actions	Remedial Technologies	Process Options	Description	Screening Comments
		Erosion protection	Surface water drainage control, including berms and check dams	Potentially applicable to all WR and GW alternatives.
Remove/Transport/Dispose and Reconstruction	Removal/ Reconstruction	Stream bank removal/reconstruction	Removal of waste rock along stream banks and reconstruction	Potentially applicable as part of all remedial actions.
	Waste rock disposal	Disposal onsite	Excavate and dispose of waste rock at an engineered onsite repository	Moderate cost. Easy implementation. Effective and potentially applicable.
	Waste rock disposal	Disposal onsite w/ stabilization	Amend waste rock and soil with lime as it is deposited in the onsite repository.	Moderate cost. Easy implementation. Effective and potentially applicable.
		Disposal onsite	Excavate and dispose of waste rock at the current identified wetland	Moderate cost. Moderate implementation. Not effective at addressing PRAOs.
		Disposal offsite	Excavate and dispose of waste rock at the Luttrell Repository	Moderate to high cost. Easy implementation. Highly effective. Potentially applicable.
Treatment	Active treatment	Conventional AMD treatment plant	For the purpose of this FS, conventional high density sludge HDS treatment plant is being considered for evaluation.	Moderate to high cost. Moderate implementation. Highly effective. Potentially applicable.
	Semi-active treatment	Quick-lime injection system	Installation of water-wheel lime injection system and treatment ponds	Moderate to high cost. Moderate implementation. Low effectiveness. Potentially applicable.
	Semi-passive Treatment	Sulfate reducing bioreactor (SRBR)	Installation of flow-control bulkhead, SRBR cells, and settling ponds	Low to moderate cost. Moderate to difficult implementation depending on topography and climate. Moderate to good effectiveness. Potentially applicable as GW alternative.
		SRBR with aeration, precipitation, and discharge	Installation of BCR, aeration system, oxidation/settling ponds, wetlands, and discharge	Low to moderate cost. Easy to moderate implementation depending on topography and climate. Moderate to good effectiveness. Potentially applicable as a GW alternative.

TABLE 3-2
Major Components of Alternatives

Alternatives	Remedial Design/Remedial Action s
No Further Action	• No remedial action would be implemented; site would remain in current condition.
Alternative WR-1—Waste Rock Capping	• Upgrade access roads for construction vehicles • Grade and bench waste rock in place • Cover with impervious liner and 2 feet of clean fill • Revegetate • Provide periodic monitoring • Implement applicable common remedial actions (Section 3.2)
Alternative WR-2—Excavate and Local Disposal	• Upgrade access roads for construction vehicles • Excavate waste rock and approximately 12 inches of soil beneath • Transport to Luttrell repository for disposal • Cover with 12 inches clean imported top soil • Revegetate • Provide periodic monitoring • Implement applicable common remedial actions (Section 3.2)
Alternative WR-3—Excavate and Dispose Onsite	• Upgrade access roads for construction vehicles • Excavate waste rock and approximately 12 inches of soil beneath • Construct lined repository engineered to accommodate approximately 60,000 yd^3 of waste rock • Transport to onsite repository for amendment and disposal • Cover with impervious liner and 24 inches clean imported top soil • Revegetate • Provide periodic monitoring • Implement applicable common remedial actions (Section 3.2)
Alternative GW-1—Mine Plugging through Reopened Mine Adit	• Upgrade access road for construction vehicles • Re-open lower mine portal to allow safe access into existing adit • Within the first competent section of the adit, Conduct investigations within adit (if possible) to identify seeps and areas of groundwater recharge • In the vicinity of the plug location, conduct geologic investigations through fractured rock to determine effectiveness of plug • Construct concrete plugs near the lower adit portal • Drill and inject grout curtain around plugs • Drill/construct a relief well for overflow if stored water in adit approaches elevation of upper adit • Provide post construction erosion control • Periodic regrout of curtains around plugs • Provide periodic monitoring of site • Implement applicable common remedial actions (Section 3.2)
Alternative GW-2—Mine Plugging through Borings from the Surface	• Upgrade access road for construction vehicles • Drill borings from surface down to mine adit through competent bedrock • Conduct investigations within adit (if possible) to identify seeps and areas of groundwater recharge • Conduct geologic investigations through fractured rock to determine effectiveness of plug • Remotely collapse mine tunnel to form ends of plug • Construct one concrete plug (lower workings) • Drill and inject grout curtain around plug • Provide post construction erosion control • Periodic regrout of curtains around plug • Provide periodic monitoring of site • Implement applicable common remedial actions (Section 3.2)

TABLE 3-2
Major Components of Alternatives

Alternatives	Remedial Design/Remedial Action s
Alternative GW-3—Active Treatment of AMD	• Upgrade access road for construction and maintenance vehicles • Provide power to site for treatment plant operation • Excavate and grade for treatment plant pad • Construct treatment plant • Re-open mine portal to allow safe access into adit • Construct one concrete mine bulkhead with no grout curtain • Construct AMD collection and distribution pipe network • Provide post construction erosion control • Construct and continuously operate a treatment plant to treat perennial discharge • Periodic delivery of lime • Periodic disposal of treatment plant generated sludges at Luttrel Repository • Periodic sampling and analysis of treatment plant influent and effluent • Implement applicable common remedial actions (Section 3.2)
Alternative GW-4—Semi-Active Treatment of AMD (Quicklime Injection System)	• Upgrade access road for construction and maintenance vehicles • Construct concrete pad for injection system • Re-open mine portal to allow safe long-term restricted access into adit • Construct one concrete mine bulkhead with no grout curtain • Excavate and grade site for downgradient settling ponds • Construct lined settling ponds • Construct lined and riprapped mixing channel • Construct AMD collection and distribution pipe network • Construct semi-active quicklime injection system • Provide post construction erosion control • Provide periodic monitoring of site • Periodic sampling and analysis of treatment system influent and effluent • Periodic pipe network flushing • Periodic disposal of treatment system sludges at Luttrel repository • Periodic lime delivery • Implement applicable common remedial actions (Section 3.2)
Alternative GW-5—Semi-Passive Treatment of AMD (SRBR)	• Upgrade access road for construction and maintenance vehicles • Re-open mine portal to allow safe long-term restricted access into adit • Construct one concrete mine bulkhead with no grout curtain • Excavate and grade site for downgradient pH adjustment pond, SRBR cells, and clarification pond • Construct lined pH adjustment pond • Construct SRBR cells • Construct lined clarification pond • Construct AMD collection and distribution pipe network • Provide post construction erosion control • Provide periodic monitoring of site • Periodic sampling and analysis of treatment system influent and effluent • Periodic pipe network flushing • Rototill pH adjustment pond approximately every 2 years • Replace pH adjustment pond approximately every 6 years • Replace SRBR cells approximately every 15 years • Periodic collection and disposal of treatment system sludges at Luttrel repository • Implement applicable common remedial actions (Section 3.2)

TABLE 3-2
Major Components of Alternatives

Alternatives	Remedial Design/Remedial Action s
Alternative GW-6—Semi-Passive Treatment of AMD (SRBR, Aeration System, Oxidation/Settling Ponds, Wetlands, and Discharge)	• Upgrade access road for construction and maintenance vehicles • Excavate and grade site for downgradient SRBR cells, aeration systems, oxidation/settling ponds, wetlands, and discharge to creek • Construct AMD collection and distribution pipe network • Construct lined SRBR cells • Construct aeration channels • Construct lined oxidation/settling ponds • Construct aerobic wetland basin • Construct discharge channel • Provide post construction erosion control • Provide periodic monitoring of site • Periodic sampling and analysis of treatment system influent and effluent • Periodic pipe network flushing • Replace limestone in SRBR approximately every 10 to 15 years • Periodic collection and disposal of treatment system sludges at Luttrel repository • Implement applicable common remedial actions (Section 3.2)

Soil would be removed to 12 inches below the bottom of the waste rock to ensure removal of all impacted soils. Removal areas are shown in Figures 3-2, 3-3, 3-4, and 3-5. Alternative WR-2 specifically includes the following actions:

- Excavation of the following waste rock areas: Crystal Dump, Twin Ore Bins Dump Area, Mammoth Road Area, and Mammoth Dump Area.
- Excavation of potentially contaminated soils up to 12 inches deep below each of the four waste rock areas.
- Import of approximately 10,000 yd^3 of replacement soils 12 inches thick to allow for revegetation of all excavated areas.

Excavated material would be placed in the local Luttrell Repository. Three haul routes were evaluated: Basin Road (26 miles round trip), Jack Creek (21 miles round trip), and Cataract Creek (36 miles round trip). Figure 3-6 shows the likely haul route after consideration of haul distance, truck size, anticipated road improvements and maintenance, and public safety. Approximately 10,000 yd^3 of replacement soil would come from offsite soil borrow sources.

Removal Locations. Figures 3-2, 3-4, and 3-5 show the locations of the areas to be excavated and replaced.

Backfill Quantities. Amended soil from an offsite source would be required to provide surface soil to allow for vegetation seeding and growth over newly excavated areas within the Site. Approximately 6 acres of surface area will be exposed as a result of the removal of waste rock, requiring approximately 10,000 yd^3 of top soil for vegetative growth.

3.3.2.3 Alternative WR-3—Excavate and Dispose Onsite

This alternative is similar to WR-2 with the following exceptions:

- An onsite lined repository would be constructed in the vicinity of the Crystal trench. This area is covered by a liner and fill placed over the liner during a previous TCRA. The repository would be properly engineered to provide adequate capacity to permanently accommodate waste rock from the Crystal Dump, Twin Ore Bins Dump (see photo 3-4), the Mammoth Road, and Dump, plus 12 inches of contaminated soil over excavation (approximately 60,000 yd^3) (see Figure 3-7 and Figure 3-8).

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FIGURE 3-2
TWIN ORE BINS DUMP AREA
Crystal Mine Feasibility Study

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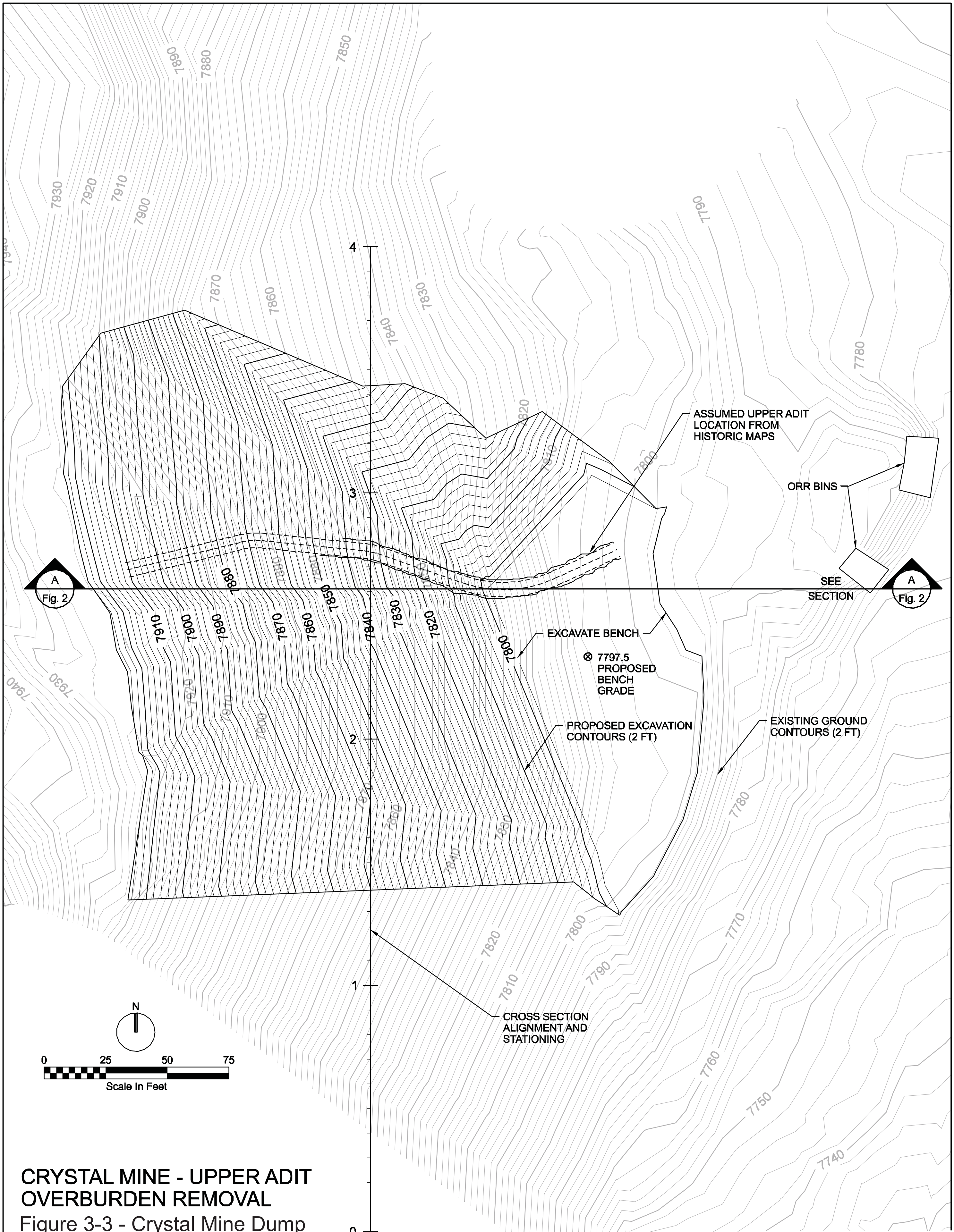

CRYSTAL MINE - UPPER ADIT OVERBURDEN REMOVAL

Figure 3-3 - Crystal Mine Dump

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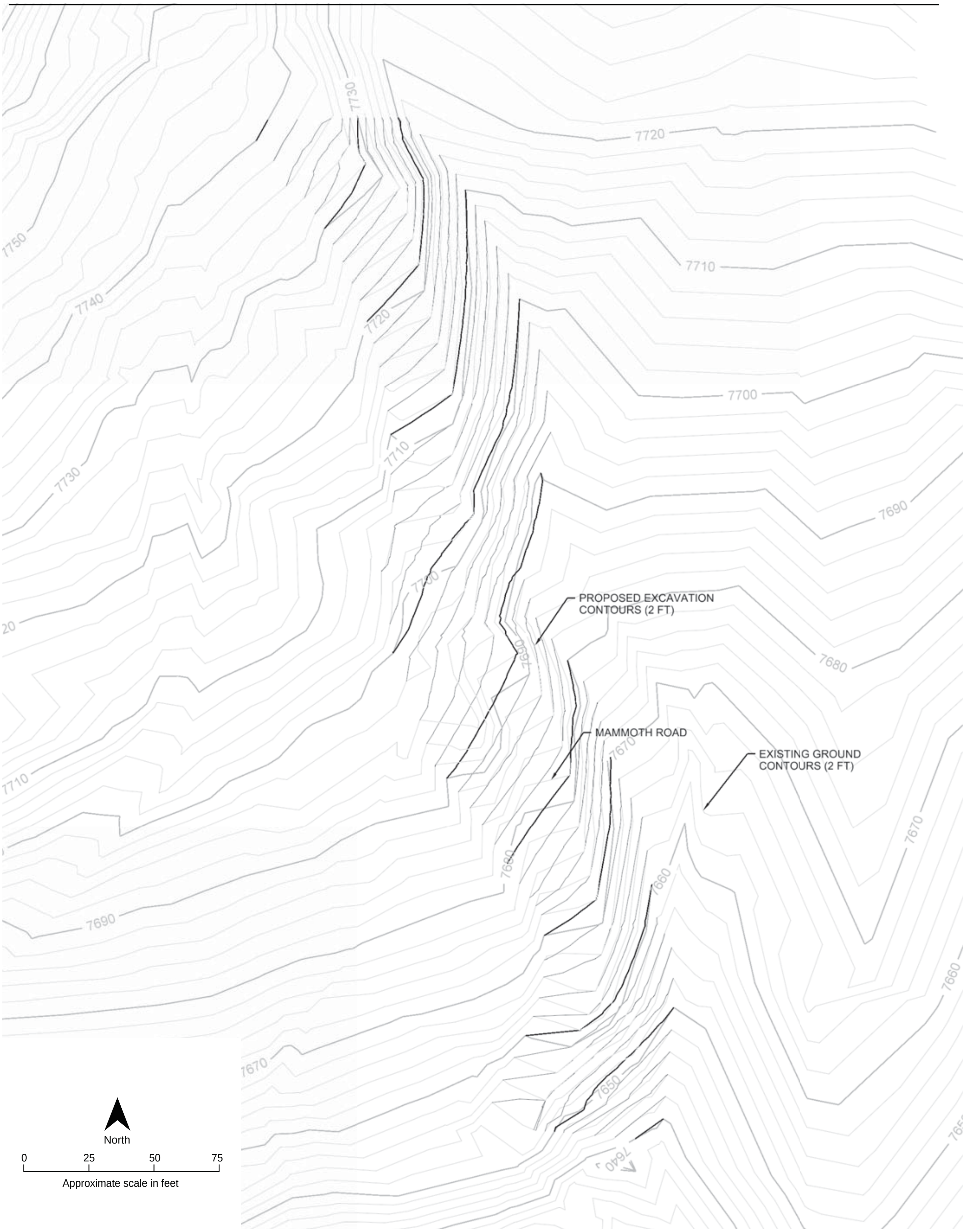

FIGURE 3-4
MAMMOTH ROAD AREA
Crystal Mine Feasibility Study

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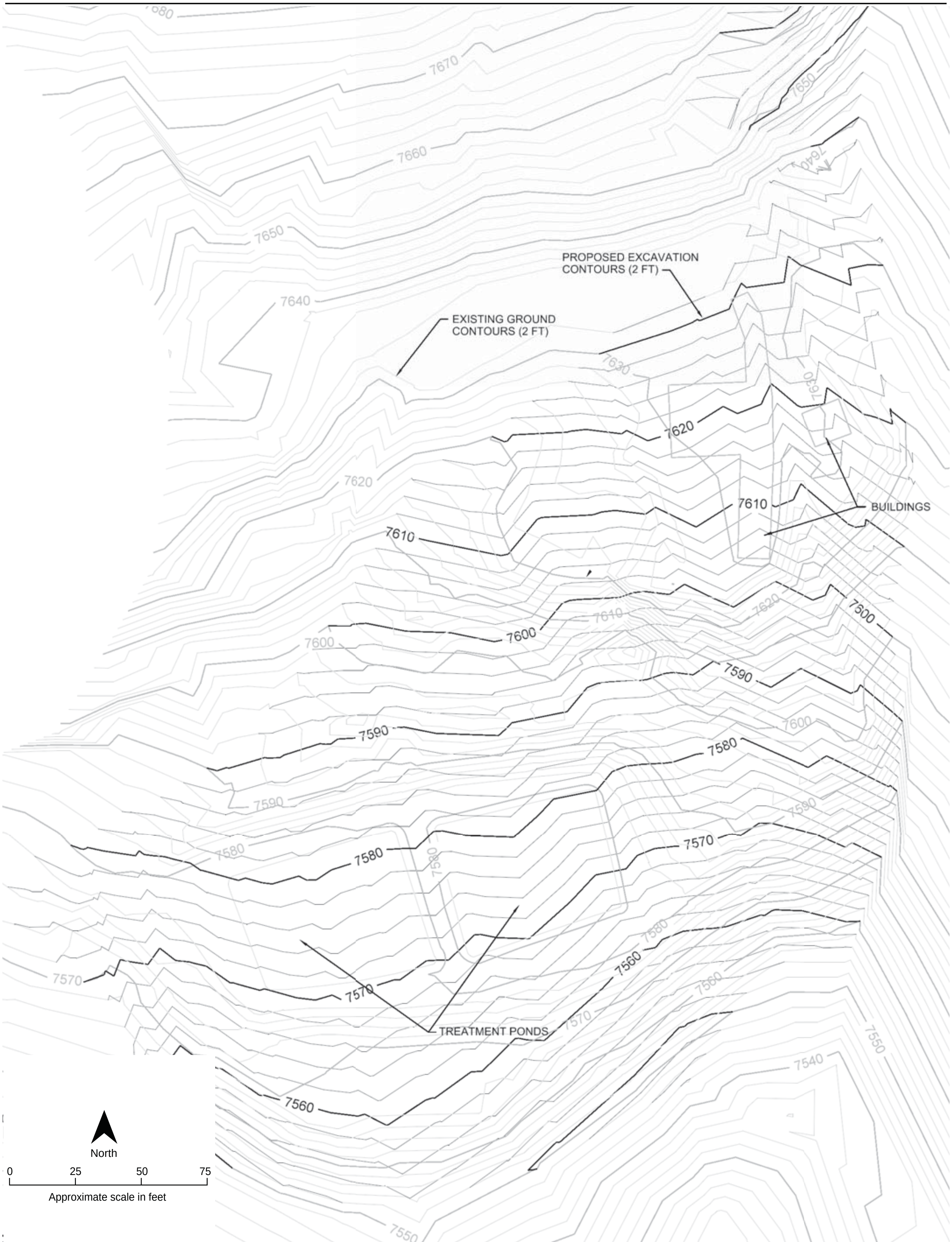

FIGURE 3-5
MAMMOTH DUMP AREA
Crystal Mine Feasibility Study

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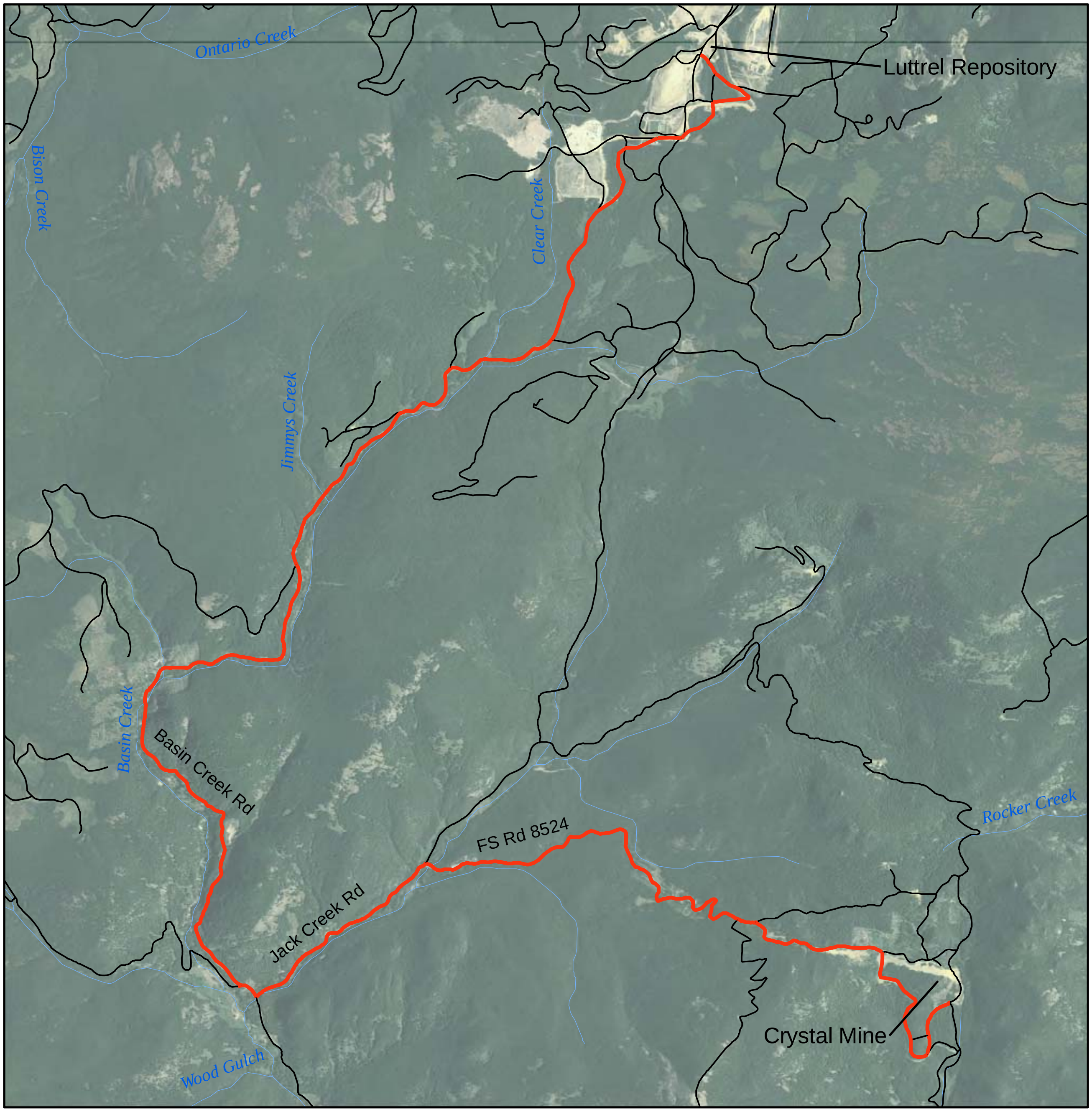

VICINITY MAP

LEGEND

- Haul Route
- Road MDOT
- NHD Stream

North

0 2,500 5,000

Approximate scale in feet

FIGURE 3-6
PROPOSED HAUL ROUTE FROM CRYSTAL MINE TO LUTTREL REPOSITORY
Crystal Mine Feasibility Study

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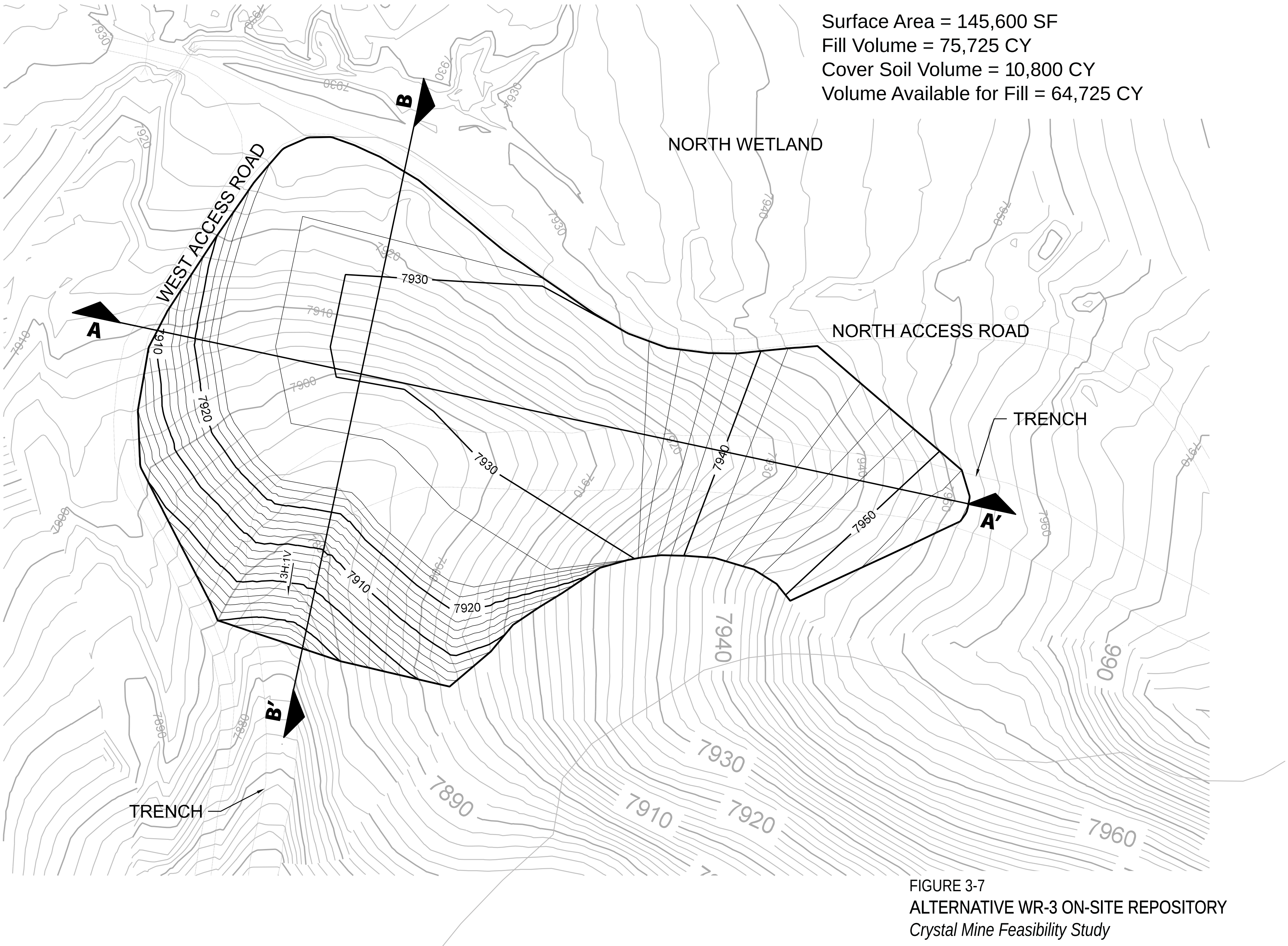

FIGURE 3-7
ALTERNATIVE WR-3 ON-SITE REPOSITORY
Crystal Mine Feasibility Study

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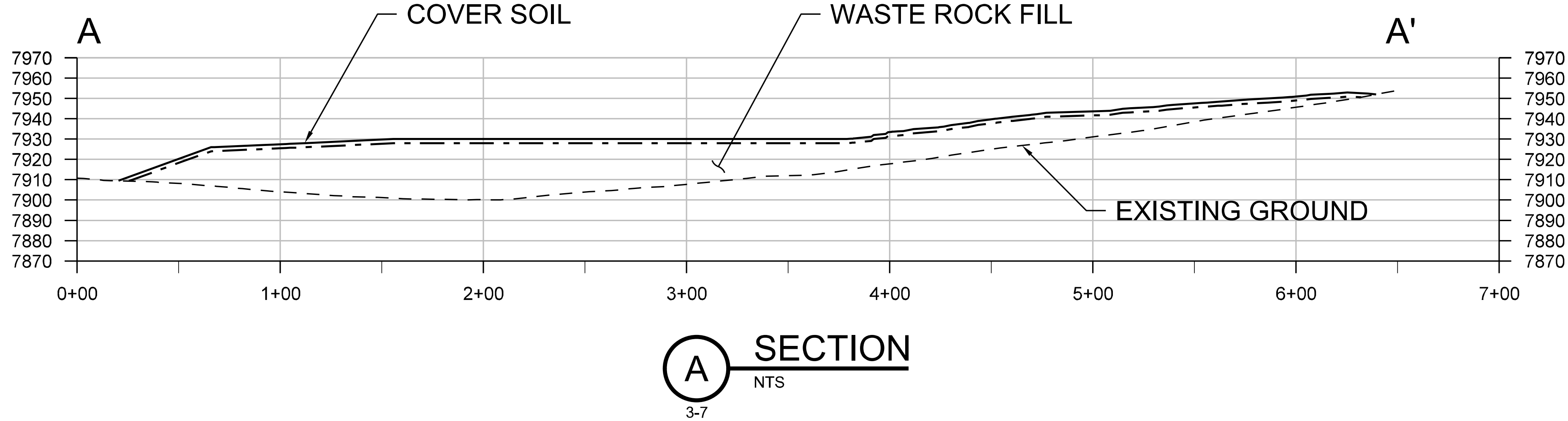

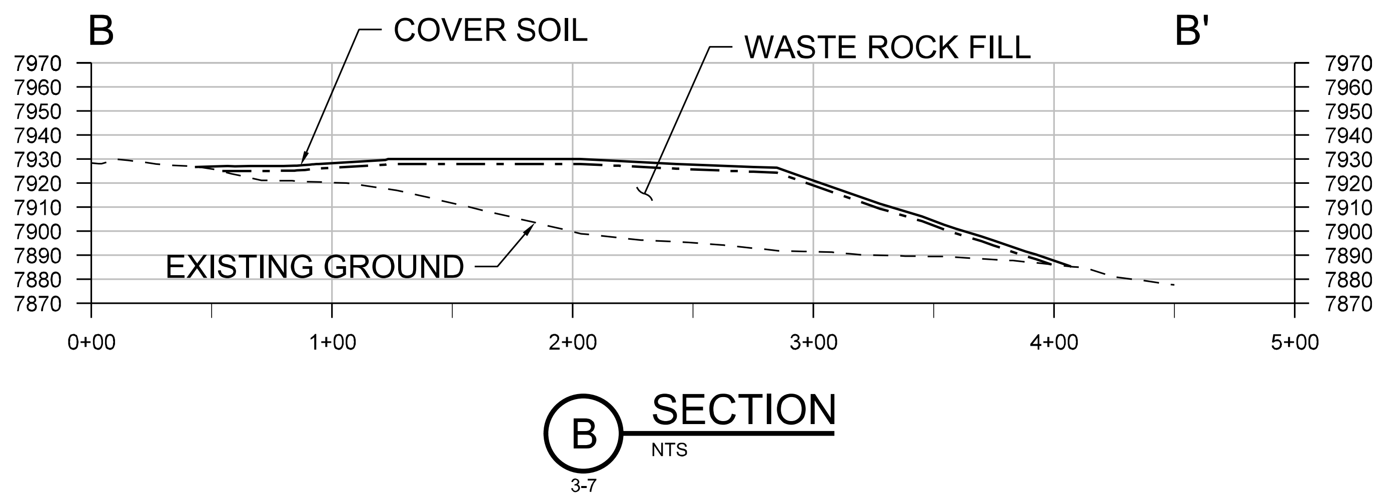

FIGURE 3-8
ALTERNATIVE WR-3 ON-SITE REPOSITORY
CROSS SECTIONS
Crystal Mine Feasibility Study

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- An onsite loop road would be upgraded and used to transport the material to the repository (see Figure 3-9).
- Upon filling, the repository would be capped with an impermeable liner and covered with 24 inches of cover and top soil and revegetated. Approximately 11,000 yd^3 of cover and top soil would be needed from a borrow source.
- The Crystal Dump (approximately 1.3 acres) would be removed to the onsite repository. The remaining hillside will be terraced and capped with approximately 4,200 yd^3 of cover and top soil from a borrow source and revegetated.
- Approximately 7,500 yd^3 of replacement soil (12 inches thick) would be required to cover all excavated waste rock areas.

PHOTOGRAPH 3-4. **The Crystal Dump at the East End of the Trench (Background) Covering the Upper Crystal Mine Portal and the Twin Ore Bins Dump (Foreground)**

Backfill Quantities. Soil from an offsite source would be required for backfill and revegetation over newly excavated areas within the Site. It is assumed that a borrow area would be located within a 5-mile radius of the Site and would be located on USFS property, requiring consultation and permitting. Approximately 7,500 yd^3 of borrow material would be transported and placed onsite. After completion, the borrow area would be reclaimed and vegetated.

3.3.3 Groundwater Media

Groundwater (GW) media alternatives would either block the flow of AMD from the adit, or, control and treat the flow before it enters receiving waters. Two alternatives are considered for blocking the flow of AMD. Both involve sealing the mine adit with an engineered plug. One approach would reopen the lower cross-cut adit to strategically place a plug in competent rock to seal the lower mine workings. The other would install a plug in the lower workings remotely through directional drilling and grouting from the surface.

Four treatment options are also evaluated. Three control the flow of AMD by blocking the adits and piping water to a treatment facility. One utilizes free flowing discharge from the lower adit. Treatment options vary from an active, fully staffed plant to an unstaffed passive system. The alternatives proposed represent viable remedial options for site cleanup. The options have been carried through a conceptual design stage in order to prepare a relative cost estimate for construction and operation. A conceptual design stage also facilitates evaluation and differentiation by EPA threshold and balancing criteria, as well as a direct comparison among other remedial options. Selection of a preferred alternative will be presented in a Proposed Plan, with a remedy being selected in the ROD. Actual design and engineering of the remedy follows approval of the ROD.

3.3.3.1 Alternative GW-1—Mine Plugging Through Reopened Mine Adit

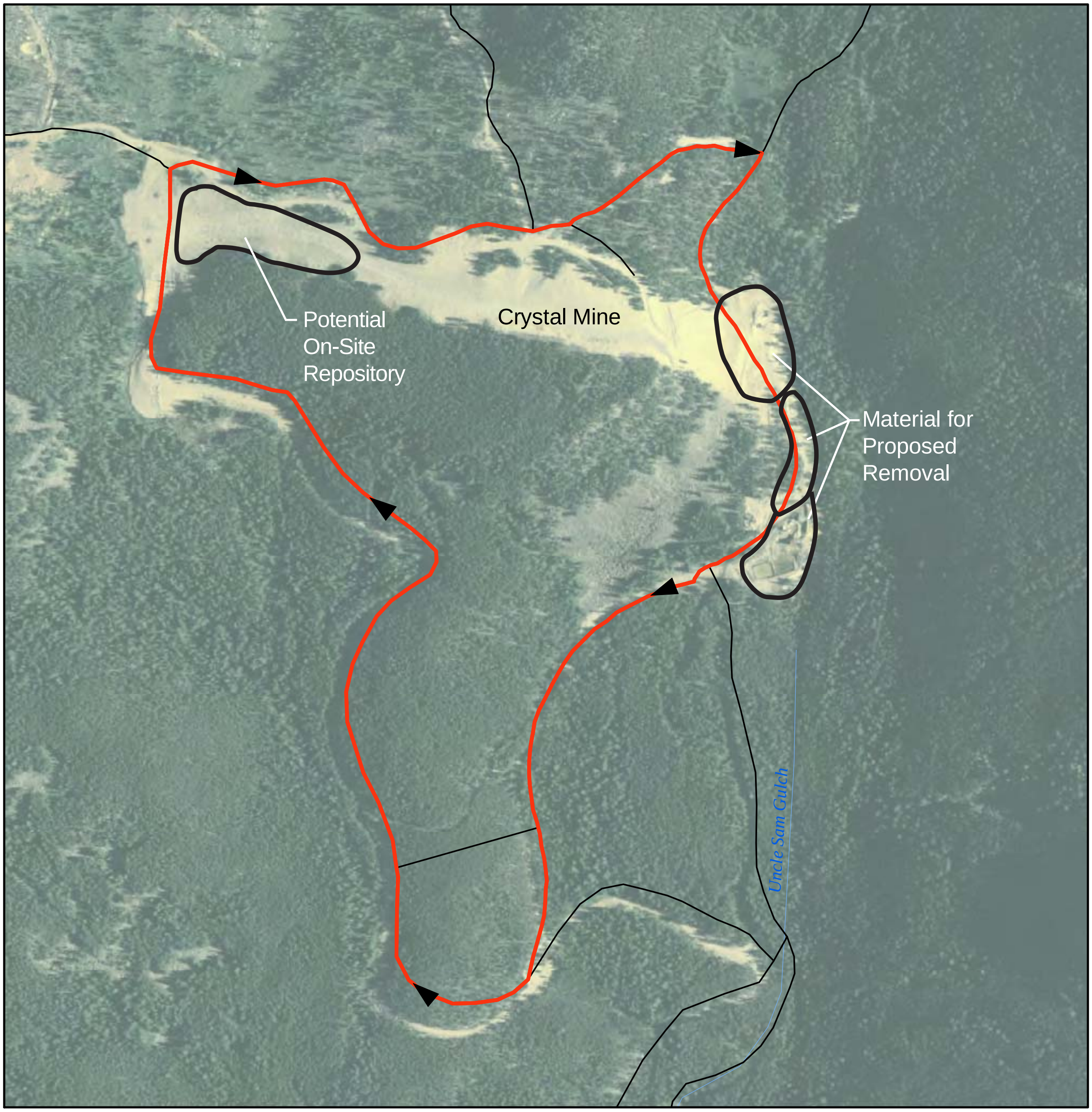
The three semi-permanent mine plugging techniques (SME, 1992) evaluated as part of this alternative are as follows:

- **Dry Plug.** Placing suitable material, such as a concrete block, at the portal of the mine.
- **Wet Plug.** Prevents air from entering adit, but allows water to discharge through the plug, similar to a water trap in a sink.
- **Hydraulic Plug.** Placing a plug within the mine to prevent water from discharging.

Of these three common permanent plug types, only a hydraulic plug would be viable in the case of the Crystal Mine. A dry plug is likely to fail from high hydraulic head forming on the backside of the plug. A wet plug allows mine drainage containing high concentrations of COCs to pass through the plug without treatment prior to discharging into streams (SME, 1992). A hydraulic plug minimizes the flow of groundwater from the mine. The resulting flooding behind the plug also prevents air from entering the mine through the adit, potentially reducing oxidation and generation of AMD. After sealing the mine adit, the surrounding area must be monitored to determine if new groundwater discharge points have developed or if significant changes to the groundwater flow regime occur.

The first step of this alternative would be to establish a safe access into the lower adit. This activity would be followed by an assessment of the competence of the adit by qualified mining engineers and geologists. The purpose of the assessment would be to evaluate the condition of the adit and determine if it is cost effective to re-open the adit beyond the portal area and look for obvious recharge points along the underground workings that could be effectively sealed off by grouting or other actions. Current conditions at the Site (collapsed portals) preclude knowing the condition of the adits without first re-opening the lower portal area. For the purpose of this alternative, it is presently assumed that portions of the adits are in the same collapsed condition as the lower portal (see Photograph 3-5).

PHOTOGRAPH 3-5. **Crystal Mine Lower Portal Current Condition**



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LEGEND

Haul Loop

Road MDOT

NHD Stream

North

0 500 1,000

Feet

FIGURE 3-9

CRYSTAL MINE SITE HAUL LOOP

Crystal Mine Feasibility Study

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Therefore, under Alternative GW-1, a plug would need to be designed and constructed within the lower Crystal Mine adit. The plug would be placed within competent bedrock, constructed of concrete, and surrounded by grout curtains in adjacent bedrock.

Alternative GW-1 would be developed in four steps: (1) reopen lower portal and adit, (2) develop bulkhead area, (3) grout bulkhead area, (4) construct bulkhead (plug), and as a contingency factor, install overflow well (in lower cross-cut adit).

Step 1, the adit would be reopened to competent rock and reinforced. The targeted area for the bulkheads is approximately 200 to 400 feet into the lower cross-cut adit, from the portal opening, based on existing records (Hansen, 2010). This location would put the plug in competent rock suitable for plugging. The adit would be reopened with conventional mining techniques and the first 200 feet reinforced with timber shoring, matching the original configurations. The lower adit was advanced during the original mining with no shoring. In keeping with safe practices this alternative anticipates reinforcing the tunnel with stainless steel mesh and matting rock bolted to the walls and potentially covered with shotcrete. A narrow gage rail system with an electric locomotive and mine cars, advanced with the tunnel shoring, would be used for reopening the mine and hauling out waste. Investigations within the cross-cut lower workings would provide information as to depth of competent bedrock, location of seeps within the workings, and information with respect to the potential effectiveness of a grout curtain through fractured rock. Once the mine adit is reopened and stabilized, and investigations are completed, the second step would begin.

Step 2 would consist of excavating an area for the plug in the existing 7-foot-wide by 9-foot-high tunnel. The finished dimensions of the new chamber would be approximately 16 feet high by 16 feet wide and 48 feet long.

Step 3 would take place in the newly excavated chamber and consist of drilling three series of radial grout holes at the start, middle, and end of the new chamber. Each set would consist of approximately forty 30-foot-long grout holes evenly spaced on the bottom, top, and sides of the excavation. Concrete grout would be injected under pressure into the bore holes until refusal and/or grout is observed in the adjacent bore hole. Following grouting, Step 4 (construction of the bulkhead plug) would be done.

In Step 4, the bulkhead would begin with damming the tunnel at the mine side of the new excavation. The dam would have a pipe installed to control water level and pressure, if needed during construction. The pipe would run through the excavation and out to the adit mouth where a valve would control flow. Both ends of the excavation would then be formed for a concrete pour in between them in the new excavation. Reinforcing steel would be installed throughout the chamber, tying into the rock bolts used to secure the chain link and matting. With the bulkheads completed, grouting would commence through a series of six holes drilled from the surface into the newly excavated chamber. Three of the holes would be used for pumping the concrete into the chamber and the other three would serve as vents for the work (see Figure 3-10).

Additional borings would be made behind the plug in the mineralized zone of the mine workings to allow installation of piezometers for future water level monitoring. Because of the corrosiveness of the trapped water behind the plugs, sulfate-resistant concrete would be used for the adit plugs and grouting. Finally, to prevent trespassers from entering the mine as well as to provide security, a security fence would be constructed at the portal.

This alternative could also incorporate a vertical drain feature (or overflow well) in the cross-cut adit to prevent rising mine water from reaching the level of the upper adit sill. To implement this option, a borehole would be drilled into the lower cross-cut adit approximately 500 feet from the portal, upgradient of the plug. The overflow well would consist of blank well casing inserted into the cross-cut adit of the lower workings, and be completed at an elevation slightly below that of the upper adit portal sill. This would allow rising water levels in mine to discharge before reaching the upper adit should the mine fill completely with water. At the surface, additional piping at the well head would direct any overflow of groundwater to a passive water treatment system.

The concepts for the hydraulic plugs and grout curtains were developed based on very limited information because the adits are currently not accessible. If the remedial decision includes opening the adit beyond the first acceptable plugging location, and additional information is obtained concerning the physical, geologic, and hydrogeologic conditions within the adits, the mine plugging concepts could change substantially.

To refurbish the mine adit and construct the plugs, the access road to the mine sites would need to be improved and a construction staging area created to accommodate construction vehicles, equipment, and mine debris/waste storage. A secondary access road may need to be constructed to accommodate a drill rig for installation of the grout curtain and installation of piezometers to monitor water level in the mine workings.

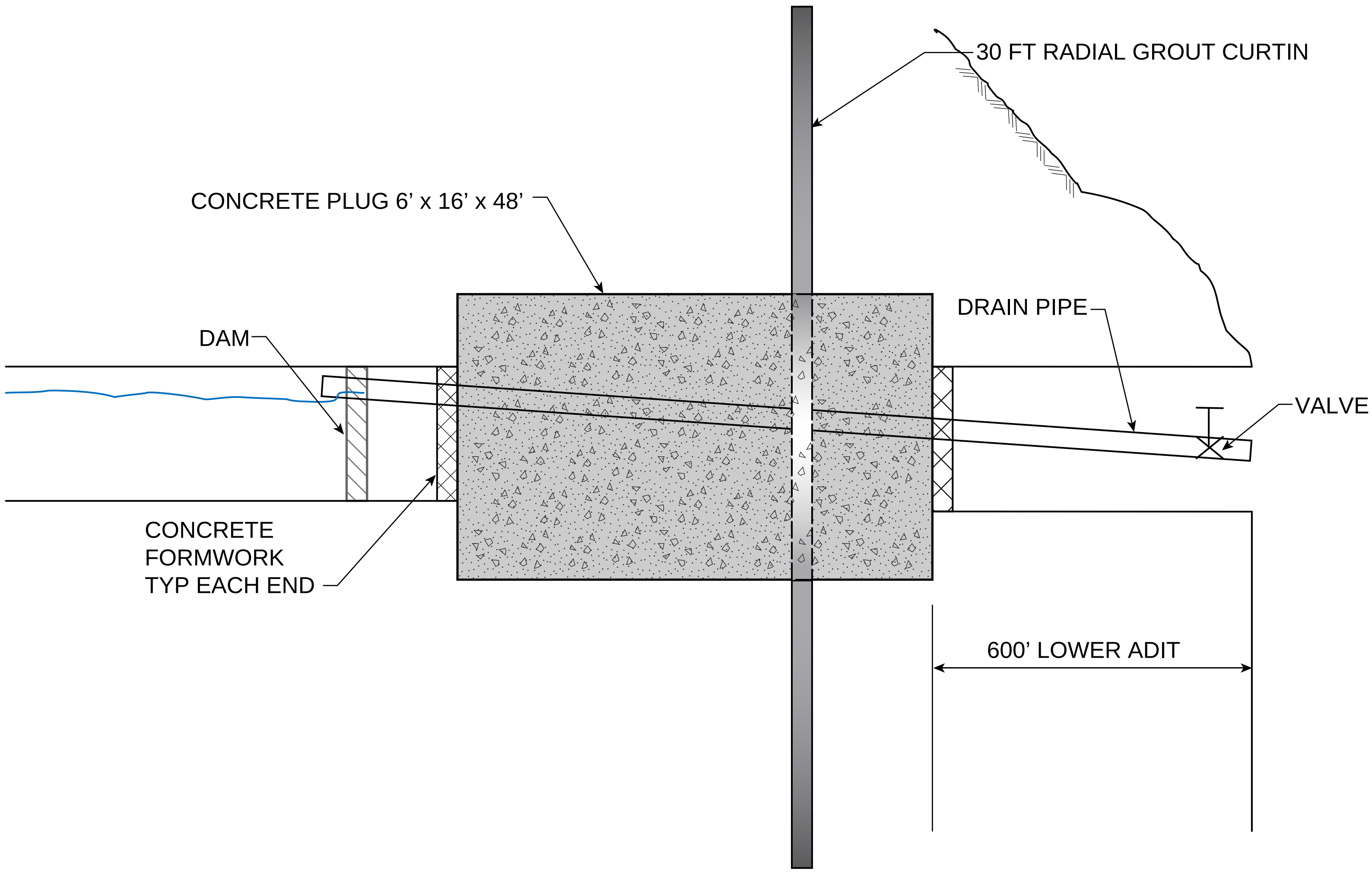
Periodic reconnaissance for new seeps and groundwater monitoring downgradient of the mine would be implemented upon completion of the hydraulic plug to ensure that the plug is working and contaminated groundwater is not escaping from the mine. Several monitoring wells would be located downgradient from the mine plugs. Groundwater monitoring upgradient of the mine would provide background concentrations of COCs for comparison. Additionally, surface water both downgradient and upgradient of the Site would be routinely monitored for COC concentrations to determine effectiveness of the plugs.

3.3.3.2 Alternative GW-2—Mine Plugging Through Borings from the Surface

A second alternative for mine plugging is injecting concrete slurry down borings that intersect the lower workings at some strategic location. In order to form a plug in the tunnel, a barrier is needed on each side so that the concrete is captured between the two barriers and fills to the tunnel roof. Because underground access would not be established to the plug area of the tunnel in this option, the barriers would be created by placing explosives in the tunnel, via the drilled shafts, at the appropriate locations. The controlled explosions would collapse rubble into the tunnel, creating a barrier. The rubble barriers would not be water tight so they would have to be grouted from the surface. As with the mine refurbishing alternative (GW-1), a grout curtain would be injected around each end of the plug to impede the flow of groundwater around the plug through the fractured rock as described in Section 3.1.4.1. The tunnel plug would be designed to be approximately 48 feet in length (actual length would be refined in remedial design) as they were in Alternative GW-1. However, in this alternative, the plug would have the same cross sectional dimensions as the tunnel. The exact number of borings required is unknown at this time but is estimated to be high. In order for the explosives to work properly in forming the plugs, multiple holes will be needed at each end. When the plug has been formed, additional borings will be required to allow grouting of both the rubble plug and the surrounding rock to prevent leakage around the plug. The final step would be to drill a series of holes between the two rubble pile plugs to allow the entire 48 feet of tunnel to be filled, forming the final plugging of the tunnel.

Unlike the plugs described in Section 3.3.3.1, the injection of concrete through borings would not include mine reopening and will not allow for a drain pipe(s) to be placed through the plugs to allow for emergency pressure relief and the possibility of future treatment.

As noted in Section 3.3.3.1, this option could also incorporate a vertical drain feature (or overflow well) in the cross-cut adit to prevent rising mine water from reaching the level of the upper adit sill. To implement this option, a borehole would be drilled into the lower cross-cut adit approximately 500 feet from the portal, upgradient of the plug. The overflow well would consist of blank well casing inserted into the cross-cut adit of the lower workings, and be completed at an elevation slightly below that of the upper adit portal sill. This would allow rising water levels in mine to discharge before reaching the upper adit should the mine fill completely with water. At the surface, additional piping at the well head would direct any overflow of groundwater to a passive water treatment system.



DETAIL

NOT TO SCALE

FIGURE 3-10

CRYSTAL MINE ADIT PLUGGING

Crystal Mine Feasibility Study

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As with Section 3.3.3.1, periodic reconnaissance for new seeps and groundwater monitoring downgradient of the mine would be implemented upon completion of the hydraulic plug to ensure that the plug is working and contaminated groundwater is not escaping from the mine. Several monitoring wells should be located downgradient from the mine plug. Groundwater monitoring up gradient of the mine would provide background concentrations of COCs for comparison. Additionally, surface water both downgradient and up gradient of the Site would be routinely monitored for COC concentrations to determine effectiveness of the plug.

3.3.3.3 Alternative GW-3—Active Treatment of AMD

Alternative GW-3 would consist of an active treatment process to treat AMD prior to reaching the receiving waters of local streams. At the Site, Alternative GW-3 would use standard technology for treating AMD with an HDS plant or comparable treatment process. If Alternative GW-3 were implemented, the HDS plant would use a treatment process similar to that shown in Figure 3-11. Construction of the HDS plant would require a permanent source of electrical power be provided to the Site, resulting in the installation of aboveground transmission lines running to the mine sites. Periodically, the sludge generated by the plant operation would require disposal. Lime and other additives used during the operation of the HDS plant would need to be shipped to the Site periodically and stored onsite.

A treatment plant sized to treat peak flows would be much larger than a plant sized to treat average flows. Therefore, to control the rate of AMD influent into the plant, a single mine bulkhead would be constructed inside the adit to block the flow of groundwater discharge and create some storage capacity. Chemically resistant pipes running through the plug would transmit the AMD to the HDS plant. During periods of high groundwater discharge, the plug would act like a dam, storing the AMD within the mine until it could be treated (see Figure 3-12 for a preliminary design of the adit drainage control).

No supplemental groundwater collection would be required to implement Alternative GW-3 at the Crystal Mine; therefore, only adit discharge would be collected and diverted to the treatment plant.

Operating the HDS plant would require year-round staffing by a part-time operator. Any additional maintenance, sampling, and disposal needs would require additional staff. Upgraded access roads to the Site would provide access from late spring through the early fall until snow starts to accumulate. Once snow has blocked access for automobiles or trucks, an alternative means of winter transportation such as snowmobiles or tracked vehicles would be required to access the Site for ongoing operations and maintenance.

3.3.3.4 Alternative GW-4—Semi-Active Treatment of AMD (Quicklime Injection System)

Alternative GW-4 would consist of a semi-active AMD treatment process. A semi-active treatment process using quicklime injection system was used in 1994 during a demonstration project conducted to treat AMD from the Crystal Mine (lower adit). The results of the original demonstration project showed promise, so Alternative GW-4 is proposed as a semi-active quicklime injection system similar to the system previously used. The treatment process would be sequenced as follows and is illustrated in Figures 3-13 through 3-16:

- Mine discharge would be blocked by an adit bulkhead, collected and piped in 6-inch HDPE piping to the quicklime injection system where a non-electrical mechanical system would inject quicklime into the stream. The mechanical injection system would be driven by a water wheel powered by the adit discharge.
- The quicklime injection system effluent stream would mix while passing through a "V" ditch lined with riprap.
- The ditch would be routed into one of two HDPE-lined settling ponds where metals would co-precipitate with hydroxide and oxyhydroxide floc and settle out.
- Effluent from the primary settling pond would drain into a secondary settling pond which would allow for additional settling time.
- Effluent from the secondary settling pond would drain directly into USG Creek.

- Whenever necessary (depending on mine discharge flow and sludge production rates), the settling ponds would be drained and the hydroxide sludges on the bottom would be excavated and placed on drying beds nearby. Once dried, the sludge would be hauled to the Luttrell Repository located on the northern boundary of the watershed. The drying beds would drain into the primary settling ponds. If the Luttrell Repository were closed or could not take sludges from the treatment systems, alternative disposal locations would need to be identified. For the purpose of this FS, it is assumed that dried sludge would go to the Luttrell Repository for disposal.
- No supplemental groundwater collection is required to implement Alternative GW-4; therefore, only adit discharge would be collected and diverted to the treatment plant.
- As evidenced by the demonstration project, Alternative GW-4 would require periodic maintenance (approximately weekly) to ensure the system is operating properly. Additionally, depending on the quicklime injection system and storage capacities of the system, the quicklime would need to be resupplied once or twice each year.
- Table 3-3 shows design parameters for the implementation of Alternative GW-4.

TABLE 3-3
Alternative 4 Design Parameters

Feature	Crystal Mine
Estimated flow rate[a]	45 gallons per minute
Groundwater collection	One adit plug with piping
Treatment	One semi-active treatment system
Post treatment mixing	340 feet of PVC-lined “V” ditch with 1-foot-thick riprap
Preliminary settling pond[b]	139,000-gallon HDPE lined, 6 feet deep, with additional 2 feet of freeboard
Secondary settling pond[b]	33,000-gallon HDPE lined, 6 feet deep, with additional 2 feet of freeboard
Additional comments	Existing lined settling ponds will need to be drained, liner removed and disposed of. Adit plug does not include grout curtain.

Notes:
[a] See Appendix D of this FS for determination of design flow rates.
[b] Size of settling ponds based on available space.
PVC = polyvinyl chloride

3.3.3.5 Alternative GW-5—Semi-Passive Treatment of AMD (SRBR)

Alternative GW-5 would be a three-stage semi-passive system utilizing a pH adjustment cell, an SRBR, and a clarification pond. The treatment system concept proposed is representative of a passive treatment process that could be employed onsite and for which a cost can be prepared for the purpose of this FS. The specific details for this treatment process will be designed after the ROD should this alternative be selected as part of the remedy for the Site. As with Alternatives GW-3 and GW-4, an adit bulkhead would be installed to control flow through an HDPE pipe and a control valve. Two parallel treatment trains would be installed to allow for one to be out of service for maintenance or repairs while the other served treatment needs. The three stages of the treatment process are described in the following text (see Figures 3-17 through 3-20).

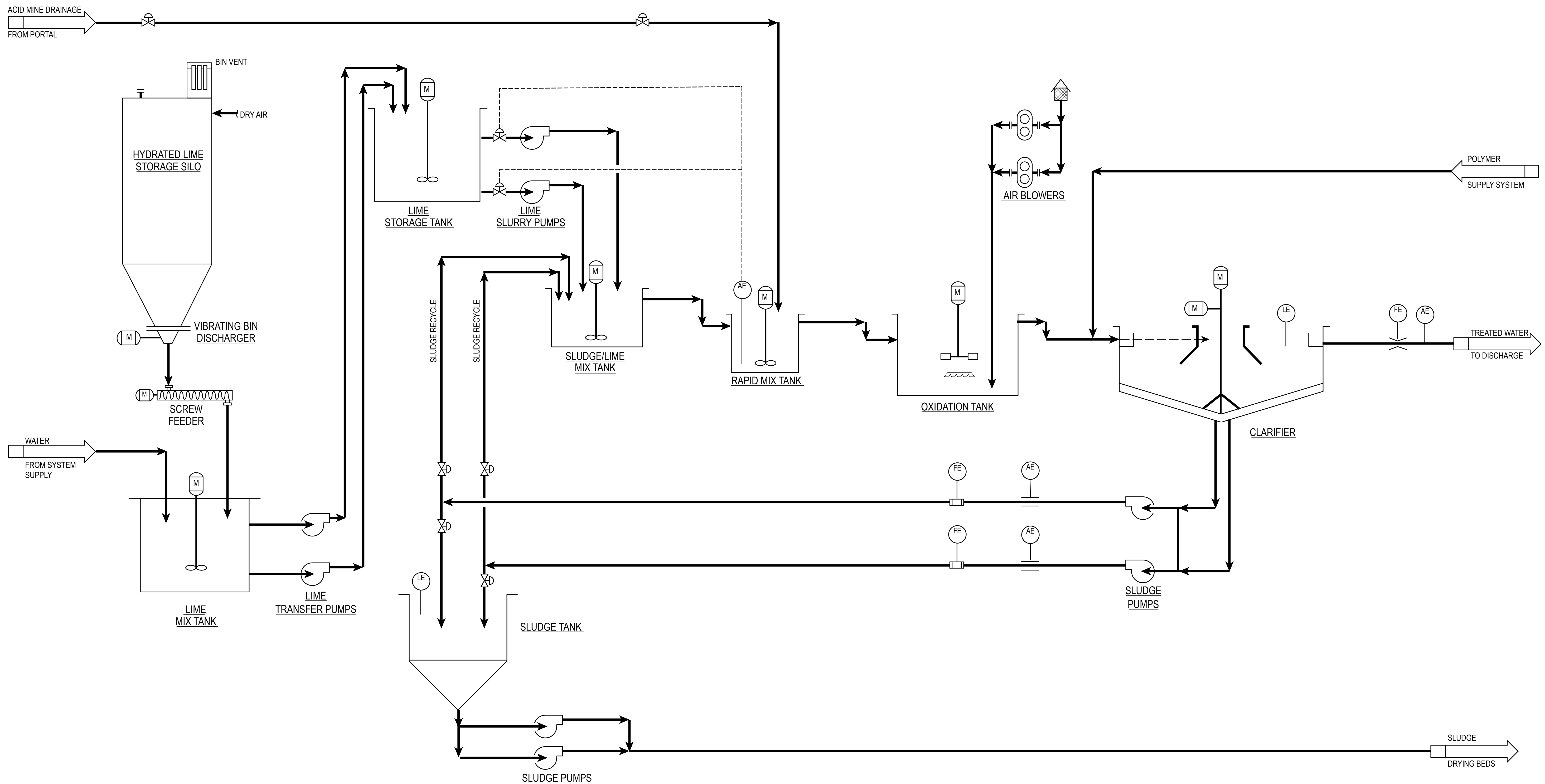

FIGURE 3-11
PROCESS FLOW DIAGRAM
Crystal Mine Feasibility Study

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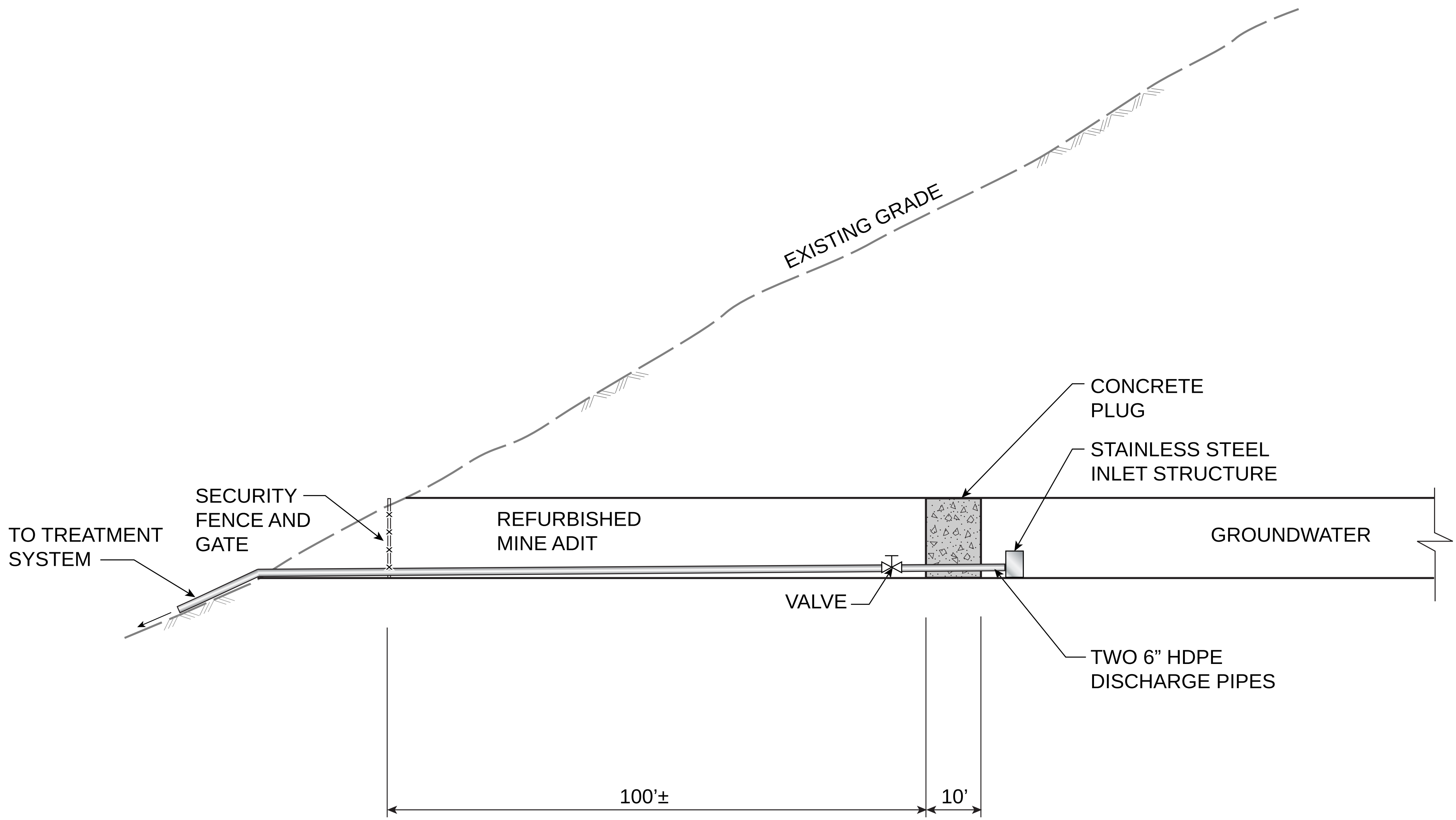

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FIGURE 3-12
ADIT DRAINAGE CONTROL
Crystal Mine Feasibility Study

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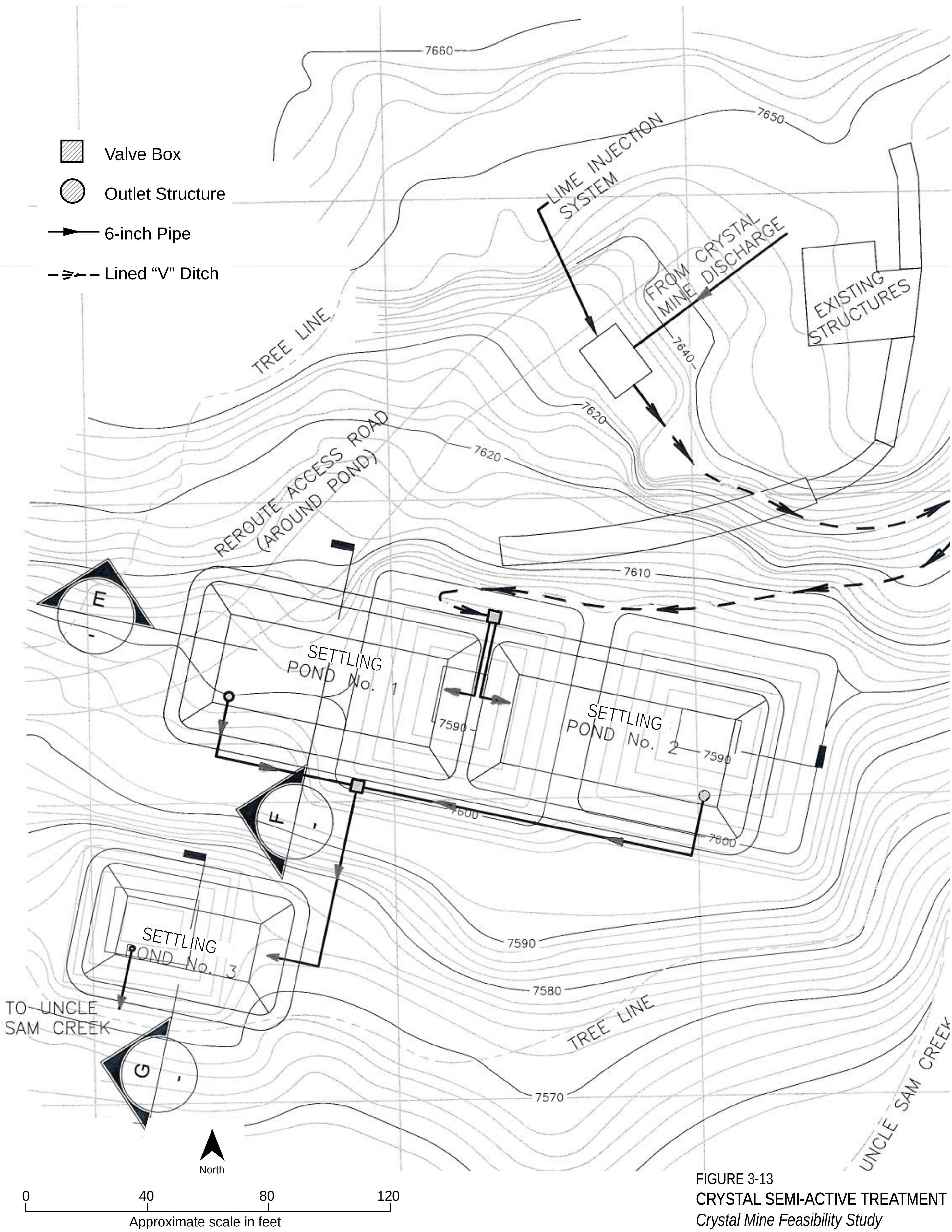

FIGURE 3-13
CRYSTAL SEMI-ACTIVE TREATMENT
Crystal Mine Feasibility Study

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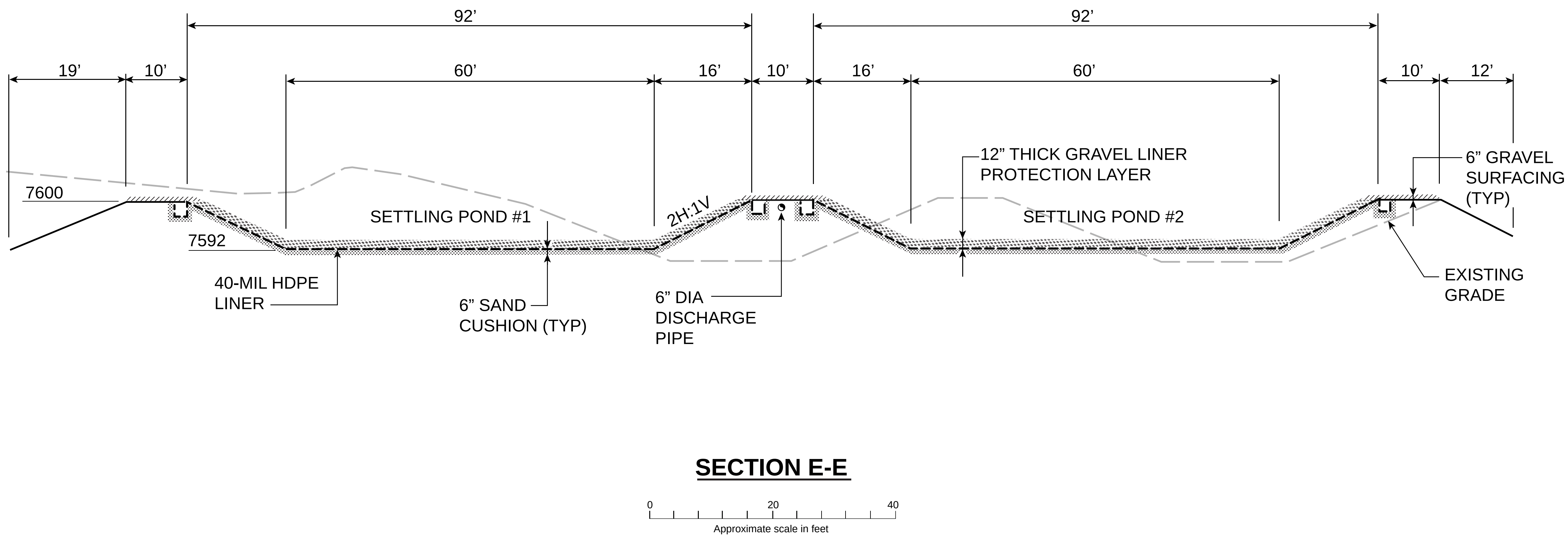

FIGURE 3-14
CRYSTAL SEMI-ACTIVE TREATMENT
SECTION E-E
Crystal Mine Feasibility Study

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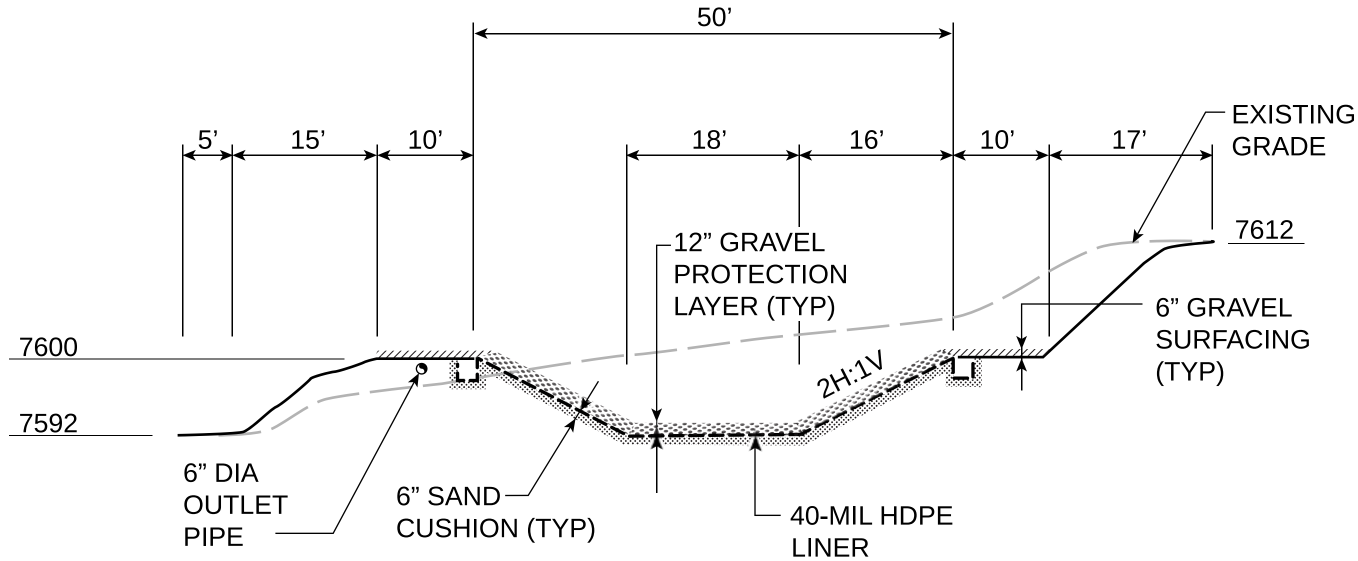

SECTION F-F

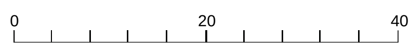

FIGURE 3-15
CRYSTAL SEMI-ACTIVE TREATMENT
SECTION F-F
Crystal Mine Feasibility Study

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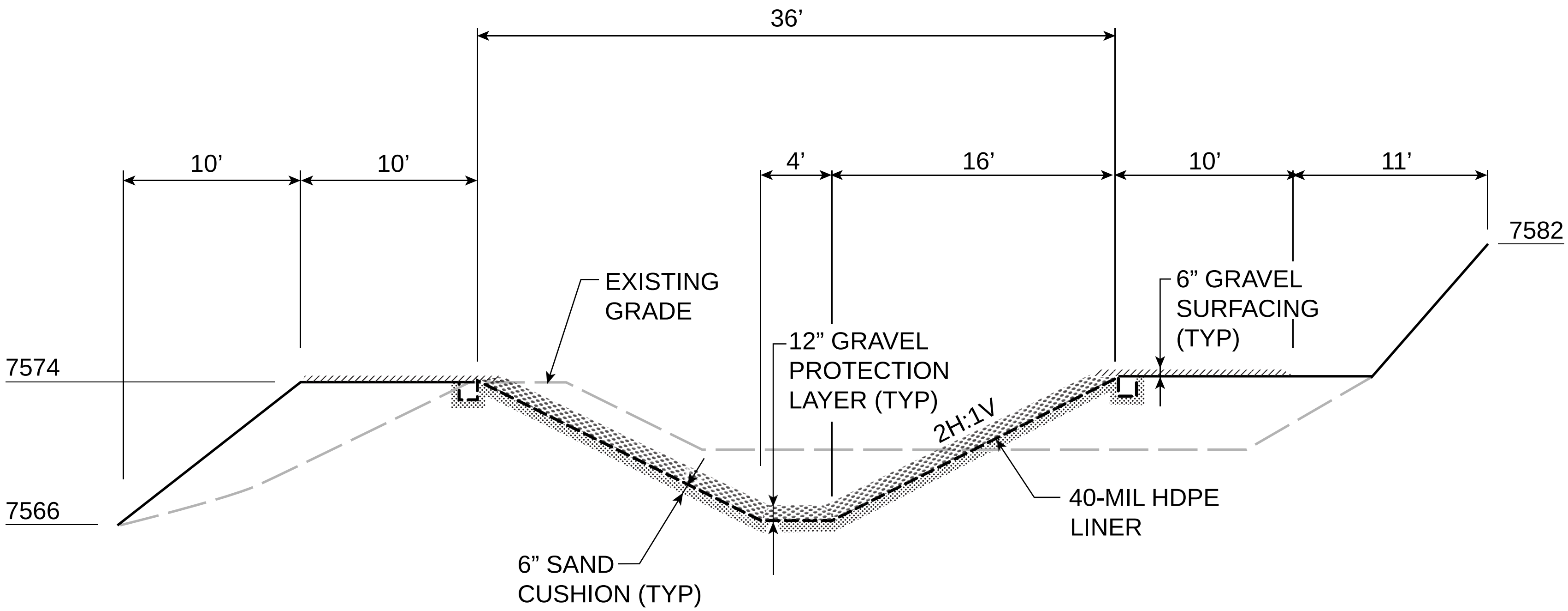

SECTION G-G

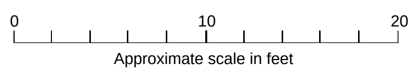

FIGURE 3-16
CRYSTAL SEMI-ACTIVE TREATMENT
SECTION G-G
Crystal Mine Feasibility Study

CH2MHILL

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ENCLOSED WEIR

DISCHARGE STRUCTURE

6 INCH SOLID PIPE

6 INCH PERFORATED PIPE

NOTES:
CONTOURS LESS THAN 7570 ELEVATION WERE NOT INCLUDED ON ORIGINAL TOPOGRAPHY MAP. CONTORURS LESS THAN 7570 WERE ASSUMED BASED ON USGS 7.5 MINUTE TOPOGRAPHY MAPS FOR THE AREA.

FIGURE 3-17
CRYSTAL SEMI-PASSIVE TREATMENT
Crystal Mine Feasibility Study

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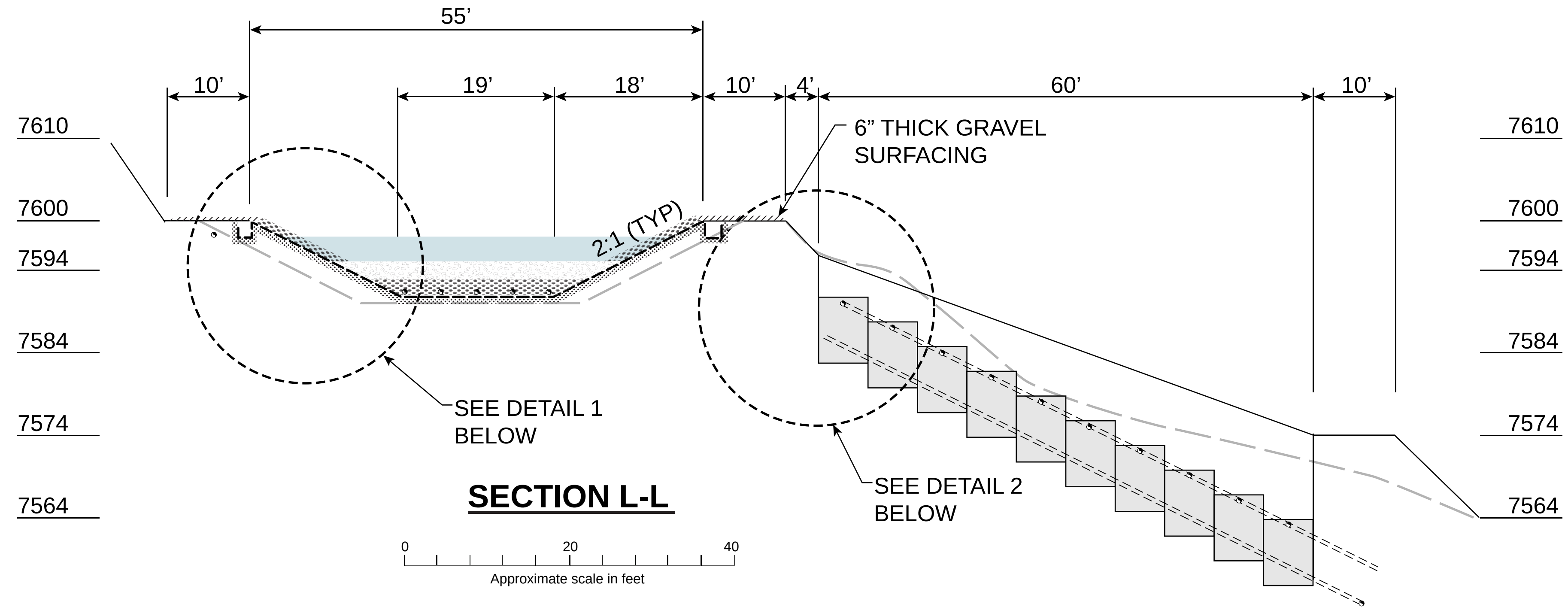
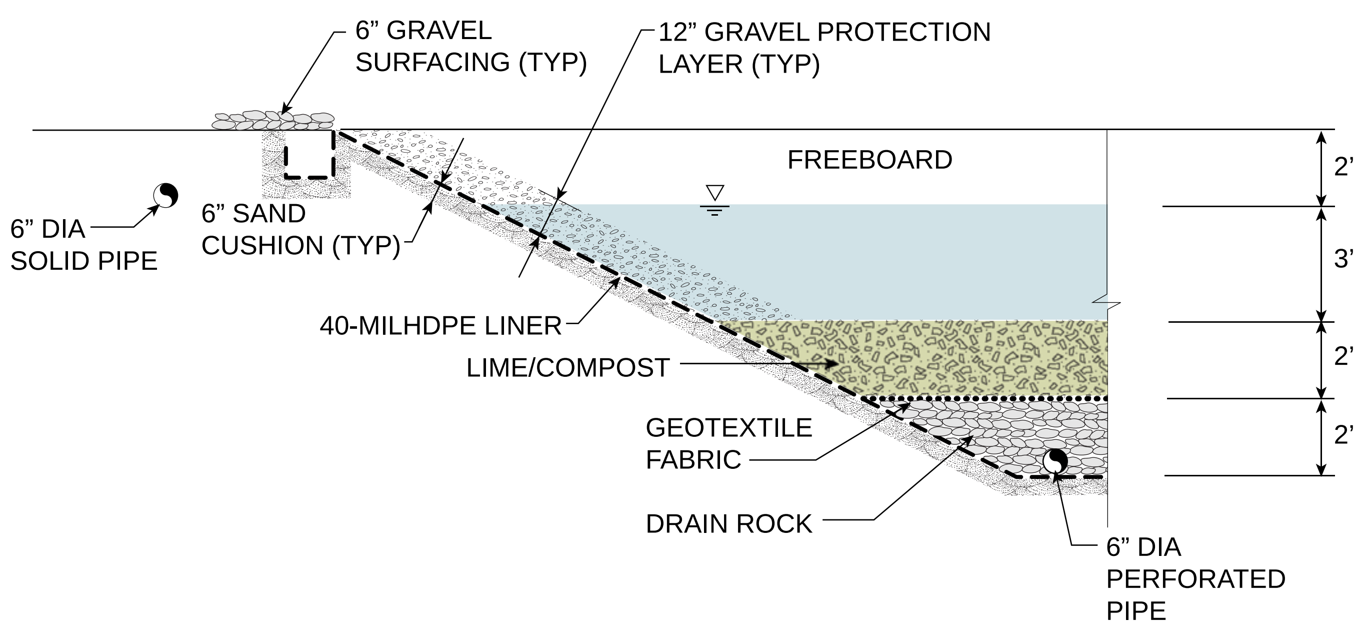
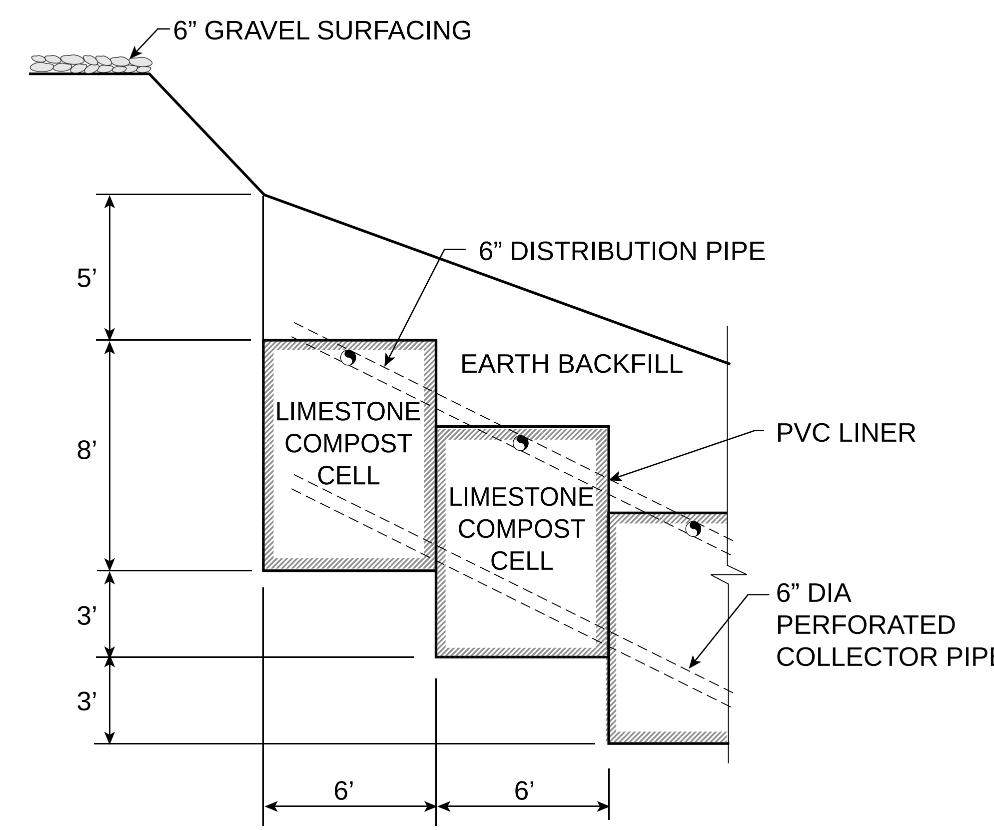


SECTION L-L



pH ADJUSTMENT POND DETAIL 1



SULFATE REDUCTION CELLS DETAIL 2

NTS

FIGURE 3-18
CRYSTAL SEMI-PASSIVE TREATMENT SECTION L-L
Crystal Mine Feasibility Study

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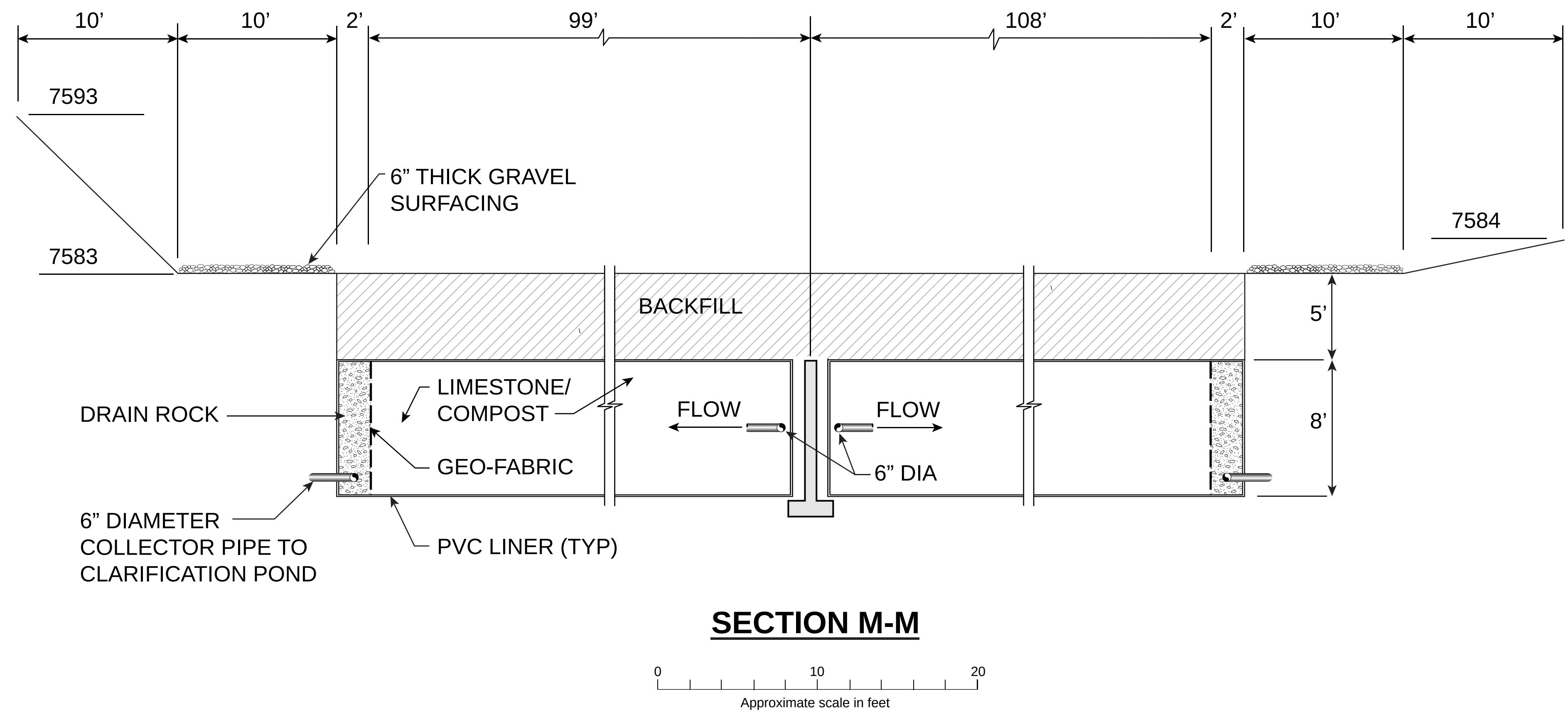

FIGURE 3-19
CRYSTAL SEMI-**PASSIVE** TREATMENT
SECTION M-M
Crystal Mine Feasibility Study

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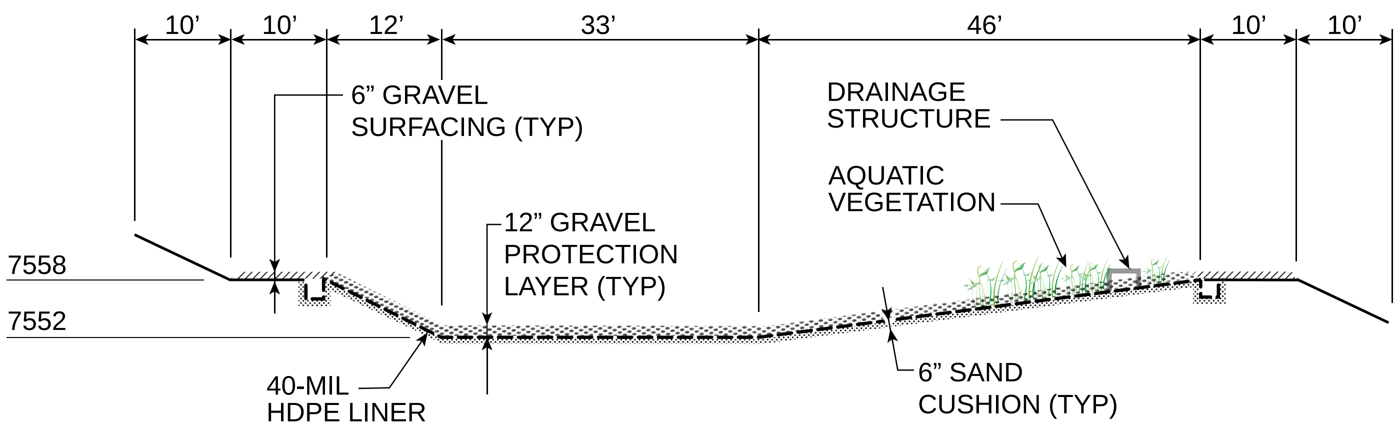

SECTION N-N

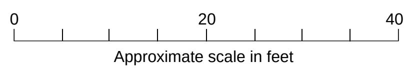

FIGURE 3-20
CRYSTAL SEMI-**PASSIVE** TREATMENT
SECTION N-N
Crystal Mine Feasibility Study

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pH Adjustment Cell (Stage 1). The pH adjustment cell would consist of three layers and is designed to increase AMD to a pH greater than 6. Details of the cell are as follows:

- The top layer would be a 3-foot-deep layer of water (mine discharge water) to act as an insulator during the winter months.
- Below the water layer would be a 2-foot-thick layer of a mixture of limestone sand and compost or stable waste, with a mix ratio of approximately 25 percent limestone to 75 percent compost by volume. The limestone/compost layer would be sized to provide approximately 16 hours retention time.
- Below the limestone/compost layer would be a 2-foot-thick layer of drain-rock with 6-inch-diameter perforated collector pipes running through the layer. The two layers would be separated by a geotextile fabric which would act as a filter keeping the limestone/compost out of the drain-rock.
- The perforated collector pipes would drain into a solid 6-inch-diameter collector pipe which would drain into the SRBR cells. The entire pH adjustment cell would be lined with an HDPE liner. To break up any scaling of the limestone that may occur, the limestone/compost layer should be rototilled approximately every 2 years and replaced approximately every 6 years.
- Water from the pH adjustment cell then flows by gravity into the SRBR cells.

SRBR (Stage 2). The SRBR consists of a series of horizontal flow-through cells. Details of the cells are as follows:

- Each cell would be comprised of limestone gravel and compost or stable waste. However, unlike the pH adjustment cell, the mix ratio would be approximately 10 percent limestone gravel and 90 percent compost by volume.
- Each cell would be about 6 feet wide by 8 feet tall and wrapped in a PVC liner.
- The total length of the SRBR cells would provide, at a minimum, 5 days retention time.
- Effluent from the pH adjustment cell would be evenly distributed to the SRBR cells at one end of each cell.
- At the opposite end of each cell, treated effluent would be collected in 6-inch-diameter perforated PVC pipes which would drain into a 6-inch solid PVC collector pipe that discharges into a clarification pond.
- For insulation purposes, 5 feet of backfill would be placed on top of the SRBR cells. The SRBR cells would need to be replaced approximately every 15 years. Between the SRBR cells and the clarification pond, the treated effluent would pass over a series of enclosed weirs or manholes to allow for aeration prior to discharging into the clarification pond. The weirs or manholes would be enclosed to reduce icing during winter.

Clarification (Stage 3). The clarification pond would allow settling of sludges and organic materials formed in the prior two stages. Details of the pond are as follows:

- Effluent from the SRBR cells would be discharged into the 6-foot-deep end of the pond which offers storage for settling sludges.
- Halfway through, the bottom of the pond would gradually rise. At the shallow end of the pond, native aquatic vegetation would provide biological filtering.
- Discharge from the pond will be directed to USG Creek by an open riprap lined channel.
- Periodically, sludge that settles in the deep end of the clarification pond would be excavated, and dried on drying beds which would drain into the clarification pond.
- The dried waste would be transported to the Luttrell Repository for disposal. If the Luttrell Repository closed or could not take sludges from the treatment systems, alternative disposal locations would need

to be identified. For the purpose of this FS, it is assumed that dried sludge would go to the Luttrell Repository for disposal.

No groundwater collection is required to implement Alternative 6 at the Site; therefore, only adit discharge would be collected and diverted to the treatment plant.

Table 3-4 shows design parameters for the implementation of Alternative 6.

TABLE 3-4
Alternative 5 Design Parameters

Feature	Crystal Mine
Estimated flow rate[a]	45 gallons per minute
Groundwater collection	One adit plug with piping
pH adjustment pond[b]	260,000-gallon HDPE lined, 6 feet deep, with additional 2 feet of freeboard
SRBR cells[c]	3,900 yd^3 PVC-wrapped cells with 5-foot thick soil cover for insulation
Clarification pond[d]	94,000-gallon HDPE lined, 6-foot-deep pond
Additional comments	Adit plug does not include grout curtain

Notes:
[a] See Appendix D of this FS for determination of design flow rates.
[b] Size of settling ponds based on available space.
[c] SRBR cell size base on 5-day retention time
[d] Pond design is based on sludge formation, storage needs, total suspended solids (TSS) retention, and to facilitate cleanout.

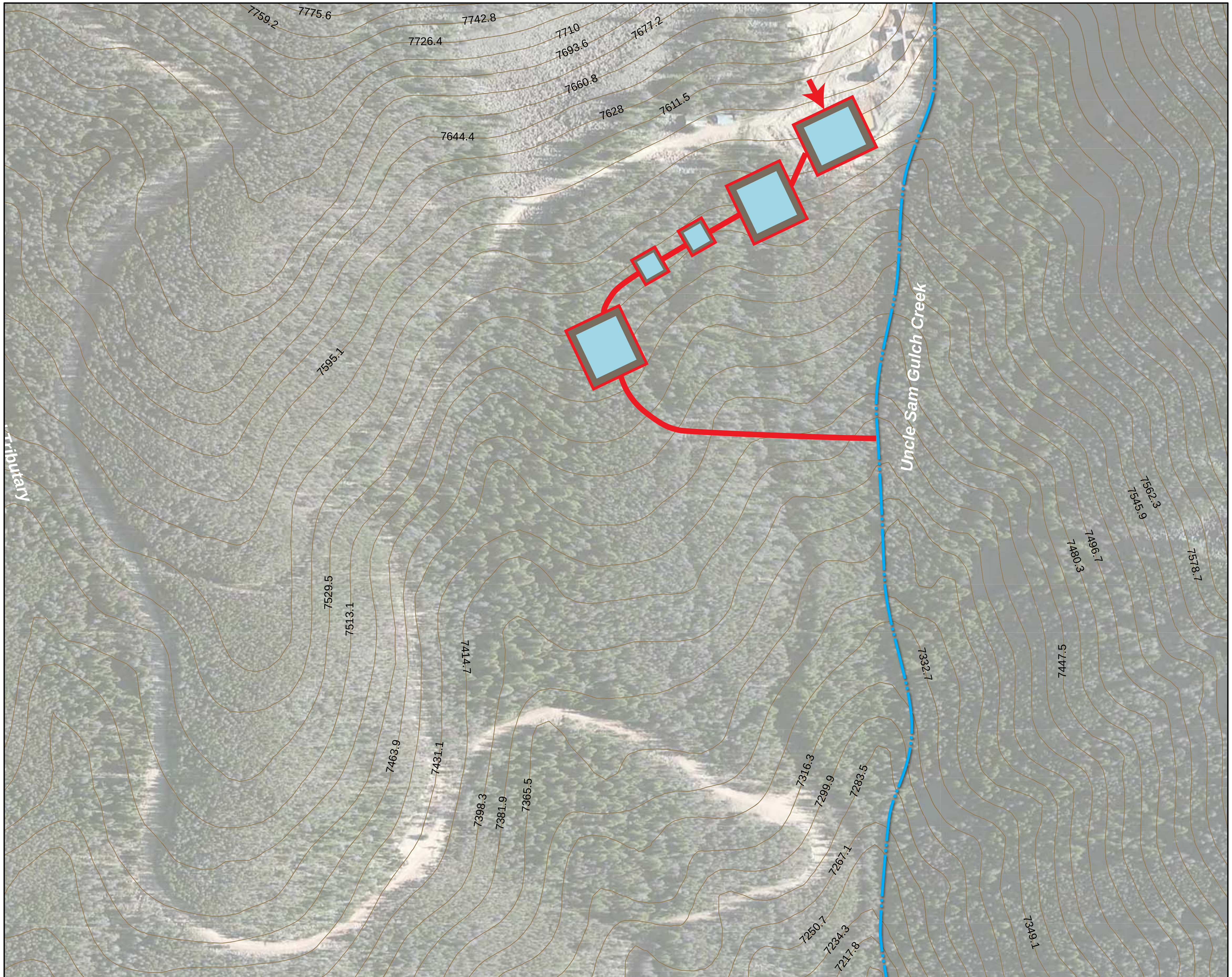
3.3.3.6 Alternative GW-6—Semi-Passive Treatment of AMD (SRBR, Aeration Systems, Oxidation/Settling Ponds, Wetlands, and Discharge)

Alternative GW-6 would be a five-stage semi-passive system utilizing (1) an SRBR, (2) aeration system, (3) oxidation/settling ponds, (4) wetland, and (5) discharge to USG Creek. Unlike Alternatives GW-2 through GW-5, an adit plug would not be installed to control flow through an HDPE pipe and control valve. Flow from the adit would continue through HDPE pipe, but would be allowed to free flow throughout the year. Two treatment trains, in series, with the first three stages described above would be installed. Piping would be designed to allow for one at a time to be taken out of service for maintenance. Only one wetland and discharge point would need to be constructed allowing for either treatment trains to discharge. The five stages of the treatment process are further described in the following text (see Figures 3-21 through 3-24). Table 3-5 provides conceptual design parameters for this Alternative.

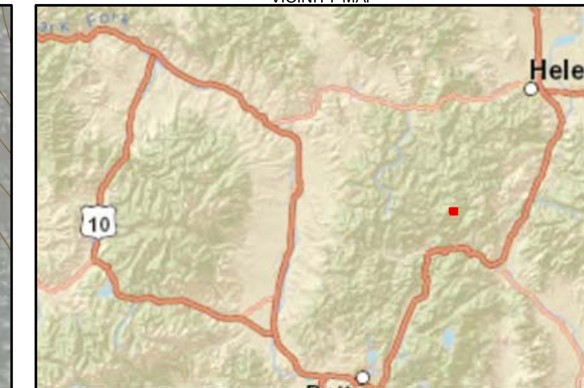
TABLE 3-5
Alternative 6 Design Parameters

Feature	Crystal Mine
Estimated flow rate[a]	45 gallons per minute
Groundwater collection	Direct piping from adit
SRBR cells[c]	2 – PVC-wrapped cells with 5-foot-thick soil cover for insulation, 6,200 yd^3 each
Aeration channels	2 – HDPE lined with rip rap, stepped channel
Oxidation/settling ponds[b,d]	2 – HDPE lined, 6.5-foot-deep ponds, 292 yd^3 each
Clarification pond[d]	1 – HDPE lined, 6-foot-deep pond, 3,000 yd^3
Additional comments	Treated effluent flows to USG Creek

Notes:
[a] See Appendix D of this FS for determination of design flow rates.
[b] Size of settling ponds based on available space.
[c] SRBR cell size base on 2-day retention time
[d] Pond design is based on sludge formation, storage needs, TSS retention, and to facilitate cleanout.



VICINITY MAP



LEGEND

DEM Generated 5 Meter Contour (Displayed Elevation in Feet)

Notes:
1. Area of interest subject to change.
2. 2011 Imagery - ArcGIS Streaming Map Service.
3. 30 meter USGS DEM used to generate contours and streams.

N

0 100 200 400
Feet

1 inch = 200 feet

FIGURE 3-21
GW-6 SEMI-PASSIVE TREATMENT AREA
Crystal Mine Feasibility Study

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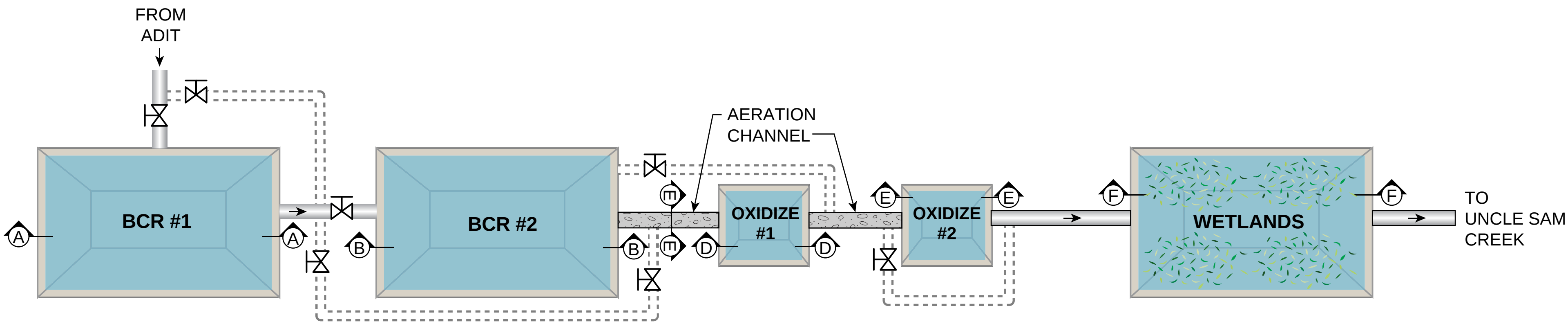

LEGEND:
Maintenance Bypass Line

FIGURE 3-22
PROCESS FLOW DIAGRAM
Crystal Mine Feasibility Study

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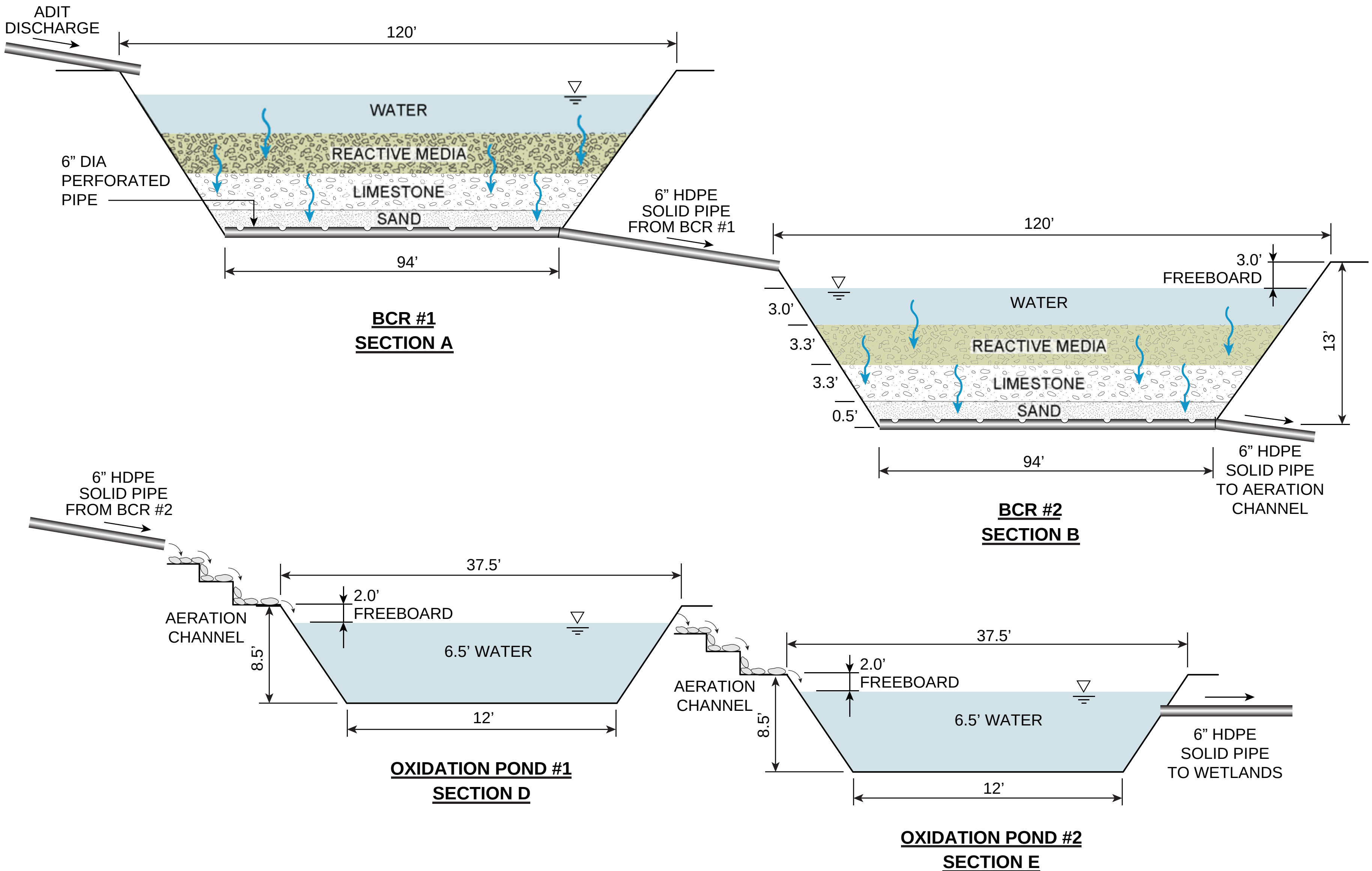

FIGURE 3-23
BIOREACTORS AND OXIDATION PONDS
Crystal Mine Feasibility Study

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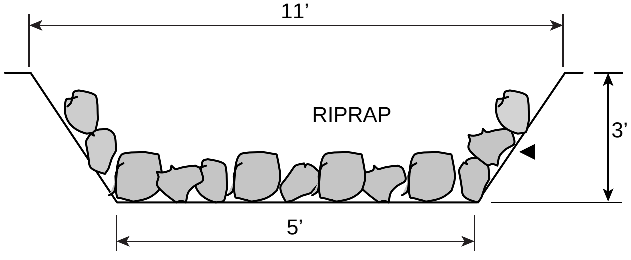
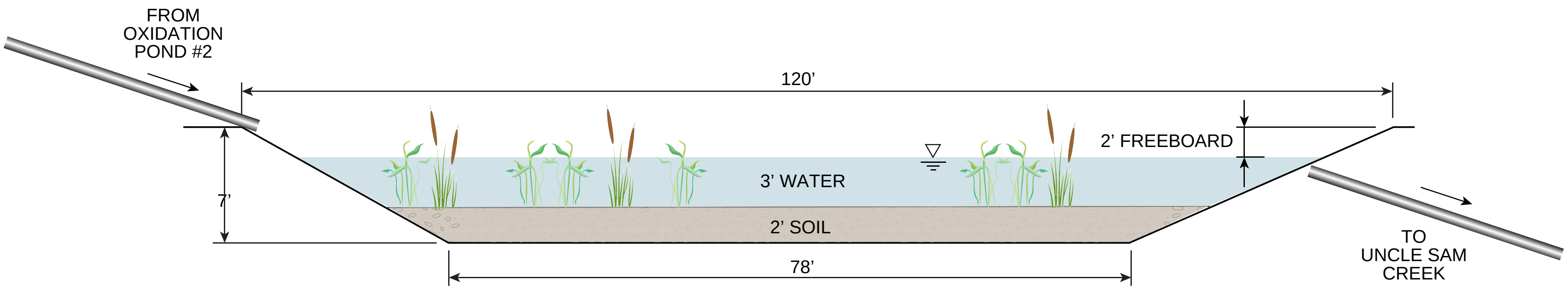


AERATION CHANNEL
SECTION C (TYP)



WETLANDS
SECTION F

FIGURE 3-24
CHANNEL CROSS SECTION AND WETLANDS
Crystal Mine Feasibility Study

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SRBR (Stage 1). The SRBR would consist of five layers and be designed to increase AMD to a pH greater than 6. Two sulfate-reducing biochemical reactors will be constructed, operated in series with optional bypass lines for maintenance. Details of the cells are as follows:

- The top layer would be a 2- to 3-foot geotextile and vegetated soil cover to prevent freezing.
- Below the top layer would be a water layer (mine discharge water) that would be 3 feet thick and consist of porous material.
- The next layer would contain the reactive media consisting of organic substrate (mixture of compost, sawdust, wood chips, hay, or straw) materials and limestone sand (well mixed), with a mix ratio of approximately 25 percent limestone to 75 percent compost by volume in the first SRBR and 10 percent limestone to 90 percent compost by volume in the second SRBR. The limestone/compost layer would be sized to provide approximately 2 days retention time.
- Below the limestone/compost layer would be a 3-foot-thick layer of limestone drain-rock with 6-inch-diameter perforated collector pipes running through the layer. The upper layer and this layer would be separated by a geotextile fabric which would act as a filter keeping the limestone/compost out of the drain rock.
- The final layer would be a cushioning/protection layer for the line which would consist of a 6-inch sand layer.
- Water from the SRBR would then flow to the aeration system.

Aeration System (Stage 2). Two short series of cascades (riprapped channels) would run from the last SRBR into the first aeration Pond, and from the first pond into the second, to promote turbulence and aeration. Construction attributes consist of the following:

- Course riprap, of appropriate size, lining a sloped, open channel to promote oxygen transfer to water, increasing DO and ORP.
- The distal end of the open channels would be constructed with 6-inch-diameter perforated collection pipes running near the bottom to divert flow into the next oxidation/settling ponds.

Oxidation/Settling Ponds (Stage 3). The precipitation/settling ponds (two in series) would facilitate the precipitation and settling of iron oxide sludges from the SRBR cells and aeration channels. Details of the conceptual pond design are as follows:

- Flow from the aeration system (riprap channels) would be discharged into the 6-foot-deep end of the initial pond which offers storage for settling sludges.
- In the second pond, the distal end gradually becomes shallower. In the shallow end of the pond, native aquatic vegetation would provide biological filtering and removal of TSS. Overflow from this pond would be directed to the wetland (Stage 4).
- Periodically, sludge that settles in the deep end of the ponds would be excavated or slurried, and dried on drying beds or pumped into sediment tubes which would drain into the ponds.
- The dried waste would be transported to the Luttrell Repository for disposal. If the Luttrell Repository were closed or could not take sludges from the treatment systems, alternative disposal locations would need to be identified. For the purpose of this FS, it is assumed that dried sludge would go to the Luttrell Repository for disposal.

Wetland (Stage 4). The wetland pond would allow for suspended solid polishing. It is assumed that discharge from the adit would be naturally reduced during the winter months. It is likely that ice may form to some degree. Its influence on the capture of total suspended solids may be adversely influenced during such periods. Details of the pond are as follows:

- The wetlands will be sized to have a retention time of approximately 1 day.
- The bottom of the wetland pond would consist of 2 feet of soil for the plants to develop roots
- The second layer would be the water layer that is 2 to 3 feet thick (variable)
- Discharge from the wetlands pond would be directed to USG Creek by an open riprap-lined channel.

4. Detailed Analysis of Alternatives

4.1 Introduction

This section presents a detailed evaluation of the remedial alternatives remaining after the development and screening of alternatives, as presented in Section 3.0. The detailed analysis of alternatives consists of an assessment of individual alternatives against each of nine evaluation criteria defined by the NCP and a comparative analysis that focuses upon the relative performance of each alternative against those criteria. The analysis of alternatives under review will reflect the scope and complexity of site problems and alternatives being evaluated and consider the relevance and significance of the factors within each criterion. The nine evaluation criteria are as follows:

- Overall Protection of Human Health and the Environment
- Contribute to compliance with ARARs
- Long-term Effectiveness and Permanence
- Reduction in Toxicity, Mobility, or Volume Through Treatment
- Short-term Effectiveness
- Implementability
- Cost
- State Acceptance
- Community Acceptance

Alternatives are assessed to determine whether they can contribute to protecting human health and the environment, in both the short and long term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the Site by eliminating, reducing, or controlling exposures to levels established during development of remediation goals. The assessment of overall protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and contribution to compliance with ARARs.

A 30-year project duration is used for net present value (NPV) analysis because all options have a similarly short design and construction phase and no option results in a complete cleanup of contaminated sources in a finite project life. However, cost evaluations for long durations of maintenance and monitoring are cumbersome and are generally not necessary for comparative evaluation between alternatives because of cost discounting under present value analysis. The period of analysis was selected to be 30 years because the increase of present value cost due to periodic expenditures for maintenance and monitoring is minimal relative to the accuracy range of the estimates. Therefore the economic life of the projects was used as the planned duration for all alternatives.

State and community acceptance are not assessed in this FS. Assessment of state concerns will not be completed until comments on the RI/FS are received but may be discussed in the proposed plan issued for public comment. The assessment of community acceptance will not be completed until comments are received on the proposed plan. These modifying criteria are evaluated by EPA in consultation with the State during the remedy selection. Following the public comment period on the proposed plan, assessment of the modifying criteria of state and community acceptance will be completed in the ROD.

The purpose of completing a detailed analysis of the remedial action alternatives is to provide sufficient information to allow EPA, in consultation with the State, to compare alternatives using the NCP evaluation criteria and to select a site remedy. The criteria used in the analysis are described in Section 4.2. The results of the detailed analysis are presented in Sections 4.3 and 4.4 and summarized by overall achievement against each of the balancing and threshold criteria in Table 4-1 (at the end of this section).

4.2 Criteria for Evaluation

As stated previously, nine criteria are defined in the NCP for evaluation of remedial alternatives. The nine criteria are divided into three categories (threshold, balancing, and modifying criteria) and are as follows (40 CFR 300.430):

- Threshold Criteria
  - Overall Protection of Human Health and the Environment
  - Compliance with ARARs
- Balancing Criteria
  - Long-term Effectiveness and Permanence
  - Reduction of Toxicity, Mobility, or Volume Through Treatment
  - Short-term Effectiveness
  - Implementability
  - Cost
- Modifying Criteria
  - State Acceptance
  - Community Acceptance

The selected interim remedy will reflect the scope and purpose of the actions being undertaken and how the action relates to long-term, comprehensive response at the Site. Remedial alternatives must be protective of human health and the environment until the Basin Watershed ROD is implemented and must contribute to compliance with ARARs. In consultation with the state, EPA indicates which alternative offers the best balance of tradeoffs, identified in the detailed analysis, among alternatives with respect to the (1) long-term effectiveness and permanence; (2) reduction of toxicity, mobility, or volume through treatment; (3) short-term effectiveness; (4) implementability; and (5) cost. The NCP describes this analysis as the primary balancing of these five factors that follows consideration of the two threshold criteria. To facilitate the evaluation, each threshold and balancing criterion is scored by EPA reflecting how well the alternative met each criterion. The score ranged from a low of "0" to a high of "5" and is posted after the criterion assessment, with the exception of compliance with ARARs. Since overall compliance with ARARs will be accomplished during remedial action for the Basin Watershed OU2, each interim remedial alternative was given a "+" if it contributed to compliance or a "-" if it did not.

State and community acceptance are factored as modifying criteria into a final balancing which determines the remedy. However, as explained previously, the modifying criteria will be addressed by EPA after presentation of the RI/FS and the proposed plan to the public and therefore are not evaluated in this FS.

4.3 Individual Analysis of Alternatives

4.3.1 Alternative 1—No Further Action

Description. This alternative would leave the Crystal Mine area in its current state. Completed and ongoing actions at the Site would remain as is. One completed action, now abandoned, consisted of a semi-active lime injection pilot project. Another completed action involved the trench located above the underground workings that was lined and filled during a TCRA. Ongoing activities consist of monitoring that is performed in accordance with the existing basin-wide plan.

Assessment

Overall Protection of Human Health and the Environment. Although the early action (MSE, 1998) showed promise in treating AMD, it did not affect overall site conditions and is not currently providing any treatment of AMD. This alternative would leave in place the waste rock and leave adit discharge flowing untreated at current levels. With the large quantity of source material, long-term natural attenuation is not expected to significantly improve water quality conditions over time. For the foreseeable future, Alternative 1 would be expected to exceed federal SDWA MCLs for arsenic, cadmium, and copper as well as Montana Numeric Water Quality Standards chronic and acute aquatic life criteria for arsenic, cadmium, copper, lead, and zinc. Alternative 1 would not be protective of human health or the environment. Score = 1.

Compliance with ARARs. Alternative 1 would not contribute to compliance with ARARs. Because no further action would occur, it would not contribute to meeting action-, chemical-, and location-specific ARARs. Score = "-".

Long-Term Effectiveness and Permanence. Because no additional actions would be taken to control the contaminants of concern, Alternative 1 would not provide a reliable or permanent interim remedy. Score = 1.

Reduction in Toxicity, Mobility, and Volume through Treatment. Alternative 1 does not provide any treatment and therefore has no effect on toxicity, mobility, or volume of COCs. Score = 1.

Short-Term Effectiveness. No short-term impacts would occur because no further action would be taken with this alternative. However, this alternative ranks low overall because the time until remedial response objectives are achieved would be hundreds of years. Score = 2.

Implementability. No implementation difficulties would be encountered with Alternative 1. Score = 5.

Costs. No costs other than those associated with monitoring ($231,000) would be associated with Alternative 1. Score = 5.

4.3.2 Waste Rock Alternatives

None of the waste rock alternatives alone would address adit discharges. Therefore, they are rated relative to one another, but will not provide for a complete remediation of Site contaminants unless they are combined with a groundwater alternative and other common elements.

4.3.2.1 Alternative WR-1—Waste Rock Capping

Description. This alternative would include capping of the waste rock with a liner and clean fill. Waste rock covers approximately 6 acres of the Site split between four different areas. Capping of this material would require grading of the waste rock to acceptable slopes, or terracing where grading is not achievable, covering the total surface area with HDPE liner, covering with 2 feet of imported clean fill (approximately 20,000 yd^{3}), and seeding with appropriate vegetation to protect against erosion. This alternative does not try to treat the COCs or source material, but seeks to isolate the source material from the environment.

Assessment

Overall Protectiveness of Human Health and Environment. This alternative would block the waste rock source of COCs, preventing them from being transported to receiving waters and isolating the waste rock from contact by visitors or intermittent workers. It would not prevent contact with excavation workers and would require an institutional control to protect the cover. Score = 3.

Compliance with ARARs. Implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2. Score = "+".

Long-Term Effectiveness and Permanence. Waste rock and contaminated soils are major sources of the COCs at the Site. This alternative would provide a permanent break in the pathway for the COCs from these sources. The long-term effectiveness and permanence of this alternative would depend on the amount of ARD reduction achieved by the proper installation of the barrier material, cover soil, and establishment of a robust vegetative cover. With proper installation, this alternative would provide an effective and permanent interim remedy for waste rock areas. Score = 3.

Reduction in Toxicity, Mobility and Volume through Treatment. This alternative would not include treatment and, therefore, would not reduce toxicity. However, by covering the contaminated waste rock and soils, it would reduce both the mobility of COCs and the volume of contaminants that receptors could be exposed to. Score = 3.

Short-Term Effectiveness. This alternative would require a large construction effort, disturbing both contaminated materials and some adjoining environment through construction of new or improved roads, grading of waste material, and reconstruction of capped areas. These activities would create potential risks to the Site workers typical of construction activities and result in some unavoidable short-term disturbance of ecological habitat. Short-term environmental impacts by implementation of this alternative would include the need to (1) improve access road and install security fencing and (2) control dust and stormwater from construction activities. Traffic from construction workers and equipment and from trucks hauling clean fill would have a minor impact on local roads and effect adjacent communities through higher use, dust, and noise. However, most of the traffic will be onsite. Reduced releases of COCs from waste rock areas are expected to occur upon construction completion. Score = 4.

Implementability. This alternative would be technically feasible and could be implemented using standard construction techniques. Sourcing and placing suitable cover material on steep slopes would present a technical challenge. Technical Score = 4.

This alternative would be administratively feasible with the most difficult aspect being meeting the substantive requirements of special use permits for use of USFS roads. Administrative Score = 4.

The most difficult aspect of this alternative would be obtaining the specialized construction expertise required for liner installation on steep slopes, which is available regionally but not locally. The availability of service and materials Score = 3.

Cost. Total net present value NPV costs for WR-1 are estimated to be approximately $4.8 million. Score = 4.

4.3.2.2 Alternative WR-2—Waste Rock Excavation and Local Disposal

Description. This alternative would include removal of the waste rock and underlying contaminated soils for disposal in an approved site. Waste rock (approximately 59,500 yd^3 covering approximately 6 noncontiguous acres of the Site) would be excavated and transported to an approved site for disposal. This option anticipates that the Luttrell site would be the acceptable and preferred disposal site. Following removal of the waste rock, the underlying soil (to a depth of 12 inches) would also be removed to ensure any COCs leached from the material did not remain. This material would also be transferred to the Luttrell site. The removed soil would be replaced with an equivalent layer of clean imported fill, estimated to be approximately 10,000 yd^3. The replacement soil would be graded to facilitate site drainage and seeded to reduce erosion.

Assessment

Overall Protectiveness of Human Health and Environment. This alternative would remove the waste rock and impacted soils below the rock, eliminating them as a source of COCs. Therefore, it is considered high in overall protectiveness. Score = 4.

Compliance with ARARs. Implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2. Score = “+”.

Long-Term Effectiveness and Permanence. Waste rock and contaminated soils are major sources of the COCs at the Site. This alternative would remove these sources, reducing the volume of COCs at the Site. The long-term effectiveness and permanence of this alternative would be dependent on the amount of AMD reduction achieved by surface water controls and on the complete removal of contaminated waste rock and soils. With proper construction this alternative would provide an effective and permanent interim remedy for waste rock and contaminated soils areas. Score = 5.

Reduction in Toxicity, Mobility and Volume through Treatment. This alternative would not include treatment and therefore would not reduce toxicity. However, by removing the contaminated waste rock and soils, it would reduce both the mobility of COCs and the total volume. Score = 4.

Short-Term Effectiveness. This alternative would require a large construction effort, disturbing both contaminated materials and some adjoining environment through construction of new or improved roads, grading of waste material, reconstruction of stream banks, and hauling contaminated materials across uncontaminated lands. These activities would create potential risks to the Site workers typical of construction activities and result in some unavoidable short-term disturbance of ecological habitat. Short-term environmental impacts by implementation of this alternative would include the need to (1) improve access road and install security fencing and (2) control dust and stormwater from construction activities. Traffic from construction workers and equipment and from trucks hauling waste to the Luttrell repository and clean fill to the Site would have a major impact on local roads and effect adjacent communities through higher use, dust, and noise. Reduced releases of COCs from waste rock areas are expected to occur upon construction completion. Score = 2.

Implementability. This alternative would be technically feasible and could be implemented using standard construction techniques. The most difficult technical aspect of this alternative would be sourcing and placing suitable cover material and the need to reconstruct access roads to the Site to accommodate haul trucks. Existing roads to the Site are very steep and have sharp curves that will need to be improved for safe hauling of waste materials. The long and difficult haul distance to Luttrell could necessitate the work going on over two construction seasons, or require use of smaller trucks, making it technically difficult to implement. This alternative is administratively feasible with the most difficult aspect being compliance with the substantive requirements of special use permits for USFS roads (if required). Technical, Administrative, and Service and Availability Score = 4.

Cost. Total NPV costs for Alternative WR-2 are estimated to be approximately $7.6 million. Score = 3.

4.3.2.3 Alternative WR-3— Waste Rock Excavation with Onsite Disposal

Description. This alternative would include removal of the waste rock and underlying contaminated soils for disposal in an onsite repository. Waste rock (approximately 60,000 yd^3 covering approximately 4.7 noncontiguous acres of the Site) would be excavated and transported to an approved site for disposal. This option incorporates a lined and capped onsite repository engineered and designed to be the permanent disposal site for waste rock from the Crystal Dump, Twin Ore Bins Dump, Mammoth Road and Dump, plus contaminated underlying soil (to a depth of 12 inches). The excavated soil would be replaced with an equivalent layer of clean imported fill, estimated to be approximately 7,500 yd^3. The replacement soil would be graded to facilitate site drainage and seeded to reduce erosion.

Assessment

Overall Protectiveness of Human Health and Environment. This alternative would remove most of the waste rock and impacted soils below the rock, eliminating them as a source of COCs. Score = 4.

Compliance with ARARs. Implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2. Score = “+”.

Long-Term Effectiveness and Permanence. Waste rock and contaminated soils are major sources of the COCs at the Site. This alternative would remove and isolate these sources, reducing the volume of COCs that receptors could be exposed to at the Site. The long-term effectiveness and permanence of this alternative would be dependent on the amount of ARD reduction achieved by surface water controls and on the efficiency of the removal of contaminated waste rock and soils to the repository. Successful slope stabilization and revegetation will contribute to the long-term effectiveness and permanence of this alternative. With proper construction this alternative would provide an effective and permanent interim remedy for waste rock and contaminated soils areas. Score = 4.

Reduction in Toxicity, Mobility and Volume through Treatment. This alternative includes amendment of soils placed in the repository and therefore would reduce toxicity. Removal of most of the contaminated waste rock and soils to a lined and capped repository would reduce the mobility of COCs. Slope stabilization, capping, and revegetating would also reduce the mobility of COCs. The volume of contaminated soils that receptors are exposed to is significantly reduced. Score = 4.

Short-Term Effectiveness. This alternative would require a large construction effort, disturbing both contaminated materials and some adjoining environment through construction of new or improved roads, grading of waste material, reconstruction of stream banks, and hauling contaminated materials across uncontaminated lands. These activities would create potential risks to the Site workers typical of construction activities and result in some unavoidable short-term disturbance of ecological habitat. Short-term environmental impacts from implementation of this alternative would include the need to (1) improve access road and install security fencing, and (2) control dust and stormwater from construction activities. Traffic from construction workers and equipment and from trucks hauling clean fill would have an impact on local roads in the immediate vicinity of the Site. The effect on local residents through higher truck use, dust, and noise would be considerably less than Alternative WR-2. Road improvements would be limited to onsite roads. Reduced releases of COCs from waste rock areas are expected to occur upon construction completion. Score = 4.

Implementability. This alternative would be technically feasible and could be implemented using standard construction techniques. The most difficult technical aspects of this alternative would be the sourcing and placing suitable cover material. Another technically difficult but achievable aspect is upgrading and maintenance of safe haul roads in steep terrain. Technical, Administrative, and Service and Availability Scores = 4

Cost. Total NPV costs for Alternative WR-3 are estimated to be approximately $5.2million. Score = 4.

4.3.3 Groundwater Alternatives

None of the groundwater alternatives alone would address contamination from the waste rock at the Site. Therefore, they are rated relative to one another, but will not provide for a complete remediation of Site contaminants unless they are combined with a waste rock alternative and other common elements.

4.3.3.1 Alternative GW-1— Mine Plugging Through Reopened Mine Adit

Description. This alternative includes sealing of the lower mine adit to block flow of AMD out of the mine. Mine sealing would be accomplished by reopening the blocked adit using traditional mine-tunneling techniques and shoring to access a point in competent rock, approximately 300 to 400 feet into the lower adit suitable for constructing a mine plug. With the plug completed, the mine drainage pipes would be shut off and AMD would be collected and stored in the mine behind the plug. An overflow well could be drilled and placed at an elevation that would prevent pooled water from entering the upper adit. If water discharges from the overflow well, it would need to be treated. For the purpose of evaluating this alternative, costs associated with treating overflow water were not considered, but would be expected to be equivalent to costs associated with alternative GW-5.

Assessment

Overall Protectiveness of Human Health and Environment. This alternative would block the point source discharge of AMD from the mine adit, removing a major contributor to the COCs at the Site. The extent to which this alternative is protective of human health and the environment is highly dependent on the effectiveness of the plugs, which is uncertain because of the unknown condition of the rock around the adit. Score = 3.

Compliance with ARARs. Determination of compliance with ARARs is deferred. As previously stated, the Site is located within the Basin Watershed OU2. Implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2. Score = “+”.

Long-Term Effectiveness and Permanence. AMD is a major source of the COCs at the Site. This alternative could provide a permanent break in the pathway for the COCs from this source. The long-term effectiveness and permanence of this alternative would be dependent on the effectiveness of the plug. If the plug is successful in blocking all AMD discharge, and the grout curtain maintains a water tight seal around the plug, and AMD does not find an alternative pathway to the surface, this alternative may provide a reliable and permanent interim remedy for AMD from the adit. Score = 3.

Reduction in Toxicity, Mobility and Volume through Treatment. This alternative would not include treatment and therefore would not reduce toxicity. However, by eliminating AMD it would reduce both the mobility of COCs and the total volume available to receptors. Reductions in COCs from adit discharge are expected to occur immediately after completion of construction. Score = 3.

Short-Term Effectiveness. Short-term construction risks are high because of confined space entry underground, which requires strict adherence to Mine Safety and Health Administration regulations, typical of tunneling projects. This alternative would require a large construction effort, disturbing both contaminated materials and some adjoining environment through reopening of the collapsed adit, and construction of new or improved roads. These activities would create potential risks to the Site workers typical of construction activities and result in some unavoidable short-term disturbance of ecological habitat. Short-term environmental impacts by implementation of this alternative would include the need to:

- Improve access road and install security fencing
- Clear and grub vegetation at the construction staging area and on the hill side in order to drill the grout curtain. Upon completing construction of the mine plug, the disturbed area around the Site would be seeded for erosion control.
- Traffic from construction workers and equipment and from trucks hauling adit waste and debris would have an impact on local roads and effect adjacent communities through higher use, dust, and noise (depending on the volume of waste requiring removal and disposal). Score = 3

Implementability. This alternative would be technically demanding, but could be implemented using standard construction and mining techniques. The most difficult technical aspect of this alternative would be reopening the collapsed adits, which requires specialized construction skills available regionally. Technical Score = 3.

This alternative is also administratively feasible with the most difficult aspect being complying with the substantive requirements of special use permits for USFS roads. Administrative Score = 4.

Local area mining expertise is readily available, and materials are available regionally. Availability of Service and Materials Score = 5.

Cost. Total NPV costs for Alternative GW-1 are estimated to be approximately $7.7 million. Score = 2.

4.3.3.2 Alternative GW-2—Mine Plugging through Borings from the Surface

Description. This alternative includes sealing of the lower mine adit to block flow of AMD out of the mine. Mine sealing would be accomplished by drilling access shafts from above the Site to intercept the lower mine adit at a location suitable for creating a plug. The plug would be installed remotely. Assuming a water tight plug can be constructed, AMD would be collected and stored in the mine behind the plug. An overflow well could be drilled and placed at an elevation that would prevent pooled water from entering the upper adit. If water discharges from the overflow well, it would need to be treated. For the purpose of evaluating this alternative, costs associated with treating overflow water were not considered but would be expected to be equivalent to costs associated with alternative GW-5.

Assessment

Overall Protectiveness of Human Health and Environment. This alternative would block the point source discharge of AMD from the mine adit, removing a major contributor to the COCs at the Site. The extent to which this alternative is protective of human health and the environment is highly dependent on the effectiveness of the plug, which is very uncertain because of the plug construction method, the unknown condition of the rock around the adit, and the reliability of the plug. Score = 2.

Compliance with ARARs. Implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2. Score = "+".

Long-Term Effectiveness and Permanence. AMD is a major source of the COCs at the Site. This alternative could provide a permanent break in the pathway for the COCs from this source. The long-term effectiveness and permanence of this alternative would be dependent on the effectiveness of the plug. If the plug is successful in blocking all AMD discharge, the grout curtain maintains a water tight seal around the plug, and AMD does not find an alternative pathway to the surface this alternative may provide a reliable and permanent interim remedy for AMD from the adit. However, waste rock, the other major source of COCs, would not be addressed under this alternative. Score = 2.

Reduction in Toxicity, Mobility and Volume through Treatment. This alternative would not include treatment and therefore does not reduce toxicity. However, by eliminating AMD it would reduce both the mobility of COCs and the total volume available to receptors. Reductions in COCs from adit discharge are expected to occur immediately after completion of construction. Score = 3.

Short-Term Effectiveness. This alternative would require a large construction effort, disturbing both contaminated materials and some adjoining environment through extensive drilling, construction of new or improved roads, removal of ponds, and reconstruction of stream banks. These activities would create potential risks to the Site workers typical of construction activities, as well as the risk inherent in the use of explosives, and result in some unavoidable short-term disturbance of ecological habitat. It should be noted that remote operations will result in less control of underground conditions and effective placement of a plug with a good seal. Short-term environmental impacts by implementation of this alternative would include the need to:

- Improve access road and install security fencing.
- Clear and grub vegetation at the construction staging area and on the hill side in order to drill the grout curtain. Upon completing construction of the mine plug, the disturbed area around the Site would be seeded for erosion control.
- Traffic from construction workers and equipment and from trucks hauling adit waste would have an impact on local roads and effect adjacent communities through higher use, dust, and noise. Score = 4.

Implementability. This alternative would be technically challenging, requiring specialized drilling and blasting techniques. A specialized track-mounted drill rig would be required because of the steep terrain. A truck- or trailer-mounted grout pump capable of pumping grout under high pressure (approximately 150 pounds per square inch or more) would be required to inject grout into the bore holes. The most difficult technical aspects of this alternative would be accurate placement of the drilled shafts and successful use of explosives to create the mine plug seals. Technical Score = 2.

This alternative would be administratively feasible with the most difficult aspect being complying with the substantive requirements of special use permits for USFS roads. Administrative Score = 4.

Successful grouting of these plug zones will likely require a considerable volume of grout to fill large voids left in the rubble and debris. These specialized construction skills and materials are anticipated to be available regionally. Availability Score = 4.

Cost. Total NPV costs for Alternative GW-2 are estimated to be approximately $12.2 million. This estimate carries considerable cost uncertainty given the nature of the activities. Score = 1.

4.3.3.3 Alternative GW-3—Active Treatment of Acid Mine Drainage

Description. This alternative includes active treatment of AMD prior to discharge reaching the receiving waters of local streams. In active treatment, an HDS plant is considered a representative treatment plant placeholder for evaluation to treat the AMD. The HDS plant would consist of a series of tanks for storing lime, mixing slurry, and mixing AMD with the slurry. The treated water would go through a clarifier prior to release to receiving waters. This process requires a number of pumps for transferring material, air blowers, injection systems and drying beds for sludge. Processed and dried sludge would need to be transferred to a repository, assumed to be Luttrell for this alternative. This alternative requires a fairly constant supply of AMD so a mine bulkhead would need to be constructed for mine water storage in the lower adit with piping and valves to control flow of AMD to the plant (see Figure 3-10). A permanent source of electricity would be required to run the plant. Staffing would be required year-round, and access roads would need to be improved to reach the Site. It is assumed that common remedial actions dealing with removal of the ponds and mine buildings will be implemented as part of the alternative. In the winter, when the road is blocked by snow, alternate transportation would be required to reach the Site.

Assessment

Overall Protectiveness of Human Health and Environment. This alternative would capture and treat the point source discharge of AMD from the mine adit, removing a major contributor to the COCs at the Site. With proper operation and maintenance this alternative would be protective of human health and the environment. Score = 5.

Compliance with ARARs. Implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2. Score = “+”.

Long-Term Effectiveness and Permanence. AMD is a major source of the COCs at the Site. This alternative would provide long-term treatment of the COCs from this source. HDS plants typically provide removal efficiencies greater than 94 percent. The long-term effectiveness and permanence of this alternative would be dependent on the successful maintenance and operation of it over time. If the treatment plant is successful in eliminating the COCs in the AMD it may provide a reliable and permanent interim remedy for AMD from the adit. Score = 5.

Reduction in Toxicity, Mobility and Volume through Treatment. This alternative would treat AMD in the adit discharge and would reduce toxicity and total volume of COCs. Mine storage of water would help reduce mobility of untreated water. Reductions in COCs from adit discharge are expected to occur immediately after completion of construction. Score = 5.

Short-Term Effectiveness. This alternative would require a large construction effort, disturbing both contaminated materials and some adjoining environment through construction of new or improved roads, removal of ponds, reconstruction of stream banks, and construction of the treatment plant. These activities would create potential risks to the Site workers typical of construction activities and result in some unavoidable short-term disturbance of ecological habitat including the following:

- Site preparation in the form of vegetation removal and site grading would need to be completed around the treatment plant area (approximately 0.5 acre).
- Installation of power lines running from the town of Basin to the Site for plant operation.
- Post-construction activities would include final grading of the construction site and erosion control seeding on all construction-impacted soils.
- Local roads would be highly impacted during construction, and see an ongoing slight rise in vehicular traffic as a result of daily activities to implement Alternative GW-3. Score = 2.

Implementability. This alternative would be technically challenging, requiring specialized treatment plant construction and operation in a remote location. Contractors familiar with HDS water treatment systems would be required to install the treatment system and trained water treatment plant operator(s) would be required for treatment plant operation. Aboveground power lines would be installed from the town of Basin along Basin Creek Road and up the County and USFS-maintained road to the site. The most difficult technical aspects of this alternative would be plugging the adit and the long-term operation and maintenance of the treatment plant. Technical Score = 2.

This alternative would be administratively feasible and would require compliance with USFS special use permit substantive requirements and County bridge weight limitations for hauling treatment plant equipment to the Site and waste sludge to the repository. Administrative Score = 4.

Expertise in operation and maintenance of this water treatment system is available regionally, but HDS treatment equipment specifically sized and configured for this Site is not. Availability of Service and Materials Score = 3.

Cost. Total NPV costs for Alternative GW-3 are estimated to be approximately $7.6 million. Some cost uncertainty is acknowledged because of unknown conditions associated with opening the adit for bulkhead construction. Score = 2.

4.3.3.4 Alternative GW-4— Semi-Active Treatment of AMD (Quicklime Injection System)

Description. This alternative includes semi-active treatment of AMD prior to discharge reaching the receiving waters of local streams. In semi-active treatment a quicklime injection system is used to treat the AMD. As with the active treatment alternative, supply of AMD would need to be controlled. Control would be provided by a concrete plug in the adit with associated piping and valves to direct a measured stream of AMD to the treatment system (see Figure 3-10).

Assessment

Overall Protectiveness of Human Health and Environment. This alternative would capture and treat the point source discharge of AMD from the mine adit, removing a major contributor to the COCs at the Site. Effectiveness in protecting human health and the environment would be dependent on long-term operations and maintenance of the treatment plant. Score = 4.

Compliance with ARARs. Implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2. Score = “+”.

Long-Term Effectiveness and Permanence. AMD is a major source of the COCs at the Site. This alternative would provide long-term treatment of the COCs from this source. Semi-active lime injection systems often provide removal efficiencies between 85 percent and 95 percent. The long-term effectiveness and permanence of this alternative would be dependent on the successful maintenance and operation of it over time. If the treatment system is successful in eliminating the COCs in the AMD, it may provide a reliable and permanent interim remedy for adit discharge. Score = 4.

Reduction in Toxicity, Mobility and Volume through Treatment. This alternative would treat AMD in the adit discharge, and reduce toxicity, mobility at the mine discharge interception point, and total volume of COCs. Reductions in COCs from adit discharge are expected to occur immediately after completion of construction. Waste rock, the other major source of COCs, would not be addressed under this alternative. Score = 4.

Short-Term Effectiveness. This alternative would require a large construction effort, disturbing both contaminated materials and some adjoining environment through construction of new or improved roads, removal of ponds, reconstruction of stream banks, and construction of the treatment ponds and ditches. These activities would create potential risks to the Site workers typical of construction activities and result in some unavoidable short-term disturbance of ecological habitat.

Short-term impacts would include:

- Excavation of roughly 5,600 yd^3 of soils.
- Clearing of approximately 2.5 acres of vegetation at the Site.
- Post construction activities, final grading of the construction site and erosion control seeding on all construction impacted soils.
- Traffic from construction workers and equipment and from trucks hauling treatment plant components would have an impact on local roads and effect adjacent communities through higher use, dust, and noise. Score = 4.

Implementability. This alternative would be technically feasible using standard construction techniques. The most difficult technical aspects of this alternative would be the plugging of the adit, and long-term operation and maintenance of the treatment system. Technical Score = 4.

A special use permit may be required from the USFS to haul reagent on USFS roads. This alternative would be administratively feasible. Administrative Score = 4.

Special skills and materials are available regionally. Availability of Services and Materials Score = 3.

Cost. Total NPV costs for Alternative GW-4 are estimated to be approximately $4.9 million. Some cost uncertainty is acknowledged because of unknown conditions associated with opening the adit for bulkhead construction. Score = 3.

4.3.3.5 Alternative GW-5— Semi-Passive Treatment of AMD (SRBR)

Description. This alternative includes semi-passive treatment of AMD prior to discharge to the receiving waters. Semi-passive treatment consists of a three stage process using a pH adjustment cell, an SRBR, and a clarification pond. Routine maintenance would not be required with this alternative but it would require some long-term maintenance. The compost layers in the first stage would require rototilling every 2 years and replacement every 6 years, the secondary cells would have to be replaced every 15 years, and the sludge from the clarification pond would need to be removed, dried, and transported to the Luttrell repository periodically. As with the active treatment alternative, supply of AMD would need to be controlled. Control would be provided by a concrete plug in the adit with associated piping and valves to direct a measured stream of AMD to the treatment system (see Figure 3-10).

Assessment

Overall Protectiveness of Human Health and Environment. This alternative would capture and treat the point source discharge of AMD from the mine adit, removing a major contributor to the COCs at the Site. The effectiveness of this alternative would be dependent on proper long-term maintenance and periodic replacement of the treatment components. Score = 3.

Compliance with ARARs. Implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2. Score = "+".

Long-Term Effectiveness and Permanence. AMD is a major source of the COCs at the Site. This alternative would provide long-term treatment of the COCs from this source. Semi-passive treatment systems can provide removal efficiencies of 75 percent to 90 percent with proper installation and maintenance. The long-term effectiveness and permanence of this alternative would be dependent on the successful maintenance of it over time. If the treatment system is successful in eliminating the COCs in the AMD, it may provide a reliable and permanent interim remedy for the adit discharge. Score = 3.

Reduction in Toxicity, Mobility and Volume through Treatment. This alternative would treat AMD in the adit discharge, and reduces toxicity, mobility at the mine discharge interception point, and total volume of COCs. Reductions in COCs from adit discharge are expected to occur relatively soon after completion of construction. Score = 3.

Short-Term Effectiveness. This alternative requires a large construction effort, disturbing both contaminated materials and some adjoining environment through construction of new or improved roads, removal of settling ponds, reconstruction of stream banks, and construction of the new treatment ponds. These activities would create potential risks to the Site workers typical of construction activities and result in some unavoidable short-term disturbance of ecological habitat.

Short-term impacts would include:

- Excavation of roughly 5,600 yd^3 of soils.
- Clearing of approximately 2.5 acres of vegetation at the Site.

- Post construction activities, final grading of the construction site and erosion control seeding on all construction impacted soils.

Traffic from construction workers and equipment and from trucks hauling treatment plant components would have an impact on local roads and effect adjacent communities through higher use, dust, and noise. Reduced COC releases would occur upon completion of construction. Score = 4.

Implementability. This alternative would be technically feasible using standard construction techniques. The most difficult technical aspects of this alternative would be the plugging of the adit, and long-term operation and maintenance of the treatment system. Technical Score = 4.

This alternative would be administratively feasible. Administrative Score = 4.

Expertise for this alternative is available locally. Availability of Service and Materials Score = 4.

Cost. Total NPV costs for Alternative GW-5 are estimated to be approximately $4.3 million. Some cost uncertainty is acknowledged because of unknown conditions associated with opening the adit for bulkhead construction. Score = 4.

4.3.3.6 Alternative GW-6— Semi-Passive Treatment of AMD (SRBR with Aeration, Settling Ponds and Wetlands Systems)

Description. This alternative includes passive treatment of AMD prior to discharge to polishing wetlands and USG Creek. Passive treatment consists of a five-stage process using SRBRs, aeration systems, and oxidation/settling ponds, wetland, and discharge system. Routine maintenance would not be required with this alternative but it would require some long-term maintenance. The compost layers in the first stage would require rototilling every 5 years and replacement every 8 to 10 years. The secondary cells would have to be replaced every 10 to 15 years. Sludge from the clarification pond would need to be removed, dried, and transported to the Luttrell repository periodically. Unlike the active treatment and semi-passive alternatives, the supply of AMD would not be controlled with this alternative. The AMD discharge would be allowed to free flow from the mine at natural rates into pipes connected to the treatment system.

Assessment

Overall Protectiveness of Human Health and Environment. This alternative would capture and treat the point source discharge of AMD from the mine adit, removing a major contributor to the COCs at the Site. The effectiveness of this alternative would be dependent on proper long-term maintenance and periodic replacement of the treatment components. Score = 3.

Compliance with ARARs. Implementation of this remedial alternative will contribute to the overall compliance with ARARs for the Basin Watershed OU2. Score = "+".

Long-Term Effectiveness and Permanence. AMD is a major source of the COCs at the Site. This alternative would provide long-term treatment of the COCs from this source. Passive treatment systems can provide removal efficiencies up to 90 percent with proper installation and maintenance. The long-term effectiveness and permanence of this alternative would depend on the successful maintenance of the system over time. If the sulfate-reducing bioreactor cells function properly, the system should be successful in eliminating the COCs in the AMD, thus providing a reliable and permanent interim remedy for the adit discharge. Score = 3.

Reduction in Toxicity, Mobility and Volume through Treatment. This alternative would treat AMD in the adit discharge and reduces toxicity and total volume of COCs. Reductions in COCs from adit discharge are expected to occur shortly after completion of construction. Score = 3.

Short-Term Effectiveness. This alternative would require a large construction effort, disturbing both contaminated materials and some adjoining environment through construction of new or improved roads, removal of settling ponds, reconstruction of stream banks, and construction of the new treatment cells, ponds, and channels. These activities would create potential risks to the Site workers typical of construction activities and result in some unavoidable short-term disturbance of ecological habitat.

Short-term impacts would include:

- Excavation of roughly 5,600 yd^3 of soils.
- Clearing of approximately 2.5 acres of vegetation at the Site.
- Post-construction activities, final grading of the construction site and erosion control seeding on all construction impacted soils.

Traffic from construction workers and equipment and from trucks hauling treatment system components would have an impact on local roads and effect adjacent communities through higher use, dust, and noise. Score = 4.

Implementability. This alternative would be technically feasible using standard construction techniques. Knowledgeable expertise and labor with equipment would be readily available. The most difficult technical aspect of this alternative would be the periodic maintenance of the treatment system and permanent establishment of the wetland vegetation. This alternative would be administratively feasible. Technical, Administrative, and Availability Scores = 4.

Cost. Total NPV costs for Alternative GW-6 are estimated to be approximately $3.7 million. Score = 4.

4.4 Comparative Analysis

In this section a comparative analysis is presented that evaluates the relative performance of each alternative in relation to each of the nine criteria. The purpose of this analysis is to identify the advantages and disadvantages of each alternative relative to one another so that key tradeoffs can be identified.

4.4.1 Alternative 1

4.4.1.1 Overall Protection of Human Health and the Environment

Alternative 1 would leave existing conditions at the Site unchanged. This alternative would not address or mitigate the identified baseline risks to human or ecological receptors.

4.4.1.2 Compliance with ARARs

Alternative 1 would not involve any construction or operation and maintenance activities. Therefore, it would not trigger any ARARs that control such activities, but it also would not promote compliance with ARARs at the Site. All other alternatives would contribute to compliance with ARARs. However, a full determination of compliance with ARARs is deferred until a ROD for the entire Basin Watershed is prepared.

4.4.1.3 Long-Term Effectiveness and Permanence

Alternative 1 would leave existing conditions at the Site unchanged. This alternative would be least effective over the long term compared to the other action alternatives.

4.4.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 does not provide any treatment and therefore has no effect on toxicity, mobility, or volume of COCs.

4.4.1.5 Short-Term Effectiveness

Alternative 1 would have the least short-term impact because no construction would occur.

4.4.1.6 Implementability

Technical Feasibility. Alternative 1 would not involve construction, so no technical constraints exist with regard to its implementation.

Administrative Feasibility. Alternative 1 would have no administrative feasibility constraints.

Availability of Services and Materials. Alternative 1 would not involve any construction activities; therefore, no constraints would be associated with the availability of services and materials.

4.4.1.7 Cost

No costs are associated with the Alternative 1.

4.4.1.8 State and Community Acceptance

State and community acceptance will be evaluated through the community involvement process. As members and representatives of the state and community provide comments, response action alternatives will be re-assessed and potentially modified. State and Community concerns will be considered by EPA during preparation of the ROD.

4.4.2 Waste Rock Alternatives

4.4.2.1 Overall Protection of Human Health and the Environment

Based on the findings of the risk assessment (CH2M HILL, 2013), which used a weight-of-evidence approach, multiple lines of evidence support the conclusion that exposure to mine-related contaminants in site media pose an unacceptable risk to human health and the environment. Arsenic in soil is the contaminant of highest potential risk to human health, and inhalation of contaminants is the exposure pathway of greatest concern. The contaminants with the highest potential for ecological risk are (1) aluminum, antimony, arsenic, cadmium, copper, lead, selenium, silver, and zinc in soil and sediment, and (2) aluminum, cadmium, copper, lead, and zinc in surface water.

The alternatives proposed in this FS offer varying degrees of human health and environmental protection as discussed in the following text.

Alternatives WR-1, WR-2, and WR-3 would attempt to control risks by covering or removing waste rock at the Site, thereby blocking or removing the exposure pathway to human and aquatic contact. Alternative WR-1, capping, would lose effectiveness over time because of weathering, erosion, or damage from other sources. It would require continued maintenance and monitoring to maintain effectiveness and is ranked as providing moderate protection to human health and the environment. Alternative WR-2, removal of waste rock, would completely eliminate the source of COCs and would provide a high degree of protection to human health and the environment. Alternative WR-3 would move all waste rock to a lined onsite repository, which would also isolate the wastes and provide a high degree of protection. WR-3 would provide this high degree of protection at a lower cost, a lower impact to the local community using potential haul roads, and with a lower carbon footprint than WR-2. EPA Guidance stresses the importance of green remediation and optimization of Superfund cleanups in the OSWER Directive 9200.3-75 entitled “National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion” (2012).

WR-1, would require ongoing monitoring and potentially significant maintenance of capped areas for effectiveness at the Site. For WR-2, the monitoring and maintenance activities would be at the Luttrell repository, where such activities are fully addressed in existing agreements between state and federal agencies. Monitoring and maintenance for WR-3 would be less intensive than for WR-1. For WR-1 and WR-3, monitoring and maintenance would occur at the Site.

4.4.2.2 Compliance with ARARs

Appendix B contains an analysis and discussion of potential ARARs for the Site.

A detailed comparison of ARARs between alternatives was not performed. The Crystal Mine OU5 cleanup will be an interim remedial action where compliance with groundwater and surface water ARARs is concerned. For now, EPA is invoking the interim action waiver as provided in 40 CFR § 300.430(f)(1)(ii)(C)(*1*) with respect to all water quality ARARs at OU5. EPA doesn’t expect that this action will result in final compliance with surface and ground water ARARs at the Basin Mining District NPL Site. Final compliance with these water ARARs may happen after all five site-wide OUs have been addressed. If not, EPA will issue a technical impracticability waiver at the time it issues the ROD for the last of the five OUs at the Site. This will be as provided in 40 CFR § 300.430(f)(1)(ii)(C)(*3*). Any waiver will explain why it is technically impracticable to meet certain water quality ARARs at that time. It should be noted that EPA expects all other ARARs for the Crystal Mine OU5 action to be complied with during or at completion of the action, as appropriate.

4.4.2.3 Long-Term Effectiveness and Permanence

Alternative WR-1, WR-2, and WR-3 provide varying degrees of long-term effectiveness with WR-1, capping, being less effective than WR-2 removal and WR-3 relocation to an onsite repository. The long-term effectiveness of the removal alternatives is expected to be high with the only variable being how thoroughly the waste rock and contaminated soils are removed and the effectiveness of the onsite isolation of wastes for WR-3. Capping, as a standalone alternative or in combination with removal, is expected to be less effective, relying on proper installation of a cap and proper maintenance and monitoring to ensure long-term effectiveness.

4.4.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

WR-2 is the only alternative that includes potential treatment of wastes placed in the onsite repository. The other alternatives do not provide reduction in toxicity or volume through treatment, however, each of these alternatives significantly reduces the mobility of the waste with WR-2 being more effective than WR-1 and slightly more effective than WR-3.

4.4.2.5 Short-Term Effectiveness

Alternatives WR-1, WR-2, and WR-3 would all initially carry some short-term physical safety risk because of the transport and operation of construction equipment. WR-2 carries the highest amount of short-term safety risk because of transport of wastes offsite to the Luttrell repository. Potential risk of short-term exposure to COCs mobilized by earth moving operations is also a concern of these alternatives. Safety risks can be mitigated by proper planning and proper implementation of health and safety plans for onsite workers. Precautions to inform the residents of Basin of the construction and to keep the general public away from the Site would also be implemented to help reduce the risk to the community. Alternative WR-2 requires the removal of over 69,000 yd^3 of contaminated materials and transport to the site of 10,000 yd^3 of clean material. Alternative WR-3 would relocate approximately 60,000 yd^3 onsite. Alternative WR-1 requires transport to the site of 20,000 yd^3 of clean materials, but the waste rock would not leave the Site. Therefore, WR-1 and WR-3 would have the shorter construction timelines, which contributes to their assessment of having lower short-term impacts.

4.4.2.6 Implementability

Technical Feasibility. Alternative WR-1, WR-2, and WR-3 would require standard earth-moving techniques. Placement of several liners at capped areas in Alternative WR-1 would require a specialty contractor, and grading and benching steep areas of the Site would be challenging. A liner is also required for the onsite repository in alternative WR-3. However, the technical difficulties of a longer haul route over steep, narrow, winding roads to the Luttrell repository in Alternative WR-2 was deemed equivalent in technical difficulty to the liner installation.

Administrative Feasibility. Administrative feasibility constraints common to Alternatives WR-1, WR-2, and WR-3 would include meeting the substantive requirements of a special-use permit for improving USFS-maintained access roads to the Site as well as requirements for any improvements to county roads, if required. Therefore, the waste rock alternatives were ranked equivalent in their administrative implementibility.

Availability of Services and Materials. The services and materials required for Alternatives WR-1, WR-2, and WR-3 are essentially the same except for the liner in Alternatives WR-1 and WR-3, and the potential for specialized transport vehicles needed to safely haul wastes to Luttrell repository in Alternative WR-2. The installation of the liner at capped areas with steep slopes in Alternative WR-1 justifies a lower score than the other two alternatives because of the need for more skilled/specialized services and more liner material. Therefore, Alternative WR-1 is ranked below Alternatives WR-2 and WR-3 in availability of services and materials.

4.4.2.7 Cost

Table 4-2 (at the end of this section) presents the costs that are common to all alternatives. Table 4-3 (at the end of this section) summarizes the direct and indirect capital costs and the long-term operation and maintenance costs for the waste rock alternatives. Direct capital costs pertain to construction, materials, land, transportation, and analysis of samples. Indirect capital costs pertain to design, legal fees, and permits. Long-term operation and maintenance costs pertain to maintenance and long-term monitoring and are presented as the present worth value. Appendix C contains information and assumptions used to estimate costs. Alternative 1 is the lowest cost option ($0), followed by Alternative WR-1 ($4.8 million), Alternative WR-3 ($5.2 million), and Alternative WR-2 ($7.6 million).

4.4.2.8 State and Community Acceptance

State and community acceptance will be evaluated through the community involvement process. As members and representatives of the state and community provide comments, remedial action alternatives will be re-assessed and potentially modified. State and Community concerns will be considered by EPA during preparation of the Interim ROD.

4.4.3 Groundwater Alternatives

4.4.3.1 Overall Protection of Human Health and the Environment

Alternatives GW-1 and GW-2 would attempt to control the exposure risks by capturing the groundwater flow within the mine complex and preventing it from discharging. If successful, these alternatives would have the potential to provide a high measure of risk reduction by breaking the exposure pathway to human and aquatic receptors. However, if not successful, these alternatives would rank low in overall protection. The risk that these alternatives carry would be allowing untreated groundwater to build up behind the plugs, potentially creating a large pressure head. As the pressure head grows, so does the potential for plug failure, seepage around the plug and grout curtain, as well as the creation of new contaminated seeps as pooled mine water moves through fractures within the host rock. Another concern is that the water could pool up behind the plug to an elevation exceeding that of the upper adit, necessitating treatment of water discharging from a relief well. This would add significant cost to these alternatives. Therefore, Alternatives GW-1 and GW-2 are rated moderate for overall protection of human health and the environment. Both alternatives are highly dependent on effectiveness of the plug construction. Alternative GW-1 provides for better control of the construction process and is therefore rated ahead of Alternative GW-2 in protection of human health and the environment.

Alternative GW-3 would use a conventional, demonstrated treatment process which offers the greatest protection to both human health and the environment. This alternative would effectively capture and reliably treat the AMD, breaking the human health and ecological exposure pathways. However, this alternative requires full-time plant operation and the highest level of maintenance to remain effective.

Alternative GW-4 would be less protective than Alternative GW-3 because under ideal conditions it provides less reduction in COCs and the treatment process is subject to variability caused by limited treatment pond capacities and potential treatment upsets or disruptions that would go undetected because of lack of regular operator attention. Although the degree of treatment of the effluent would be acceptable, it would be less efficient and reliable than that of Alternative GW-3.

Alternative GW-5 and GW-6 would be less protective than either Alternative GW-3 or Alternative GW-4 because it offers less direct control over the treatment process and has lower overall reduction efficiencies. These alternatives would rely on a natural chemical process for pH adjustments with a biological process to reduce sulfates. The treatment process would be restricted to cells constructed within ponds, somewhat limiting the exposure pathway. However, the settling and polishing ponds are open and their effectiveness would be subject to variability caused by capacity, influenced by local precipitation patterns, and seasonal variations in temperature.

4.4.3.2 Compliance with ARARs

Appendix B contains an analysis and discussion of potential ARARs for the Crystal Mine.

A detailed comparison of ARARs between alternatives was not performed. The Crystal Mine OU5 cleanup will be an interim remedial action where compliance with groundwater and surface water ARARs is concerned. For now, EPA is invoking the interim action waiver as provided in 40 CFR § 300.430(f)(1)(ii)(C)(*1*) with respect to all water quality ARARs at OU5. EPA doesn't expect that this action will result in final compliance with surface and ground water ARARs at the Basin Mining District NPL Site. Final compliance with these water ARARs may happen after all five site-wide OUs have been addressed. If not, EPA will issue a technical impracticability waiver at the time it issues the ROD for the last of the five OUs at the Site. This will be as provided in 40 CFR § 300.430(f)(1)(ii)(C)(*3*). Any waiver will explain why it is technically impracticable to meet certain water quality ARARs at that time. It should be noted that EPA expects all other ARARs for the Crystal Mine OU5 action to be complied with during or at completion of the action, as appropriate.

4.4.3.3 Long-Term Effectiveness and Permanence

The long-term effectiveness of Alternatives GW-1 and GW-2 would potentially range from as low as 25 percent to as high as 90 percent. This large potential range is because of uncertainties associated with the competence of fractured bedrock surrounding the underground workings, lack of information concerning geologic conditions and potential sources within the mine workings, and uncertainties concerning the efficiency of the grout curtain. Alternative GW-1 would provide greater effectiveness and permanence than Alternative GW-2 because of the controlled nature of the plug construction versus Alternative GW-2, which relies on remote techniques for blasting, grouting, and plug placement. Groundwater seeps around and through the grout curtain can occur over time as groundwater head pressure builds behind the grout curtain. The grout curtain would degrade over time because of the corrosiveness of the groundwater built up behind the grout curtain. As a result the grout curtain would require replacement approximately every 10 years.

Alternative GW-3 would offer the greatest long-term effectiveness because of the process control that is available to the trained operator of the plant. Typical removal efficiencies at similar HDS treatment plants at other mine sites are often greater than 99 percent. Operational upsets within the treatment system would reduce the removal efficiencies at times, but could be readily diagnosed and corrected by the operator. Telemetry and system alarms allow for rapid operation and maintenance response by the operator in the event of a treatment system upset. Continuous monitoring of plant influent and effluent could help regulate chemical feed rates, and contaminants would be removed from the water prior to discharge. Alternative GW-3 requires the greatest level of operations and maintenance effort to ensure long-term effectiveness. Given the remote location of the Site (it is only accessible by snowmobile in the winter) this is a significant constraint for at least 6 months each year.

Alternative GW-4 would offer the potential for 85 to 95 percent effectiveness of removal of COCs. Upsets within the system could be diagnosed and corrected by trained operators. However, because of the lower level of operation and maintenance required, and no telemetry or alarms included with Alternative GW-4, upsets within the treatment system would take longer to discover, diagnose, and correct when compared to Alternative GW-3. Also, as sludge precipitates out and collects in the primary and secondary settling ponds, the retention time would drop which would affect the long-term effectiveness of the system. Proper operations and maintenance for the treatment ponds and process would contribute significantly to the long-term effectiveness and permanence of this treatment alternative.

Alternatives GW-5 and GW-6 would offer 75 to 90 percent long-term effectiveness. The reduced effectiveness of these alternatives is because the anaerobic biological processes are not as effective or efficient as chemical precipitation and a cold climate may influence the robust function of the processes. Upsets (such as scaling) within the treatment system could go longer without being identified and managed when compared to Alternatives GW-3 and GW-4. Scaling in GW-5, which is the buildup of precipitate on limestone in the pH adjustment pond, would reduce the effectiveness of the pond over time, resulting in lower pH of effluent water, thus reducing the effectiveness of the SRBR cells. Scaling in GW-6 is less of an issue because the water will go anaerobic as it moves through the bioreactors. However, aeration of the water as it flows into the settling ponds will generate precipitation of iron oxyhydroxides in the form of sludge that will need to be disposed of periodically. Proper operations and maintenance for the treatment ponds/cells and process would contribute significantly to the permanence of this treatment alternative.

4.4.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives GW-3, GW-4, GW-5, and GW-6 would all offer treatment, while Alternatives 1, GW-1, and GW-2 do not. All treatment alternatives would reduce the toxicity, mobility, and volume of arsenic and metal contaminants in the AMD. In the process, sludges and wastes are created as a byproduct of all four treatment alternatives and must be properly disposed of in a local repository. The predicted treatment efficiency of each alternative reflects its ability to reduce toxicity, mobility, and volume of contaminants in the AMD. As briefly cited in Section 4.3, the potential efficiencies for the proposed alternatives are as follows:

- **No Action**—no reduction
- **Mine Plugging (GW-1 and GW-2)**—25 to 90 percent reduction
- **Active Treatment (GW-3)**—greater than 99 percent reduction
- **Semi-Active Treatment (GW-4)**—potentially 85 to 95 percent reduction
- **Semi-Passive Treatment (SRBR) (GW-5 and GW-6)**—potentially 75 to 95 percent reduction

Alternative GW-3 would offer the greatest amount of control of sludges by drying the sludges as part of the treatment process. Alternatives GW-4, GW-5, and GW-6 would require excavation and drying of sludges prior to disposal. In addition, it is presumed that some of the excavated materials would be characterized as hazardous by Toxicity Characteristic Leaching Procedure testing prior to disposal at the Luttrell Repository or in an onsite repository. Because Alternatives GW-5 and GW-6 have less control, resulting in the potential for greater mobility of COCs when compared to Alternative GW-4, Alternative GW-4 is rated higher than Alternatives GW-5 and GW-6.

Because of the lack of any treatment process, Alternatives 1, GW-1, and GW-2 are rated lower than Alternatives GW-3, GW-4, GW-5, and GW-6.

4.4.3.5 Short-Term Effectiveness

Alternatives GW-1 and GW-2 would initially carry some short-term safety risk because of the transport and operation of construction equipment. While working around and in the mines, safety of workers is a concern. Potential exposure risk from contact of AMD is also a concern in the short-term with these two alternatives. Safety risks can be mitigated by proper planning and proper implementation of health and safety plans for onsite workers. Precautions to inform the residents of Basin of the construction and to keep the general public away from the Site would also be implemented to help reduce the risk to the community. Depending on the condition of the mines, construction might be completed in one field season versus the two field seasons predicted for the other alternatives. Because of the inherent risk in mine tunnel construction Alternative GW-1 is considered to have greater short-term impacts than Alternative GW-2.

Alternative GW-3 would require improving the access road to the Site to allow for installation of power and utilities and year-round site access. Structures to house the treatment process and store additives would need to be built. This alternative would carry similar short-term safety concerns as discussed for Alternatives GW-1 and GW-2. The safety concerns would be mitigated in a similar manner. Precautions to inform the residents of Basin of the construction and to keep the general public away from the Site would also be implemented to help reduce the risk to the community. Construction would probably require two field seasons, but when complete the treatment process should be fully effective.

Alternatives GW-4, GW-5, and GW-6 would impose the lowest amount of short-term impacts on the mine sites and the local populations. Implementation of these alternatives would carry similar safety concerns as previously described, but would need to be applied over two construction seasons. Precautions to inform the residents of Basin of the construction and to keep the general public away from the Site would also be implemented to help reduce the risk to the community. Unlike Alternative GW-3, when construction is complete, several years may be required before these systems meet their optimal treatment efficiencies.

Implementation of Alternative GW-4, GW-5, or GW-6 would have the greatest short-term effectiveness of the alternatives considered. They would result in the lowest increase in local traffic, as well as having the lowest impact on the local community.

4.4.3.6 Implementability

Technical Feasibility. Alternative GW-1 would require specialized services to re-open mine portals and construct safe entry points into the mines. Assessment and inspection of the adits for evaluation of seepage and recharge and strategic placement of mine plugs would require special mining expertise and equipment. However, these activities are technically feasible to execute. Alternative GW-2 would require specialized services to place underground explosives. Drilling and injecting of the grout curtain around the adit plugs are also technically feasible but challenging considerations associated with Alternative GW-2. Alternatives GW-1 is more technically implementable than GW-2 because of its remote application. Technical feasibility constraints associated with Alternative GW-3 would be the construction, year-round operation of the treatment plant, and providing power to the Site. Since these constraints are dependent on hiring appropriate contractors and not on site-specific variables Alternative GW-3, in spite of the need for power and year-round access, is considered more technically implementable than all of the other GW alternatives although start-up and successful commissioning of active systems can be challenging.

Technical feasibility challenges associated with Alternatives GW-4, GW-5, and GW-6 are installing the treatment ponds/cells, installing HDPE and PVC liners, collecting contaminated groundwater, and successful start-up. These alternatives are considered equivalent in technical implementability, below Alternative GW-3 and above Alternative GW-1 and GW-2.

All proposed alternatives with the exception of Alternative 1 are consistent with the long-term remedial plan for the Basin Watershed OU2 cleanup.

Administrative Feasibility. All of the groundwater alternatives would require meeting the substantive requirements of a special use permit for construction and installation on USFS property and improving USFS-maintained access roads. In addition, waste sludges generated by the treatment alternatives would have to be characterized and managed in compliance with state and federal solid and hazardous waste regulations. Alternatives GW-1 and GW-2, with no sludge generation, would be equivalent and slightly more implementable than Alternative GW-3, GW-4, GW-5, and GW-6. Alternatives GW-3, GW-4, GW-5, and GW-6 would be equivalent and slightly harder to implement than Alternative 1 and GW-1 and GW-2.

Availability of Services and Materials. Most of the services and materials associated with the implementation of Alternatives GW-1 and GW-2 would be available regionally. Specialized drilling services required by Alternative GW-2 would be more difficult to obtain than the other features of the alternatives and therefore Alternative GW-2 is ranked below Alternative GW-1 in availability of services and materials.

Alternative GW-3 would require the construction of a water treatment plant which would require specialized supply and services available regionally. Alternative GW-3 is ranked lowest of the five groundwater alternatives in availability of services and materials, and because of the lack of power and difficulty with winter access to the Site.

Alternatives GW-4, GW-5, and GW-6 would require specialized construction capabilities available regionally. These alternatives are equivalent and ranked above Alternative GW-3 but below Alternatives GW-1 and GW-2.

4.4.3.7 Cost

Table 4-2 (at the end of this section) presents the costs that are common to all alternatives. Table 4-4 (at the end of this section) summarizes the direct and indirect capital costs and the long-term operation and maintenance costs for the groundwater alternatives. Direct capital costs pertain to construction, materials, land, transportation, and analysis of samples. Indirect capital costs pertain to design, legal fees, and permits. Long-term operation and maintenance costs pertain to maintenance and long-term monitoring and are presented as the present worth value. Appendix C contains information and assumptions used to estimate costs. Ranked by cost, the groundwater alternatives from least to most costly are Alternative GW-6 ($ 3.7 million), Alternative GW-5 ($4.3 million), Alternative GW-4 ($4.9 million), Alternative GW-3 ($7.6 million), Alternative GW-1 ($7.7 million), and Alternative GW-2 ($12.2 million).

4.4.3.8 State and Community Acceptance

State and community acceptance will be evaluated through the community involvement process. As members and representatives of the state and community provide comments, remedial action alternatives will be re-assessed and potentially modified. State and Community concerns will be considered by EPA during preparation of the ROD.

4.4.4 Summary of Comparative Analysis

The eight remedial alternatives were compared against each other by media to evaluate the relative performance of each alternative in relation to each of the criteria (Table 4-1). A rating scale of 1 through 5 was used for each criterion in the waste rock media and 1 through 5 was used for each criterion in the groundwater media, with 1 being the lowest rated and successive higher numbers reflecting higher ratings.

In summary, Alternative 1 would not change existing conditions and would not offer protection of human health or the environment. Both waste rock alternatives and all six groundwater alternatives would offer enhanced protection of human health and the environment through interruption of COC pathways, or treatment of AMD discharge. None of the alternatives address both AMD and waste rock together, and, therefore, none are completely protective of human health and environment on their own. It is anticipated that a phased remedial approach incorporating a waste rock and a groundwater option would need to be implemented in order to adequately protect human health and the environment.

TABLE 4-1
Comparative Analysis

Criterion	No Further Action	Waste Rock Alternatives			Groundwater Alternatives					
	1	WR-1	WR-2	WR-3	GW-1	GW-2	GW-3	GW-4	GW-5	GW-6
Effectiveness										
Human health and environment	1	3	4	4	3	2	5	4	3	3
Compliance with ARARs deferred	-	+	+	+	+	+	+	+	+	+
Long-term effectiveness	1	3	5	4	3	2	5	4	3	3
Reduction in toxicity, mobility, volume	1	3	4	4	3	3	5	4	3	3
Short-term effectiveness	2	4	2	4	3	4	2	4	4	4
Implementability										
Technical	5	4	4	4	3	2	2	4	4	4
Administrative	5	4	4	4	4	4	4	4	4	4
Availability of service and materials	5	3	4	4	5	4	3	3	4	4
State and Community Acceptance										
Cost										
Present worth cost ranking	5	4	3	4	2	1	2	3	4	4
Present worth cost ($000,000)	.23	4.8	7.6	6.5	7.7	12.2	7.6	4.9	4.3	3.7
Total Score	**25**	**28+**	**30+**	**32+**	**26+**	**22+**	**28+**	**30+**	**29+**	**29+**

Notes:
Common Elements: Cost of common elements is in addition to alternative costs—see Table 4-2.
+ indicates the alternative promotes ARAR compliance in the Basin Watershed

TABLE 4-2
Cost of Common Elements (in addition to Remedial Alternative Costs)

	Surface Water Runoff Controls	Stream Bank Reconstruction	Removal of Ponds and Buildings
Capital Cost (NPV)	$101,000	$639,000	$259,000

TABLE 4-3
Cost Comparison—Waste Rock

	Alternative 1	WR-1	WR-2	WR-3
Capital Cost	$0	$4,328,000	$7,098,000	$4,687,000
NPV of Operation and Maintenance	$0	$472,703	$472,703	$472,703
Total NPV	$0	$4,801,000	$7,571,000	$5,160,000

TABLE 4-4
Cost Comparison—Groundwater

	Alternative 1	GW-1	GW-2	GW-3	GW-4	GW-5	GW-6
Capital Cost	$0	$6,534,000	$11,409,000	$4,781,000	$3,315,000	$3,296,000	$2,570,000
NPV of Operation and Maintenance	$231,000	$1,164,000	$818,583	$2,874,000	$1,681,000	$1,053,000	$1,170,000
Total NPV	$231,000	$7,698,000	$12,228,000	$7,655,000	$4,996,000	$4,349,000	$3,740,000

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Appendix A
Treatability Study: Preliminary Activities—Piezometer Installation and Groundwater Hydrogeology, Crystal Mine Wetland Area; and 2012 Installation, Sampling, and Testing of Groundwater Monitoring Wells – Crystal Mine OU5 Basin, Montana

Treatability Study: Preliminary Activities - Piezometer Installation and Groundwater Hydrogeology, Crystal Mine Wetland Area

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DATE: October 13, 2011

INTRODUCTION

Surface water draining into, and through, the wetland area north of the Crystal Trench is believed to be a possible source of water recharge into the underground workings of the Crystal mine. This water interacts with the sulfide mineralization in the mine and eventually discharges as acid mine drainage. A deep boring, located adjacent to the wetlands, exposed intermittent zones of fractured bedrock (potential pathways) down to the lower workings. It was hypothesized that if surface water and shallow groundwater in this area could be diverted and controlled, then the subsurface water recharge into the mine workings could possibly be reduced or eliminated; and thus could prove to be an effective remediation measure to control acid mine drainage. This potential condition formed the basis for a treatability study discussed during the development and evaluation of viable remedial alternatives for the feasibility study. The objective of the treatability study was to divert the surface water and shallow groundwater moving through the wetland (soil –bedrock interface) and monitor the lower adit discharge volume, to gage an associated reduction. If the surface diversion significantly reduced the adit discharge volume (>75%), the remedy for the balance of the mine discharge would likely favor a passive treatment scheme instead of a more aggressive mine plugging action.

Potential sources of water that could enter the mine's lower workings include downward percolation of surface water through fractured rock or open fractures, surface runoff into trenches, pits, and shallow shafts in the vicinity, and local groundwater movement through a fracture-dominated bedrock aquifer. Based on anecdotal historic evidence from miners (Hansen, 2010), the majority of the inflow into the lower workings of the Crystal Mine entered through a large quartz vein near the western terminus of the lower workings. These workings are spatially oriented beneath the wetland area north of the Crystal trench (approximately 300 feet below ground surface). The "Hydrogeologic Conditions and Groundwater Movement" Technical Memorandum (CH2M HILL, 2011) describes perceived groundwater flow through the area in more detail.

In September 2011, a subsurface investigation of the southern portion of the wetland, north of the Crystal Trench area, was conducted to:

- Evaluate depth to bedrock and nature of shallow bedrock,
- evaluate the presence and extent of groundwater perched on the shallow bedrock, and
- determine whether this area is a surface water dominated recharge site that eventually supplies water into the Crystal mine, or, conversely, if the wetland overlays an area of more regional groundwater discharge in the vicinity.

Field data and additional subsurface investigation results describe the local groundwater flow, define the extent of subsurface saturation, describe the vertical groundwater gradient, and provide a better understanding of subsurface flow prior to investing in a costly water diversion design and construction. This preliminary characterization will determine whether the capture and diversion of the surface water and shallow groundwater would have the desired effect of significantly reducing the source of water infiltrating and migrating downward into the mine.

The investigation consisted of:

- excavation of test pits to competent bedrock and installation of shallow piezometers to measure shallow subsurface flow, and
- drilling boreholes to multiple depths and installating piezometers at different elevations to evaluate the groundwater conditions and measure the vertical gradients exposed by differences in static water levels.

TEST PIT INVESTIGATION

The objective of test pit investigation was to evaluate groundwater flow in the shallow subsurface (upper 10 to 15 feet) in the wetland vicinity and measure depth to solid bedrock to determine if the area is suitable for a surface and shallow groundwater collection system.

Thirteen (13) test pits were excavated by Schnell Excavating using a Komatsu PC 200-LC track-mounted excavator with a 36-inch wide bucket. The test pits ranged in depth from 5 to 12 feet, and were excavated to hard but typically fractured granitic rock that caused bucket refusal. Prior to excavation, eight (8) test pit locations were staked in an effort to achieve a representative site sampling array. Based on preliminary findings, five additional test pits were excavated in order to more completely characterize the subsurface. Attachment A includes a map that shows the test pit locations.

Test pit logs that describe total depth, lithology and depth of soil and weathered rock, presence of groundwater, excavation stability, and other relevant information were completed in the field. Upon documenting soil profile characteristics, depth of refusal, and occurrence of groundwater, the test pits were backfilled to grade with excavated materials. In test pits where moisture or seepage was observed, standpipe piezometers were installed to evaluate shallow groundwater conditions. These piezometers consisted of a 10-foot long, 1-inch PVC pipe with hand-cut slots that were typically placed 3 to 9 feet below ground surface. The PVC piezometers were held in place during the pit backfilling and surrounded by native materials. Attachment B contains draft field copies of the test pit logs.

The test pit locations were surveyed by licensed surveyors. Survey points included the ground surface elevation and coordinates, and the piezometer measuring point elevations and coordinates. Table 1 provides a summary of the test pit information

TEST PIT FINDINGS

The subsurface stratigraphy in the test pits generally consisted of surficial soils capping highly weathered, in-place granite that overlies hard granitic bedrock. The surficial soils were typically between 2 and 6 feet thick and consisted of brown to orange to gray silty sand, clayey sand, and sandy clay. These soils are alluvially-transported and derived from the surrounding underlying granite. The weathered granite layer is decomposed into silty sand, clayey sand, and sandy clay, and has relic rock structure visible. The non-weathered granite is typically gray and hard but fractured near the surface. The depth to hard granite ranged from 6 to 12 feet below ground surface.

Seepage from the test pit walls was typically between 4.5 and 7 feet below ground surface, and was most commonly observed emanating from iron oxide stained fractures and loose sandy zones in the highly weathered granitic rock, rather than the uppermost soil layers. In CWTP-10, seepage was observed beneath a thick clay layer. The seepage rate into the test pit walls from the fractured rock was generally low; and was estimated to be typically less than one gallon per minute (gpm). The highest observed seepage rate was in CWTP-6 and was estimated to be approximately one gpm. Depth-to-water measurements in the test pit piezometers indicated that the shallow groundwater is generally within one to two feet of the ground surface.

The test pit observations indicated that the shallow subsurface water is not perched in the uppermost surficial soils, but rather flowing through fractures and weathered sandy zones within the weathered bedrock. Photos 1 and 2 illustrate this condition.

Photo 1 – Seepage from iron-stained fracture in weathered granitic rock.

Photo 2: Seepage from two fractures in weathered granitic rock, approximately 6 feet bgs.

The seepage is occurring through discrete fractures and the weathered zones, rather than diffuse seepage and groundwater flow through the unconsolidated soils. Given these conditions, to successfully and efficiently collect and divert shallow groundwater through surface diversions would be difficult. The zones of shallow transmission are heterogeneous, hence the collector pipes would likely intercept some, but probably not all shallow fracture flow zones. In addition, the shallow groundwater discharging from the weathered granite appears to be true subsurface flow, rather than shallow surface water that is infiltrating downward into the bedrock.

DRILLING AND PIEZOMETER INSTALLATION

The drilling and geologic exploration was conducted in September 2011 and supervised by a CH2M HILL engineering geologist. The borings were drilled by Axis Drilling, Inc. of Belgrade, MT, under subcontract to CH2M HILL. The borings were advanced using a track-mounted drilling rig, equipped with a Tubex 3-7/8" diameter downhole hammer. Six-inch casing was advanced to 15 feet below ground surface, and the remainder of the borings were advanced open-hole in the rock. The borings were drilled to depths of 25, 80, and 138 feet, to encounter the different vertical water-bearing zones within weathered and fractured bedrock.

The piezometer casings and screens consisted of threaded, flush-jointed, 1-inch-diameter, Schedule 40 PVC. A ten-foot section of factory-slotted 0.020-inch slot screen was installed at the bottom of each well. Colorado silica sand (10-20 gradation) was placed around the screen to act as a filter pack. The filter pack was placed to approximately 1 to 2 feet above the top of the well screen. A seal of bentonite pellets was placed in the boring annulus above the sand and hydrated to provide a seal on the top of the sand pack and isolate the screened interval. Bentonite chips were poured in the remainder of the annulus to within 1 foot of the ground surface. The wells were finished using an above-ground monument that consists of a 4-inch-square steel casing cemented into the ground with approximately 2.0 feet of stickup and a locking cover. Table 2 provides a summary of the borehole depths, screen intervals, and groundwater elevations. Attachment A shows the locations of the piezometers and test pits. Attachment C contains draft field copies of the boring logs.

The piezometers were purged by inserting a ¾" HDPE tubing to the bottom of the piezometers and blowing out the water with the air compressor. This was done in order to ensure that water that entered the piezometer casing during installation was evacuated and the piezometer was allowed to recover through the sealed screened interval. Table 2 provides a summary of the piezometers and groundwater elevations.

PIEZOMETER FINDINGS

The piezometers were drilled open-hole (below 15 feet in depth) to evaluate the subsurface rock properties and presence of fractured and weathered zones that could transmit groundwater, and whether there were numerous water-bearing zones. Boring CWB-3 was drilled first to a depth of 138.2 feet bgs to evaluate the overall stratigraphy and presence of water-bearing zones. This boring indicated that the subsurface in the vicinity consists of alternating layers of weathered brownish-gray granite with clayey zones to hard, gray granite with greenish mineral alteration. In addition, occasional hard but fractured quartz veins were encountered at depths of 102 and 128 feet. These quartz veins appeared to transmit more groundwater and thus when quartz vein was intercepted near the target depth it was a logical choice to screen and complete the piezometer at this depth (128 to 138 feet bgs).

Boring CWB-2 was drilled 4 feet away from CWB-3 and thus encountered similar stratigraphy, but quartz veins were observed from 77 to 80 feet in depth. Therefore the screen in this piezometer was placed 70 to 80 feet bgs to capture water in these quartz veins. Boring CWB-1 was drilled to a depth of 25.5 feet bgs and screened from 15.5. to 25.5 in wet, saturated, weathered granite. During the drilling it was noted that the boreholes all produced water throughout their depth, which suggest that numerous water-bearing fractures and zones are present in the subsurface and that the subsurface is generally saturated.

Depth to groundwater in each piezometer was measured after allowing several days of water level recovery after piezometer development. The depths to water were converted to water level elevations in feet above sea level in order to determine general groundwater saturation conditions and calculate the vertical gradient. The static water level elevations are summarized in Table 2.

The highest groundwater level elevation was measured in CWB-3, the deepest screened interval, and the static level was actually 1.2 feet higher than the ground surface. This indicates that artesian conditions exist at depth.

Piezometers CWB-2 and CWB-1, with screen intervals from 70 to 80 feet and 15.5 to 25.5 feet below ground surface respectively, each showed static water levels less than 0.5 feet below the ground surface elevation, which also indicates artesian conditions.

The groundwater elevations in the piezometers were used to calculate vertical groundwater gradient and determine if the vertical gradient is upward or downward (Table 2). There are upward vertical gradients between wells CWB-2 and CWB-1, and wells CWB-3 and CWB-2 of 0.016 and 0.024 feet, respectively. Overall, the data indicate an average upward vertical gradient of 0.02 ft/ft between wells CWB-3 and CWB-1. The upward vertical gradient indicates that the groundwater actually flows upward through the subsurface. The presence of these artesian conditions in the subsurface indicates this is a discharge zone fed by a higher-elevation distant recharge area.

TABLE 1
Test Pit Summary

Test Pits	Ground Elev. (ft amsl)	MP Elev. (ft amsl)	Depth to water (ft bmp)	Depth to Rock (ft bgs)	Water Level Elev. (ft)	Rock Elev. (ft)
CWTP-1	7927.18	7927.90	4.33	6.0	7923.57	7921.2
CWTP-2	7929.09	---	(DRY)	7.0	---	7922.1
CWTP-3	7938.05	7938.85	3.6	11.0	7935.25	7927.1
CWTP-4	7938.95	7939.58	2.49	12.0	7937.09	7927.0
CWTP-5	7942.10	---	(DRY)	11.0	---	7931.1
CWTP-6	7941.14	7942.01	1.59	8.5	7940.42	7932.6
CWTP-7	7943.31	7943.68	3.49	7.5	7940.19	7935.8
CWTP-8	7931.59	---	(DRY)	6.0	---	7925.6
CWTP-9	7932.34	---	(DRY)	6.0	---	7926.3
CWTP-10	7947.97	7947.97	1.02	9.5	7946.95	7938.5
CWTP-11	7946.28	---	(DRY)	8.5	---	7937.8
CWTP-12	7941.27	7941.27	2.78	12.0	7938.49	7929.3
CWTP-13	7934.38	7934.38	1.91	11.0	7932.47	7923.4

TABLE 2
Borehole and Piezometer Summary

Piezometer	Borehole Depth (ft bgs)	Screen interval (ft bgs)	MP Elevation (ft amsl)	Depth to water (ft bmp)	Water Level Elev. (ft)	Vertical Distance Between Screen Midpoints (ft)	Vertical Groundwater Gradient (ft/ft)	Vertical Gradient Direction (up/down)
CWB-1	25.5	15.5 - 25.5	7941.53	2.86	7938.67	54.5 (B2 - B1)	0.016 (B-2 to B-1)	Up
CWB-2	80.0	70.0 - 80.0	7941.70	2.15	7939.55	58.2 (B3 - B2)	0.024 (B-3 to B-2)	Up
CWB-3	138.2	128.2 - 138.2	7941.60	0.68	7940.92	112.7 (B3 - B1)	0.020 (B-3 to B-1)	Up

CONCLUSIONS AND RECOMMENDATIONS

- Acid mine drainage from the lower Crystal Mine adit portal is hypothesized to originate as surface water in the wetland above the western portion of the lower workings, that infiltrates downward into the lower workings as groundwater. The path of the groundwater flow into the mine could either be a single large, transmissive fault or open fracture, a collapsed mine shaft or raise that intercepts a fracture, flow through a dense network of fractures, or a combination of all the above. Because of complex subsurface conditions and limited subsurface data, it is not evident which of these is the case, or if it is a combination.
- However, based on the available data, several characteristics of site conditions are evident. These include:
  - In the shallow subsurface (upper 10 feet), shallow groundwater was observed to flow through fractures and sandy zones in the weathered granite, rather than through the uppermost shallow soils as surface flow.
  - In the deeper subsurface (upper 140 feet), numerous vertical water-bearing zones and fractures exist within the granitic bedrock, and artesian conditions were observed during drilling and post-drilling monitoring. Several quartz veins that appear to transmit larger quantities of groundwater were observed. It is likely that a large network of quartz veins and fractures are present in the bedrock profile from the ground surface down to the mine workings, and these structural features provide conduits for groundwater movement through the area.
  - The recharge area for the wetlands is possibly quite large and extends beyond the immediate surface wetland area. The presence of artesian conditions in the deep piezometers indicates a high degree of saturation in the area. In addition, the artesian conditions indicate that the wetland is likely a groundwater discharge area.
- It is difficult or impossible to determine the specific source of the water that discharges from the alleged quartz vein and fractures associated with the west end of the mine's lower working. The orientation and persistence of this vein is not known, and it may collect and transmit water from a long distance. This vein may intersect other veins in the subsurface and form a complex network of groundwater fracture flow. If the shallow surface flow in the wetland area is collected and diverted, but it doesn't represent the total, or a significant portion of the total source of groundwater in the subsurface quartz veins and bedrock fractures, then the flow contributing to recharge into the lower workings will likely show little, if any, reduction in volume. Thus, the remedial goal of eliminating acid drainage would not be achieved. The large recharge area and large amount of subsurface flow through the fractures in the bedrock are too prevalent and dispersed to effectively collect.
- In conclusion, based on the deep saturated subsurface conditions, collecting and diverting shallow groundwater and surficial flows through surface diversions would would likely intercept some of the flow, but probably only a small percentage of shallow fracture flow zones. In addition, the source of the deeper artesian groundwater is likely from beyond the boundaries of the wetland area and collecting this water would be extremely costly and difficult to accomplish.
- Based on the information presented in this technical memorandum, it is recommended that EPA not implement the north wetland surface water diversion as proposed, and leave the area in its current condition as a sustainable high alpine wetland.

REFERENCES

CH2M HILL, 2010. *Hydrogeologic Conditions and Groundwater Movement, Crystal Mine site.* Technical Memorandum.

Hansen, B., 2010. Personal communication

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Attachment A – Test Pit and Piezometer Location Map

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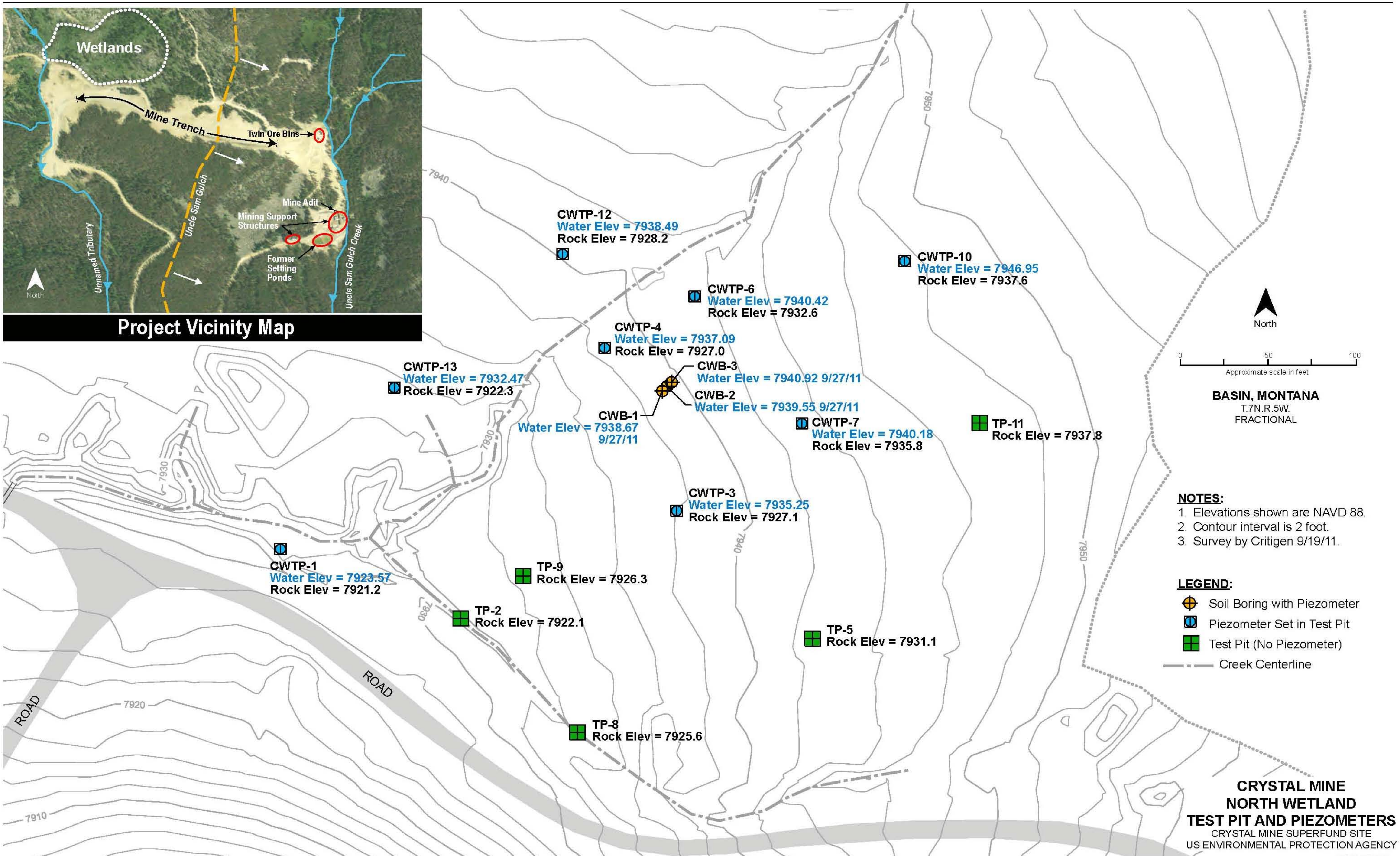
Wetlands
Mine Trench
Twin Ore Bins
Mine Adit
Mining Support Structures
Former Settling Ponds
Uncle Sam Gulch
Uncle Sam Gulch Creek
Unnamed Tributary
North
Project Vicinity Map
CWTP-12
Water Elev = 7938.49
Rock Elev = 7928.2
CWTP-10
Water Elev = 7946.95
Rock Elev = 7937.6
CWTP-6
Water Elev = 7940.42
Rock Elev = 7932.6
CWTP-4
Water Elev = 7937.09
Rock Elev = 7927.0
CWTP-13
Water Elev = 7932.47
Rock Elev = 7922.3
CWB-3
Water Elev = 7940.92 9/27/11
CWB-2
Water Elev = 7939.55 9/27/11
CWB-1
Water Elev = 7938.67
9/27/11
CWTP-7
Water Elev = 7940.18
Rock Elev = 7935.8
TP-11
Rock Elev = 7937.8
CWTP-3
Water Elev = 7935.25
Rock Elev = 7927.1
CWTP-1
Water Elev = 7923.57
Rock Elev = 7921.2
TP-9
Rock Elev = 7926.3
TP-2
Rock Elev = 7922.1
TP-5
Rock Elev = 7931.1
TP-8
Rock Elev = 7925.6
ROAD
ROAD
7910
7920
7930
7940
7950
North
0
50
100
Approximate scale in feet
BASIN, MONTANA
T.7N.R.5W.
FRACTIONAL
NOTES:
1. Elevations shown are NAVD 88.
2. Contour interval is 2 foot.
3. Survey by Critigen 9/19/11.
LEGEND:
Soil Boring with Piezometer
Piezometer Set in Test Pit
Test Pit (No Piezometer)
Creek Centerline
CRYSTAL MINE
NORTH WETLAND
TEST PIT AND PIEZOMETERS
CRYSTAL MINE SUPERFUND SITE
US ENVIRONMENTAL PROTECTION AGENCY
CH2MHILL.

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Attachment B – Field Copies of Test Pit Logs

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<table>
<tr><td>Project:</td><td colspan="3">Crystal Mine</td></tr>
<tr><td>Test Pit Number:</td><td>CWTP-1</td><td>Northing (ft)[1]:</td><td>779175.9</td></tr>
<tr><td>Location:</td><td>Crystal Wetland</td><td>Easting (ft)[1]:</td><td>1270681.1</td></tr>
<tr><td>Logger:</td><td>G. Warren</td><td>Water Level (bmp):</td><td>4.33'</td></tr>
<tr><td>Elevation (mp):</td><td>7927.9</td><td>Contractor:</td><td>Schnell</td></tr>
<tr><td>Date Excavated:</td><td>9/15/2011</td><td>Excavation Equipment:</td><td>Komatsu Exc. PC200</td></tr>
<tr><td>Depth Below Surface (ft)</td><td>Sample Interval[2]</td><td>General Soil Description[2]</td><td>Comments[2]</td></tr>
<tr><td>1</td><td rowspan="7"></td><td>Sand/brown</td><td rowspan="5">Digging at base of road fill berm on north side of road, south side of channel

See photos of intact wx rock and fractures/veins

Seepage at 4.6'</td></tr>
<tr><td>2</td><td>Gray clay layer</td></tr>
<tr><td>3</td><td rowspan="2">Silty sand, clayey sand and sandy clay (SM-SC-CL), brown to orange, wx/decomposed granite intact but wx to soil</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td><td>Iron stained Fracture with gray clay seams</td></tr>
<tr><td>6</td><td rowspan="2">Broken granite cobbles/angular

Hard but fractured granite</td><td rowspan="2">Hard rock at 6', rock surface wavy

Install 1" PVC piezo, slots 3'-6.5' bgs, out 3' off top, 0.5' stick up</td></tr>
<tr><td>7</td></tr>
<tr><td colspan="4">End of Test Pit 1 - Total Depth: 6.5'</td></tr>
<tr><td colspan="4">Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.   Notes:

[2]All information is transcribed from field notebooks.</td></tr>
</table>

Project:	Crystal Mine		
Test Pit Number:	CWTP-2	Northing (ft)[1]:	779133.9
Location:	Crystal Wetland	Easting (ft)[1]:	1270786.2
Logger:	G. Warren	Water Level (bmp):	Dry
Elevation (ground):	7929.09	Contractor:	Schnell
Date Excavated:	9/15/2011	Excavation Equipment:	Komatsu Exc. PC200
Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		Sand with clay to clayey sand (SC), brown with gray mottling, moist, fine-coarse sand derived from wx granite and till, occasional clayey pockets	Dig parallel to channel
2			
3			Vertical walls
4			3 photos
5			
6		Gravel with sandy clay (GC), approximately 8" minus angular wx granite clasts	
7		7' Fractured granite bedrock	No water inflow, hard digging, refusal
8			Total depth = 7.5' Backfill, no piezo pipe

End of Test Pit 2 - Total Depth: 7.5'

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

Project:	Crystal Mine		
Test Pit Number:	CWTP-3	Northing (ft)[1]:	779199.0
Location:	Crystal Wetland	Easting (ft)[1]:	1270912.3
Logger:	G. Warren	Water Level (bmp):	3.6'
Elevation (mp):	7938.85	Contractor:	Schnell
Date Excavated:	9/15/2011	Excavation Equipment:	Komatsu Exc. PC200
Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		OL topsoil/peat	
2		Sand with silt to sandy clay (SW to CL), mixed, brown to orange to gray mottled, wet	See photo Wet sandy material, generally wet 2-4' (to top of CH)
3			
4		Fat sandy clay (CL), light brown and orange, moist, very plastic	Looks more "wetlandy"
5		Clayey sand to sandy clay, light orange brown, very moist, intact rock structure/texture, in-place wx granite (regolith)	
6			Minor seepage, less than 1 gpm, from sandy seam
7			
8			Seepage at 8', less than 1 gpm from sandy seam
9			Install piezo 1" pipe, slots 4'-10' (3'-9' bgs) Bottom at 9' bgs
10			
11		Harder granite at 11'	Total depth = 11' at hard rock
End of Test Pit 3 - Total Depth: 11.0'			

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

Project:	Crystal Mine		
Test Pit Number:	**CWTP-4**	Northing (ft)[1]:	779297.3
Location:	Crystal Wetland	Easting (ft)[1]:	1270870.2
Logger:	G. Warren	Water Level (bmp):	2.49
Elevation (mp):	7939.58	Contractor:	Schnell
Date Excavated:	9/15/2011	Excavation Equipment:	Komatsu Exc. PC200
Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		Silt (OL), peat	
2		Sandy clay (CL), silty sand (SM-SW) to clayey sand, light brown to orange brown to yellow and gray, moist to very moist	Approximately 15' from channel
3			
4			
5		Highly wx granite to sandy clay, RO to RI, iron stains and veins	Vertical walls, but caving below 5' in wx rock
6			Seepage at 6' bgs In fractures in wx rock
7		Clayey sand and sandy clay, derived from wx granite clasts (feldspar wx to clay)	
8			Approximately 1 gpm
9			Photos of wx granite and seepage
10			Discrete seepage in fractures; not diffuse flow through soils
11			Install 1" PVC piezo, slot 4'-9' bgs, 1' stick up
12		Hard granite at 12' bgs	Hard digging Total depth = 12'
End of Test Pit 4 - Total Depth: 12.0'			

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

Project:	Crystal Mine		
Test Pit Number:	CWTP-5	Northing (ft)[1]:	779121.8
Location:	Crystal Wetland	Easting (ft)[1]:	1270991.5
Logger:	G. Warren	Water Level (bmp):	Dry
Elevation (ground):	7942.1	Contractor:	Schnell
Date Excavated:	9/15/2011	Excavation Equipment:	Komatsu Exc. PC200
Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		Sand (SW), trace silt and clay, dry to slightly moist, light brown with some ox stain, derived from wx granite/till	East edge of wetland on "higher ground"
2			
3			Vertical wall
4			3 photos
5		Sand (SW) gray, highly wx/decomposed granite, intact rock fabric but H=RO, feldspar wx to clay	
6			
7			
8		Occasional gravel/intact granite cobbles/angular to subangular breaks down to sand and clayey sand, gray, H=RO-RI and occational R2 pieces	Slightly harder digging
9			
10			Dry, no water in flow, no piezo
11		Harder fractured granite	Refusal at 11'
End of Test Pit 5 - Total Depth: 11.0'			

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

Project:	Crystal Mine		
Test Pit Number:	**CWTP-6**	Northing (ft)[1]:	779328.3
Location:	Crystal Wetland	Easting (ft)[1]:	1270922.8
Logger:	G. Warren	Water Level (bmp):	1.59
Elevation (ground):	7942.01	Contractor:	Schnell
Date Excavated:	9/15/2011	Excavation Equipment:	Komatsu Exc. PC200
Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		Silt (OL)	
2		Sandy clay to clayey sand (CL-SC), gray brown to orange brown, sloping contacts and "pockets" of jumbled material, fine	Vertical wall
3			2 photos 13 and 14
4			Seepage at 4.5' bgs Approximately 1 gpm
5		Wet silty to clayey sand (SC), orange, wet, some highly wx granite	Caving below 5' in wet sandy material
6			
7		Occasional angular cobbles (broken granite)	
8		Hard granite at 8.5'	Install 1" PVC piezo, slots 3.5'-8.5' bgs Total depth= 8.5'
9			
End of Test Pit 6 - Total Depth: 8.5'			

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

Project:	Crystal Mine		
Test Pit Number:	**CWTP-7**	Northing (ft)[1]:	779251.7
Location:	Crystal Wetland	Easting (ft)[1]:	1270985.3
Logger:	G. Warren	Water Level (bmp):	3.49
Elevation (mp):	7943.68	Contractor:	Schnell
Date Excavated:	9/15/2011	Excavation Equipment:	Komatsu Exc. PC200
Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		Large rounded boulders at surface (till), silty (OL)	
2		Layers of brown sand with silt (SW), orange brown, sandy clay	Wet but no seepage
3		Weakly stratified sand/silt/clay	Wet but no seepage
4		Pockets of tan clay layers	Wall caved
5		Getting into broken rock with sandy infill in fractures	3 photos
6			
7		Hard and fractured granite	Install 1" PVC pipe piezometer, slots 3'-8' bgs and 2' stick up
8			Total depth= 7.5' refusal
End of Test Pit 7 - Total Depth: 7.5'			

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

Project:	Crystal Mine		
Test Pit Number:	**CWTP-8**	Northing (ft)[1]:	779065.2
Location:	Crystal Wetland	Easting (ft)[1]:	1270854.3
Logger:	G. Warren	Water Level (bmp):	Dry
Elevation (ground):	7931.59	Contractor:	Schnell
Date Excavated:	9/15/2011	Excavation Equipment:	Komatsu Exc. PC200
Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		Sand with silt, dry to slightly moist, clayey sand pockets, some gray and orange mottling, occasional fine gravels	3 photos Vertical walls
2			
3		Boulders at 3'	Harder digging
4		Gravel (boulders), with sand, silt, clay matrix	
5			Dig around boulders to loosen up
6		Fractured granite rouce 6'	Rock surface is irregular, cannot dig, refusal at 6.6',
7		Hard and fractured granite Total depth= 6'	Dry- no water in flow, no piezo installed, backfill
End of Test Pit 8 - Total Depth: 6'			

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

Project:	Crystal Mine		
Test Pit Number:	**CWTP-9**	Northing (ft)[1]:	779159.5
Location:	Crystal Wetland	Easting (ft)[1]:	1270822.7
Logger:	G. Warren	Water Level (bmp):	Dry
Elevation (ground):	7932.34	Contractor:	Schnell
Date Excavated:	9/15/2011	Excavation Equipment:	Komatsu Exc. PC200
Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		Silt (OL), dark brown	Approximately 20' from channel
2		Gravelly sand and silt (GM), orange to gray, dry, wx granite rock fragments	
3			
4		Wx, fractured granite, breaks into angular clasts, 1' minus	
5			Dry, no seepage
6		Harder	Total depth= 6' Diggable but with great effort, no piezo installed
7		Hard Granite	
End of Test Pit 9 - Total Depth: 6'			

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

Project:	Crystal Mine		
Test Pit Number:	CWTP-10	Northing (ft)[1]:	779349.7
Location:	Crystal Wetland	Easting (ft)[1]:	1271045.3
Logger:	G. Warren	Water Level (bmp):	1.02
Elevation (mp):	7947.97	Contractor:	Schnell
Date Excavated:	9/16/2011	Excavation Equipment:	Komatsu Exc. PC200
Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		Brown silty sand (SM-SW), moist, fine to medium	North east of TP-6
2			
3		Sandy clay (CL), mottled orange and gray, moist, very stiff, plastic	Seepage below clay layer
4			
5		Granite rock highly wx to slity clayey sand (SM-SC), mottled gray and orange, rock texture and structure visible	Seepage below 5', approximately 1 gpm, photo of fracture and seepage
6			
7			
8			Caving along fractures in dense granite
9		Hard Granite	Seepage Photos of seepage from fracture
10			Total depth=9.5' Install piezo 1" PVC, slots 4'-9' bgs, 1' stick up
End of Test Pit 10 - Total Depth: 9.5'			

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

Project:	Crystal Mine		
Test Pit Number:	CWTP-11	Northing (ft)[1]:	779251.9
Location:	Crystal Wetland	Easting (ft)[1]:	1271089.2
Logger:	G. Warren	Water Level (bmp):	Dry
Elevation (ground):	7946.28	Contractor:	Schnell
Date Excavated:	9/16/2011	Excavation Equipment:	Komatsu Exc. PC200
Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		Organic silt (OL)	
2		Silty clayey sand	
3		Highly wx (decomposed) granite steeply dipping gray and orange clay seams. Wx to sand and clayey sand	See photos "perched" water in sandy material, "u" shaped clay seam (see photos). This is likely from above
4			
5			
6			
7			Very minor seepage at 6-8' bgs, less than 1 gpm (trickle)
8		Hard granite at 8.5'	Total depth= 8.5' (no piezo)
9			Total depth= 8.5' (no piezo)
End of Test Pit 11 - Total Depth: 8.5'			

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

Project:	Crystal Mine		
Test Pit Number:	**CWTP-12**	Northing (ft)[1]:	779353.9
Location:	Crystal Wetland	Easting (ft)[1]:	1270845.7
Logger:	G. Warren	Water Level (bmp):	2.78'
Elevation (mp):	7941.27	Contractor:	Schnell
Date Excavated:	9/16/2011	Excavation Equipment:	Komatsu Exc. PC200

Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		Silt (OL)	North west side of main channel
2		Stratified sand/silt and clay and silty sand to sandy clay, mottled gray and orange derived from wx granite/till	
3			
4	3' to 4' bag sample	Black fine sand seam (alluvial)	
5			Vertical walls
6		Wx granite (RO), wx to silty sand, clayey sand and sandy clay (SM-SC-CL), several orange oxidized veins and yellow alteration feldspar altered to clay, moist	Very minor seepage from quartz vein in wx rock; approximately 6' bgs
7			Slot 4'-9' bgs, 1' stick up, install piezo but really very minor seepage, << 1 gpm
8			
9			Whole wall caved in (photo)
10			Dry, no water in flow, no piezo
11		Angular broken granite	
12		Hard granite but fractured	Total depth=12'

End of Test Pit 12 - Total Depth: 12.0'

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

Project:	Crystal Mine		
Test Pit Number:	CWTP-13	Northing (ft)[1]:	779273.3
Location:	Crystal Wetland	Easting (ft)[1]:	1270747.5
Logger:	G. Warren	Water Level (bmp):	1.91
Elevation (mp):	7934.38	Contractor:	Schnell
Date Excavated:	9/16/2011	Excavation Equipment:	Komatsu Exc. PC200
Depth Below Surface (ft)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1		Silty sand (SM), black, organic, mosit (swamp deposit)	
2			
3			Walls stay vertical
4		Decomposed granite to clay (CL) with sand; white/yellow/orange, layers and veins and mottled, medium plasticity. Feldspar wx to clay	
5			2-3 photos
6			
7			Very minor seepage (trickle) at 7' bgs
8			Install piezo 1" PVC pipe, slots 3'-9' bgs, 1' stick up
9			Dipping contact
10		Highly wx granite white to light green (chlorite alteration), RO, breaks down to silty sand	
11			Total depth= 11'
12		Hard granite but fractured	
End of Test Pit 13 - Total Depth: 11.0'			

Notes:

[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

[2]All information is transcribed from field notebooks.

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Attachment C – Field copy of Boring Logs

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CH2MHILL

PROJECT NUMBER:	BORING NUMBER:
406950.TT.01	CWB-1+2 SHEET 1 OF 1

ROCK CORE LOG

PROJECT : Crystal Mine Wetland Investigation, Crystal Wetland LOCATION : Crystal Wetland

ELEVATION : 7941.7 ft DRILLING CONTRACTOR : Axis Drilling

DRILLING METHOD AND EQUIPMENT : DK Track Rig, Tubex, Vertical Orientation

WATER LEVELS : 0.1 ft below ground surface START : 9/22/11 09:00 END : 9/22/2011 LOGGER : G. Warren, P.G.

DEPTH BELOW SURFACE (ft)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES: R Q D (%)	DISCONTINUITIES: FRACTURES PER FOOT	DISCONTINUITIES: DESCRIPTION — DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	GRAPHIC LOG	LITHOLOGY: ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS: SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
						Weathered granite, cuttings are brown sand, silt and clay, very moist to wet, but overall not too much water	09:00 begin drilling with 6" steel casing Depth to water is 0.07' below ground surface after completion
10							
						continued weathered granite	Drive 6" casing to 15', drill 3.5" open hole with hammer
20							
						continued weathered granite	CWB-1 Total depth = 25.5' (drilled 4' south of CWB-2)
30							
40							
						Harder granite bedrock layer	A bit more water at 45'
50							
						Back to clayey weathered granite, cuttings are tan-gray goopy sand/silt clay	Driller notes it feels like clayey layers with water in between
60							
						Harder at 60', cuttings of broken granite rock	
70							
						continued granite with occasional quartz veins at 76'-80'	CWB-2 Total depth = 80'
80							
90							

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:
406950.TT.01	CWB-3 SHEET 1 OF 2

ROCK CORE LOG

PROJECT : Crystal Mine Wetland Investigation, Crystal Wetland LOCATION : Crystal Wetland

ELEVATION : 7941.6 ft DRILLING CONTRACTOR : Axis Drilling

DRILLING METHOD AND EQUIPMENT : DK Track Rig, Tubex and Hydraulic Hammer and Air, Vertical Orientation

WATER LEVELS : -1.2 ft below ground surface START : 9/20/11 13:30 END : 9/21/2011 LOGGER : G. Warren, P.G.

DEPTH BELOW SURFACE (ft)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES: R Q D (%)	DISCONTINUITIES: FRACTURES PER FOOT	DISCONTINUITIES: DESCRIPTION — DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	GRAPHIC LOG	LITHOLOGY: ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS: SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
						Weathered granite to sandy clay, light brown, moist	Drill 6" surface casing to 15', begin drilling at 13:30 Depth to water is 1.2' above ground surface after completion
10						Sandy clay (weathered granite) harder granite at 12'	Wet cuttings at 12' Dry at 15' but some water when resume
20						Harder granite with some moisture Clayey seams/ fractures	Drill casing to 15' and continue open hole with 3 7/8" hammer bit
30						continued granite	Cuttings wet
40						continued granite with clayey zones, gray wet cuttings	Hole making a good amount of water
50						continued granite	Hammer getting washed out, hard to blow cuttings
60						Harder granite, cuttings sandy and rock chips, not clayey like above	Switch to 3.5" bit
70						continued granite	
80							

CH2MHILL

PROJECT NUMBER:	BORING NUMBER:
406950.TT.01	CWB-3 SHEET 2 OF 2

ROCK CORE LOG

PROJECT : Crystal Mine Wetland Investigation, Crystal Wetland LOCATION : Crystal Wetland

ELEVATION : 7941.6 ft DRILLING CONTRACTOR : Axis Drilling

DRILLING METHOD AND EQUIPMENT : DK Track Rig, Tubex and Hydraulic Hammer and Air, Vertical Orientation

WATER LEVELS : -1.2 ft below ground surface START : 9/20/11 13:30 END : 9/21/2011 LOGGER : G. Warren, P.G.

DEPTH BELOW SURFACE (ft)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES: R Q D (%)	FRACTURES PER FOOT	DESCRIPTION: DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	GRAPHIC LOG	LITHOLOGY: ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS: SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
						continued granite	Stop at 80' for the day Resume on 9/21/11 at 17:30 A lot of water in the hole over night, blow it out with air
90						Cuttings of hard granite with greenish stain (chlorite?) and some iron stained pieces Gouge like, sandy material at 96'-98', harder to drill	
100						Harder to drill below 98' and more iron stain and brownish gray return Quartz vein at 102'; big quartz pieces in return Harder rock	Sand getting in hammer and making it hard to work
110						continued hard rock	Quartz vein makes more water
120						continued hard drilling, granite with greenish stain	
130						Quartz vien at 128'-130', big pieces coming out in cuttings	Slower drilling, hard to remove cuttings Want to install piezo to intercept water in quartz vein at 128'-130'
140						Stop at 138'	
150							
160							

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2012 Installation, Sampling, and Testing of Ground Water Monitoring Wells - Crystal Mine OU5 Basin, Montana

PREPARED FOR:	Kristine Edwards/USEPA
COPY TO:	Dennis Smith/BOI Dick Sloan/MDEQ File
PREPARED BY:	Allan Erickson/BOI
DATE:	November 7, 2012
PROJECT NUMBER:	406950.RR.01

Introduction

Subsurface water from the area north of the Crystal Trench may be entering the underground workings of the Crystal mine. Groundwater entering the mine workings interacts with the exposed sulfide mineralization and eventually discharges as acid mine drainage. Reducing or eliminating groundwater inflow into the workings of the Crystal Mine could prove to be an effective remediation measure to control acid mine drainage.

Previous investigations to evaluate the groundwater flow in the area were summarized in a draft remedial investigation report and treatability study technical memoranda (CH2M HILL, 2010; CH2M HILL, 2011). Groundwater moving through the deeper bedrock fracture system is assumed to be the likely source of water entering the mine workings. EPA requested the installation of deep monitoring wells to assess the vertical and lateral movement of groundwater, subsurface water quality, and hydraulic characteristics of the bedrock flow system. The following sections provide details about the wells that were installed, the collection of water quality samples at each installed well, and the aquifer testing conducted on wells CMW-2 and CMW-3.

Well Installation

Four ground water monitoring wells were installed via air rotary drilling method from August 20 – September 9, 2012. The drilling contractor advanced two 8-inch boreholes to 304 feet below ground surface (ft bgs) and 310 ft bgs, and two 6-inch boreholes to 150 ft bgs and 300 ft bgs. Two of the ground water monitoring wells were installed in the northern portion of the identified wetland area (CMW-1 and CMW-2), one ground water well was installed on the western edge of the historic adits and south of the wetland (CMW-4), and the final ground water well was installed on the northern and eastern edges of the known position of the adits (CMW-3), as shown on Figure 1.

The monitoring well casing and screens consisted of threaded and flush-jointed 2-inch or 4-inch diameter Schedule 80 PVC. Colorado silica sand (10-20 gradation) was utilized as the screen pack for the 20-foot section screens. Details regarding the well diameter, total depth of each well borehole, screen intervals, screen slot size, and static water depths can be found in Table 1.

Each well was developed by bailing and surge/pumping methods to remove fines in the well. However, due to the low water production observed at all wells, a total of 3 well volumes of water were not achievable, with the exception of CMW-2 (shallow well). At least one well volume of water was removed from each ground water well during development of the deep wells (CMW-1, CMW-3, and CMW-4).

TABLE 1
Well Installation Information
Crystal Mine – Well Installation

Well Location	Diameter (inches)	Total Depth (feet)	Screen Interval (ft below grade surface)	Screen Slot Size (inches)	Top of Sand Pack (ft below grade surface)	Static Depth To Water (ft below casing)	Well Coordinates (LDP)	Casing Elevation (ft msl)
CMW-1	2	300	278-298	0.02	274	21.95	779850.2N 1271279.2E	7,986.68
CMW-2	2	150	128-148	0.02	123	16.71	779864.9N 1271281.4E	7,987.34
CMW-3	4	310	282-302	0.02	276	86.02	778993.8N 1271859.5E	7,992.06
CMW-4	4	304	283.5-303.5	0.02	276.5	58.22	779090.8N 1271144.5E	7,953.51

Following completion of well development and the stabilization of water levels, the depth to ground water was measured to construct ground water contours and to calculate vertical and horizontal gradients. Table 1 shows a summary of depth to ground water and ground water elevations. The depth to ground water at paired wells CMW-1 and CMW-2 shows that the vertical hydraulic gradient in the area is downward with static water at CMW-1 at 7964.73 ft mean sea level (MSL) and CMW-2 at 7970.63 ft MSL. This is in contrast to the upward gradient observed in piezometers installed in the center of the wetland located northwest of the trench in 2011 (CH2M HILL, 2011). The upward gradient observed in the piezometers likely resulted from the completion (screening) of the deeper piezometer in a very transmissive fracture.

Figure 2 illustrates the potentiometric surface based on ground water elevations for the deep monitoring wells CMW-1, CMW-2, and CMW-3. The ground water flow is in the south to southwestern direction.

Ground Water Sampling

Each of the newly-installed ground water monitoring wells was sampled for total metals, dissolved metals, chloride, sulfate, and alkalinity. Samples were collected at the completion of well development prior to de-watering the well and/or when the field chemistry parameters were stabilized. The final stabilized field chemistry parameter for each well is detailed in Table 2. Table 3 depicts the results of the ground water sampling conducted at each well.

TABLE 2
Field Chemistry Parameters
Crystal Mine – Well Installation

Well Location	pH	Dissolved Oxygen (mg/L)	Conductivity (S/m)	Turbidity (NTU)	Temperature (°C)	ORP (mV)
CMW-1	8.86	16.46	0.329	737	7.56	160
CMW-2	7.42	18.55	0.32	63.9	4.91	192
CMW-3	9.02	8.22	0.345	Equipment error	3.64	181
CMW-4	8.27	11.87	0.337	467	6.79	187

Aquifer Testing

As discussed above, during the development of each well it was observed that each of the newly-installed deep wells did not have the ability to generate sufficient water to conduct a constant-rate aquifer test. It was evident that pumping the wells would remove the storage in each well and not pull water from the bedrock, indicating very little porosity in the parent rock and no apparent secondary porosity from fractures intercepted by the screened interval. In order to evaluate the hydraulic conductivity of the deep fractured bedrock, CMW-3 was pumped down to the top of the pump, at which time the pump was shut down and recovery of the well was recorded by an In-Situ Level-Troll® pressure transducer.

Similar to CMW-3, to evaluate the shallow fractured bedrock hydraulic conductivity, CMW-2 was pumped down to just above the intake of the 2-inch pump. Recovery data was recorded by an In-Situ Level-Troll®. Although three well volumes were removed from CMW-2 during development, a pro-longed constant rate test was not possible due to the low recharge rate of CMW-2.

Water level data from each test were analyzed by the following four methods via AQTESOLV(2007) ground water modeling program:

- Theis (1935)
- Hantush- Jacob (1955)
- Cooper- Jacob (1946)
- Theis (1935) t/t’ recovery method

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TABLE 3

Crystal Mine Groundwater Quality Laboratory Results - Validated

Crystal Mine – Well Installation

		Total Metals (μg/L)																	Dissolved Metals (μg/L)													Anions (mg/L)		Alkalinity (mg/L)	
Site	**Date Sample Collected**	**Al**	**Sb**	**As**	**Cd**	**Ca**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**K**	**Se**	**Ag**	**Na**	**Ti**	**Zn**	**Al**	**Sb**	**As**	**Cd**	**Cu**	**Fe**	**Pb**	**Mn**	**Ni**	**Se**	**Ag**	**Ti**	**Zn**	**Cl**	**SO_4**	**$CaCO_3$**	**Total**
CMW-1	9/11/2012	2520	2.1	5.6	0.05U	19700	2	1300	1.6	4410	25.9	2.5U	3560	0.77J	0.05U	44900	0.5U	10.0U	2440	2.4	6.1	0.05U	2.2	1390	2	28.4	2.5U	0.8J	0.05U	0.5U	10.0U	12.6	101	35.0	50.9
CMW-2	9/8/2012	50.0U	0.5U	1.6	0.05U	14200	0.93U	20.0U	0.5U	3440	5.7	2.5U	820J	0.5U	0.05U	8120	0.5U	10.0U	50.0U	0.5U	1.6	0.05U	0.93U	20.0U	0.5U	5.8	2.5U	0.5U	0.05U	0.5U	10.0U	4.8	10.4	51.9	51.9
CMW-2SD	9/8/2012	50.0U	0.5U	1.5	0.05U	14200	0.93U	20.0U	0.5U	3450	7.1	2.5U	816J	0.5U	0.05U	9960	0.5U	10.0U	50.0U	0.5U	1.7	0.05U	0.93U	20.0U	0.5U	7.4	2.5U	0.5U	0.05U	0.5U	10.0U	4.2	9.5	52.9	52.9
CMW-3	9/11/2012	37400	1.4	**20.9**	0.24	29200	21.6	16200	**43.6**	10400	298.0	9.4	6980	2.2	0.22	20900	0.5U	117.0	20000	1.3	**16.5**	0.17	18.4	10400	**29.1**	257	6.7	1.1	0.16	0.5U	94.4	11.8	20.1	31.5	40.4
CMW-3FD	9/11/2012	23800	0.91J	**14.2**	0.18	35800	57.7	12600	**32.2**	8900	336.0	8.0	6350	1.8	0.15	20400	0.5U	144.0	21400	1.3	**16.4**	0.19	48.5	12000	**29.2**	339	9.2	1.2	0.13	0.5U	139.0	11.7	20.1	32.6	40.3
CMW-4	9/10/2012	98.1J	1.2	1.6	0.05U	13500	2.5	57	0.5U	3490	17.3	2.5U	1640	0.5U	0.05U	7600	0.5U	10.0U	96.8J	1.3	1.7	0.05U	2.4	43	0.5U	17	2.5U	0.5U	0.05U	0.5U	10.0U	4.5	9.2	47.9	47.9
2012 (October) Montana DEQ Circular 7 - WQ Standards (Human Health)			**6.0**	**10**	**5**		**1300**		**15.0**			**100**		**50**	**100**		**2**	**2000**		**6.0**	**10**	**5**	**1300**		**15**		**100**	**50**	**100**	**2**	**2000**				

Notes:

All samples analyzed without qualifiers are of the Highest Quality (Enforcement Quality) as defined by *CFR SSI Data Management/Date Validation Plan* (PTI 1992, and Revision, Addendum)

ND = Not Detected at or above adjusted reporting limit

Bolded Values indicate an exceedance of Mt DEQ Circular 7 WQ standards for human health.

J = Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit

U = indicates the compound was analyzed for, but not detected

SD = MS/MSD for lab matrix spikes. The lab also analyzed it as a true sample.

FD is a Field duplicate

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The primary underlying assumptions for the methods listed above include the following:

- Symmetrical relationship between drawdown and recovery. Thus, recovery values increase with increasing time.
- Residual recovery assumes a maximum drawdown that declines with increasing time.
- Starting residual recovery values were prorated based on the total drawdown and time into the test.
- In AQTESOLV, 20 foot thickness for the aquifer, based on the screen lengths.
- Aquifer extends infinitely.

Hydraulic conductivity values estimated by the Theis, Hantush- Jacob, Cooper-Jacob, and Theis recovery method for the recovery data for CMW-3 ranged from 1.62E-02 to 1.94E-02 feet/day (Table 4). For CMW-2, hydraulic conductivity values estimated for the recovery data ranged from 2.99E-02 to 6.14E-02 feet/day (Table 4). These values are consistent with accepted and published values for slightly fractured, dense, competent rock, as observed in the field during drilling at depth and during previous field investigations. However the variability of this fracture dominated bedrock aquifer was demonstrated during the drilling of an abandoned boring within a 100 feet of the final well location. This boring happened to intercept a permeable fracture at approximately 280 feet and was quite prolific in making water. This underscores the fact that the hydraulic conductivity can vary significantly over short distances at this site, resulting in a large range of potential hydraulic conductivity (K).

TABLE 4
Aquifer Test Modeling Results
Crystal Mine – Well Installation

Well Location	Cooper-Jacob (ft/d)	Theis (ft/d)	Hantush-Jacob (ft/d)	Theis (Recovery) (ft/d)
CMW-3	1.94E-02	1.94E-02	1.94E-02	1.62E-02
CMW-2	3.33E-02	3.45E-02	6.14E-02	2.99E-02

References

CH2M HILL, 2010. Hydrogeologic Conditions and Groundwater Movement, Crystal Mine Site.

CH2M HILL, 2011. Treatability Study: Preliminary Activities – Piezometer Installation and Groundwater Hydrogeology, Crystal Mine Wetland Area.

Cooper, H.H and Jacob, C.E. *A Generalized Graphic Method for Evaluating Formation Constants and summarizing well-field history*. Transitions of the American Geophysical Union. Vol.27. 1964

Hantush, J.E. and Jacob, C.E. *Nonsteady Radial Flow in an Infinite Leaky Aquifer.* Transactions of the American Geophysical Union. Vol. 36, No. 1P 95-100. 1955

Theis, C.V. *The Relation Between the Lower of the Rate and Duration of Discharge of Well Ground Water Storage.* Transactions of the American Geophysical Union. Vol. 16, Part 2. 1935

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Figures

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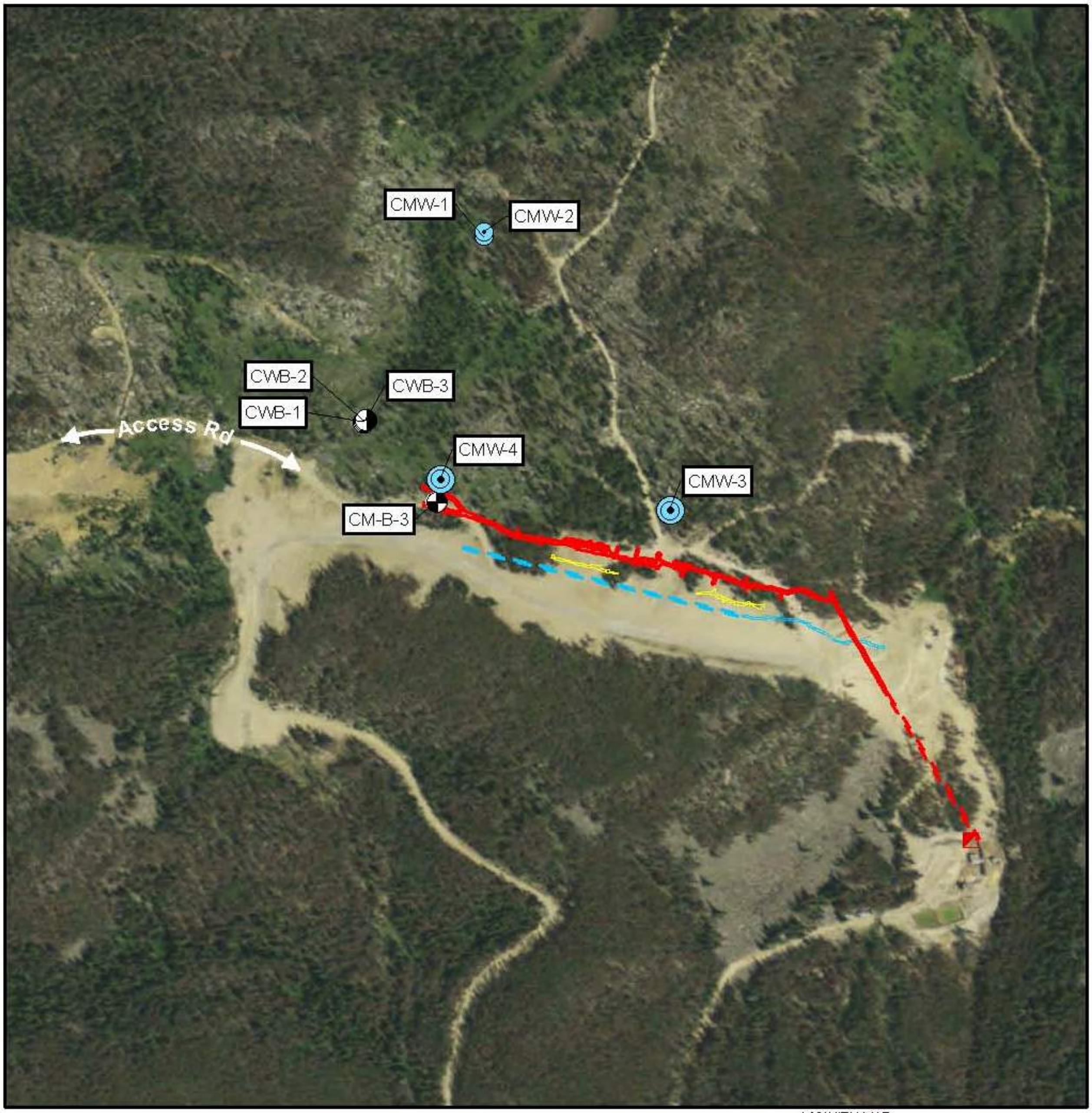


LEGEND

- Mine Adit
- 2011 Piezometer
- 2011 Adit Access Boring

2012 Monitoring Well

- 2-inch Diameter
- 4-inch Diameter

- Crystal Mine,1936 Map, Upper Tunnel (estimated)
- Crystal Mine, Hansen 1976, Upper Tunnel
- Crystal Mine, Hansen 1976, Intermediate Tunnel
- Crystal Mine, Hansen 1976, Lower Tunnel
- Crystal Mine, Hansen 1976, Lower Tunnel - Extrapolated

Note:
1. 2009 NAIP Orthophoto.

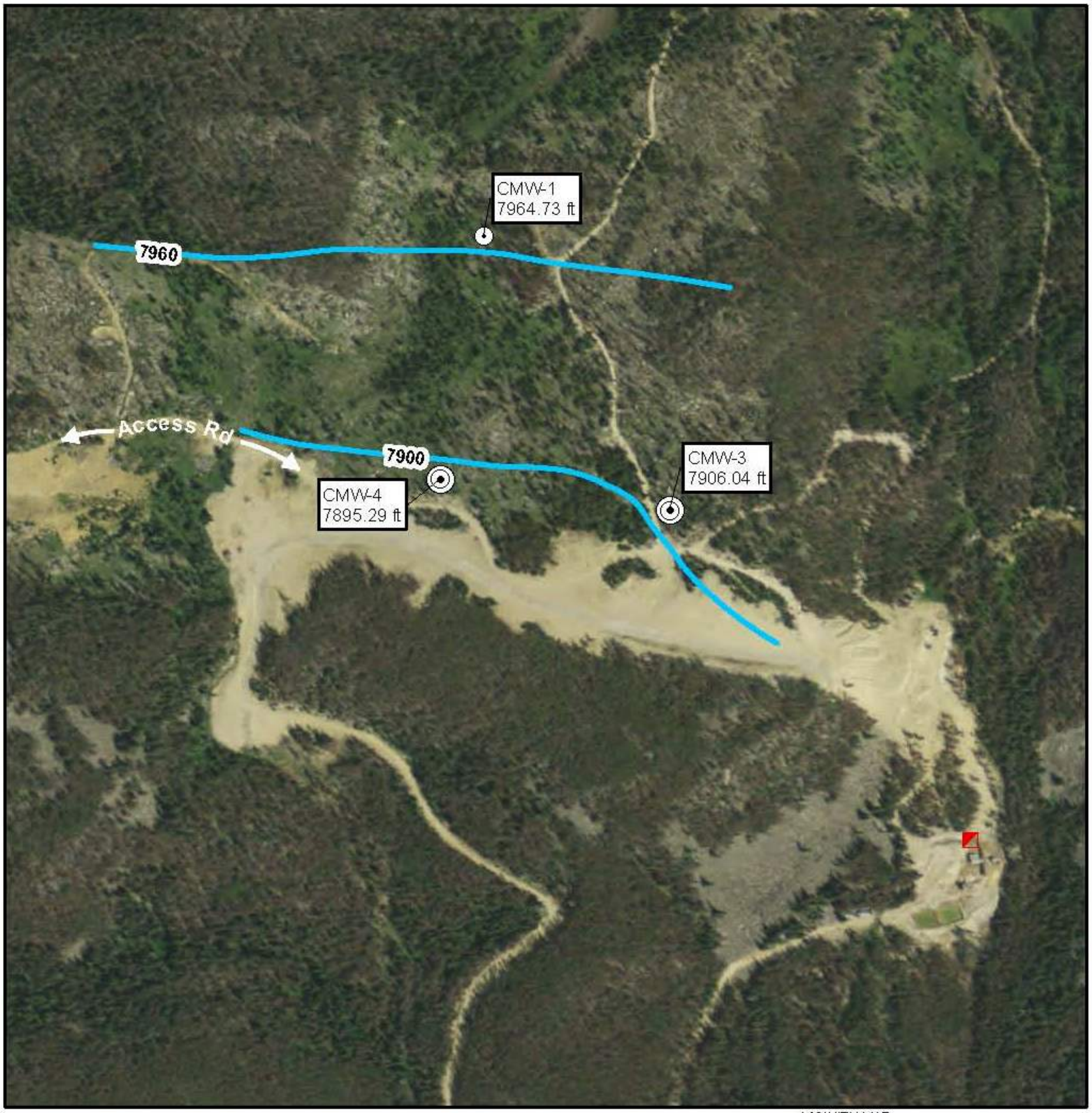
N

0 150 300 600
Feet

VICINITY MAP

Figure 1
Wetland Monitoring Well Locations
Crystal Mine, Montana
Crystal Mine Well Installation

CH2MHILL.



VICINITY MAP

Notes:
1. Area of interest subject to change.
2. 20009 NAIP Orthophoto.

LEGEND

Mine Adit

Monitoring Well

2-inch Diameter

4-inchDiameter

Groundwater Elevation (ft msl)

N

0 150 300 600
Feet

Figure 2
Potentiometric Groundwater Elevation Map
Crystal Mine, Montana
Crystal Mine Well Installation

Appendix A – Laboratory Data Sheets

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Pace Analytical Services, Inc.
602 S 25th Street
Billings, MT 591014549
(406)254-7226

September 26, 2012

Dennis Smith
CH2M Hill
322 E. Front Street
Boise, ID 83702

RE: Project: Crystal Mine
Pace Project No.: 10205092

Dear Dennis Smith:

Enclosed are the analytical results for sample(s) received by the laboratory on September 12, 2012. The results relate only to the samples included in this report. Results reported herein conform to the most current TNI standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

revised w/metals removed. Re-shipped w/ICPMSmetals reported for 005 & 006

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Samantha Rupe

samantha.rupe@pacelabs.com
Project Manager

Enclosures

cc: Mark Cichy, CH2M Hill
Bryan Jones, CH2M Hill
Mike Wirtz, CH2M Hill

Pace Analytical
www.pacelabs.com

Pace Analytical Services, Inc.
602 S 25th Street
Billings, MT 591014549
(406)254-7226

CERTIFICATIONS

Project:	Crystal Mine
Pace Project No.:	10205092

Minnesota Certification IDs

1700 Elm Street SE Suite 200, Minneapolis, MN 55414
A2LA Certification #: 2926.01
Alaska Certification #: UST-078
Alaska Certification #MN00064
Arizona Certification #: AZ-0014
Arkansas Certification #: 88-0680
California Certification #: 01155CA
Colorado Certification #Pace
Connecticut Certification #: PH-0256
EPA Region 8 Certification #: Pace
Florida/NELAP Certification #: E87605
Georgia Certification #: 959
Hawaii Certification #Pace
Idaho Certification #: MN00064
Illinois Certification #: 200011
Kansas Certification #: E-10167
Louisiana Certification #: 03086
Louisiana Certification #: LA080009
Maine Certification #: 2007029
Maryland Certification #: 322
Michigan DEQ Certification #: 9909
Minnesota Certification #: 027-053-137
Mississippi Certification #: Pace
Montana Certification #: MT CERT0092
Nebraska Certification #: Pace
Nevada Certification #: MN_00064
New Jersey Certification #: MN-002
New York Certification #: 11647
North Carolina Certification #: 530
North Dakota Certification #: R-036
North Dakota Certification #: R-036A
Ohio VAP Certification #: CL101
Oklahoma Certification #: 9507
Oregon Certification #: MN200001
Oregon Certification #: MN300001
Pennsylvania Certification #: 68-00563
Puerto Rico Certification
Tennessee Certification #: 02818
Texas Certification #: T104704192
Utah Certification #: MN00064
Virginia/DCLS Certification #: 002521
Virginia/VELAP Certification #: 460163
Washington Certification #: C754
West Virginia Certification #: 382
Wisconsin Certification #: 999407970

Montana Certification IDs

602 South 25th Street, Billings, MT 59101
EPA Region 8 Certification #: 8TMS-Q
Idaho Certification #: MT00012
Montana Certification #: MT CERT0040
NVLAP Certification #: 101292-0
Minnesota Dept of Health Certification #: 030-999-442

Ormond Beach Certification IDs

8 East Tower Circle, Ormond Beach, FL 32174
Alabama Certification #: 41320
Arizona Certification #: AZ0735
Colorado Certification: FL NELAC Reciprocity
Connecticut Certification #: PH-0216
Florida Certification #: E83079
Georgia Certification #: 955
Guam Certification: FL NELAC Reciprocity
Hawaii Certification: FL NELAC Reciprocity
Illinois Certification #: 200068
Indiana Certification: FL NELAC Reciprocity
Kansas Certification #: E-10383
Kentucky Certification #: 90050
Louisiana Certification #: FL NELAC Reciprocity
Louisiana Environmental Certificate #: 05007
Maine Certification #: FL01264
Massachusetts Certification #: M-FL1264
Michigan Certification #: 9911
Mississippi Certification: FL NELAC Reciprocity
Missouri Certification #: 236
Montana Certification #: Cert 0074
Nevada Certification: FL NELAC Reciprocity
New Hampshire Certification #: 2958
New Jersey Certification #: FL765
New York Certification #: 11608
North Carolina Environmental Certificate #: 667
North Carolina Certification #: 12710
Pennsylvania Certification #: 68-00547
Puerto Rico Certification #: FL01264
Tennessee Certification #: TN02974
Texas Certification: FL NELAC Reciprocity
US Virgin Islands Certification: FL NELAC Reciprocity
Virginia Environmental Certification #: 460165
Washington Certification #: C955
West Virginia Certification #: 9962C
Wisconsin Certification #: 399079670
Wyoming (EPA Region 8): FL NELAC Reciprocity

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SAMPLE SUMMARY

Project: Crystal Mine
Pace Project No.: 10205092

Lab ID	Sample ID	Matrix	Date Collected	Date Received
10205092001	**CMW-1GW0912**	Water	09/11/12 08:30	09/12/12 10:09
10205092002	**CMW-2GW0912**	Water	09/08/12 11:40	09/12/12 10:09
10205092003	**CMW-2GW0912MS**	Water	09/08/12 11:40	09/12/12 10:09
10205092004	**CMW-2GW0912SD**	Water	09/08/12 11:40	09/12/12 10:09
10205092005	**CMW-3GW0912**	Water	09/11/12 11:00	09/12/12 10:09
10205092006	**CMW-3GW0912FB**	Water	09/11/12 11:00	09/12/12 10:09
10205092007	**CMW-4GW0912**	Water	09/10/12 12:00	09/12/12 10:09

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SAMPLE ANALYTE COUNT

Project: Crystal Mine
Pace Project No.: 10205092

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
10205092001	**CMW-1GW0912**	EPA 200.7	JTJ	9	PASI-O
		EPA 200.7	JTJ	5	PASI-O
		EPA 200.8	DRS	8	PASI-O
		EPA 200.8	HEA	8	PASI-O
		EPA 300.0	EJS	2	PASI-MT
		SM 2320B	PH1	2	PASI-M
10205092002	**CMW-2GW0912**	EPA 200.7	JTJ	9	PASI-O
		EPA 200.7	JTJ	5	PASI-O
		EPA 200.8	DRS	8	PASI-O
		EPA 200.8	HEA	8	PASI-O
		EPA 300.0	EJS	2	PASI-MT
		SM 2320B	PH1	2	PASI-M
10205092003	**CMW-2GW0912MS**	EPA 200.7	JTJ	9	PASI-O
		EPA 200.7	JTJ	5	PASI-O
		EPA 200.8	DRS	8	PASI-O
		EPA 200.8	HEA	8	PASI-O
		EPA 300.0	EJS	2	PASI-MT
		SM 2320B	PH1	2	PASI-M
10205092004	**CMW-2GW0912SD**	EPA 200.7	JTJ	9	PASI-O
		EPA 200.7	JTJ	5	PASI-O
		EPA 200.8	DRS	8	PASI-O
		EPA 200.8	HEA	8	PASI-O
		EPA 300.0	EJS	2	PASI-MT
		SM 2320B	PH1	2	PASI-M
10205092005	**CMW-3GW0912**	EPA 200.7	JTJ	9	PASI-O
		EPA 200.7	JTJ	5	PASI-O
		EPA 200.8	DRS, HEA	8	PASI-O
		EPA 200.8	HEA	8	PASI-O
		EPA 300.0	EJS	2	PASI-MT
		SM 2320B	PH1	2	PASI-M
10205092006	**CMW-3GW0912FB**	EPA 200.7	JTJ	9	PASI-O
		EPA 200.7	JTJ	5	PASI-O
		EPA 200.8	DRS	8	PASI-O
		EPA 200.8	HEA	8	PASI-O
		EPA 300.0	EJS	2	PASI-MT
		SM 2320B	PH1	2	PASI-M
10205092007	**CMW-4GW0912**	EPA 200.7	JTJ	9	PASI-O

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SAMPLE ANALYTE COUNT

Project: Crystal Mine
Pace Project No.: 10205092

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
		EPA 200.7	JTJ	5	PASI-O
		EPA 200.8	DRS	8	PASI-O
		EPA 200.8	HEA	8	PASI-O
		EPA 300.0	EJS	2	PASI-MT
		SM 2320B	PH1	2	PASI-M

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PROJECT NARRATIVE

Project: Crystal Mine
Pace Project No.: 10205092

Method: **EPA 200.7**
Description: 200.7 MET ICP
Client: CH2M Hill
Date: September 26, 2012

General Information:
7 samples were analyzed for EPA 200.7. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

QC Batch: ICP/10283

A matrix spike and matrix spike duplicate (MS/MSD) were performed on the following sample(s): 10205092004,92131120001

M1: Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.

- MS (Lab ID: 465293)
  - Calcium
  - Magnesium
  - Sodium
- MSD (Lab ID: 465294)
  - Calcium
  - Magnesium
  - Sodium

Additional Comments:

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PROJECT NARRATIVE

Project: Crystal Mine
Pace Project No.: 10205092

Method: **EPA 200.7**
Description: 200.7 MET ICP, Dissolved
Client: CH2M Hill
Date: September 26, 2012

General Information:
7 samples were analyzed for EPA 200.7. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Additional Comments:

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PROJECT NARRATIVE

Project: Crystal Mine
Pace Project No.: 10205092

Method: **EPA 200.8**
Description: 200.8 MET ICPMS
Client: CH2M Hill
Date: September 26, 2012

General Information:
7 samples were analyzed for EPA 200.8. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Internal Standards:
All internal standards were within QC limits with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Additional Comments:

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PROJECT NARRATIVE

Project: Crystal Mine
Pace Project No.: 10205092

Method: **EPA 200.8**
Description: 200.8 MET ICPMS, Dissolved
Client: CH2M Hill
Date: September 26, 2012

General Information:
7 samples were analyzed for EPA 200.8. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Internal Standards:
All internal standards were within QC limits with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Additional Comments:

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PROJECT NARRATIVE

Project: Crystal Mine
Pace Project No.: 10205092

Method: **EPA 300.0**
Description: 300.0 IC Anions
Client: CH2M Hill
Date: September 26, 2012

General Information:
7 samples were analyzed for EPA 300.0. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Internal Standards:
All internal standards were within QC limits with any exceptions noted below.

Surrogates:
All surrogates were within QC limits with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

Analyte Comments:

QC Batch: MT/10149

E: Analyte concentration exceeded the calibration range. The reported result is estimated.

- MS (Lab ID: 1289875)
  - Sulfate
- MS (Lab ID: 1289877)
  - Chloride
  - Sulfate

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PROJECT NARRATIVE

Project: Crystal Mine
Pace Project No.: 10205092

Method: **SM 2320B**
Description: 2320B Alkalinity
Client: CH2M Hill
Date: September 26, 2012

General Information:
7 samples were analyzed for SM 2320B. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Additional Comments:

This data package has been reviewed for quality and completeness and is approved for release.

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ANALYTICAL RESULTS

Project: Crystal Mine
Pace Project No.: 10205092

Sample: CMW-1GW0912 **Lab ID: 10205092001** Collected: 09/11/12 08:30 Received: 09/12/12 10:09 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7								
Aluminum	**2520**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 20:08	7429-90-5	
Calcium	**19700**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:08	7440-70-2	
Iron	**1300**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 20:08	7439-89-6	
Magnesium	**4410**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:08	7439-95-4	
Manganese	**25.9**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:08	7439-96-5	
Nickel	**2.5U**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:08	7440-02-0	
Potassium	**3560**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:08	7440-09-7	
Sodium	**44900**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:08	7440-23-5	
Zinc	**10.0U**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 20:08	7440-66-6	
200.7 MET ICP, Dissolved	Analytical Method: EPA 200.7								
Aluminum, Dissolved	**2440**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 11:50	7429-90-5	
Iron, Dissolved	**1390**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 11:50	7439-89-6	
Manganese, Dissolved	**28.4**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 11:50	7439-96-5	
Nickel, Dissolved	**2.5U**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 11:50	7440-02-0	
Zinc, Dissolved	**10.0U**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 11:50	7440-66-6	
200.8 MET ICPMS	Analytical Method: EPA 200.8								
Antimony	**2.1**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:23	7440-36-0	
Arsenic	**5.6**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:23	7440-38-2	
Cadmium	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:23	7440-43-9	
Copper	**2.0**	ug/L	1.0	0.93	1	09/14/12 05:45	09/18/12 12:23	7440-50-8	
Lead	**1.6**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:23	7439-92-1	
Selenium	**0.77J**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:23	7782-49-2	
Silver	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:23	7440-22-4	
Thallium	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:23	7440-28-0	
200.8 MET ICPMS, Dissolved	Analytical Method: EPA 200.8								
Antimony, Dissolved	**2.4**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:49	7440-36-0	
Arsenic, Dissolved	**6.1**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:49	7440-38-2	
Cadmium, Dissolved	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/15/12 02:49	7440-43-9	
Copper, Dissolved	**2.2**	ug/L	1.0	0.93	1	09/14/12 05:45	09/15/12 02:49	7440-50-8	
Lead, Dissolved	**2.0**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:49	7439-92-1	
Selenium, Dissolved	**0.80J**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:49	7782-49-2	
Silver, Dissolved	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/15/12 02:49	7440-22-4	
Thallium, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:49	7440-28-0	
300.0 IC Anions	Analytical Method: EPA 300.0								
Chloride	**12.6**	mg/L	1.0	0.18	1		09/18/12 12:59	16887-00-6	
Sulfate	**101**	mg/L	10.0	1.2	10		09/18/12 16:22	14808-79-8	
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	**35.0**	mg/L	5.0	2.5	1		09/14/12 15:38		
Alkalinity, Total as CaCO3	**50.9**	mg/L	5.0	2.5	1		09/14/12 15:38		

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ANALYTICAL RESULTS

Project: Crystal Mine
Pace Project No.: 10205092

Sample: CMW-2GW0912 **Lab ID: 10205092002** Collected: 09/08/12 11:40 Received: 09/12/12 10:09 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7								
Aluminum	**50.0U**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 20:12	7429-90-5	
Calcium	**14200**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:12	7440-70-2	
Iron	**20.0U**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 20:12	7439-89-6	
Magnesium	**3440**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:12	7439-95-4	
Manganese	**5.7**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:12	7439-96-5	
Nickel	**2.5U**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:12	7440-02-0	
Potassium	**820J**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:12	7440-09-7	
Sodium	**8120**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:12	7440-23-5	
Zinc	**10.0U**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 20:12	7440-66-6	
200.7 MET ICP, Dissolved	Analytical Method: EPA 200.7								
Aluminum, Dissolved	**50.0U**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 11:54	7429-90-5	
Iron, Dissolved	**20.0U**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 11:54	7439-89-6	
Manganese, Dissolved	**5.8**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 11:54	7439-96-5	
Nickel, Dissolved	**2.5U**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 11:54	7440-02-0	
Zinc, Dissolved	**10.0U**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 11:54	7440-66-6	
200.8 MET ICPMS	Analytical Method: EPA 200.8								
Antimony	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:27	7440-36-0	
Arsenic	**1.6**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:27	7440-38-2	
Cadmium	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:27	7440-43-9	
Copper	**0.93U**	ug/L	1.0	0.93	1	09/14/12 05:45	09/18/12 12:27	7440-50-8	
Lead	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:27	7439-92-1	
Selenium	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:27	7782-49-2	
Silver	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:27	7440-22-4	
Thallium	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:27	7440-28-0	
200.8 MET ICPMS, Dissolved	Analytical Method: EPA 200.8								
Antimony, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:52	7440-36-0	
Arsenic, Dissolved	**1.6**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:52	7440-38-2	
Cadmium, Dissolved	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/15/12 02:52	7440-43-9	
Copper, Dissolved	**0.93U**	ug/L	1.0	0.93	1	09/14/12 05:45	09/15/12 02:52	7440-50-8	
Lead, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:52	7439-92-1	
Selenium, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:52	7782-49-2	
Silver, Dissolved	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/15/12 02:52	7440-22-4	
Thallium, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:52	7440-28-0	
300.0 IC Anions	Analytical Method: EPA 300.0								
Chloride	**4.8**	mg/L	1.0	0.18	1		09/18/12 14:02	16887-00-6	
Sulfate	**10.4**	mg/L	1.0	0.12	1		09/18/12 14:02	14808-79-8	
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	**51.9**	mg/L	5.0	2.5	1		09/14/12 15:18		
Alkalinity, Total as CaCO3	**51.9**	mg/L	5.0	2.5	1		09/14/12 15:18		

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ANALYTICAL RESULTS

Project: Crystal Mine
Pace Project No.: 10205092

Sample: CMW-2GW0912MS | **Lab ID: 10205092003** | Collected: 09/08/12 11:40 | Received: 09/12/12 10:09 | Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7								
Aluminum	**50.0U**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 20:24	7429-90-5	
Calcium	**14200**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:24	7440-70-2	
Iron	**20.0U**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 20:24	7439-89-6	
Magnesium	**3520**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:24	7439-95-4	
Manganese	**6.5**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:24	7439-96-5	
Nickel	**2.5U**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:24	7440-02-0	
Potassium	**847J**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:24	7440-09-7	
Sodium	**8820**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:24	7440-23-5	
Zinc	**10.0U**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 20:24	7440-66-6	
200.7 MET ICP, Dissolved	Analytical Method: EPA 200.7								
Aluminum, Dissolved	**50.0U**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 12:06	7429-90-5	
Iron, Dissolved	**20.0U**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 12:06	7439-89-6	
Manganese, Dissolved	**7.7**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 12:06	7439-96-5	
Nickel, Dissolved	**2.5U**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 12:06	7440-02-0	
Zinc, Dissolved	**10.0U**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 12:06	7440-66-6	
200.8 MET ICPMS	Analytical Method: EPA 200.8								
Antimony	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:30	7440-36-0	
Arsenic	**1.6**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:30	7440-38-2	
Cadmium	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:30	7440-43-9	
Copper	**0.93U**	ug/L	1.0	0.93	1	09/14/12 05:45	09/18/12 12:30	7440-50-8	
Lead	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:30	7439-92-1	
Selenium	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:30	7782-49-2	
Silver	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:30	7440-22-4	
Thallium	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:30	7440-28-0	
200.8 MET ICPMS, Dissolved	Analytical Method: EPA 200.8								
Antimony, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:54	7440-36-0	
Arsenic, Dissolved	**1.7**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:54	7440-38-2	
Cadmium, Dissolved	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/15/12 02:54	7440-43-9	
Copper, Dissolved	**0.93U**	ug/L	1.0	0.93	1	09/14/12 05:45	09/15/12 02:54	7440-50-8	
Lead, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:54	7439-92-1	
Selenium, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:54	7782-49-2	
Silver, Dissolved	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/15/12 02:54	7440-22-4	
Thallium, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 02:54	7440-28-0	
300.0 IC Anions	Analytical Method: EPA 300.0								
Chloride	**4.6**	mg/L	1.0	0.18	1		09/18/12 17:25	16887-00-6	
Sulfate	**10.1**	mg/L	1.0	0.12	1		09/18/12 17:25	14808-79-8	
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	**51.4**	mg/L	5.0	2.5	1		09/14/12 15:22		
Alkalinity, Total as CaCO3	**51.4**	mg/L	5.0	2.5	1		09/14/12 15:22		

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ANALYTICAL RESULTS

Project: Crystal Mine
Pace Project No.: 10205092

Sample: CMW-2GW0912SD **Lab ID: 10205092004** Collected: 09/08/12 11:40 Received: 09/12/12 10:09 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7								
Aluminum	**50.0U**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 20:28	7429-90-5	
Calcium	**14200**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:28	7440-70-2	
Iron	**20.0U**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 20:28	7439-89-6	
Magnesium	**3450**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:28	7439-95-4	
Manganese	**7.1**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:28	7439-96-5	
Nickel	**2.5U**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:28	7440-02-0	
Potassium	**816J**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:28	7440-09-7	
Sodium	**9960**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:28	7440-23-5	
Zinc	**10.0U**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 20:28	7440-66-6	
200.7 MET ICP, Dissolved	Analytical Method: EPA 200.7								
Aluminum, Dissolved	**50.0U**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 12:18	7429-90-5	
Iron, Dissolved	**20.0U**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 12:18	7439-89-6	
Manganese, Dissolved	**7.4**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 12:18	7439-96-5	
Nickel, Dissolved	**2.5U**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 12:18	7440-02-0	
Zinc, Dissolved	**10.0U**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 12:18	7440-66-6	
200.8 MET ICPMS	Analytical Method: EPA 200.8								
Antimony	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:47	7440-36-0	
Arsenic	**1.5**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:47	7440-38-2	
Cadmium	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:47	7440-43-9	
Copper	**0.93U**	ug/L	1.0	0.93	1	09/14/12 05:45	09/18/12 12:47	7440-50-8	
Lead	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:47	7439-92-1	
Selenium	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:47	7782-49-2	
Silver	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:47	7440-22-4	
Thallium	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:47	7440-28-0	
200.8 MET ICPMS, Dissolved	Analytical Method: EPA 200.8								
Antimony, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:01	7440-36-0	
Arsenic, Dissolved	**1.7**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:01	7440-38-2	
Cadmium, Dissolved	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/15/12 03:01	7440-43-9	
Copper, Dissolved	**0.93U**	ug/L	1.0	0.93	1	09/14/12 05:45	09/15/12 03:01	7440-50-8	
Lead, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:01	7439-92-1	
Selenium, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:01	7782-49-2	
Silver, Dissolved	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/15/12 03:01	7440-22-4	
Thallium, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:01	7440-28-0	
300.0 IC Anions	Analytical Method: EPA 300.0								
Chloride	**4.2**	mg/L	1.0	0.18	1		09/18/12 17:57	16887-00-6	
Sulfate	**9.5**	mg/L	1.0	0.12	1		09/18/12 17:57	14808-79-8	
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	**52.9**	mg/L	5.0	2.5	1		09/14/12 15:27		
Alkalinity, Total as CaCO3	**52.9**	mg/L	5.0	2.5	1		09/14/12 15:27		

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ANALYTICAL RESULTS

Project: Crystal Mine
Pace Project No.: 10205092

Sample: CMW-3GW0912 **Lab ID: 10205092005** Collected: 09/11/12 11:00 Received: 09/12/12 10:09 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7								
Aluminum	**37400**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 20:40	7429-90-5	
Calcium	**29200**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:40	7440-70-2	
Iron	**16200**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 20:40	7439-89-6	
Magnesium	**10400**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:40	7439-95-4	
Manganese	**298**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:40	7439-96-5	
Nickel	**9.4**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:40	7440-02-0	
Potassium	**6980**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:40	7440-09-7	
Sodium	**20900**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:40	7440-23-5	
Zinc	**117**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 20:40	7440-66-6	
200.7 MET ICP, Dissolved	Analytical Method: EPA 200.7								
Aluminum, Dissolved	**20000**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 12:22	7429-90-5	
Iron, Dissolved	**10400**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 12:22	7439-89-6	
Manganese, Dissolved	**257**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 12:22	7439-96-5	
Nickel, Dissolved	**6.7**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 12:22	7440-02-0	
Zinc, Dissolved	**94.4**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 12:22	7440-66-6	
200.8 MET ICPMS	Analytical Method: EPA 200.8								
Antimony	**1.4**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:51	7440-36-0	
Arsenic	**20.9**	ug/L	1.0	0.50	1	09/14/12 05:45	09/25/12 19:54	7440-38-2	
Cadmium	**0.24**	ug/L	0.10	0.050	1	09/14/12 05:45	09/25/12 19:54	7440-43-9	
Copper	**21.6**	ug/L	1.0	0.93	1	09/14/12 05:45	09/25/12 19:54	7440-50-8	
Lead	**43.6**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:51	7439-92-1	
Selenium	**2.2**	ug/L	1.0	0.50	1	09/14/12 05:45	09/19/12 13:10	7782-49-2	
Silver	**0.22**	ug/L	0.10	0.050	1	09/14/12 05:45	09/25/12 19:54	7440-22-4	
Thallium	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:51	7440-28-0	
200.8 MET ICPMS, Dissolved	Analytical Method: EPA 200.8								
Antimony, Dissolved	**1.3**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:09	7440-36-0	
Arsenic, Dissolved	**16.5**	ug/L	1.0	0.50	1	09/14/12 05:45	09/25/12 22:53	7440-38-2	
Cadmium, Dissolved	**0.17**	ug/L	0.10	0.050	1	09/14/12 05:45	09/25/12 22:53	7440-43-9	
Copper, Dissolved	**18.4**	ug/L	1.0	0.93	1	09/14/12 05:45	09/25/12 22:53	7440-50-8	
Lead, Dissolved	**29.1**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:09	7439-92-1	
Selenium, Dissolved	**1.1**	ug/L	1.0	0.50	1	09/14/12 05:45	09/17/12 12:24	7782-49-2	
Silver, Dissolved	**0.16**	ug/L	0.10	0.050	1	09/14/12 05:45	09/25/12 22:53	7440-22-4	
Thallium, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:09	7440-28-0	
300.0 IC Anions	Analytical Method: EPA 300.0								
Chloride	**11.8**	mg/L	1.0	0.18	1		09/18/12 18:28	16887-00-6	
Sulfate	**20.1**	mg/L	1.0	0.12	1		09/18/12 18:28	14808-79-8	
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	**31.5**	mg/L	5.0	2.5	1		09/14/12 15:43		
Alkalinity, Total as CaCO3	**40.4**	mg/L	5.0	2.5	1		09/14/12 15:43		

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ANALYTICAL RESULTS

Project: Crystal Mine
Pace Project No.: 10205092

Sample: CMW-3GW0912FB **Lab ID: 10205092006** Collected: 09/11/12 11:00 Received: 09/12/12 10:09 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7								
Aluminum	**23800**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 20:44	7429-90-5	
Calcium	**35800**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:44	7440-70-2	
Iron	**12600**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 20:44	7439-89-6	
Magnesium	**8900**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:44	7439-95-4	
Manganese	**336**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:44	7439-96-5	
Nickel	**8.0**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:44	7440-02-0	
Potassium	**6350**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:44	7440-09-7	
Sodium	**20400**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:44	7440-23-5	
Zinc	**144**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 20:44	7440-66-6	
200.7 MET ICP, Dissolved	Analytical Method: EPA 200.7								
Aluminum, Dissolved	**21400**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 12:26	7429-90-5	
Iron, Dissolved	**12000**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 12:26	7439-89-6	
Manganese, Dissolved	**339**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 12:26	7439-96-5	
Nickel, Dissolved	**9.2**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 12:26	7440-02-0	
Zinc, Dissolved	**139**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 12:26	7440-66-6	
200.8 MET ICPMS	Analytical Method: EPA 200.8								
Antimony	**0.91J**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:54	7440-36-0	
Arsenic	**14.2**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:54	7440-38-2	
Cadmium	**0.18**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:54	7440-43-9	
Copper	**57.7**	ug/L	1.0	0.93	1	09/14/12 05:45	09/18/12 12:54	7440-50-8	
Lead	**32.2**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:54	7439-92-1	
Selenium	**1.8**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:54	7782-49-2	
Silver	**0.15**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:54	7440-22-4	
Thallium	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:54	7440-28-0	
200.8 MET ICPMS, Dissolved	Analytical Method: EPA 200.8								
Antimony, Dissolved	**1.3**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:12	7440-36-0	
Arsenic, Dissolved	**16.4**	ug/L	1.0	0.50	1	09/14/12 05:45	09/25/12 22:55	7440-38-2	
Cadmium, Dissolved	**0.19**	ug/L	0.10	0.050	1	09/14/12 05:45	09/25/12 22:55	7440-43-9	
Copper, Dissolved	**48.5**	ug/L	1.0	0.93	1	09/14/12 05:45	09/25/12 22:55	7440-50-8	
Lead, Dissolved	**29.2**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:12	7439-92-1	
Selenium, Dissolved	**1.2**	ug/L	1.0	0.50	1	09/14/12 05:45	09/17/12 12:27	7782-49-2	
Silver, Dissolved	**0.13**	ug/L	0.10	0.050	1	09/14/12 05:45	09/25/12 22:55	7440-22-4	
Thallium, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:12	7440-28-0	
300.0 IC Anions	Analytical Method: EPA 300.0								
Chloride	**11.7**	mg/L	1.0	0.18	1		09/18/12 19:00	16887-00-6	
Sulfate	**20.1**	mg/L	1.0	0.12	1		09/18/12 19:00	14808-79-8	
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	**32.6**	mg/L	5.0	2.5	1		09/14/12 15:48		
Alkalinity, Total as CaCO3	**40.3**	mg/L	5.0	2.5	1		09/14/12 15:48		

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ANALYTICAL RESULTS

Project: Crystal Mine
Pace Project No.: 10205092

Sample: CMW-4GW0912 **Lab ID: 10205092007** Collected: 09/10/12 12:00 Received: 09/12/12 10:09 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7								
Aluminum	**98.1J**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 20:48	7429-90-5	
Calcium	**13500**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:48	7440-70-2	
Iron	**57.0**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 20:48	7439-89-6	
Magnesium	**3490**	ug/L	500	250	1	09/14/12 05:45	09/15/12 20:48	7439-95-4	
Manganese	**17.3**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:48	7439-96-5	
Nickel	**2.5U**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 20:48	7440-02-0	
Potassium	**1640**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:48	7440-09-7	
Sodium	**7600**	ug/L	1000	500	1	09/14/12 05:45	09/15/12 20:48	7440-23-5	
Zinc	**10.0U**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 20:48	7440-66-6	
200.7 MET ICP, Dissolved	Analytical Method: EPA 200.7								
Aluminum, Dissolved	**96.8J**	ug/L	100	50.0	1	09/14/12 05:45	09/15/12 12:30	7429-90-5	
Iron, Dissolved	**43.2**	ug/L	40.0	20.0	1	09/14/12 05:45	09/15/12 12:30	7439-89-6	
Manganese, Dissolved	**17.0**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 12:30	7439-96-5	
Nickel, Dissolved	**2.5U**	ug/L	5.0	2.5	1	09/14/12 05:45	09/15/12 12:30	7440-02-0	
Zinc, Dissolved	**10.0U**	ug/L	20.0	10.0	1	09/14/12 05:45	09/15/12 12:30	7440-66-6	
200.8 MET ICPMS	Analytical Method: EPA 200.8								
Antimony	**1.2**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:58	7440-36-0	
Arsenic	**1.6**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:58	7440-38-2	
Cadmium	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:58	7440-43-9	
Copper	**2.5**	ug/L	1.0	0.93	1	09/14/12 05:45	09/18/12 12:58	7440-50-8	
Lead	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:58	7439-92-1	
Selenium	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:58	7782-49-2	
Silver	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/18/12 12:58	7440-22-4	
Thallium	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/18/12 12:58	7440-28-0	
200.8 MET ICPMS, Dissolved	Analytical Method: EPA 200.8								
Antimony, Dissolved	**1.3**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:14	7440-36-0	
Arsenic, Dissolved	**1.7**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:14	7440-38-2	
Cadmium, Dissolved	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/15/12 03:14	7440-43-9	
Copper, Dissolved	**2.4**	ug/L	1.0	0.93	1	09/14/12 05:45	09/15/12 03:14	7440-50-8	
Lead, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:14	7439-92-1	
Selenium, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:14	7782-49-2	
Silver, Dissolved	**0.050U**	ug/L	0.10	0.050	1	09/14/12 05:45	09/15/12 03:14	7440-22-4	
Thallium, Dissolved	**0.50U**	ug/L	1.0	0.50	1	09/14/12 05:45	09/15/12 03:14	7440-28-0	
300.0 IC Anions	Analytical Method: EPA 300.0								
Chloride	**4.5**	mg/L	1.0	0.18	1		09/18/12 19:31	16887-00-6	
Sulfate	**9.2**	mg/L	1.0	0.12	1		09/18/12 19:31	14808-79-8	
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity,Bicarbonate (CaCO3)	**47.9**	mg/L	5.0	2.5	1		09/14/12 15:53		
Alkalinity, Total as CaCO3	**47.9**	mg/L	5.0	2.5	1		09/14/12 15:53		

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QUALITY CONTROL DATA

Project: Crystal Mine
Pace Project No.: 10205092

QC Batch: ICP/10283 — Analysis Method: EPA 200.7
QC Batch Method: EPA 200.7 — Analysis Description: 200.7 MET
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

METHOD BLANK: 465244 — Matrix: Water
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Aluminum	ug/L	50.0U	100	09/15/12 19:12	
Calcium	ug/L	250U	500	09/15/12 19:12	
Iron	ug/L	20.0U	40.0	09/15/12 19:12	
Magnesium	ug/L	250U	500	09/15/12 19:12	
Manganese	ug/L	2.5U	5.0	09/15/12 19:12	
Nickel	ug/L	2.5U	5.0	09/15/12 19:12	
Potassium	ug/L	500U	1000	09/15/12 19:12	
Sodium	ug/L	500U	1000	09/15/12 19:12	
Zinc	ug/L	10.0U	20.0	09/15/12 19:12	

LABORATORY CONTROL SAMPLE: 465245

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum	ug/L	2500	2680	107	85-115	
Calcium	ug/L	12500	13100	105	85-115	
Iron	ug/L	2500	2630	105	85-115	
Magnesium	ug/L	12500	13300	106	85-115	
Manganese	ug/L	250	256	103	85-115	
Nickel	ug/L	250	262	105	85-115	
Potassium	ug/L	12500	13500	108	85-115	
Sodium	ug/L	12500	13500	108	85-115	
Zinc	ug/L	1250	1260	101	85-115	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 465293 465294

Parameter	Units	92131120001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	ug/L	ND	2500	2500	2550	2520	101	100	70-130	1	20	
Calcium	ug/L	433000	12500	12500	416000	411000	-132	-176	70-130	1	20	M1
Iron	ug/L	8480	2500	2500	10400	10300	79	74	70-130	1	20	
Magnesium	ug/L	33400	12500	12500	41700	40700	66	58	70-130	2	20	M1
Manganese	ug/L	143	250	250	397	386	102	97	70-130	3	20	
Nickel	ug/L	ND	250	250	257	254	103	102	70-130	.9	20	
Potassium	ug/L	11100	12500	12500	23000	22800	95	94	70-130	.6	20	
Sodium	ug/L	77600	12500	12500	84900	83900	59	51	70-130	1	20	M1
Zinc	ug/L	40.0	1250	1250	1270	1250	98	97	70-130	2	20	

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QUALITY CONTROL DATA

Project: Crystal Mine
Pace Project No.: 10205092

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 465295 465296

Parameter	Units	10205092004 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	ug/L	50.0U	2500	2500	2650	2610	106	104	70-130	2	20	
Calcium	ug/L	14200	12500	12500	28000	27600	111	107	70-130	2	20	
Iron	ug/L	20.0U	2500	2500	2640	2600	105	104	70-130	2	20	
Magnesium	ug/L	3450	12500	12500	16600	16400	106	104	70-130	1	20	
Manganese	ug/L	7.1	250	250	268	268	104	104	70-130	.2	20	
Nickel	ug/L	2.5U	250	250	264	263	105	105	70-130	.2	20	
Potassium	ug/L	816J	12500	12500	14200	13900	107	105	70-130	2	20	
Sodium	ug/L	9960	12500	12500	23800	23200	111	106	70-130	3	20	
Zinc	ug/L	10.0U	1250	1250	1250	1260	100	101	70-130	1	20	

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QUALITY CONTROL DATA

Project: Crystal Mine
Pace Project No.: 10205092

QC Batch: ICP/10279 — Analysis Method: EPA 200.7
QC Batch Method: EPA 200.7 — Analysis Description: 200.7 MET Dissolved
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

METHOD BLANK: 465228 — Matrix: Water
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Aluminum, Dissolved	ug/L	50.0U	100	09/15/12 11:42	
Iron, Dissolved	ug/L	20.0U	40.0	09/15/12 11:42	
Manganese, Dissolved	ug/L	2.5U	5.0	09/15/12 11:42	
Nickel, Dissolved	ug/L	2.5U	5.0	09/15/12 11:42	
Zinc, Dissolved	ug/L	10.0U	20.0	09/15/12 11:42	

LABORATORY CONTROL SAMPLE: 465229

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum, Dissolved	ug/L	2500	2600	104	85-115	
Iron, Dissolved	ug/L	2500	2600	104	85-115	
Manganese, Dissolved	ug/L	250	267	107	85-115	
Nickel, Dissolved	ug/L	250	264	105	85-115	
Zinc, Dissolved	ug/L	1250	1260	100	85-115	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 465282 465283

Parameter	Units	10205092002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum, Dissolved	ug/L	50.0U	2500	2500	2750	2700	109	107	70-130	2	20	
Iron, Dissolved	ug/L	20.0U	2500	2500	2700	2680	108	107	70-130	.6	20	
Manganese, Dissolved	ug/L	5.8	250	250	264	271	103	106	70-130	3	20	
Nickel, Dissolved	ug/L	2.5U	250	250	264	265	106	106	70-130	.1	20	
Zinc, Dissolved	ug/L	10.0U	1250	1250	1290	1270	103	102	70-130	1	20	

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QUALITY CONTROL DATA

Project: Crystal Mine
Pace Project No.: 10205092

QC Batch: ICPM/10282 Analysis Method: EPA 200.8
QC Batch Method: EPA 200.8 Analysis Description: 200.8 MET
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

METHOD BLANK: 465240 Matrix: Water
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Antimony	ug/L	0.50U	1.0	09/18/12 11:32	
Arsenic	ug/L	0.50U	1.0	09/18/12 11:32	
Cadmium	ug/L	0.050U	0.10	09/18/12 11:32	
Copper	ug/L	0.93U	1.0	09/18/12 11:32	
Lead	ug/L	0.50U	1.0	09/18/12 11:32	
Selenium	ug/L	0.50U	1.0	09/18/12 11:32	
Silver	ug/L	0.050U	0.10	09/18/12 11:32	
Thallium	ug/L	0.50U	1.0	09/18/12 11:32	

LABORATORY CONTROL SAMPLE: 465241

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Antimony	ug/L	50	47.4	95	85-115	
Arsenic	ug/L	50	49.7	99	85-115	
Cadmium	ug/L	5	4.9	98	85-115	
Copper	ug/L	50	52.8	106	85-115	
Lead	ug/L	50	48.5	97	85-115	
Selenium	ug/L	50	50.8	102	85-115	
Silver	ug/L	5	5.2	104	85-115	
Thallium	ug/L	50	49.1	98	85-115	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 465289 465290

Parameter	Units	92131143001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Antimony	ug/L	ND	50	50	48.6	49.8	96	98	70-130	2	20	
Arsenic	ug/L	1.1	50	50	50.6	50.6	99	99	70-130	.02	20	
Cadmium	ug/L	0.13	5	5	4.9	4.8	94	93	70-130	1	20	
Copper	ug/L	50.1	50	50	99.6	106	99	111	70-130	6	20	
Lead	ug/L	1.8	50	50	38.7	38.3	74	73	70-130	1	20	
Selenium	ug/L	1.0	50	50	49.4	49.2	97	96	70-130	.3	20	
Silver	ug/L	1.8	5	5	6.5	6.7	95	98	70-130	2	20	
Thallium	ug/L	ND	50	50	39.3	38.9	79	78	70-130	1	20	

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QUALITY CONTROL DATA

Project: Crystal Mine
Pace Project No.: 10205092

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 465291 465292

Parameter	Units	10205092007 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Antimony	ug/L	1.3	50	50	50.0	50.3	98	98	70-130	.7	20	
Arsenic	ug/L	1.7	50	50	52.2	51.9	101	101	70-130	.7	20	
Cadmium	ug/L	0.050U	5	5	4.8	4.8	95	95	70-130	.1	20	
Copper	ug/L	2.4	50	50	55.9	55.2	107	105	70-130	1	20	
Lead	ug/L	0.50U	50	50	49.6	50.3	98	100	70-130	1	20	
Selenium	ug/L	0.50U	50	50	48.6	49.6	97	99	70-130	2	20	
Silver	ug/L	0.050U	5	5	5.2	5.2	104	104	70-130	.5	20	
Thallium	ug/L	0.50U	50	50	50.1	50.8	100	102	70-130	1	20	

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QUALITY CONTROL DATA

Project: Crystal Mine
Pace Project No.: 10205092

QC Batch: ICPM/10280 Analysis Method: EPA 200.8
QC Batch Method: EPA 200.8 Analysis Description: 200.8 MET Dissolved
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

METHOD BLANK: 465232 Matrix: Water
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Antimony, Dissolved	ug/L	0.50U	1.0	09/15/12 02:44	
Arsenic, Dissolved	ug/L	0.50U	1.0	09/15/12 02:44	
Cadmium, Dissolved	ug/L	0.050U	0.10	09/15/12 02:44	
Copper, Dissolved	ug/L	0.93U	1.0	09/15/12 02:44	
Lead, Dissolved	ug/L	0.50U	1.0	09/15/12 02:44	
Selenium, Dissolved	ug/L	0.50U	1.0	09/15/12 02:44	
Silver, Dissolved	ug/L	0.050U	0.10	09/15/12 02:44	
Thallium, Dissolved	ug/L	0.50U	1.0	09/15/12 02:44	

LABORATORY CONTROL SAMPLE: 465233

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Antimony, Dissolved	ug/L	50	51.2	102	85-115	
Arsenic, Dissolved	ug/L	50	51.5	103	85-115	
Cadmium, Dissolved	ug/L	5	5.1	101	85-115	
Copper, Dissolved	ug/L	50	55.4	111	85-115	
Lead, Dissolved	ug/L	50	50.5	101	85-115	
Selenium, Dissolved	ug/L	50	50.0	100	85-115	
Silver, Dissolved	ug/L	5	5.2	105	85-115	
Thallium, Dissolved	ug/L	50	52.8	106	85-115	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 465285 465286

Parameter	Units	10205092003 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Antimony, Dissolved	ug/L	0.50U	50	50	51.2	50.6	102	101	70-130	1	20	
Arsenic, Dissolved	ug/L	1.7	50	50	53.1	52.5	103	102	70-130	1	20	
Cadmium, Dissolved	ug/L	0.050U	5	5	5.1	5.0	102	100	70-130	2	20	
Copper, Dissolved	ug/L	0.93U	50	50	54.0	53.3	108	106	70-130	1	20	
Lead, Dissolved	ug/L	0.50U	50	50	50.0	49.3	100	99	70-130	1	20	
Selenium, Dissolved	ug/L	0.50U	50	50	51.5	50.5	103	101	70-130	2	20	
Silver, Dissolved	ug/L	0.050U	5	5	5.2	5.1	104	102	70-130	3	20	
Thallium, Dissolved	ug/L	0.50U	50	50	52.9	52.3	106	105	70-130	1	20	

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QUALITY CONTROL DATA

Project: Crystal Mine
Pace Project No.: 10205092

QC Batch: MT/10149 Analysis Method: EPA 300.0
QC Batch Method: EPA 300.0 Analysis Description: 300.0 IC Anions
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

METHOD BLANK: 1289873 Matrix: Water
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Chloride	mg/L	0.18U	1.0	09/18/12 09:50	
Sulfate	mg/L	0.12U	1.0	09/18/12 09:50	

LABORATORY CONTROL SAMPLE: 1289874

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Chloride	mg/L	20	21.6	108	90-110	
Sulfate	mg/L	20	20.7	104	90-110	

MATRIX SPIKE SAMPLE: 1289875

Parameter	Units	10205247001 Result	Spike Conc.	MS Result	MS % Rec	% Rec Limits	Qualifiers
Chloride	mg/L	1.5	20	22.9	107	80-120	
Sulfate	mg/L	24.0	20	47.0	115	80-120	E

MATRIX SPIKE SAMPLE: 1289877

Parameter	Units	10205092001 Result	Spike Conc.	MS Result	MS % Rec	% Rec Limits	Qualifiers
Chloride	mg/L	12.6	20	36.6	120	80-120	E
Sulfate	mg/L	101	200	311	105	80-120	E

SAMPLE DUPLICATE: 1289876

Parameter	Units	10205247002 Result	Dup Result	RPD	Max RPD	Qualifiers
Chloride	mg/L	1.5	1.5	1	20	
Sulfate	mg/L	23.8	23.7	.2	20	

SAMPLE DUPLICATE: 1289878

Parameter	Units	10205092002 Result	Dup Result	RPD	Max RPD	Qualifiers
Chloride	mg/L	4.8	4.8	.8	20	
Sulfate	mg/L	10.4	10.3	.9	20	

REPORT OF LABORATORY ANALYSIS

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QUALITY CONTROL DATA

Project: Crystal Mine
Pace Project No.: 10205092

QC Batch: WET/27676 — Analysis Method: SM 2320B
QC Batch Method: SM 2320B — Analysis Description: 2320B Alkalinity
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

METHOD BLANK: 1287673 — Matrix: Water
Associated Lab Samples: 10205092001, 10205092002, 10205092003, 10205092004, 10205092005, 10205092006, 10205092007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Alkalinity, Total as CaCO3	mg/L	2.5U	5.0	09/14/12 13:44	
Alkalinity,Bicarbonate (CaCO3)	mg/L	2.5U	5.0	09/14/12 13:44	

LABORATORY CONTROL SAMPLE & LCSD: 1287674 1287675

Parameter	Units	Spike Conc.	LCS Result	LCSD Result	LCS % Rec	LCSD % Rec	% Rec Limits	RPD	Max RPD	Qualifiers
Alkalinity, Total as CaCO3	mg/L	40	39.7	40.2	99	100	90-110	1	30	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1287676 1287677

Parameter	Units	10204823005 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Alkalinity, Total as CaCO3	mg/L	111	40	40	151	149	100	95	80-120	1	30	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1287678 1287679

Parameter	Units	10205247001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Alkalinity, Total as CaCO3	mg/L	185	40	40	229	229	110	109	80-120	.1	30	

Pace Analytical Services, Inc.
602 S 25th Street
Billings, MT 591014549
(406)254-7226

QUALIFIERS

Project:	Crystal Mine
Pace Project No.:	10205092

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to changes in sample preparation, dilution of the sample aliquot, or moisture content.

ND - Not Detected at or above adjusted reporting limit.

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

PRL - Pace Reporting Limit.

RL - Reporting Limit.

S - Surrogate

1,2-Diphenylhydrazine (8270 listed analyte) decomposes to Azobenzene.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

TNI - The NELAC Institute.

LABORATORIES

PASI-M	Pace Analytical Services - Minneapolis
PASI-MT	Pace Analytical Services - Montana
PASI-O	Pace Analytical Services - Ormond Beach

ANALYTE QUALIFIERS

E	Analyte concentration exceeded the calibration range. The reported result is estimated.
M1	Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.

Pace Analytical Services, Inc.
602 S 25th Street
Billings, MT 591014549
(406)254-7226

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: Crystal Mine
Pace Project No.: 10205092

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
10205092001	**CMW-1GW0912**	EPA 200.7	ICP/10283	EPA 200.7	ICP/6677
10205092002	**CMW-2GW0912**	EPA 200.7	ICP/10283	EPA 200.7	ICP/6677
10205092003	**CMW-2GW0912MS**	EPA 200.7	ICP/10283	EPA 200.7	ICP/6677
10205092004	**CMW-2GW0912SD**	EPA 200.7	ICP/10283	EPA 200.7	ICP/6677
10205092005	**CMW-3GW0912**	EPA 200.7	ICP/10283	EPA 200.7	ICP/6677
10205092006	**CMW-3GW0912FB**	EPA 200.7	ICP/10283	EPA 200.7	ICP/6677
10205092007	**CMW-4GW0912**	EPA 200.7	ICP/10283	EPA 200.7	ICP/6677
10205092001	**CMW-1GW0912**	EPA 200.7	ICP/10279	EPA 200.7	ICP/6676
10205092002	**CMW-2GW0912**	EPA 200.7	ICP/10279	EPA 200.7	ICP/6676
10205092003	**CMW-2GW0912MS**	EPA 200.7	ICP/10279	EPA 200.7	ICP/6676
10205092004	**CMW-2GW0912SD**	EPA 200.7	ICP/10279	EPA 200.7	ICP/6676
10205092005	**CMW-3GW0912**	EPA 200.7	ICP/10279	EPA 200.7	ICP/6676
10205092006	**CMW-3GW0912FB**	EPA 200.7	ICP/10279	EPA 200.7	ICP/6676
10205092007	**CMW-4GW0912**	EPA 200.7	ICP/10279	EPA 200.7	ICP/6676
10205092001	**CMW-1GW0912**	EPA 200.8	ICPM/10282	EPA 200.8	ICPM/4265
10205092002	**CMW-2GW0912**	EPA 200.8	ICPM/10282	EPA 200.8	ICPM/4265
10205092003	**CMW-2GW0912MS**	EPA 200.8	ICPM/10282	EPA 200.8	ICPM/4265
10205092004	**CMW-2GW0912SD**	EPA 200.8	ICPM/10282	EPA 200.8	ICPM/4265
10205092005	**CMW-3GW0912**	EPA 200.8	ICPM/10282	EPA 200.8	ICPM/4265
10205092006	**CMW-3GW0912FB**	EPA 200.8	ICPM/10282	EPA 200.8	ICPM/4265
10205092007	**CMW-4GW0912**	EPA 200.8	ICPM/10282	EPA 200.8	ICPM/4265
10205092001	**CMW-1GW0912**	EPA 200.8	ICPM/10280	EPA 200.8	ICPM/4267
10205092002	**CMW-2GW0912**	EPA 200.8	ICPM/10280	EPA 200.8	ICPM/4267
10205092003	**CMW-2GW0912MS**	EPA 200.8	ICPM/10280	EPA 200.8	ICPM/4267
10205092004	**CMW-2GW0912SD**	EPA 200.8	ICPM/10280	EPA 200.8	ICPM/4267
10205092005	**CMW-3GW0912**	EPA 200.8	ICPM/10280	EPA 200.8	ICPM/4267
10205092006	**CMW-3GW0912FB**	EPA 200.8	ICPM/10280	EPA 200.8	ICPM/4267
10205092007	**CMW-4GW0912**	EPA 200.8	ICPM/10280	EPA 200.8	ICPM/4267
10205092001	**CMW-1GW0912**	EPA 300.0	MT/10149		
10205092002	**CMW-2GW0912**	EPA 300.0	MT/10149		
10205092003	**CMW-2GW0912MS**	EPA 300.0	MT/10149		
10205092004	**CMW-2GW0912SD**	EPA 300.0	MT/10149		
10205092005	**CMW-3GW0912**	EPA 300.0	MT/10149		
10205092006	**CMW-3GW0912FB**	EPA 300.0	MT/10149		
10205092007	**CMW-4GW0912**	EPA 300.0	MT/10149		
10205092001	**CMW-1GW0912**	SM 2320B	WET/27676		
10205092002	**CMW-2GW0912**	SM 2320B	WET/27676		
10205092003	**CMW-2GW0912MS**	SM 2320B	WET/27676		
10205092004	**CMW-2GW0912SD**	SM 2320B	WET/27676		
10205092005	**CMW-3GW0912**	SM 2320B	WET/27676		
10205092006	**CMW-3GW0912FB**	SM 2320B	WET/27676		
10205092007	**CMW-4GW0912**	SM 2320B	WET/27676		

Pace Analytical®
www.pacelabs.com

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page: 1 of 1

1496434

Section A Required Client Information:	Section B Required Project Information:	Section C Invoice Information:
Company: CH2M HILL	Report To: Dennis Smith	Attention:
Address: 322 E Front St.	Copy To:	Company Name:
Suite 200 Boise ID 83702		Address:
Email To: Dennis.Smith@CH2M.com	Purchase Order No.:	Pace Quote Reference:
Phone: Fax:	Project Name: Crystal Mine	Pace Project Manager:
Requested Due Date/TAT:	Project Number:	Pace Profile #:

REGULATORY AGENCY

☐ NPDES ☐ GROUND WATER ☐ DRINKING WATER
☐ UST ☐ RCRA ☐ OTHER ______

Site Location STATE: ______

Requested Analysis Filtered (Y/N)

Section D Required Client Information

Matrix Codes (MATRIX / CODE): Drinking Water DW, Water WT, Waste Water WW, Product P, Soil/Solid SL, Oil OL, Wipe WP, Air AR, Tissue TS, Other OT

SAMPLE ID (A-Z, 0-9 / ,-) Sample IDs MUST BE UNIQUE

Pace Project No./ Lab I.D.: 10205092

ITEM #	SAMPLE ID	MATRIX CODE	SAMPLE TYPE (G=GRAB C=COMP)	COMPOSITE START DATE	COMPOSITE START TIME	COMPOSITE END/GRAB DATE	COMPOSITE END/GRAB TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Unpreserved	H_2SO_4	HNO_3	HCl	NaOH	$Na_2S_2O_3$	Methanol	Other	Analysis Test (Y/N)	Metals (N)	Diss metals (Y)	Alkalinity (N)	Sulfate & chloride (N)	Residual Chlorine (Y/N)	Pace Project No./ Lab I.D.
1	CMW-1GW0912	WT	G			9/11/12	0830		4	X		X							X	X	X	X		001
2	CMW-2GW0912	WT	G			9/18/12	1140		4	X		X							X	X	X	X		002
3	CMW-2GW0912MS	WT	G			9/18/12	1140		4	X		X							X	X	X	X		003
4	CMW-2GW0912SD	WT	G			9/18/12	1140		4	X		X							X	X	X	X		004
5	CMW-3GW0912	WT	G			9/11/12	1100		4	X		X							X	X	X	X		005
6	CMW-3GW0912FD	WT	G			9/11/12	1100		4	X		X							X	X	X	X		006
7	CMW-4GW0912	WT	G			9/10/12	1200		4	X		X							X	X	X	X		007
8																								
9																								
10																								
11																								
12																								

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	SAMPLE CONDITIONS			
	FedEx			MWalter - Pace	9/12/12	1009				
							0.0	Y	Y	Y
							Temp in °C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)

29 of 30

ORIGINAL

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: Allen Erickson

SIGNATURE of SAMPLER: [signature] DATE Signed (MM/DD/YY): 9/11/12 1649

PaceAnalytical	Document Name: Sample Condition Upon Receipt Form	Document Revised: 27Jul2012 Page 1 of 1
	Document No.: F-MT-C-184-rev.01	Issuing Authority: Pace Minnesota Quality Office

[redacted] **Client Name:** CH2M Hill

Project #: WO#: 10205092

10205092

Courier: ☐ Fed Ex ☐ UPS ☐ USPS ☐ Client ☐ Commercial ☐ Pace ☐ Other:

acking Number: Peterson 5370 1131 2613

stody Seal on Cooler/Box Present? ☒ Yes ☐ No **Seals Intact?** ☒ Yes ☐ No

Optional: Proj. Due Date: Proj. Name:

cking Material: ☒ Bubble Wrap ☒ Bubble Bags ☐ None ☐ Other: **Temp Blank?** ☒ Yes ☐ No

rmometer Used: ☒ 1383045 ☐ 135 **Type of Ice:** ☒ Wet ☐ Blue ☐ None ☒ Samples on ice, cooling process has begun

ler Temperature: 0.0 **Biological Tissue Frozen?** ☐ Yes ☐ No **Date and Initials of Person Examining Contents:** MW 9/10/12

p should be above freezing to 6°C

	Yes	No	N/A	Comments:
hain of Custody Present?	☒	☐	☐	1.
hain of Custody Filled Out?	☒	☐	☐	2.
hain of Custody Relinquished?	☐	☒	☐	3.
ampler Name and Signature on COC?	☒	☐	☐	4.
amples Arrived within Hold Time?	☒	☐	☐	5.
hort Hold Time Analysis (<72 hr)?	☐	☒	☐	6.
ush Turn Around Time Requested?	☐	☒	☐	7.
ufficient Volume?	☒	☐	☐	8.
orrect Containers Used?	☒	☐	☐	9.
-Pace Containers Used?	☒	☐	☐	
ontainers Intact?	☒	☐	☐	10.
iltered Volume Received for Dissolved Tests?	☒	☐	☐	11. samples still have sediment in them
ample Labels Match COC?	☒	☐	☐	12.
-Includes Date/Time/ID/Analysis Matrix: H2O				
ll containers needing acid/base preservation have een checked? Noncompliances are noted in 13.	☒	☐	☐	13. ☒ HNO_3 ☐ H_2SO_4 ☐ NaOH ☐ HCl
ll containers needing preservation are found to be in ompliance with EPA recommendation? (HNO_3, H_2SO_4, HCl<2; NaOH>12)	☒	☐	☐	Sample # 001-007 (2/2)
xceptions: VOA, Coliform, TOC, Oil and Grease, /I-DRO (water)	☐	☒		Initial when completed: MW Lot # of added preservative:
amples checked for dechlorination?	☐	☐	☒	14.
eadspace in VOA Vials (>6mm)?	☐	☐	☒	15.
ip Blank Present?	☐	☐	☒	16.
ip Blank Custody Seals Present?	☐	☐	☒	
ace Trip Blank Lot # (if purchased): N/A				

LIENT NOTIFICATION/RESOLUTION **Field Data Required?** ☐ Yes ☐ No

Person Contacted: Date/Time:

Comments/Resolution:

Project Manager Review: [signature] **Date:** 9-12-12

: Whenever there is a discrepancy affecting North Carolina compliance samples, a copy of this form will be sent to the North Carolina DEHNR Certification Office (i.e out of incorrect preservative, out of temp, incorrect containers)

Appendix B
Identification and Description of Applicable or Relevant and Appropriate Requirements

Summary of Potential Federal and State Applicable or Relevant and Appropriate Requirements (ARARs) Crystal Mine OU5 – Basin Mining Area NPL Site

I. INTRODUCTION

Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. ' 9621(d), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR Part 300 (1990), and guidance and policy issued by the U.S. Environmental Protection Agency (EPA) require that remedial actions under CERCLA comply with substantive provisions of applicable or relevant and appropriate standards, requirements, criteria, or limitations (ARARs) from State of Montana and federal environmental laws and state facility siting laws during and at the completion of the remedial action. These requirements are threshold standards that any selected remedy must meet, unless an ARAR waiver is granted.

This document identifies potential ARARs for possible remedial actions to be conducted at the former Crystal Mine Operable Unit 5 (OU5), of the Basin Mining Area National Priorities List Site. The following ARARs or groups of related ARARs are each identified by a statutory or regulatory citation, followed by a brief explanation of the ARAR and how and to what extent the ARAR is expected to apply to the activities to be conducted under this remedial action. EPA expects that there will be no physical remedial action except that institutional controls will be adopted. These will control any earth work on the site, building modifications, or possible removal of waste materials. Even though EPA may not implement a cleanup as part of this action, there may nevertheless be actions which need to be undertaken in compliance with certain ARARs. These ARARs are set forth below.

Substantive provisions of the requirements listed below are identified as ARARs pursuant to 40 Code of Federal Regulations (CFR) ' 300.400. ARARs must be attained during and at the completion of the remedial action.[1] No Federal, State or local permit shall be required for the portion of any removal or remedial action conducted entirely on site in accordance with Section 121(e) of CERCLA.

II. TYPES OF ARARs

ARARs are either Aapplicable@ or Arelevant and appropriate.@ Both types of requirements are mandatory under CERCLA and the NCP.[2] Applicable requirements are those cleanup standards, standards of control, and other substantive requirements, criteria or limitations promulgated under federal environmental or state environmental and facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a

---

[1] 40 CFR § 300.435(b)(2); Preamble to the National Oil and Hazardous Substances Pollution Contingency Plan, 55 Federal Register (FR) 8755-8757 (March 8, 1990).

[2] CERCLA ' 121(d)(2)(A), 42 U.S.C. ' 6921(d)(2)(A). See also, 40 CFR ' 300.430(f)(1)(i)(A).

state in a timely manner and that are more stringent than federal requirements may be applicable.[3]

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not Aapplicable@ to hazardous substances, pollutants, contaminants, remedial actions, locations, or other circumstances 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. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.[4]

The determination that a requirement is relevant and appropriate is a two-step process: (1) determination if a requirement is relevant and (2) determination if a requirement is appropriate. In general, this involves a comparison of a number of site-specific factors, including an examination of the purpose of the requirement and the purpose of the proposed CERCLA action; the medium and substances regulated by the requirement and the proposed action; the actions or activities regulated by the requirement and the remedial action; and the potential use of resources addressed in the requirement and the remedial action. When the analysis results in a determination that a requirement is both relevant and appropriate, such a requirement must be complied with to the same degree as if it were applicable.[5]

ARARs are contaminant, location, or action specific. Contaminant specific requirements address chemical or physical characteristics of compounds or substances on sites. These values establish acceptable amounts or concentrations of chemicals which may be found in or discharged to the ambient environment.

Location specific requirements are restrictions placed upon the concentrations of hazardous substances or the conduct of cleanup activities because they are in specific locations. Location specific ARARs relate to the geographical or physical positions of sites, rather than to the nature of contaminants at sites. Action specific requirements are usually technology based or activity based requirements or limitations on actions taken with respect to hazardous substances, pollutants or contaminants. A given cleanup activity will trigger an action specific requirement. Such requirements do not themselves determine the cleanup alternative, but define how chosen cleanup methods should be performed. At this time, EPA does not expect that there will be a physical cleanup at OU5 and therefore, there will be no action specific requirements for the OU5 remedial action. However, the institutional controls to be adopted as part of the action could trigger several of the ARARs listed below. If there is earthwork or excavation at OU5, if there are changes in structures of buildings, of if asbestos is discovered, several of the ARARs below could be triggered.

---

[3] 40 CFR ' 300.5.

[4] 40 CFR ' 300.5.

[5] CERCLA Compliance with Other Laws Manual, Vol. I, OSWER Directive 9234.1-01, August 8, 1988, p. 1-11.

Many requirements listed as ARARs are promulgated as identical or near identical requirements in both federal and state law, usually pursuant to delegated environmental programs administered by EPA and the state. The Preamble to the NCP provides that such a situation results in citation to the state provision and treatment of the provision as a federal requirement.

Also contained in this list are policies, guidance or other sources of information which are Ato be considered@ in the implementation of the record of decision (ROD). Although not enforceable requirements, these documents are important sources of information which EPA and the State of Montana Department of Environmental Quality (MDEQ) may consider, especially in regard to the evaluation of public health and environmental risks; or which will be referred to, as appropriate, in developing cleanup actions.[6] These final ARARs will be set forth as performance standards for any and all remedial design or remedial action work plans.

III. ARARS WAIVER

40 CFR § 300.430(f)(1)(ii)(C)(*1*) provides:

> (C) An alternative that does not meet an ARAR under federal environmental or state environmental or facility siting laws may be selected under the following circumstances:
> (1) The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement;
> ***

The Crystal Mine OU5 cleanup will be an interim remedial action where compliance with groundwater and surface water ARARs is concerned. EPA doesn't expect that this action will result in final compliance with surface and ground water ARARs at the Basin Mine Area NPL Site. Final compliance with these water ARARs may happen after all 5 OUs at the Site have been addressed. If not, EPA will issue a technical impracticability waiver at the time it issues the ROD for the last of the five OUs at the Site. This will be as provided for at 40 CFR § 300.430(f)(1)(ii)(C)(*3*). Any waiver will explain why it is technically impracticable to meet certain water quality ARARs at that time. For now, EPA is invoking the interim action waiver provided for at 40 CFR § 300.430(f)(1)(ii)(C)(*1*) with respect to all water quality ARARs at OU5. It should be noted that EPA expects all other ARARs for the Crystal Mine - OU5 action to be complied with during or at completion of the action, as appropriate.

6 40 CFR § 300.400(g)(3); Preamble to the NCP, 55 Fed. Reg. 8744-8746 (March 8, 1990).

APPENDIX

Summary of Federal and State

Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)

Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
Federal ARARs and TBCs							
National Historic Preservation Act (NHPA) National Register of Historic Places Determinations of eligibility for inclusion in the National Register of Historic Places Protection of historic properties Requirements for environmental information documents and third-party agreements for EPA actions subject to NEPA Historic Sites Act of 1935	16 United States Code (U.S.C.). 470 36 Code of Federal Regulations (CFR) 60 36 CFR 63 16 U.S.C. 461, et seq.	**Applicable**	This statute and implementing regulations require federal agencies to take into account the effect of this response action upon any district, site, building, structure, or object that is included in or eligible for the National Register of Historic Places (generally, 50 years old or older).	It is not anticipated that proposed areas for remedial action at the Crystal Mine Site are eligible for the National Register of Historic Places. If cultural resources on, or eligible for, the national register are identified, it will be necessary to determine if there will be an adverse effect and, if so, how the effect may be minimized or mitigated, in consultation with the appropriate State Historic Preservation Office (SHPO). [A cultural resource inventory of the site was prepared and submitted to the Montana SHPO. Findings indicated that the site did not qualify for the National Register of Historic Places.]		✓	
Archaeological and Historic Preservation Act Requirements for environmental information documents and third-party agreements for EPA actions subject to NEPA Protection of archaeological	16 U.S.C. 469 43 CFR 7	**Applicable**	This statute and implementing regulations establish requirements for the evaluation and preservation of historical and archaeological data, which may be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program.	The unauthorized removal of archaeological resources from public or Indian lands is prohibited without a permit and any archaeological investigations at a site must be conducted by a professional archaeologist.		✓	

APPENDIX
Summary of Federal and State
Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)
Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
resources							
Fish and Wildlife Coordination Act Responsible official requirements Rules implementing the Fish and Wildlife Conservation Act of 1980	16 U.S.C. 661 et seq.,	**Applicable**	This statute and implementing regulations require coordination with federal and state agencies for federally funded projects to ensure that any modification of any stream or other water body affected by any action authorized or funded by the federal agency provides for adequate protection of fish and wildlife resources.	The eastern edge of the Crystal mine Site is located adjacent to Uncle Sam Gulch Creek, a small steep tributary to Cataract Creek. If the remedial action involves activities that affect wildlife and/or non-game fish, federal agencies must first consult with the USFWS and the relevant state agency with jurisdiction over wildlife resources.		✓	
Floodplain Management requirements	Executive Order No. 11988	**Applicable**	These require that actions be taken to avoid, to the extent possible, adverse effects associated with direct or indirect development of a floodplain, or to minimize adverse impacts if no practicable alternative exists.	These standards are applicable to all actions within floodplain areas. The floodplain associated with Uncle Sam Gulch Creek is small because of the high elevation, incised topography, and first order nature of this tributary. No future development within the floodplain is anticipated.		✓	
Protection of Wetlands Regulations	Executive Order No. 11990	**Applicable**	This ARAR requires federal agencies and the PRPs to avoid, to the extent possible, the adverse impacts associated with the destruction or loss of wetlands and to avoid support of new construction in wetlands if a practicable alternative exists.	Wetlands exist within the areas for remediation at the Crystal Mine. These standards would be applicable.		✓	✓

APPENDIX
Summary of Federal and State
Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)
Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
Endangered Species Act (ESA)	16 U.S.C. 1531	**Applicable**	This statute and implementing regulations provide that federal activities not jeopardize the continued existence of any threatened or endangered species. ESA Section 7 requires consultation with the United States Fish and Wildlife Service (USFWS) to identify the possible presence of protected species and mitigate potential impacts on such species.	If threatened or endangered species are identified within the areas identified for remediation, activities must be designed to conserve the species and their habitat.		✓	
Migratory Bird Treaty Act List of Migratory Birds	16 U.S.C. 703, et seq. 50 CFR 10.13	**Relevant and Appropriate**	Makes it unlawful to "hunt, take, capture, kill," or take various other actions adversely affecting a broad range of migratory birds, without the prior approval of the Department of the Interior.	The selected remedial actions will be carried out in a manner to avoid adversely affecting migratory bird species, including individual birds or their nests.		✓	
Bald Eagle Protection Act	16 U.S.C. 668, et seq.	**Applicable**	This requirement establishes a federal responsibility for protection of bald and golden eagles, and requires continued consultation with the U.S. Fish and Wildlife Service during remedial design and remedial construction to ensure that any cleanup of the site does not unnecessarily adversely affect the bald and golden eagles.	If bald or golden eagles are identified within the areas identified for remediation, activities must be designed to conserve the species and their habitat.		✓	

APPENDIX

Summary of Federal and State

Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)

Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
Native American Graves Protection and Repatriation Act	25 U.S.C. 3001, et seq.	**Applicable**	The Act prioritizes ownership or control over Native American cultural items, including human remains, funerary objects and sacred objects, excavated or discovered on federal or tribal lands. Federal agencies and museums that have possession or control over Native American human remains and associated funerary objects are required under the Act to compile an inventory of such items and, to the extent possible, identify their geographical and cultural affiliation. Once the cultural affiliation of such objects is established, the federal agency or museum must expeditiously return such items, upon request by a lineal descendent of the individual Native American or tribe identified.	No known cultural items, including human remains, funerary objects and sacred objects are located on the site. If such items are discovered during excavation activities then the provisions of this regulation will be applicable.		✓	✓
American Indian Religious Freedom Act	42 U.S.C. 1996 et seq.	**Applicable**	This Act establishes a federal responsibility to protect and preserve the inherent right of American Indians to believe, express and exercise the traditional religions of American Indians. This right includes, but is not limited to, access to sites, use and possession of sacred objects,	The Act requires Federal agencies to protect Indian religious freedom by refraining from interfering with access, possession and use of religious objects, and by consulting with Indian organizations regarding proposed actions affecting their religious freedom.		✓	

APPENDIX

Summary of Federal and State

Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)

Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
			and the freedom to worship through ceremonials and traditional rites.				
Clean Water Act	33 U.S.C. 1251 et seq. 33 CFR 330	**Relevant and Appropriate**	Regulates discharge of dredged or fill materials into waters of the United States.	A portion of the Crystal Mine site to be remediated is located adjacent to Uncle Sam Gulch Creek. No discharges of dredged or fill materials into waters of the United States are planned during remedial actions. Measures must be taken to prevent any such discharges. As provided under Section 303 of the Clean Water Act, 33 U.S.C. 1313, the State of Montana has promulgated water quality standards. See the discussion concerning State surface water quality requirements.		✓	
National Ambient Air Quality Standards	40 CFR 50.6 (PM-10) 40 CFR 50.12 (lead)	**Applicable**	These provisions establish standards for PM-10 and lead emissions to air. (Corresponding state standards are found at ARM 17.8.222 [lead] and ARM 17.8.223 [PM-10].) The PM-10 standard is 150 micrograms per cubic meter ($\mu g/m^3$), 24-hour average concentration, and the lead standard is 1.5 $\mu g/m^3$, maximum arithmetic mean averaged over a calendar quarter.	The selected remedial actions will be carried out in a manner that will comply with all the National Ambient Air Quality Standards.	✓		✓

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Summary of Federal and State

Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)

Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
Protection and Enhancement of the Cultural Environment	16 U.S.C. 470 Executive Order No. 11593	**Applicable**	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 remedial activities should threaten cultural resources.		✓	
The Archaeological Resources Protection Act of 1979	16 U.S.C. 470aa-47011	**Relevant and Appropriate**	Requires a permit for any excavation or removal of archeological resources from public lands or Indian lands.	Substantive portions of this act may be relevant and appropriate if archeological resources are encountered during onsite remedial action activity involving public lands or Indian lands.		✓	
Federal and State RCRA Subtitle D and Solid Waste Management Requirements	40 CFR 257	**Applicable**	Establishes criteria under Subtitle D of the Resource Conservation and Recovery Act for use in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health or the environment.	Solid waste requirements are listed herein because contaminated soil to be addressed in the remedial action is considered solid waste.			✓
Federal RCRA Subtitle C Requirements	42 U.S.C. Section 9621, et seq. 40 CFR 261-268	**Relevant and Appropriate**	RCRA Subtitle C and implementing regulations are designated as applicable for any hazardous wastes that are actively "generated" or that were "placed" or "disposed" after 1980.	RCRA Subtitle C requirements will generally not be relevant and appropriate for those wastes for which EPA has specifically determined that Subtitle C regulation is not warranted (i.e., wastes covered by the Bevill exclusion). Thus mining contaminated soil is assumed to not be classified as hazardous			✓

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Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
				waste. However these regulations may be relevant and appropriate to any unknown, potentially hazardous wastes encountered during excavation of contaminated soils (e.g. buried drums, etc.).			
Occupational Safety and Health Act	29 CFR 1910	**To Be Considered**	Provides standards and guidance for worker protection during conduct of construction activities.	OSHA regulations are construction standards and not environmental standards. These regulations are requirements for remedial activities as provided by law.			
Federal Aviation Administration (FAA) Regulations	14 CFR 77.13, et seq. 14 CFR 139.341 14 CFR 157	**To Be Considered**	Describes the standards used for determining obstructions to air navigation, navigational aids, or navigational facilities. Provides procedures for identifying, marking, and lighting construction and other unserviceable areas. Includes procedures for providing notice of construction, alteration, activation, and deactivation of airports.	FAA regulations are construction standards and not environmental standards. No permit is required for response actions conducted entirely on-site.			

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Summary of Federal and State
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Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
FEMA Flood Insurance Rate Map	Map ID 3001280005A, (01/05/2001)	**To Be Considered**	The FEMA flood insurance rate map (FIRM) indicates the special flood hazard area delineated by Zone A and areas outside delineated by Zone X.	This map contains TBC information to be used when remediating property within floodplain areas. However it is unlikely that FEMA has mapped the flood plain with in Uncle Sam Gulch, because of its remote location and lack of development beyond a mine property.			
State of Montana ARARs and TBCs							
Groundwater Protection	Administrative Rules of Montana (ARM) 17.30.1005 ARM 17.30.1006 ARM 17.30.1011	**Applicable but Waived**[3]	Explains the applicability and basis for the groundwater standards in ARM 17.30.1006, which establish the maximum allowable changes in groundwater quality and may limit discharges to groundwater. Provides that groundwater is classified I through IV based on its present and future most beneficial uses and also sets the standards for the different classes of groundwater listed in department Circular WQB-7.[1] This section provides that any groundwater whose existing quality is higher than the standard for its classification	The OU addressed in this feasibility study does address contaminated groundwater. Measures will be taken to prevent contamination of groundwater.	✓		✓

APPENDIX
Summary of Federal and State
Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)
Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
			must be maintained at that high quality in accordance with MCA 75-5-303 and ARM 17.30.7.				
Montana Water Quality Act and Regulations	Montana Code Annotated (MCA) 75-5-101, et seq. ARM 17.30.607	**Applicable but Waived**[3]	The Montana Water Quality Act establishes requirements for restoring and maintaining the quality of surface and groundwater. Montana's regulations classify State waters according to quality, place restrictions on the discharge of pollutants to State waters, and prohibit degradation of State waters. Tributaries to the Boulder River have been classified B-1. Basin Creek and Cataract Creek and their tributaries are part of the Boulder River drainage.	The OU addressed in this feasibility study does address contaminated groundwater and surface water. Due to the proximity of remedial actions to surface waters, measures will be taken to prevent contamination of surface waters.	✓		✓
Montana Water Quality Act and Regulations (Continued)	ARM 17.30.623		Waters classified B-1 are, after conventional treatment for removal of naturally present impurities, suitable for drinking, culinary and food processing purposes. These waters are also suitable for bathing, swimming and recreation, growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers, and use for agricultural and industrial				

APPENDIX
Summary of Federal and State
Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)
Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
	ARM 17.30.637		purposes. This regulation also specifies water quality standards for waters classified B-1, which set limits on the allowable levels of pollutants and prohibit certain discharges to those waters.				
	MCA 75-5-303		Provides that surface waters must be free of substances attributable to industrial practices or other discharges that will: (a) settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines; (b) create floating debris, scum, a visible oil film (or be present in concentrations at or in excess of 10 milligrams per liter) or globules of grease or other floating materials; (c) produce odors, colors or other conditions which create a nuisance or render undesirable tastes to fish flesh or make fish inedible; (d) create concentrations or combinations of materials which are toxic or harmful to human, animal, plant or aquatic life; (e) create conditions which produce undesirable aquatic life.				
	MCA 75-5-605		This provision states that existing				

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Summary of Federal and State
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Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
	ARM 17.30.705		uses of state waters and the level of water quality necessary to protect the uses must be maintained and protected. This section of the Montana Water Quality Act prohibits the causing of pollution of any state waters. Pollution is defined as contamination or other alteration of physical, chemical, or biological properties of state waters which exceeds that permitted by the water quality standards. Also, it is unlawful to place or cause to be placed any wastes where they will cause pollution of any state waters Existing and anticipated uses of surface water and water quality necessary to support those uses must be maintained and protected unless degradation is allowed under the nondegradation rules at ARM 17.30.708.				
Substantive MPDES Permit Requirements	ARM 17.30.1342-1344	**Applicable**	These set forth the substantive requirements applicable to all MPDES and National Pollutant Discharge Elimination System	Treated discharge into waters of the State of Montana (Uncle Sam Gulch Creek) is planned as part of the final remedial	✓		✓

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Summary of Federal and State

Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)

Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
			(NPDES) permits.	action. This discharge will be made in consultation with the State of Montana. Measures must be taken to prevent any uncontrolled discharges.[2]			
Stormwater Runoff Control Requirements	ARM 17.24.633 ARM 17.30.1341	**Applicable**	All surface drainage from a disturbed area must be treated by the best technology currently available. DEQ has issued general storm water permits for certain activities. The substantive requirements of the permits are applicable for the following activities: for construction activities B General Permit for Storm Water Discharge Associated with Construction Activity, Permit No. MTR100000 (April 16, 2007).	These requirements would be applicable to disturbed remedial areas. Generally, the permits require best management practices (BMP) and all reasonable steps to minimize or prevent any discharge which has a reasonable likelihood of adversely affecting human health or the environment.			✓

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Summary of Federal and State
Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)
Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
Montana Ambient Air Quality Regulations	ARM 17.8.206 ARM 17.8.220 ARM 17.8.222 ARM 17.8.223 ARM 17.8.304(2) ARM 17.8.308	**Applicable**	This provision establishes sampling, data collection, and analytical requirements to ensure compliance with ambient air quality standards. Settled particulate matter shall not exceed a thirty (30) day average of 10 grams per square meter. Lead emissions to ambient air shall not exceed a ninety (90) day average of 1.5 micrograms per cubic liter of air. PM-10 concentrations in ambient air shall not exceed a 24 hour average of 150 micrograms per cubic meter of air and an annual average of 50 micrograms per cubic meter of air. Emissions into the outdoor atmosphere shall not exhibit an opacity of 20% or greater averaged over 6 consecutive minutes. There shall be no production, handling, transportation, or storage of any material, use of any street, road, or parking lot, or	No Comments.	✓		✓

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Summary of Federal and State
Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)
Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
	ARM 17.8.604(2)		operation of a construction site or demolition project unless reasonable precautions are taken to control emissions of airborne particles. The 20% opacity limit described above is also specified for these activities. Lists material that may not be disposed of by open burning except as approved by the department.	Open burning may be applicable if actions addressed clearing and grubbing debris through open burning.			
Montana Mine Reclamation Regulations	ARM 17.24.761	**Relevant and Appropriate**	Specifies measures for controlling fugitive dust emissions during reclamation activities, such as watering, chemically stabilizing, or frequently compacting and scraping roads, promptly removing rock, soil or other dust-forming debris from roads, restricting vehicle speeds, and promptly revegetating regraded lands.	Some measures identified in this regulation could be considered relevant and appropriate to control fugitive dust emissions in connection with excavation, earth moving and transportation activities conducted as part of the remedy at the site.			
Montana Antiquities Act	MCA 22-3-421, et seq	**Relevant and Appropriate**	Addresses the responsibilities of State agencies regarding historic and prehistoric sites including buildings, structures, paleontological sites, archaeological sites on state owned lands. This act requires avoidance or mitigation of impacts to heritage property or	If historic or prehistoric sites are discovered during excavation activities on any state-owned lands then the provisions of this regulation may apply. These regulations may be relevant and appropriate for lands with other types of ownership.		✓	

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Summary of Federal and State

Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)

Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
			paleontological remains.				
Montana Human Skeletal Remains and Burial Site Protection Act	MCA 22-3-801	**Applicable**	Provides that all graves within the State of Montana are adequately protected.	If human skeletal remains or burial site are encountered during remedial activities at the site, then requirements will be applicable.		✓	✓
Montana Floodplain and Floodway Management Act and Regulations	MCA 76-5-101, et seq. ARM 36.15.601, et seq.	**Applicable**	Specifies types of uses and structures that are allowed or prohibited in the designated 100-year floodway and floodplain. These regulations prohibit, in both the floodway and the floodplain, solid and hazardous waste disposal and the storage of toxic or hazardous materials.	Mine areas to be remediated are located adjacent to Uncle Sam Gulch Creek. These standards are applicable to all actions within potential floodplain areas.		✓	
Montana Natural Streambed and Land Preservation Act and Regulations	MCA 75-7-101, et.seq. ARM 36.2.401, et.seq.	**Applicable**	Establishes minimum standards which would be applicable if a response action alters or affects a streambed, including any channel change, new diversion, riprap or other streambank protection project, jetty, new dam or reservoir or other commercial, industrial or residential development. Projects must be designed and constructed using methods that minimize adverse impacts to the stream (both upstream and downstream) and	A portion of the Crystal Mine site to be remediated is adjacent to Uncle Sam Gulch Creek. The remedial actions will alter or affect a streambed or its banks, the adverse effects of any such action must be minimized.		✓	✓

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Summary of Federal and State
Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)
Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
			future disturbances to the stream.				
Montana Natural Streambed and Land Preservation Act and Regulations (continued)	MCA 87-5-502 and 504	**Applicable**	Provides that a state agency or subdivision shall not construct, modify, operate, maintain or fail to maintain any construction project or hydraulic project which may or will obstruct, damage, diminish, destroy, change, modify, or vary the natural existing shape and form of any stream or its banks or tributaries in a manner that will adversely affect any fish or game habitat.				
Montana Solid Waste Requirements	MCA 75-10-212	**Applicable**	Prohibits dumping or leaving any debris or refuse upon or within 200 yards of any highway, road, street, or alley of the State or other public property, or on privately owned property where	The listed requirements apply to the offsite transportation of solid wastes to disposal facilities, should that remedial option be chosen.			✓

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Summary of Federal and State

Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered Information (TBCs)

Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
			hunting, fishing, or other recreation is permitted.				
	ARM 17.50.523		Specifies that solid waste must be transported in such a manner as to prevent its discharge, dumping, spilling or leaking from the transport vehicle.	While a repository for placement of the wastes from this OU may be obtained and developed as part of other response actions for this site, the placement of the wastes from the remedial actions must be consistent with these applicable requirements.			
	ARM 17.50.1009(1)(c)		Requires that solid waste facilities not discharge pollutants in excess of state standards. A solid waste facility must contain a leachate collection system unless there is no potential for migration of a constituent in Appendix I or II to 40 CFR 258.				
	ARM 17.50.1204		Solid waste facilities must either be designed to ensure that MCLs are not exceeded or the solid waste facility must contain a composite liner and leachate collection system that complies with specified criteria.				
	ARM 17.50.1109		Requires a run-on control system to prevent flow onto the active portion of the solid waste facility during the peak discharge from a 25-year storm and a run-off control system from the active portion of the solid waste facility				

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Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
	ARM 17.50.1403		to collect and control at least the water volume resulting from a 24-hour, 25-year storm.				
	ARM 17.50.1404		Sets forth closure requirements for solid waste facilities. Solid waste facilities must meet the following criteria: (1) install a final cover that is designed to minimize infiltration and erosion; (2) design and construct the final cover system to minimize infiltration through the closed unit by the use of an infiltration layer that contains a minimum 18 inches of earthen material and has a permeability less than or equal to the permeability of any bottom liner, barrier layer, or natural subsoils or a permeability no greater than 1 X 10-5 cm/sec, whichever is less; and (3) minimize erosion of the final cover by the use of a seed bed layer that contains a minimum of six inches of earthen material that is capable of sustaining native plant growth.				
			Post closure care requires maintenance of the integrity and effectiveness of any final cover, including making repairs to the				

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Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
			cover as necessary to correct the effects of settlement, subsidence, erosion, or other events, and preventing run-on and run-off from eroding or otherwise damaging the cover and compliance with the groundwater monitoring requirements found at ARM Title 17, chapter 50, subchapter 13.				
	MCA 75-10-206		Allows variances to be granted from solid waste regulations if failure to comply with the rules does not result in a danger to public health or safety or compliance with specific rules would produce hardship without producing benefits to the health and safety of the public that outweigh the hardship.				

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Crystal Mine Site (OU5)

Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
Noxious Weeds	MCA 7-22-2101 (8)(a) ARM 4.5.201, et seq.	**Applicable**	Defines "noxious weeds" as any exotic plant species established or that may be introduced in the state which may render land unfit for agriculture, forestry, livestock, wildlife, or other beneficial uses or that may harm native plant communities and that is designated: (I) as a statewide noxious weed by rule of the department; or (ii) as a district noxious weed by a board, following public notice of intent and a public hearing.	Applicable requirements for the alternatives which include establishment of seed during restoration.			✓
Occupational Health Act	MCA 50-70-101, et seq ARM 17.74.101 ARM 17.74.102	**To Be Considered**	Addresses occupational noise. In accordance with this section, no worker shall be exposed to noise levels in excess of the levels specified in this regulation. Addresses occupational air contaminants. The purpose of this rule is to establish maximum threshold limit values for air contaminants under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects.	OSHA regulations are construction standards and not environmental standards. These regulations would be considered for onsite remedial activities. This regulation addresses only limited categories of workers and for most workers the similar federal standard in 29 CFR 1910.95 applies. In accordance with this rule, no worker shall be exposed to air contaminant levels in excess of the threshold limit values listed in the regulation. This			

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Statutes, Regulations, Standards, or Requirements	Citations or References	ARAR Determination	Description	Comment	Chemical-Specific	Location-Specific	Action-Specific
				regulation addresses only limited categories of workers and for most workers the similar federal standard in 29 CFR 1910.1000 applies			
State of Montana ARARs and TBCs							
Montana Safety Act	MCA 50-71-201 through 203	**To Be Considered**	States that every employer must provide and maintain a safe place of employment, provide and require use of safety devices and safeguards, and ensure that operations and processes are reasonably adequate to render the place of employment safe	The employer must also do everything reasonably necessary to protect the life and safety of its employees during remedial activities			
Employee and Community Hazardous Chemical Information Act	MCA 50-78-201, 202, and 204	**To Be Considered**	States that each employer must post notice of employee rights, maintain at the work place a list of chemical names of each chemical in the work place, and indicate the work area where the chemical is stored or used.	Employees must be informed of the chemicals at the work place and trained in the proper handling of the chemicals during remedial activities.			

[1]Montana Department of Environmental Quality, Water Quality Division, Circular DEQ-7, Montana Numeric Water Quality Standards (August 2010).
[2]Montana's MPDES regulations are more stringent than the Federal NPDES regulations
[3]40 CFR § 300.430(f)(1)(ii)(C)(1)

Acronyms

ARAR	Applicable or Relevant and Appropriate Requirements
ARM	Administrative Rules of Montana
BTCA	best technology currently available
CFR	Code of Federal Regulations
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
FAA	Federal Aviation Administration
MCA	Montana Code Annotated
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
OU	operable unit
PRP	potentially responsible party
TBCs	to be considered information
U.S.C	United States Code
USFWS	United States Fish and Wildlife Services

ARAR Determination Legend

Applicable requirements refer to those cleanup standards, standards of control and other substantive environmental protection requirements, criteria or limitations under Federal or State law that specifically address hazardous substance, pollutant, contaminat, remedial action, location or other circumstances found at a CERCLA site. Only those State standards more stringent than Federal Stadards, identified in a timely manner, and applied consistently may be applicable.

Relevant and Appropriate requirements are those cleanup standards, standards of control and other substantive requirements under Federal or State environmental citing laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location or other circumstances found at a CERCLA site address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to the particular site. Only those State standards more stringent than Federal Standards, identified in a timely manner, and applied consistently may be applicable.

Regulations that are not considered environmental or facility location standards but are important regulations for remedial alternatives. These are "*To Be Considered*."

Appendix C
Alternative and Common Element Cost Estimates

Crystal Mine Site Cost Estimate
Alternative WR-1 - Waste Rock Capping

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$50,000	$50,000	
Road Improvements	10,600	LF	$50	$530,000	Two miles of road improvement from Bullion mine to Crystal mine
Liner	261,360	Sq Ft	$1	$237,838	6 acres of liner
Common Fill	20,000	CY	$11	$211,800	Dozer spread
Hauling	20,000	CY	$15	$307,600	Assume 25 miles one way
Dust Control	15	Day	$1,685	$25,275	
Compaction	20,000	CY	$1	$28,400	12" lift, wheel compacted
Road Gravel	3,900	CY	$30	$117,000	For road improvements from Bullion mine to Crystal mine
Erosion Control Seeding	1	Acres	$2,000	$2,000	Reseed contractor staging area
Surface Water Control		LS		$101,000	Runon - Runoff Control
StreamBank Reconstruction		LS		$639,000	Reconstruction of 1,000 ft of USG Creek
Removal/Disposal of Ponds and Structures		LS		$259,000	2 ponds and mine structures
Subtotal Capital Costs				$2,508,913	
Contingencies (50%)				$1,254,456	Contingencies at 50% due to site uncertainties
Engineering and SDC (15%)				$564,505	
Subtotal Capital Costs				$4,328,000	

Operations and Maintenance

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Miscellaneous Equipment and Supplies	1	LS/YR	$500	$500	
Monitoring	1	LS/YR	$20,000	$20,000	Monthly sampling of streams and quarterly sampling of monitoring wells
Subtotal O & M Costs				$20,500	
Contingencies (50%)				$10,250	
Net Present Value of O& M Costs				$472,703	Assumes 5% discount rate for 30 years

Alternative WR-1 Total Present Worth Costs **$4,801,000**

Crystal Mine Site Cost Estimate

Alternative WR-2 - Excavate and Local Disposal

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$50,000	$50,000	
Road Improvements	10,600	LF	$50	$530,000	Two miles of road improvement from Bullion mine to Crystal mine
Excavate	69,500	CY	$5	$380,165	Waste rock and soil
Hauling	69,500	CY	$15	$1,042,500	25 miles to Luttrell
Disposal	69,500	CY	$10	$695,000	Assumes Luttrell repository
Common Fill	10,000	CY	$11	$105,900	Dozer spread
Hauling	10,000	CY	$15	$153,800	Assume 25 miles one way
Dust Control	15	Day	$1,685	$25,275	
Compaction	10,000	CY	$1	$14,200	12" lift, wheel compacted
Road Gravel	3,900	CY	$30	$117,000	For road improvements from Bullion mine to Crystal mine
Erosion Control Seeding	1	Acres	$2,000	$2,000	Reseed contractor staging area
Surface Water Control		LS		$101,000	Runon - Runoff Control
StreamBank Reconstruction		LS		$639,000	Reconstruction of 1,000 ft of USG Creek
Removal/Disposal of Ponds and Structures		LS		$259,000	2 ponds and mine structures
Subtotal Capital Costs				$4,114,840	
Contingencies (50%)				$2,057,420	Contingencies at 50% due to site uncertainties
Engineering and SDC (15%)				$925,839	
Subtotal Capital Costs				$7,098,000	

Operations and Maintenance

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Miscellaneous Equipment and Supplies	1	LS/YR	$500	$500	
Monitoring	1	LS/YR	$20,000	$20,000	Monthly sampling of streams and quarterly sampling of monitoring wells
Subtotal O & M Costs				$20,500	
Contingencies (50%)				$10,250	
Net Present Value of O& M Costs				$472,703	Assumes 5% discount rate for 30 years

Alternative WR-2 Total Present Worth Costs **$7,571,000**

Crystal Mine Site Cost Estimate
Alternative WR-3 - Excavate and Dispose Onsite

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$50,000	**$50,000**	
Earthwork				**$1,293,081**	
Aggregate	11,700	SY	$10.14	$118,638	3/4", 6" deep
Rough Grade Road	11,700	SY	$0.85	$9,945	
Waste Rock Excavation (Crystal Dump)	24,500	CY	$6.91	$169,295	Crystal Dump excavation
Waste Rock Excavation	35,500	CY	$6.91	$245,305	
Contaminated Soil Over Excavation	7,500	CY	$5.33	$39,975	
Replacement Soil	7,500	CY	$2.79	$20,925	
Cover Soil on Liner	11,000	CY	$34.39	$378,290	
Cap Soil	4,200	CY	$34.39	$144,438	
Waste Rock Hauling	24,500	CY	$2.35	$57,575	Crystal Dump hauled to repository
Waste Rock Hauling	35,500	CY	$2.35	$83,425	
Dust Control	15	day	$1,684.67	$25,270	
Restoration	22,264	SY	$2.74	**$61,003**	Mechanical seeding and fine grading.
Liners				**$313,950**	
Cap HDPE Liner	288,000	SF	$0.91	$262,080	
Cap in place HDPE Liner	57,000	SF	$0.91	$51,870	
Common Elements				**$999,000**	
Surface Water Control		LS		$101,000	Runon - Runoff Control
StreamBank Reconstruction		LS		$639,000	Reconstruction of 1,000 ft of USG Creek
Removal/Disposal of Ponds and Structures		LS		$259,000	2 ponds and mine structures
Subtotal Capital Costs				**$2,717,034**	
Contingencies (50%)				$1,358,517	Contingencies at 50% due to site uncertainties
Engineering and SDC (15%)				$611,333	
Subtotal Capital Costs				$4,687,000	

Operations and Maintenance

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Miscellaneous Equipment and Supplies	1	LS/YR	$500	$500	
Monitoring	1	LS/YR	$20,000	$20,000	Monthly sampling of streams and quarterly sampling of monitoring wells
Subtotal O & M Costs				$20,500	
Contingencies (50%)				$10,250	
Net Present Value of O& M Costs				$472,703	Assumes 5% discount rate for 30 years

Alternative WR-3 Total Present Worth Costs **$5,160,000**

Crystal Mine Site Cost Estimate
Alternative GW-1 - Mine Plugging Through Re-opened Mine Adit

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$50,000	$50,000	
Road Improvements	10,600	LF	$50	$530,000	Two miles of road improvement from Bullion mine to Crystal mine
Reopen Mine Tunnels	600	FT	$1,248	$748,500	2 adits, 600' lower tunnel and 150' upper tunnel (removed only 1 adit)
Mine Sealing - Grout Curtain	240	EA	$2,910	$698,400	One grout curtain at each end of each concrete plug
Mine Out Plug Area	1	LS	$71,200	$71,200	Over excavate each tunnel for plug
Plug	1	LS	$140,200	$140,200	Bulkheads, concrete and construction, one plug per tunnel
Road Gravel	3,900	CY	$30	$117,000	For road improvements from Bullion mine to Crystal mine
Erosion Control Seeding	1	Acres	$2,000	$2,000	Reseed contractor staging area
6" HDPE Pipe	340	LF	$20	$6,800	HDPE pipes running through concrete plugs
Pipe Intake Grating and Valves	2	EA	$5,000	$10,000	
Verticle Drain	1	EA	$35,000	$35,000	Overflow well will consist of 6-inch schedule 40 blank PVC casing to 150 feet. Cost for mob, drilling of 8-inch borehole, and installation of blank casing.
Monitoring Wells	6	EA	$30,000	$180,000	One upgradient and two downgradient monitoring wells for each grout curtain
Geological Investigations	1	LS	$200,000	$200,000	Investigate geologic suitability for mine sealing
Surface Water Control		LS		$101,000	Runon - Runoff Control
StreamBank Reconstruction		LS		$639,000	Reconstruction of 1,000 ft of USG Creek
Removal/Disposal of Ponds and Structures		LS		$259,000	2 ponds and mine structures
Subtotal Capital Costs				$3,788,100	
Contingencies (50%)				$1,894,050	Contingencies at 50% due to uncertainties of mine sealing
Engineering and SDC (15%)				$852,323	
Subtotal Capital Costs				$6,534,000	

Operations and Maintenance

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Miscellaneous Equipment and Supplies	1	LS/YR	$500	$500	
Replace Grout Curtains	1	LS/YR	$30,000	$30,000	Replace grout curtains every ten years--yearly cost is 1/10 of replacement cost
Monitoring	1	LS/YR	$20,000	$20,000	Monthly sampling of streams and quarterly sampling of monitoring wells
Subtotal O & M Costs				$50,500	
Contingencies (50%)				$25,250	
Net Present Value of O& M Costs				$1,164,463	Assumes 5% discount rate for 30 years

Alternative GW-1 Total Present Worth Costs **$7,698,000**

Crystal Mine Site Cost Estimate

Alternative GW-2 - Remote Mine Plugging Through Borings from the Surface

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$50,000	$50,000	
Road Improvements	10,600	LF	$50	$530,000	Two miles of road improvement from Bullion mine to Crystal mine
Drilling	15,150	FT	$300	$4,545,000	1 adit, 300' bgs
Mine Sealing	1	EA	$46,200	$46,200	One grout curtain at each end of concrete plug and plug concrete.
Road Gravel	3,900	CY	$30	$117,000	For road improvements from Bullion mine to Crystal mine
Erosion Control Seeding	1	Acres	$2,000	$2,000	Reseed contractor staging area
Verticle Drain	1	EA	$35,000	$35,000	Overflow well will consist of 6-inch schedule 40 blank PVC casing to 150 feet. Cost for mob, drilling of 8-inch borehole, and installation of blank casing.
Monitoring Wells	3	EA	$30,000	$90,000	One upgradient and two downgradient monitoring wells for grout curtain
Geological Investigations	1	LS	$200,000	$200,000	Investigate geologic suitability for mine sealing
Surface Water Control		LS		$101,000	Runon - Runoff Control
StreamBank Reconstruction		LS		$639,000	Reconstruction of 1,000 ft of USG Creek
Removal/Disposal of Ponds and Structures		LS		$259,000	2 ponds and mine structures
Subtotal Capital Costs				$6,614,200	
Contingencies (50%)				$3,307,100	Contingencies at 50% due to uncertainties of mine sealing
Engineering and SDC (15%)				$1,488,195	
Subtotal Capital Costs				$11,409,000	

Operations and Maintenance

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Miscellaneous Equipment and Supplies	1	LS/YR	$500	$500	
Replace Grout Curtains	1	LS/YR	$15,000	$15,000	Replace grout curtains every ten years--yearly cost is 1/10 of replacement cost
Monitoring	1	LS/YR	$20,000	$20,000	Monthly sampling of streams and quarterly sampling of monitoring wells
Subtotal O & M Costs				$35,500	
Contingencies (50%)				$17,750	
Net Present Value of O& M Costs				$818,583	Assumes 5% discount rate for 30 years

Alternative GW-2 Total Present Worth Costs **$12,228,000**

Crystal Mine Site Cost Estimate
Alternative GW-3 - Active Treatment of AMD

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$100,000	$100,000	
Road Improvements	10,600	LF	$50	$530,000	Two miles of road improvement from Bullion mine to Crystal mine
Extend Power	2	Miles	$40,000	$80,000	Extend power from Bullion mine site
Site Preparation and Grading	1,500	SY	$2	$3,000	75' x 150'
Adit Plug	1	EA	$50,000	$50,000	
Road Gravel	3,900	CY	$30	$117,000	10,600' long by 20' wide by 6" deep
Erosion Control Seeding	1	Acres	$2,000	$2,000	
Reinforced Concrete (slab)	420	CY	$455	$191,100	75' x 150' x 12" thick
6" HDPE Pipe	110	LF	$20	$2,200	From adit to treatment plant
Pipe Intake Grating and Valves	1	LS	$2,500	$2,500	
PVC 6" Solid Pipe	200	LF	$15	$3,000	200 ft discharge pipe to Uncle Sam Creek
Treatment Plant Structure	1	LS	$1,000,000	$1,000,000	Construction of 45 GPM HDS treatment plant
Surface Water Control		LS		$101,000	Runon - Runoff Control
StreamBank Reconstruction		LS		$639,000	Reconstruction of 1,000 ft of USG Creek
Removal/Disposal of Ponds and Structures		LS		$259,000	2 ponds and mine structures
Subtotal Capital Costs				$3,079,800	
Contingencies (35%)				$1,077,930	
Engineering and SDC (15%)				$623,660	
Subtotal Capital Costs				$4,781,000	

Operations and Maintenance

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Labor (Operators)	1,230	HR/YR	$50	$61,500	Assume 1/2 time operation, plus 120 hrs misc O&M/yr
Chemicals (lime)	15	TONS/YR	$120	$1,800	Assume lime supply from limestone quarry near Helena, MT
Power Costs	91,000	KwH/YR	$0.09	$8,190	
Miscellaneous Equipment and Supplies	1	LS/YR	$9,000	$9,000	
Equipment Replacement Fund	1	LS/YR	$20,000	$20,000	Replace elect and mechanical equip every 15 years
Sludge disposal	1,000	CY/YR	$10	$10,000	Dewatered, hauled 10 miles one way to Luttrell Repository
Monitoring	1	LS/YR	$28,000	$28,000	Monthly sampling of streams and weekly sampling of processes
Subtotal O & M Costs				$138,490	
Contingencies (35%)				$48,472	
Net Present Value of O& M Costs				$2,874,057	Assumes 5% discount rate for 30 years

Alternative GW-3 Total Present Worth Costs **$7,655,000**

Crystal Mine Site Cost Estimate

Alternative GW-4 - Semi-Active Treatment of AMD (Quicklime Injection System)

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$100,000	$100,000	
Road Improvements	11,600	LF	$50	$580,000	Two miles of road improvement from Bullion mine to Crystal mine plus access roads around ponds/cells
Excavation	950	CY	$10	$9,500	
Backfill	950	CY	$10	$9,500	
Conveyance Ditches	50	CY	$50	$2,500	320 ft long, 2 ft wide, 2 ft deep
Adit Plug	1	EA	$50,000	$50,000	
Road Gravel	4,100	CY	$30	$123,000	Access road plus road around settling ponds
Liner Protection Gravel	460	CY	$30	$13,800	12" on top of liner and 6" below liner
Rip Rap	30	CY	$40	$1,200	
Erosion Control Seeding	2	Acres	$2,000	$4,000	
Reinforced Concrete (slab)	10	CY	$455	$4,550	16 ft x 16 ft by 12 in thick
6" HDPE Pipe	110	LF	$20	$2,200	
Pipe Intake Grating and Valves	1	LS	$2,500	$2,500	
PVC 6" Solid Pipe	450	LF	$15	$6,750	
HDPE Liner	11,100	SF	$1	$11,100	4400 sq ft for pond 1 & 2, 2373 for pond 3
PVC Liner	1,280	SF	$0.75	$960	320' x 4' wide for "V" ditch
Treatment Plant Structure	1	LS	$200,000	$200,000	Estimate from Aquafix
Outlet Structure	3	LS	$5,000	$15,000	
Surface Water Control		LS		$101,000	Runon - Runoff Control
StreamBank Reconstruction		LS		$639,000	Reconstruction of 1,000 ft of USG Creek
Removal/Disposal of Ponds and Structures		LS		$259,000	2 ponds and mine structures
Subtotal Capital Costs				$2,135,560	
Contingencies (35%)				$747,446	
Engineering and SDC (15%)				$432,451	
Subtotal Capital Costs				$3,315,000	

Operations and Maintenance

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Labor (Operators)	400	HR/YR	$50	$20,000	Assume 6 hrs/wk, plus 88 hrs/yr for misc O&M
Chemicals	15	TONS/YR	$120	$1,800	Assume lime supply from limestone quarry near Helena, MT
Miscellaneous Equipment and Supplies	1	LS/YR	$4,500	$4,500	
Equipment Replacement Fund	1	LS/YR	$6,700	$6,700	Replace lime feed equipment every 15 years
Sludge disposal	2,000	CY/YR	$10	$20,000	Based on operating experience from Aquafix pilot study
Monitoring	1	LS/YR	$28,000	$28,000	Monthly sampling of streams and weekly sampling of processes
Subtotal O & M Costs				$81,000	
Contingencies (35%)				$28,350	
Net Present Value of O& M Costs				$1,680,978	Assumes 5% discount rate for 30 years

Alternative GW-4 Total Present Worth Costs **$4,996,000**

Crystal Mine Site Cost Estimate

Alternative 5 - Semi-Passive Treatment (Sulfate Reducing Bioreactor)

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$50,000	$50,000	
Road Improvements	11,600	LF	$50	$580,000	Two miles of road improvement from Bullion mine to Crystal mine plus access roads around ponds/cells
Excavation	4,426	CY	$10	$44,260	
Backfill	4,426	CY	$10	$44,260	
Adit Plug	1	LS	$50,000	$50,000	
Liner Protection Gravel	550	CY	$30	$16,500	12" on top of liner and 6" below liner
Drain Rock	380	CY	$40	$15,200	
Road Gravel	4,100	CY	$30	$123,000	Two miles of road improvement from Bullion mine to Crystal mine plus access roads around ponds/cells
Limestone Gravel	320	CY	$80	$25,600	Assume supply from limestone quarry near Helena, MT
Limestone Sand	120	CY	$80	$9,600	Assume supply from limestone quarry near Helena, MT
Compost	3,560	CY	$20	$71,200	
Erosion Control Seeding	2	Acres	$2,000	$4,000	
6" HDPE Pipe	110	LF	$20	$2,200	
Pipe Intake Grating and Valves	1	LS	$2,500	$2,500	
PVC 6" Solid Pipe	670	LF	$15	$10,050	
PVC 6" Perforated Pipe	690	LF	$15	$10,350	
HDPE Liner	14,781	SF	$1	$7,391	For polishing pond
PVC Liner	56,000	SF	$0.75	$42,000	Wrap individual SRBR cells in PVC liner
Geotextile Fabric	7,296	SF	$0.30	$2,189	
Outlet Structure	1	EA	$5,000	$5,000	
Weir Box	3	EA	$3,000	$9,000	
Surface Water Control		LS		$101,000	Runon - Runoff Control
StreamBank Reconstruction		LS		$639,000	Reconstruction of 1,000 ft of USG Creek
Removal/Disposal of Ponds and Structures		LS		$259,000	2 ponds and mine structures
Subtotal Capital Costs				$2,123,299	
Contingencies (35%)				$743,155	
Engineering and SDC (15%)				$429,968	
Subtotal Capital Costs				$3,296,000	

Operations and Maintenance

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Labor (Operators)	100	HR/YR	$50	$5,000	Assume 6 hrs/mo plus 28 hrs/yr for misc O&M
Rototilling of pH Adjustment Cell	1	LS/YR	$250	$250	Assume $500 every two years
Periodic Replacement of pH Adjustment Cell	1	LS/YR	$5,500	$5,500	Assume $33,000 to replace media every 6 yrs
Periodic Replacement of SRBR Beds	1	LS/YR	$13,000	$13,000	Assume $200,000 to reconstruct SRBR cells every 15 yrs
Miscellaneous Equipment and Supplies	1	LS/YR	$4,500	$4,500	
Sludge disposal	350	CY/YR	$10	$3,500	Disposal of pH adjustment (1/6 per year) and SRBR (1/15 per year) media at Luttrell Repository
Monitoring	1	LS/YR		$19,000	Monthly sampling of streams and processes
Subtotal O & M Costs				$50,750	
Contingencies (35%)				$17,763	
Net Present Value of O& M Costs				$1,053,205	Assumes 5% discount rate for 30 years

Alternative GW-5 Total Present Worth Costs **$4,349,000**

Crystal Mine Site Cost Estimate
Alternative GW-6 - Passive Treatment

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$60,000.00	**$60,000**	
Road Improvements	2,600	LF	$27.86	**$72,436**	1/2 mile improvements around mine and ponds
BCR Ponds	2	EA		**$435,346**	
Excavation	12,448	CY	$11.08	$137,924	Common, no rock ex
Liner	32,000	FT^2	$0.97	$31,040	40 mil HDPE
Sand Layer	331	CY	$21.09	$6,981	Single 6" lift, light compaction
Limestone Layer	2,432	CY	$62.69	$152,462	2 18" lifts, light compaction
Reactive Layer	2,764	CY	$38.69	$106,939	2 18" lifts, light compaction
Oxidation/Settling Ponds	2	EA		**$9,575**	
Excavation	584	CY	$11.08	$6,471	Common, no rock ex
Liner	3,200	FT^2	$0.97	$3,104	40 mil HDPE
Aeration Channels	2	EA		**$2,159**	
Excavation	67	CY	$8.38	$561	
Rip Rap	30	CY	$53.24	$1,597	12" +/-
Piping & Valves				**$22,764**	
6" solid HDPE	1,000	FT	$12.56	$12,560	
6" Gate Valves	7	EA	$1,457.68	$10,204	
Wetlands				**$30,760**	
Excavation	3,080	CY	$8.38	$25,810	
Reveg	0.33	Acres	$15,000.00	$4,950	From ESG, 1 gallon plants, 20' spacing, no land costs
Common Elements				**$999,000**	
Surface Water Control		LS		$101,000	Runon - Runoff Control
StreamBank Reconstruction		LS		$639,000	Reconstruction of 1,000 ft of USG Creek
Removal/Disposal of Ponds and Structures		LS		$259,000	2 ponds and mine structures
Subtotal Capital Costs				$1,632,039	
Contingencies (50%)				$816,020	Contingencies at 50% due to site uncertainties
Engineering and SDC (15%)				$122,403	
Subtotal Capital Costs				$2,570,000	

Operations and Maintenance

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Labor (Operators)	100	HR/YR	$50	$5,000	Assume 6 hrs/mo plus 28 hrs/yr for misc O&M
Rototilling of pH Adjustment Cell	1	LS/YR	$250	$250	Assume $500 every two years
Periodic Replacement of pH Adjustment Cell	1	LS/YR	$5,500	$5,500	Assume $33,000 to replace media every 6 yrs
Periodic Replacement of SRBR Beds	1	LS/YR	$13,000	$13,000	Assume $200,000 to reconstruct SRBR cells every 15 yrs
Miscellaneous Equipment and Supplies	1	LS/YR	$4,500	$4,500	
Sludge disposal	350	CY/YR	$10	$3,500	Disposal of pH adjustment (1/6 per year) and SRBR (1/15 per year) media at Luttrell Repository
Monitoring	1	LS/YR		$19,000	Monthly sampling of streams and processes
Subtotal O & M Costs				$50,750	
Contingencies (50%)				$25,375	
Net Present Value of O& M Costs				$1,170,228	Assumes 5% discount rate for 30 years

Alternative WR-1 Total Present Worth Costs **$3,740,000**

Crystal Mine Site Cost Estimate
Common Element - Surface Water BMPs

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$50,000	**$50,000**	
BMPs				**$8,358**	
Select Grading	4,500	SY	$1	$3,825	
Drainage Swales	100	CY	$5	$533	
Wattles and Bales	1,000	LF	$4	$4,000	
Subtotal Direct Costs				**$58,358**	
Overheads/Profit/Ins/Bonds			20%	**$11,672**	
Subtotal Capital Costs				$70,030	
Contingencies (25%)				$17,507	Contingencies at 50% due to site uncertainties
Engineering and SDC (15%)				$13,131	
Subtotal Capital Costs				$101,000	

Surface Water BMPs - Total Cost **$101,000**

Crystal Mine Site Cost Estimate
Common Element - Pond and Structure Removal

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$50,000	**$50,000**	
Pond Removal				**$65,250**	
Sediment Removal	550	CY	$5	$2,750	2' deep in each pond
Liner Removal	7,000	SF	$1	$7,000	
Disposal	550	CY	$10	$5,500	At Luttrell
Water Treatment	50,000	GAL	$1	$50,000	Dispose at Luttrell
Structure Demolition	1	LS	$10,000	**$10,000**	Demo, pile, and burn on site.
				$0	
Overheads/Profit/Ins/Bonds			20%	**$25,050**	
				$0	
				$0	
				$0	
Subtotal Capital Costs				$150,300	
Contingencies (50%)				$75,150	Contingencies at 50% due to site uncertainties
Engineering and SDC (15%)				$33,818	
Total Capital Costs				$259,000	

Wetlands Diversion - Total Cost **$259,000**

Crystal Mine Site Cost Estimate
Common Element - Streambank Reconstruction

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Mobilization and Demobilization	1	LS	$50,000	$50,000	
Excavate	11,000	CY	$5	$60,170	Waste rock and soil
Hauling	11,000	CY	$15	$165,000	5 miles one way
Common Fill	3,500	CY	$11	$37,065	Dozer spread
Hauling	3,500	CY	$15	$53,830	Assume 5 miles one way
Restoration/Seeding	2	Acres	$2,000	$4,600	Seed repository cap and Crystal Dump
Subtotal Capital Costs				$370,665	
Contingencies (50%)				$185,333	Contingencies at 50% due to site uncertainties
Engineering and SDC (15%)				$83,400	
Total Capital Costs				$639,000	

Stream Reconstruction - Total Cost **$639,000**

Crystal Mine Site Cost Estimate
Alternative 1 - No Action

Capital Costs

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Subtotal Capital Costs				$0	
Contingencies (50%)				$0	
Engineering and SDC (15%)				$0	
Subtotal Capital Costs				$0	

Operations and Maintenance

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Monitoring	1	LS/YR	$10,000	$10,000	Monthly sampling of streams and quarterly sampling of monitoring wells
Subtotal O & M Costs				$10,000	
Contingencies (50%)				$5,000	
Net Present Value of O& M Costs				$230,587	Assumes 5% discount rate for 30 years

Alternative 1 Total Present Worth Costs **$231,000**

Appendix D
Crystal Mine—Adit Discharge Design Flow Rate Memorandum

Design Flow Rates for Bullion and Crystal Mine Sites

PREPARED FOR: John Lincoln (BOI)
B.T. Thomas (ATL)
Gary Hickman (CVO)

PREPARED BY: CH2M HILL

DATE: February 17, 2009

The purpose of this memo is to explain the methods used to develop annual hydrographs for the mine adit discharges associated with the Bullion and Crystal Mines located in the Basin Watershed OU2, Basin, Montana. Understanding the annual variation in flow rates was essential to the development of treatment alternatives discussed in the Basin Watershed OU2 engineering evaluation and cost assessment (EE/CA).

Through an agreement with Region 8 EPA, the U.S. Geological Survey (USGS) has periodically monitored adit discharge (flow and chemical constituents) at the Bullion and Crystal mines since 1999. This information served as the basis for developing annual hydrographs. Discharge rates were plotted on a per-month basis for each mine site to create hydrographs showing annual tendencies as well as average and peak flows (Figures 1 and 2).

- Average discharge from the Bullion mine site was calculated to be approximately 0.01 CFS (4.5 GPM), with a peak flow of about 0.016 CFS (7.18 GPM) occurring during the month of July.
- Average discharge from the Crystal mine site was calculated to be approximately 0.05 CFS (22.4 GPM) with a peak flow of about 0.082 CFS (36.8 GPM) occurring during the month of July.

Annual discharge (Q) data collected by the USGS from 1929 through 2008 of the Boulder River near the town of Boulder, Montana, was reviewed and used as representative data to determine peak flow years (Figure 3). Over the past 79 years of record, it was determined that historic peak flows for the Boulder River result in approximately twice the annual flow when compared to average years. Based on this historic data, it was determined that a multiplier of two should be applied to the average adit discharge value to estimate peak discharge for high flow years for the Bullion and Crystal mines (Equation 1 and 2).

Bullion: $Q_{Peak} = Q_{Avg}$ (4.5 gpm) x Peak Flow Multiplier (2) = 9.0 gpm…….EQ-1

Crystal: $Q_{Peak} = Q_{Avg}$ (22.4 gpm) x Peak Flow Multiplier (2) = 44.8 gpm…...EQ-2

Application of the peak flow estimates plus associated shallow groundwater is illustrated by an independent sampling project performed by Montana State University at the Bullion Mine site. In the fall of 2004, Montana State University (MSU) measured the flow from the upper adit of the Bullion mine during a week of heavy precipitation. Discharge from this adit plus groundwater interflow into the drainage channel between the upper adit and lower adit, as well as along Jill Creek between the Bullion mine adit discharge ditch and the confluence of Jack Creek were measured. Discharge at these locations were recorded as 13.5 gpm and 15.1 gpm, respectively (Table 1).

Table 1 Montana State University – Capstone Research Project – Bullion Mine, Basin MT Fall 2004 Measurement of total flow.

Measurement Location	Total Flow (gpm)
Upper Adit	10.0
Groundwater, Upper to Middle Adit	1.6
Groundwater, Middle to Lower Adit	1.9
Subtotal	**13.5**
Jill Creek (Bullion Discharge to Jack Creek)	15.1
Total	**28.6**

Equation 3 shows the total flow rate of adit discharge and groundwater interflow that requires capture and treatment at this site.

Bullion: Q_{Tot} = 10.0 gpm + 3.4 gpm + 15.1 gpm = 28.5 gpm………..EQ-3

Our previous calculations showed the need to size our treatment system by a factor of 2X to account for wet years. The adit discharge during MSU's fall 2004 sampling was measured at 10.0 gpm which is 2.2 times the average flow (4.5 GPM) measured by the U.S. Geological Survey.

Recommendation:

Based on the measured flow during the MSU fall 2004 (Equation 3), all treatment systems for the Bullion mine are to be designed to treat up to 30 gpm.

Based on the peak flow estimate (Equation 2), all treatment systems for the Crystal mine are to be designed to treat up to 45 gpm.

Figure 1: Bullion Mine Discharge Rate

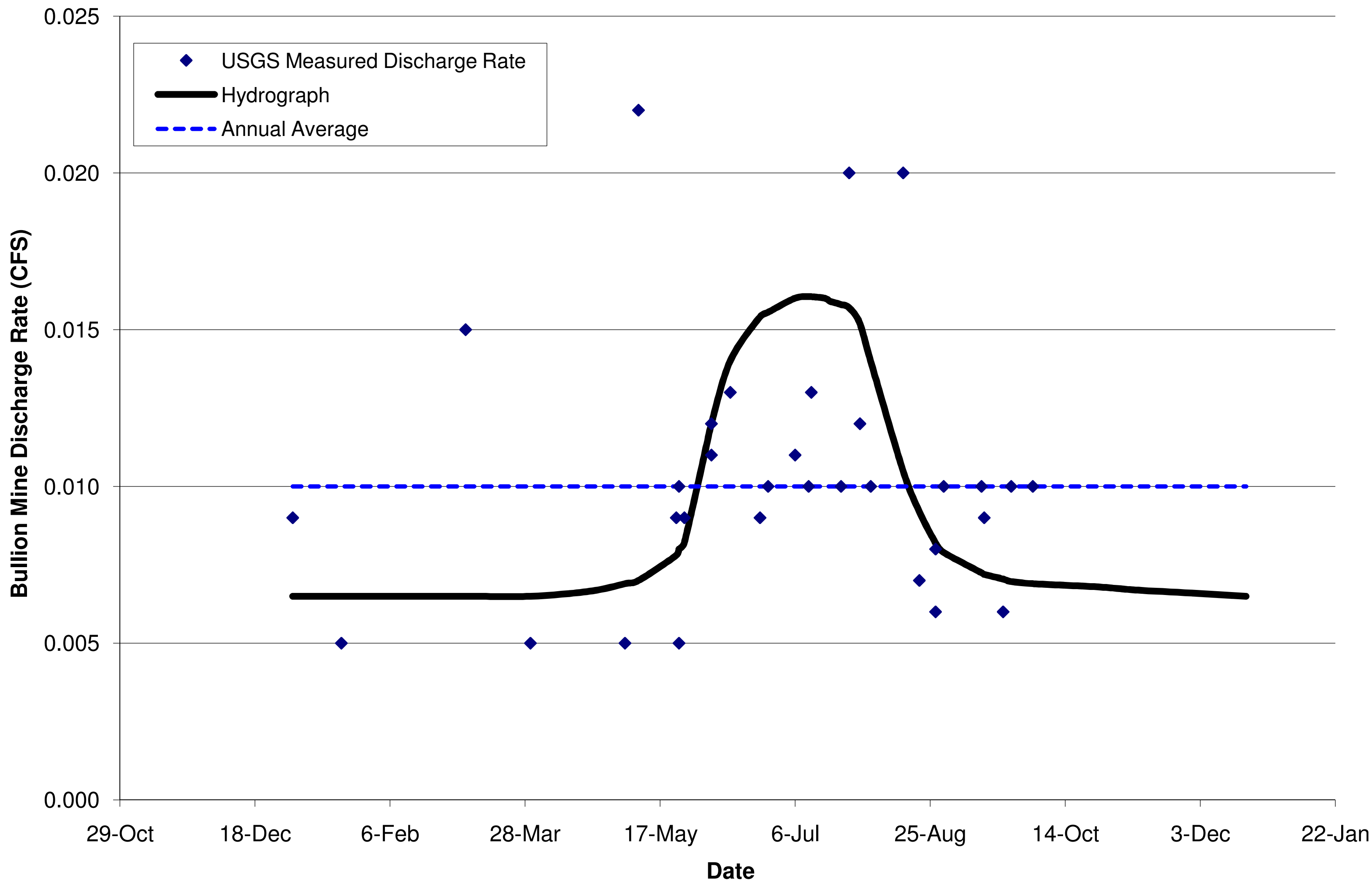

Figure 2: Crystal Mine Adit Discharge