# Crystal Mine Operable Unit 05

of the Basin Mining Area Superfund Site

Jefferson County, Montana

# Final Interim Record of Decision



### **U.S. Environmental Protection Agency Region 8**

10 West 15th Street Suite 3200 Helena, Montana 59626

April 2015

# Final Interim Record of Decision

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Appendix A, ARARs Requirements and Waivers

April 2015



U.S. ENVIRONMENTAL PROTECTION AGENCY REGION 8, MONTANA OFFICE

### Part 1 Declaration

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#### Part 1 Declaration

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### **Site Name and Location**

### Site Name and Location

Basin Mining Area Superfund Site Jefferson County, Montana CERCLIS ID: MTD982572562 Site ID No: 0801057 Crystal Mine Site Operable Unit 5

# **Statement of Basis and Purpose**

This decision document presents the selected remedial action for the Crystal Mine Operable Unit (OU) 5 Superfund Site (Site) in Jefferson County, Montana. The remedy was selected in accordance with the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), 42 USC §9601 et seq., as amended, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR Part 300, as amended. This decision was based on the administrative record established in accordance with section 113(d) of CERCLA and is available for review at the Boulder Library in Boulder, Montana and at the U.S. Environmental Protection Agency (EPA) Region 8 records center in Helena, Montana.

The Montana Department of Environmental Quality (MDEQ) and U.S. Forest Service, Region One (USFS), both supporting agencies, concur with the selected interim remedy.

# **Assessment of Site**

Hazardous substances in the form of metal contaminants are being released into the environment by the Crystal Mine, and they pose a risk to human health and the environment. The response actions described in this interim Record of Decision (ROD) are necessary to protect public health or welfare or the environment from actual or threatened releases of hazardous substances.

### **Description of Selected Remedy**

This interim ROD describes the selected remedy for the Crystal Mine OU5, located within the Basin Mining Area Superfund Site, Jefferson County, Montana. This remedy complements previous removal actions by remediating acid mine drainage (AMD) and soil contamination to finish Site cleanup. The Basin Watershed OU2 ROD will make the final determination regarding the need and extent of any additional actions at OU5.

The AMD from the lower adit comprises a principal threat waste at the Site. Contaminated waste rock and soil deposited by mining activities are considered a non-principal threat waste. A brief description of the selected remedy (a combination of alternatives WR-3 and GW-6 from the proposed plan) is as follows:

#### Source Control:

• Implement source water control by constructing runoff conveyance features and by sealing latent mine structures that allow water into underground workings (for example, exposed/caved shafts).

#### Treatment (Water and Soil):

- Design and construct an onsite repository to hold and encapsulate contaminated waste rock and soils from the Site. Excavate and haul waste rock and contaminated soils to repository.
- Grade and stabilize excavated dump and waste rock areas, cover with clean soil and vegetate.
- Design and reconstruct Uncle Sam Gulch (USG) Creek adjacent to the mine boundary, stabilize banks and vegetate.
- Open and stabilize lower adit portal. Portal opening will be secured to prevent unauthorized human entry, if warranted, and accommodate appropriate wildlife access (for example, bats), if recommended by the Montana Fish, Wildlife and Parks (MDFWP) or the U.S. Fish and Wildlife Service (USFWS).
- Design and construct passive treatment system.
- Collect mine adit flow using a diversion structure and piping. Convey the collected water to the semipassive treatment system.

The five stages of the semi-passive treatment system (SPTS) are as follows (see the *Crystal Mine Feasibility Study* for more detail):

**Stage 1 - Sulfate Reducing Biochemical Reactor (SRBR)**. The SRBR will adjust pH and convert sulfate and trace metals in the water into metal sulfides that remain with the media.

**Stage 2 - Aeration System.** Two short series of cascades (riprapped channels) will run from the last SRBR into the first aeration pond, and from the first pond into the second, to promote turbulence and aeration.

**Stage 3 - Oxidation/Settling Ponds.** The precipitation/settling ponds (two in series) will facilitate the precipitation and settling of iron oxide sludges from the SRBR cells and aeration channels.

**Stage 4 - Wetland.** The wetland pond will allow for suspended solid polishing. It is assumed that discharge from the adit will be naturally reduced during the winter months.

**Stage 5 - Discharge Channel.** An overflow and discharge channel (riprapped) will convey the treated mine water from the distal end of the wetlands to USG Creek. This comprises the final stage of the SPTS.

#### **Operation and Maintenance:**

Periodic replacement of the SRBR media will be required. Sludge that settles in the deep end of the oxidation ponds will also require removal, drying and disposal at the Luttrell Repository.

#### Institutional Controls:

- Institutional controls (ICs) to prohibit residential use, prevent installation of drinking water wells and to
  protect the remedy will be required throughout the Site. ICs include administrative land management
  methods necessary to maintain the effectiveness of the remedy and protect human health by
  preventing exposure to contaminated soil and ground water that creates an unacceptable risk to human
  health. ICs will be tailored to the size, location and complexity of the area.
- The EPA and MDEQ will work with adjacent landowner agencies (primarily USFS) on the specific application of this remedy including protective ICs.

#### Long-term Monitoring and Maintenance:

Long-term monitoring and maintenance activities will be needed to assure the remedy remains effective. An Operation, Monitoring and Maintenance (OMM) Plan will be developed as part of the remedy and will contain the following:

- Construction and post-construction monitoring of adit discharge and USG Creek water quality.
- Water quality monitoring and maintenance of the SPTS, including biochemical reactor media replacement, sludge removal from the settling ponds and long-term monitoring.
- Periodic inspection/maintenance of the repository, soil and vegetative cover and erosion controls.
- Monitoring and maintenance of ICs.

# **Statutory Determinations**

The selected remedy is protective of human health and the environment, complies with federal and state requirements that are applicable or relevant and appropriate to the remedial action unless justified by a waiver, is cost effective, and utilizes permanent solutions and alternative technologies to the maximum extent practicable.

This remedy also satisfies the statutory preference for treatment as a principal element of the remedy (for example, reduces the toxicity, mobility or volume of hazardous substances, pollutants or contaminants through treatment).

Because this remedy will result in hazardous substances remaining onsite above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within 5 years after initiation of the remedial action, and at a minimum every 5 years thereafter, to ensure that the remedy is, or will be, protective of human health and the environment.

### **ROD Data Certification Checklist**

The following information is included in the decision summary section of this interim ROD. Additional information can be found in the administrative record file for this Site.

- 1. Contaminants of concern and their respective concentrations (Section 5).
- 2. Baseline risks represented by the contaminants of concern (Section 7).
- 3. Cleanup levels established for contaminants of concern and the basis for these levels (Section 7).
- 4. Discussion of principal threat wastes (Section 11).
- 5. Current and reasonably anticipated future land use assumptions used in the baseline risk assessment (Section 6).
- 6. Potential land use and ground water use that will be available as a result of the selected remedy (Section 12).
- 7. Estimated capital, annual operation and maintenance (O&M), and total present worth costs, discount rate, and the number of years over which the remedy cost estimates are projected (Section 12).
- 8. Key factors that led to selecting the remedy (Sections 10, 11 and 12).

This interim ROD documents the selected remedy for the Basin Mining Area Superfund Site, Crystal Mine Operable Unit 5, Jefferson County, Montana. The following authorized officials from their respective Agencies approve the selected remedy as described in this ROD.

Martin Hestmark Assistant Regional Administrator Office of Ecosystems Protection and Remediation

Date: \_\_\_\_\_

Tom Livers Director Montana Department of Environmental Quality

Date: \_\_\_\_\_

David E. Schmid Regional Forester (Acting) United States Forest Service, Region One

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Martin Hestmark Assistant Regional Administrator Office of Ecosystems Protection and Remediation

Date: 4/24/15

Tom Livers Director Montana Department of Environmental Quality

Date: \_\_\_\_\_

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Martin Hestmark Assistant Regional Administrator Office of Ecosystems Protection and Remediation

Date:

Tom livers

Tom Livers Director Montana Department of Environmental Quality

Date: 4/20/15

David E. Schmid Regional Forester (Acting) United States Forest Service, Region One

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Martin Hestmark Assistant Regional Administrator Office of Ecosystems Protection and Remediation

Date: \_\_\_\_\_

Tom Livers Director Montana Department of Environmental Quality

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David E. Schmid Regional Forester (Acting) United States Forest Service, Region One

Date: \_ 4/17/15-

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A ARARs Requirements and Waiver

## Section 1. Site Name, Location, and Description

Basin Mining Area Superfund Site Crystal Mine Site OU5 Jefferson County, Montana				
Site ID Number:	0801057			
CERCLIS ID:	MTD982572562			
Lead Agency:	U.S. Environmental Protection Agency (EPA)			
Support Agency:	Montana Department of Environmental Quality (MDEQ)			
Cleanup Funding:	The EPA Superfund Trust Fund			
Site Type:	Abandoned Mine (Historic hard rock mine)			

Mining-waste related contamination in the Basin watershed and in the Town of Basin resulted in the listing of the Basin Mining Area on the National Priorities List (NPL) on October 22, 1999. The west-central Montana mining area includes the watersheds of Basin and Cataract Creek and portions of the Boulder River below the confluence with these heavily impacted streams (see Exhibits 1-1 and 1-2).



Location of Basin Mining District in West Central Montana





The Basin Mining Area NPL site is divided into the following relevant Operable Units (OUs): the Town of Basin OU1, Basin Watershed OU2, Luttrell Repository OU3, Buckeye/Enterprise Mine OU4, Crystal Mine OU5, and Bullion Mine OU6.

Approximately 300 abandoned hard rock mines exist within the Basin Watershed OU2, according to a remedial investigation (RI) conducted by CDM Federal Programs Corporation (CDM) for the EPA (CDM, 2005b). Findings from the Basin Watershed OU2 RI identified the Bullion OU6 and Crystal OU5 Mines, with their associated AMD, as the largest contributors of mine-related contamination into the surface water system (see Exhibit 1-3).

The Crystal Mine is located at the head of Uncle Sam Gulch (T7N, R5W, Sections 18,19, 20) within the Cataract Creek Drainage, about 8 miles north of the Town of Basin. The Site is located adjacent to Uncle Sam Gulch (USG) Creek, a small tributary to Cataract Creek. The watershed landforms consist of predominantly steep slopes and narrow valleys. Access throughout the watershed is limited to existing, unpaved, secondary roads maintained by the USFS. The roads are snow covered and typically impassible from late fall to early summer (NRCS, 2009).

The mine resides on mining claims encompassing approximately 40 acres, 22 of which are disturbed from mining activities. The Site is located between 7640 feet (ft) above mean sea level (amsl) and 8100 ft amsl, and is surrounded by the Beaverhead-Deerlodge National Forest.

The surface expression of the Crystal Mine is superimposed on an east-west trending subbasin drainage divide (at 8100 feet amsl). The east end of this subbasin intercepts an incised subdrainage (USG) which is oriented north-south and drains to the south (see Exhibit 1-4). USG Creek originates northeast of the Site from a series of alpine bogs and wet meadows. The creek flows north to south where it erodes and undercuts waste rock piles while forming the eastern edge of the Site. The stream reach parallel to the Site is slightly gaining in volume, relatively straight and approximately 1,100 feet long. The gradient along this reach is approximately 22 percent, or a vertical foot of elevation for every 4.6 linear feet of stream channel.

The principal vein minerals at the Site are crystalline quartz and fine-grained pyrite, which contained gold, silver, copper, lead and zinc. Pyrite (iron sulfide), sphalerite (zinc sulfide), and galena (lead sulfide) are the most abundant ore minerals in the mine. Gold is associated with pyrite, arsenopyrite and copper minerals. Silver is associated with tetrahedrite and galena.

The Site is now a significant source of AMD that is impacting water quality in USG Creek and Cataract Creek. Elevated concentrations of arsenic and trace metals (particularly antimony, aluminum, cadmium, copper, lead, selenium and zinc) are present in Site soils, mine discharge, and downstream surface water and sediment. The principal source of AMD is discharge from the lower Crystal adit and several springs within the mine area, which contribute to the total metal load in USG Creek downstream of Crystal Mine. USG Creek flows into Cataract Creek approximately 2 miles downstream of its confluence with the Crystal Mine discharge.







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### 2.1 Site Background and History

The development of the Crystal Mine dates back to 1883. Mining activities were conducted by several different companies from 1885 to 1901. The Crystal Mine was reportedly idle from 1926 until 1936 and then operated by different companies throughout the 1940s and 1950s. The Bullock brothers operated the Crystal Mine on a small scale between 1969 and 1984. In 1983, the Bullock Brothers Construction Company sold and shipped about 350 tons of ore to the ASARCO Smelter at East Helena, Montana. This was the last ore shipment for the Crystal Mine.

Relevant historic activities and Site investigations are explained in more detail in Section 1.5 of the 2013 Crystal Mine OU5 RI (EPA).

(1897) Claim Surveyed. The Crystal claim was located in 1883 by unnamed parties.

(1891 to 1974) Mining Begin/Finish. The mine was initially worked intermittently through the 1890s. A small tunnel was opened and ore shipped by Kennedy and Reed of Butte in 1900 (RTI, 2011). Mining on the Site was terminated in the mid-1980s with excavation of the Crystal Mine surface trench.

#### (1994 to 2008) Site Investigations

*March 1994. Abandoned Hardrock Mine Priority Sites – Summary Report (Red Book).* Identified and inventoried abandoned and inactive hard rock mine sites in Montana (state and federal lands) that exhibited severe environmental degradation to surface water and ground water. The Site ranked 20 out of 263, or in the top 10 percent.

April 1994. Abandoned-Inactive Mines Program Deerlodge National Forest, Cataract Creek Drainage. Volume II. Prepared by Montana Bureau of Mines and Geology (MBMG). Contains a preliminary characterization of abandoned and inactive mines on Deerlodge National Forest Lands. The results of the sampling and analysis were used to estimate the nature and extent of contaminants as well as potential threat to human health and environment.

1998. Final Report—Remote Mine Site Demonstration Project, Mine Waste Technology Program Activity III, Project I. In 1994, MSE Technology Applications, Inc. (MSE) initiated a treatment study on the discharge from the Crystal Mine lower adit.

2004. Integrated Investigations of Environmental Effects of Historical Mining in the Basin and Boulder Mining Districts, Boulder River Watershed, Jefferson County, Montana. In 1996 the U.S. Geological Survey (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 (see Exhibit 2-1).

2005. Remedial Investigation Report Addendum, Basin Mining Area Superfund Site, Operable Unit 2, Jefferson County, Montana. In 2001, the EPA authorized a remedial investigation/feasibility study (RI/FS) of the Basin Watershed OU2 in which the Crystal Mine was included. 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, USG Creek. The results exceeded both ecological and human health benchmarks for arsenic, cadmium, copper, lead and zinc (CDM, 2005b).

### 2.2 Regulatory Activities

Regulatory and government interest in the site began in the 1990s. The following is a list of relevant regulatory activities that have occurred at the Site.

**1998-99. Preliminary Assessment/Site Investigation**. EPA conducted a preliminary assessment (PA) and site investigation (SI) of the Basin Mining Area in 1998 and 1999. The Crystal Mine OU5 and Bullion Mine OU6 were included in the PA/SI. Elevated concentrations of arsenic, copper, lead and zinc were detected in soils, mine wastes and surface water.

**1999.** National Priority Listing. The Crystal Mine was proposed for the Superfund NPL as part of the Basin Mining Area in October 1999.

**2000. Action Memorandum.** Formal designation of the Site as OU5 occurred on April 12, 2000.

2001 to 2002. Time Critical Removal Action for the Crystal "trench area." The objective of the time critical removal action (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 back-filling the trench with rock and capping it with an impervious liner to prevent surface water runoff from entering the underground workings through 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.

2010-2013. Remedial Investigation, Feasibility Study, Human Health and Ecological Risk Assessment. A focused RI/FS and risk assessment of the Site was initiated by the EPA in 2010. The RI/FS was completed in November 2013.

**2014. Proposed Plan.** The proposed plan for the Crystal Mine OU5 was distributed for public review in March 2014. A public meeting to explain the proposed remedial action, answer questions and accept comments was held on March 19, 2014.

EXHIBIT 2-1 Location of Boulder River Watershed and Study Area, Montana.



Adapted from USGS Professional Paper 1652 (2004)

**2014-2015. Time Critical Removal Action.** Two sediment ponds containing contaminated mine water and sludges are located below the lower adit. Accelerated erosion of support berms has resulted in the risk of pond failure and release of sludges onto USFS land below the ponds. To address this risk, the EPA removal program will drain water from the ponds to USG Creek. Consolidated sludge and liner material will be transported to the Luttrell Repository for disposal.

### 2.3 Enforcement History

Between 1999 and 2000, a potentially responsible party (PRP) search was conducted for the Crystal Mine that identified former operators, all now defunct mining companies, and past and current land owners. In 2000 and again in 2008 the EPA sent out information request letters to all owners and operators of mining claims contributing to contamination of the Crystal Mine. Based upon this investigation, the EPA was unable to identify any viable PRPs.

# Section 3. Community Participation

Community involvement in the cleanup of the Basin Mining Area began prior to the NPL listing of the site and has continued through several EPA response actions taken within the NPL site. This involved four different superfund activities, including the cleanup of the Town of Basin OU1 (2002-2004) with two 5-year reviews (2007, 2012), a TCRA by the EPA at the Crystal Mine (2001-2002), the RI/FS of the Basin Watershed OU2 (2001- 2005), and the current RI/FS and interim ROD process for the Crystal Mine OU5.

- 1) Cleanup of the Town of Basin Contaminated surface water from the Crystal Mine flows into Cataract Creek, a tributary to the Boulder River located approximately one-quarter mile east of the Town of Basin. The EPA prepared a detailed community involvement plan (CIP) for the Town of Basin in March 2000 describing activities for which public participation would be solicited. Activities were posted in local newspapers (Butte Standard, Boulder Monitor and Helena Independent Record) prior to their occurrence, and public opinion and comments were captured in a responsiveness summary to a ROD for the town in 2001 (CDM). From 2002 to 2004, cleanup of mining waste within the town commenced. This activity triggered heightened community interaction as remedial activities progressed from property to property. Public involvement continued as interviews of public officials and residents of Basin were conducted to evaluate the success of the Town of Basin cleanup during subsequent 5-year reviews (2007, 2012). A fact sheet discussing prudent use and contact with the surface water and soils from the watershed was prepared and distributed to town residents by the EPA and MDEQ in December 2012.
- 2) **TCRA at the Crystal Mine** As described in Section 2.2 of this interim ROD, an EPA initiative to line and backfill the Crystal Mine trench was implemented in 2002. Prior to this action, a notice was posted in local newspapers (Butte Standard, Boulder Monitor and Helena Independent Record) to inform the local community of increased traffic on Basin Creek Road and to solicit comments.
- 3) RI/FS of the Basin Watershed OU2 The EPA conducted the RI/FS for the Basin Watershed OU2 concurrent with cleanup of the Town of Basin. The Basin Watershed OU2 RI/FS included the Crystal Mine OU5. Public participation was solicited through a public notice describing where the final documents could be found for review. In June 2003, a final draft proposed plan was prepared by the EPA describing the preferred remedy for the Basin Watershed OU2. The EPA did not publicly release the draft proposed plan. Instead, EPA decided to conduct interim cleanups of the most detrimental sources of surface water contamination within the Basin Watershed OU2 (Bullion Mine and Crystal Mine).
- 4) Current RI/FS, Proposed Plan and ROD Process for the Crystal Mine OU5 RI/FS reports for the Crystal Mine were completed in November 2013 and distributed to local repositories in the towns of Boulder and Basin. A proposed plan describing the preferred cleanup for the Site was prepared and distributed to the local community on March 7, 2014. The official public comment period ran from March 19 to April 21, 2014. Copies of the proposed plan were distributed to the State of Montana and the USFS, property owners for the Crystal Mine, the Basin post office and community members who attended the public meeting. The proposed plan was also posted on the EPA website for the Basin Mining Area Superfund Site (under Crystal Mine OU5). A notice of availability of the proposed plan and a letter to the editor were published in the local newspapers (Butte Standard, Boulder Monitor and Helena Independent Record) at the beginning of the public meeting on March 19, 2014 at the Basin School to explain the preferred remedy and the ROD process to the community and solicit their comments. Comments verbalized at this meeting were generally supportive of the proposed clean-up plan. A transcript of the meeting was placed in the Administrative Record for the Site. No written comments were received during the public comment period.
# Section 4. Scope and Role of Operable Unit or Response Actions

As with many Superfund sites, the problems at the Basin Mining Area NPL Site (77 square miles) are complex. As a result, EPA has organized the work into the following 6 operable units, of which the Crystal Mine is OU5:

- **Operable Unit 1 The Town of Basin**. The Town of Basin is located at the mouth of the Basin Watershed OU2. Mine wastes within town represented the most immediate threat to human health. The ROD was completed on March 30, 2001, and remedial action was completed December 16, 2004.
- **Operable Unit 2 Basin Watershed**. The Basin watershed is the largest operable unit (77 square miles) and encompasses OUs 3, 4, 5 and 6. The RI/FS and a draft proposed plan were completed between 2002 and 2005. A final proposed plan and cleanup of the watershed will follow interim actions at OU5 and OU6. EPA has decided to conduct interim actions at OU5 and OU6 first because the acidic adit discharges from these OUs significantly degrades water quality within the Basin watershed. Upon completion of the interim remedies at these two mine sites, a ROD for the remainder of the watershed will be written.
- **Operable Unit 3 Luttrell Repository**. Luttrell is the regional repository located on the divide between Ten Mile Creek and the Basin watershed. Construction of this repository was initiated in 2000. The site currently accepts mining wastes associated with response actions performed by the USFS, the State of Montana and the EPA, Region 8.
- **Operable Unit 4 Buckeye/Enterprise Mines**. Contaminated soils and mining waste removal were completed at these sites in 2006.
- Operable Unit 5 Crystal Mine. A removal action to line and cover a surface mine trench was
  performed between 2001 and 2002. The purpose of the action was to prevent snow melt and
  precipitation from infiltrating and migrating into underground mine workings. Contaminated mine
  wastes and AMD from the lower adit remain unremediated. Another removal action will be performed
  in 2014 and 2015 to remove two sediment ponds containing contaminated mine water and sludge.
  Because of erosion of support berms, the ponds are in jeopardy of failing. Water will be discharged to
  USG Creek. Consolidated sludge and liner material will be transported to the Luttrell Repository for
  disposal.
- **Operable Unit 6 Bullion Mine.** In a joint removal action by the USFS and the EPA, contaminated mine and mill wastes were removed to the local repository at Luttrell. Another removal action will be performed in 2014 and 2015 to treat pooled mine water, discharge the treated water to Jill Creek and remove the contaminated adit debris plug materials to the Luttrell Repository.

As noted above, the EPA decided to prioritize remedial action at the two mine sites (Crystal OU5 and Bullion OU6) in the Basin Watershed OU2 that contribute the most to water quality degradation. Upon completion of the interim remedies at these two mine sites, a ROD for the Basin Watershed OU2 will be written. The interim action at the Crystal Mine will focus on reducing surface water infiltration into the mine workings and treating the mine-contaminated water discharging from the lower adit. In addition, waste rock will be excavated and deposited in an onsite repository, the Site will be graded for slope stabilization and vegetated, and USG Creek will be remediated to a stable configuration.

The anticipated sequence of cleanup activities for the Crystal Mine starts with design and construction of an onsite repository. Waste rock from dumps and contaminated soils will be excavated and deposited in the onsite repository and USG Creek will be remediated and stabilized. Contaminated wood, metal, and plastic debris will be transported to the Luttrell Repository. Next, the Site will be graded, stabilized and revegetated to discourage erosion. Source water control measures will be implemented by constructing surface runoff conveyance features and by sealing latent mine structures (such as open trenches or mine shafts) that allow water into underground workings. AMD from the mine will then be captured and treated through a semi-passive biochemical treatment process to mitigate the existing impact of AMD on USG Creek. Land and water use controls will be established. Prescribed monitoring of the reclamation and maintenance of the treatment system will begin, and the implementation of ICs will conclude the sequence of remedial actions.

Remediation of the mine discharge will improve water quality, reduce risks to human and ecological receptors, and contribute to meeting downstream total maximum daily load (TMDL) goals for Cataract Creek. This interim ROD will be consistent with the previous removal actions as well as the final remedy selected for the Basin Watershed OU2.

### 5.1 Conceptual Site Model

A conceptual site model (CSM) for the Site was prepared to help with identification of 1) potential sources of metals and arsenic; 2) probable pathways of movement of these contaminants from source material into soils, ground water and surface water; and 3) the potential assimilation into aquatic and terrestrial receptors. An accurate conceptual site model facilitates evaluation of potential risks to human health and the environment (EPA, 1989).

The Basin watershed is largely underlain by the Boulder batholith, a relatively small batholith, exposed at the surface as granite (more specifically quartz monzonite) and serving as the host rock for rich mineralized deposits. Regional uplift brought the deep-seated granite to the surface, where erosion exposed the granite and the extremely rich mineral veins. Hundreds of millions of dollars' worth of copper, silver, gold, zinc, lead and other metals have been mined from the batholith, using both underground and pit mining methods.

Snowmelt and precipitation infiltrates the shallow, unconsolidated glacial till and alluvial surface soils at the Site. Ground water flow generally follows surface topography and infiltrates downward through the shallow soils to the uppermost fractured and weathered zone of the Boulder batholith bedrock. This ground water then migrates primarily through fractures or faults in the bedrock, some of which are mineralized and host the ore deposits exploited by mining. The ground water at the Crystal Site flows into the underground mine workings. This water moves through the workings and discharges from the lower adit at an average rate of approximately 26 gallons per minute (gpm).

The model for the Site was developed from existing data (previous sampling and Basin Watershed OU2 RI) and information obtained from RI field activities performed from 2010 to 2012. Prominent Site features are presented in Exhibit 5-1.





Helena



- Mine Adit
- -> Surface Runoff Drainage Direction
- MineTrench
- Topographic Divide
- ----- Digitized\DEM Generated Streams



### Waste Dump

- Mammoth Road
- Mammoth Dump
- Twin Ore Bin Dump
- Crystal Dump
- Notes: 1. Area of interest subject to change. 2. 2011 Imagery ArcGIS Streaming Map Service. 3. 30 meter USGS DEM used to generate streams.



Exhibit 5-1 Crystal Mine Prominent Site Features

The surface of the Site includes an east-west trending linear, previously mined, trench feature located on a subbasin drainage divide. The trench was an 800- to 1,000-foot-long excavation that the EPA lined and backfilled during the 2002 TCRA. Other features at the Site include numerous waste rock piles, twin ore bins that held material mined from the upper adit, five historic out-buildings, a visible portal leading to the lower underground workings, remnants of an old trestle, several ore chutes and two lined ponds built over a waste rock dump. The slope below the east end of the trench is steep (greater than 25 percent) and covered with waste rock. Waters from USG erode and undercut waste rock piles while forming the eastern edge of the active mine site. Drainage from the lower adit is presently directed into the two lined settling ponds. Overflow from the ponds runs approximately 300 yards downslope across USFS land, and then discharges into USG Creek. During high flow, the adit discharge splits and flows to the ponds and directly to USG Creek from the portal (Exhibit 5-2). The ponds will be removed during a 2014-2015 TCRA in an effort to avoid failure of the pond liner and a release of the sludges they contain.

The majority of the Site is barren of top soil and vegetation due to mining impacts. Mineralized waste rock and decomposed granite constitute the soil surface. This material is easily eroded and highly mobile during rainfall and surface runoff events, as evidenced by numerous erosion rills. In the high elevations associated with the Site, ground water is present in small, unconsolidated glacial/alluvial deposits as well as in the fractured bedrock. Shallow ground water flow generally follows surface topography. Ground water is not developed for drinking at or near the Site. Surface water associated with the drainage basin and wetlands north of the trench area infiltrates the shallow soils, migrates through fractured bedrock and intercepts the lower underground mine workings. This water moves laterally through the workings, discharges from the lower adit at an average rate of approximately 26 gpm and intercepts USG Creek approximately 300 yards downstream from the onsite settling ponds. Ground water discharge from the adit is highest in the spring, responding to snowmelt and runoff. An illustration of the CSM is presented in Exhibit 5-3.



Old Settling Ponds on

Mammoth Dump

Ore Loading Trestle on

Mammoth Dump

Dying Trees from Acid Mine

Drainage

A1

**A**' Cross Section Locations See Figure 5-3)

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Crystal Mine Trench (Remediated)

Twin Ore Bins and Dump

Uncle Sam Gulch Creek (Note: Proximity to Waste Rock). Upstream is non-impacted

Crystal Dump (Note: Erosion Rills and lack of vegetation)

Lower Adit Portal with culvert installed for safety (Note: Acid Mine Drainage)

Waste Rock Dump Erosion into Uncle Sam Creek

Mine Support Structures on Mammoth Dump

> EXHIBIT 5-2 CRYSTAL MINE CONCEPTUAL SITE MODEL (PLAN VIEW) Crystal Mine OU5 ROD

> > - CH2MHILL



**CRYSTAL MINE SITE PLAN** TRENCH AND DUMP **CROSS-SECTION** Crystal Mine OU5 ROD

CH2MHILL

### 5.1.1 Potential Contamination Sources

Potential sources of contamination at the Site include waste rock, mineralized host rock, and mineralized soils that generate acid rock drainage (ARD). Water pooled and flowing within the Crystal Mine workings is converted into acid mine drainage (AMD), which discharges from the lower adit and into receiving streams.

### 5.1.2 Waste Rock and Acid Rock Drainage

Waste rock, host rock and mineralized overburden not removed from the Site for processing are distributed across the Site and represent one of the primary sources of arsenic and metals. The geologic zone of interest for mining consisted of vein minerals of crystalline quartz and fine-grained pyrite. Lenses of sulfide minerals occur within portions of the vein and contribute to the acid-generating potential of the waste rock. Pyrite (iron sulfide), sphalerite (zinc sulfide) and galena (lead sulfide) are the most abundant ore minerals in the mine. Gold, silver, copper, lead and zinc appear in the higher-grade veins. The depth of waste rock varies across the Site from less than 1 foot in the vicinity of the trench to 18-plus feet near the twin ore bins and the old settling ponds. Contaminant concentrations, depth and volumes of waste rock onsite are presented in later sections of this document.

### 5.1.3 Adit Discharge and Acid Mine Drainage

The lower adit portal leads to an 800-foot-long cross-cut tunnel through granite that leads to the mineralized zone where the underground mining occurred. While the mine was being worked, waste rock and ore were transported out of the lower workings of the mine through this adit. Since mine closure, several sections of timber in the adit have collapsed. Ground water has pooled behind these natural earth and rock plugs. Exposure of the mineralized rock to infiltrating ground water and bacteria in the mine workings has resulted in a constant discharge of acidic water from the adit portal (see Exhibit 5-4) and ultimately into USG Creek. This represents a substantial and continuing source of arsenic and metals at the Site.

### EXHIBIT 5-4



Acid Mine Drainage from Collapsed Adit at the Crystal Mine

### 5.2 Movement and Behavior of Contaminants of Concern

Oxidation of metal sulfides produces acidity (hydrogen ions), free metal ions and sulfate. Acidic conditions increase the mobility of most metals, whereas alkaline environments inhibit metal mobility. Arsenic, a metalloid, behaves differently and may become more mobile in high pH environments. As free metal ions move into the ground water or surface water, geochemical reactions can occur to enhance or inhibit mobility. Oxidation reduction potential (ORP) also influences metal mobility in water. Because the reactions influencing form and mobility of metals and arsenic in ground water and surface water are primarily dissolution, precipitation and adsorption, the chemical and physical factors that dominate these reactions will have a strong influence on the form and mobility of metals and arsenic as well. Therefore, the acidity, alkalinity, oxidation-reduction conditions, hardness and the presence of organic material in ground water and surface water are important factors influencing the movement and behavior of contaminants.

### 5.2.1 Contaminants of Concern

The contaminants of concern (COCs) at the Site are aluminum, antimony, arsenic, cadmium, copper, lead, manganese, selenium, silver and zinc. In soils, antimony, arsenic, cadmium, copper, lead, manganese, selenium and zinc are the focus for terrestrial life because significant concentrations of these contaminants still remain throughout the Site. In surface water, and ground water discharging to surface water, elevated concentrations of aluminum, cadmium, copper, lead and zinc are of particular concern because of their toxicity to aquatic life and potential toxicity to plants in riparian areas. Stream sediment data show that antimony, arsenic, cadmium, copper, lead, manganese, silver and zinc exist at concentrations high enough to cause adverse effects on stream macroinvertebrates (aquatic life).

## 5.2.2 Contamination Mobilization, Transport and Pathways, and the Exposure Model

Metals-laden materials can be mobilized from Site sources in a number of ways. These processes include erosion, runoff, infiltration and wind-borne transport. The most likely transport pathways for contaminants are through surface water, ground water, air, vegetation and soil pore water (vadose zone). Along these pathways, exchange of COCs may occur between:

- Soil and ground water
- Stream sediment and surface water
- Soil and vegetation
- Surface water and ground water
- Vegetation and surface water

Specific pathways between abiotic and biological elements of the Site will be discussed in more detail by the screening risk assessment. A source, pathway, receptor exposure diagram (conceptual exposure model [CEM]) specific to the Site is presented in Exhibit 5-5.

The major mobilization mechanisms for the contaminants at the Site are summarized below. Detailed descriptions of these mechanisms and contaminant transport phenomena are presented in Section 2.3 of the RI/FS Report.

- Erosion and runoff. Stream bank erosion, especially during high flows, may cause stream bank materials containing arsenic and metals to erode directly into the stream. The degree to which materials may be transported is influenced by climatic conditions, infiltration, slope, soil conditions, animal-human activity, the proximity of waste rock and metals-impacted soil and the presence of vegetation.
- Infiltration and vadose zone transport. Soluble metals of concern in source material may be leached by infiltrating water and carried into underlying soil and shallow ground water.

- **Ground water inflow into the fluvial system.** Ground water discharging to the surface through a mine adit is a particularly important transport mechanism at the Site. Adit discharge water originates from the infiltration of precipitation and snowmelt into the soil profile and its migration into underlying bedrock fractures. Movement of water down through fractures intercepts the mineralized zone and underground workings created by mining. Once the ground water discharges from the portal, exposure to the atmosphere may result in precipitation, co-precipitation and absorptive processes that change free metal ions to less-mobile forms. Arsenic and metals that remain in solution are transported as a point discharge until they infiltrate into the soil or intercept runoff or other surface water such as USG Creek.
- **Physical transport of sediments.** Transient sediment deposits may form along the creek as point bar deposits or within the streambed itself, where metals may reside for a long time until they are remobilized by a change in flow regime.
- Surface water flow to ground water. Surface water may transport contaminants into ground water along stream reaches that lose water into shallow alluvial aquifers.
- **Ground water flow into surface water.** Ground water contributing to base flow for streams during low flow periods may transport contaminants from floodplain areas. The floodplain for the first order USG Creek is very small and poorly developed in the steep upper channel reach adjacent to the mine.
- Airborne transport. Contaminants could potentially be carried on dust particles entrained by the wind. Variables influencing the degree to which this transport mechanism might occur include climatic conditions, surface area, or exposed and sparsely vegetated source materials.



Notes: C = Potentially complete pathway; quantitatively evaluated in the risk assessment

-- = Incomplete pathway

I = Potentially complete pathway; considered insignificat and not quatitatively evaluated in the risk assessment

Potential Receptors											
Current and Future Recreational Users (Adolescent and Adult)	Future Intermittent Worker	Future Excavation Worker	Hypothetical Industrial Worker	Terrestrial Wildlife (birds and mammals)	Vegetation (upland plants)	Aquatic Biota (fish and invertebrates)					
		С									
		C I									
					 C						
C    	C I 	C I 	C I 	C    C	  C 	  					
С	С	С	С	I							
С				C I							
				I							
С				С							
Ι				Ι		C C					
Ι				С		С					

EXHIBIT 5-5 CRYSTAL MINE CONCEPTUAL EXPOSURE MODEL FOR POTENTIAL HUMAN HEALTH AND ECOLOGICAL RECEPTORS Crystal Mine OU5 ROD

### 5.3 Summary of Previous Site Response Actions

The Crystal Mine has been subjected to several previous remedial activities including an adit discharge treatment demonstration project, a removal action and remedial planning. These are summarized below; additional details are found in Section 3.3 of the RI report.

- A 1994-1996 remote mine site demonstration project consisted of a semi-active process focused directly
  on the treatment of AMD discharging from the lower adit (MSE, 1998). Effluent draining from the lower
  adit of the Crystal Mine was injected with quicklime (calcium oxide) 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. Sludge buildup in the settling ponds was pumped periodically into
  the Crystal Mine airshaft for disposal.
- The 2002 removal action was directed toward mitigating surface recharge to the underground workings of the mine in an attempt to reduce the volume of AMD discharging from the lower adit. The objective of the removal action was to reduce the collection of snowmelt and rain runoff in the trenched surface feature caused by previous mining. The collection of surface water runoff in this feature was thought to contribute to the recharge of the Crystal Mine underground workings and production of AMD. This work (see Exhibit 5-6) appeared to help reduce the rate of AMD discharge from the lower adit by about 25 percent.
- Initial remedial planning included a draft engineering evaluation/cost assessment (EE/CA) prepared to evaluate potential remedial options for the Site. An evaluation of alternatives for effectiveness, implementability and cost was completed. No one alternative consistently outperformed the others with respect to meeting all the evaluation criteria. The EPA later decided to implement an interim ROD rather than an EE/CA. Refer to Section 3.3 of the RI and the draft EE/CA document (EPA, 2009a) for detailed information.
- A sampling and analysis plan (SAP) and quality assurance project plan (QAPP) were prepared to guide the 2010 field activities of the RI. These documents (EPA, 2010) described the purpose and scope designed to characterize the Site and the surrounding area. The field investigation focused on the acquisition of data to define human and ecological risk associated with arsenic and metals concentrations in soils, surface water and shallow ground water associated with the Site; develop an accurate model depicting exposure pathways; and obtain the information necessary to complete the RI/FS process.

### EXHIBIT 5-6 Completed Removal Work on the Crystal Mine Trench



### 5.4 Site Description

### 5.4.1 Climate

The Site receives an average annual precipitation of approximately 29 inches. The highest precipitation for the area generally occurs in May, June and July. Temperature extremes for the Site range from highs near 85 degrees Fahrenheit (°F) in late summer to lows near -40°F in December and January. Snowfall accumulation typically occurs between October and March.

### 5.4.2 Drainage and Hydrology

USG Creek, a tributary to Cataract Creek, drains the eastern side of the Site. USG Creek flows southsoutheast approximately 2.5 miles to its confluence with Cataract Creek (see Exhibits 1-2 and 1-3). Surface water from the west side of the Site and a wetland area northwest of the trench flows into an unnamed tributary that joins USG approximately 0.8 miles downstream of the Site. Runoff from the lower adit and adit discharge is intercepted by two sediment retention ponds that overflow into USG Creek.

The beneficial use classification for the entire Missouri River drainage (including Cataract Creek), unless otherwise identified, is B-1. The B-1 classification states that the water quality of the stream must be sufficient to support recreational activities such as bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life and other wildlife; agricultural and industrial water supply; and drinking, culinary and food processing purposes after conventional treatment. The Site has three wetland areas that total 21 acres in size. The northernmost wetland is located directly northwest of the Crystal trench. The second wetland area is the riparian zone associated with USG Creek near the eastern portion of the mine site. The third wetland area is formed by a small seep at the southern-most corner of the mine site (see Exhibit 5-1).

### 5.4.3 Soils and Geologic Setting

Bedrock geologic units in the vicinity include volcanic rocks of the Elkhorn Mountains Volcanics and intrusive rocks of the Butte Pluton. The Elkhorn Mountain Volcanics are described as welded tuff and minor volcanic sandstone and conglomerate. The Butte Pluton consists of granite or granodiorite.

Surficial geologic units in the vicinity include glacial till in high areas, alluvial deposits along USG, bog/swamp deposits in the wetland area, and talus and colluvial deposits on steep slopes.

Geologic structures in the vicinity of the Site consist of faults/shear zones, joints, fractures and lineaments. The geologic structure influences the orientation and location of the ore bodies, which in turn controls the configuration and location of the mining activity. The Crystal vein occupies an east-trending shear zone that is more than 3.5 miles in length. Faults shown on geologic mapping also indicate a north-trending cross fault in the Crystal vein, and beneath USG, where the ore vein is offset to the north.

The majority of the soils consist of stoney loam to 15 inches in depth overlying bedrock. Along the lower portion of the where glacial till has been deposited, soils consists of bouldery loamy sand to 60 inches in depth.

### 5.4.4 Disturbed Areas, Surface Features, Historical Features

The majority of the land within the Basin Creek Watershed is managed by the USFS or U.S. Bureau of Land Management (BLM). The historic land use for claim properties in the watershed includes mining, logging, grazing, recreation and limited residential. A few residences are located along Cataract Creek, with the Town of Basin at the mouth of the watershed. No known potable water supply wells are located within a 1-mile radius of the Site, but water from Cataract Creek is used for irrigation, supports impaired fisheries and discharges to the Boulder River, which is a drinking water source for the Towns of Basin and Boulder.

Disturbed, barren, erosion-prone surfaces cover the Site and include the filled-in surface trench, waste rock dumps, ore load-out areas, and an access road across the Site. Most of the Site is not vegetated, as waste rock piles and contaminated soil combined with harsh Site conditions have inhibited revegetation. A twin ore bin is located below the Crystal dump in the vicinity of the upper adit. Other historic wooden mining structures include a couple of miner's cabins, a covered ore rail load out, an assay building, and an outhouse. The two sediment retention ponds and a concrete platform for the quick-lime injection demonstration project are located in the lower portion of the Site.

Cultural and historic resources within the Site were characterized during the RI. When the Site was first examined in 1998, the surface workings of the mine covered portions of three mining claims. These claims (along with the Crystal, St. Lawrence, Jack and Commerce) comprise the Crystal group. The investigation noted that the remains at the Crystal Mine reflect basically two different periods of operations—the initial production period at the turn of the twentieth century, and another period of 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 (Rossillion and Haynes, 1999). In 2011, Renewable Technologies, Inc. (RTI) conducted an updated inventory of the Site to note any changes that might have occurred since 1998 and reconsider Site eligibility in light of the 2003 historic evaluation guidance document. RTI concluded that the 1998 National Register evaluation for the Crystal Mine (24JF1567) continues to stand as a thorough and defensible evaluation (RTI, 2011). A complete copy of the inventory is presented as a reference to the RI report (EPA, 2013).

### 5.5 Summary of Previous Site Characterization Water Studies

Water quality at, or in the vicinity of the Site was evaluated by several investigations in the past, all with the intent of assessing impacts of mining on USG Creek, a tributary of Cataract Creek. This historic data, when coupled with data gathered during the RI, indicates the Crystal Mine has been a substantial and long-term degrading influence on USG Creek that is sustained through its confluence with Cataract Creek.

At least five major investigations were carried out over a period from 1989 through 2010. They are listed below.

- Abandoned-Inactive Mines Program Deerlodge National Forest, Basin Creek Drainage. Volume I, Basin Creek Drainage and Volume II, Cataract Creek Drainage (MBMG, 1994 and 1995). Results showed:
  - Adit discharge from the Crystal Mine degraded water quality all along its flow path including USG Creek.
  - Surface waters from above Crystal Mine, in USG Creek, and above and below the confluence with Cataract Creek exceeded primary and secondary maximum contaminant levels (MCLs) in effect in 1992 and 1993. Primary and secondary MCLs for aluminum, cadmium, copper, iron, lead, manganese, zinc and pH were all exceeded directly below the Crystal Mine (dissolved metals analyses).
- Montana Department of State Lands sampled the Crystal Mine adit discharge (Pioneer Technical Services and Thomas, Dean and Hoskins, Inc, 1994), finding:
  - Acidic water (pH 3.41).
  - Adit discharge exceeded Federal Safe Drinking Water Act (SDWA) MCLs for arsenic, cadmium and copper.
  - Adit discharge exceeded the chronic and acute aquatic life criteria for arsenic, cadmium, copper, lead and zinc presented in the Montana Numeric Water Quality Standards, Circular DEQ-7 (MDEQ, 2010).

- As part of their remote mine site demonstration project (1994-1996), MSE collected discharge data from the Crystal Mine lower adit for baseline flow conditions and associated water quality. Water quality was also sampled weekly over a 2-year period to document influent water quality versus treated effluent.
  - Concentrations varied greatly during this period. For example dissolved arsenic ranged from less than 30 μg/L (micrograms per liter) to 62,700 μg/L; dissolved zinc varied from 46,000 to 90,800 μg/L.
     Primary, secondary MCLs were exceeded for several elements, and acute and chronic criteria for freshwater were exceed for copper, iron and zinc.
- Basin Watershed OU2 RI/FS (CDM 2005a and 2005b). The Crystal Mine was identified in the RI as the most serious source of water quality degradation within the Cataract Creek drainage. Water quality samples indicated all constituents except mercury exceeded both ecological and human health benchmarks established in the RI (2005a) for arsenic, cadmium, copper, lead and zinc (Table 5-1).
- U.S. Geological Survey Studies Professional Paper 1652 (USGS, 2004). The USGS performed a 5-year study in the Boulder River Basin to evaluate abandoned mines and issues related to AMD and its effects on the environment.
- Pertinent, supplemental USGS monitoring information, including adit discharge data for the Crystal Mine, were summarized for June 2003 through August 2010. Concentrations for all analytes exceeded one or more federal or state water quality criteria cited in the original Basin Watershed RI for human health and aquatic life.

Table 5-1 presents ecological and human health benchmarks established for the original Basin Watershed RI performed from 2002 to 2005.

	Media	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
al ·ks*	Surface Water (µg/L)	150	0.15	4.1	1.16	0.65	42.1
Ecological Benchmarks*	Sediment (mg/kg)	5.9	0.596	18.7	53	0.13	110
Ecc Benc	Soil (mg/kg)	10	1.6	40	50	0.1	50
ks**	Surface Water <sup>a</sup> (µg/L)	10	5	1,300	15	0.05	2,000
hmar	Sediment <sup>b</sup> (mg/kg)	3,740	No data	No data	1,000	10,825	No data
Bencl	Residential <sup>c</sup> Soil (mg/kg)	120	562	3,100	1,000	337	23,000
ealth	Industrial Soil <sup>c</sup> (mg/kg)	49	No data	82,000	No data	1,050	610,000
Human Health Benchmarks**	Recreational <sup>d</sup> Soil (mg/kg)	1,440	No data	No data	1,000	4,165	No data
Hum	Ground water <sup>a</sup> (µg/L)	10	5	1,300	15	2	2,100

### TABLE 5-1

2002 Ecological and Human Health Benchmarks for Crystal Mine Contaminants of Concern

*Source: Basin Mining Area, Operable Unit 2, Jefferson County, Montana. Remedial Investigation Report, April 2005. Tables 4.1-2 and 4.1-3 (CDM, 2005b)* 

Notes:

\*Tables 2-1 to 2-3, Draft Ecological Risk Evaluation (CDM, 2002)

\*\* a Circular WQB-7, Montana Numeric Water Quality Standards (Total Recoverable Analyses) (MDEQ, 2004)

<sup>b</sup> Preliminary Remediation Goals; Final RI Report for Town of Basin OU1, Jefferson Co., MT

<sup>c</sup> EPA Region III, RBC Table, April 13, 2000

<sup>d</sup> Executive Summary – Draft Preliminary Human Health Risk Assessment - Upper Ten Mile Creek Mining Site Watershed OU4 (CDM, 2000)

<sup>e</sup> Executive Summary – Final Human Health Risk Assessment report for Town of Basin OU1, Jefferson Co., MT (CDM, 2000)

A tracer study performed on USG Creek from 1997 to 1998 by the USGS (through discharge and load profiles) identified the Crystal Mine adit discharge as the primary source of sulfate, cadmium, copper, iron, lead, manganese and zinc loading to USG Creek. The study estimated that approximately 46.6 pounds per day (lb/day) of zinc was added to Cataract Creek along its full reach. Of this load, 75 percent (34.9 lb/day) came from USG Creek.

Based on this record of data, it is evident that the discharge from the Crystal Mine lower adit is acidic and high in contaminants of concern. The results and conclusions from this previous body of work were incorporated into the RI (EPA, 2013), and are described in greater detail under specific media in this ROD.

## 5.6 Summary of Previous Site Characterization Soil and Waste Rock Studies

Soils and waste rock at or in the vicinity of the Site were evaluated by several investigations in the past, all with the intent of assessing the impact of the mining relative to human and ecological exposures and risk. One of the risk components previously evaluated was the proximity of the contaminated source material to USG Creek and the potential for erosion by overland flow to carry it into the creek. Another dealt with the potential for waste material to produce ARD. Site soils were not sampled for neutralization potential/acid potential (NP/AP) and percent sulfide, "but the arsenic, lead and zinc concentrations are similar to mines with a known high probability to generate ARD" (CDM, 2005a). It was further concluded that AMD/ARD from adit drainage and waste rock into USG Creek was one of the major sources of contaminated sediments for contaminants of potential concern (COPCs) within the Cataract Creek drainage (CDM, 2005a).

Results of the field investigation completed by U.S. Bureau of Reclamation (Reclamation) (2002) showed soil and waste rock piles around the Crystal Mine and the trench exceeded Montana soil cleanup guidelines for gold panner/rockhound recreational receptors for arsenic (323 mg/kg [milligrams per kilogram]) at 43 locations, and exceeded the soil cleanup goal for lead (2,200 mg/kg) at three locations with the highest occurring just west of the upper adit portal.

Relevant information from these studies was incorporated into the RI (EPA, 2013), and is described in greater detail under specific media in this ROD.

### 5.7 2010 Field Activities

Field investigations directed the acquisition of data (surface water, shallow ground water, soils, wetlands and so forth) to characterize and define human and ecological risk associated with the Site and to obtain the information necessary to complete the feasibility study. In 2010, the following field data collection activities were implemented:

- A drilling program designed to intercept and investigate several points along the lower workings and adit portal.
- Soil test pit sampling and measurement of COPC concentrations using field x-ray fluorescence (XRF) instrumentation and laboratory analyses.
- Synoptic flow gauging and sampling along USG Creek for analysis of COPC levels and other water quality parameters.
- A spring inventory and sampling in the vicinity and downgradient of the Site for analysis of COPC levels and other water quality parameters.
- An ecological assessment including a wetlands survey, a threatened and endangered species inventory, and a benthic macroinvertebrate survey of USG Creek.
- MBMG conducted several additional field activities including flume installation on the discharging lower adit, continuous flow monitoring, and adit discharge sampling under an agreement with MDEQ.

Based on the preliminary findings of the 2010 investigations, agency review comments, and need for additional data, supplemental investigations were conducted in 2011 and 2012. These investigations included stream sediment sampling, surface soil sampling to measure the bioavailability of arsenic and lead, and hydrogeologic investigations in the northern wetland area.

### 5.8 Surface Water Investigations

Water quality samples were collected from stations at four locations along USG Creek: above the mine (USC-1), below the confluence with a small tributary (USC-2), at the small tributary (USC-Tributary), and downstream of the mine and discharge channel from the lower ponds (USC-3) (see Exhibit 5-7). Mine adit discharge was also sampled as part of this investigation. Synoptic sampling of waters was conducted in the early summer and then again in the fall. Physical and chemical characterization of the waters and comparisons to standards for human health and aquatic health were determined.

### 5.8.1 Synoptic Sampling of Uncle Sam Gulch Creek

The purpose of a synoptic sampling of USG Creek was to identify and document, if possible, seasonal changes in flow and water quality in the reach of the creek impacted by the Site. At each location, stream discharge was measured and water samples were collected and analyzed for major ions and total and dissolved contaminants of interest (COIs). Field parameters were also measured (pH, dissolve oxygen, specific conductivity, temperature and turbidity) at each designated station. Details of sampling, field measurements, analytical procedures and assessment of data quality are described in the RI. Field measurements determined in the spring and fall are shown in Table 5-2.

Site	Period	Flow (gpm)	рН	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	Temp. (C°)	ORP (mV)	Turbidity (NTU)
Crystal	Spring	27.1	3.9	1	19.8	3.6	327	7
Mine Adit	Fall	17.3	4.5	87.1	6.95	5.7	270	6.6
USC-1	Spring	85.12	5.5	0.7	23	4.6	137	3
	Fall	40.32	5.8	4.3	9.21	5.1	87	2.5
USC-2	Spring	71.68	5.9	0.03	20.3	5.4	99	0
	Fall	62.72	5.6	5	9.27	6.5	108	0
USC-3	Spring	170.24	4.9	0258	27	4.74	239	18.7
	Fall	116.48	5.6	22	8.89	10.6	166	7.5
USC-Trib	Spring	22.1	5.6	0.73	25.4	4.29	166	2.1
	Fall	22.4	5.5	7.2	9.16	5.8	202	3.5

TABLE 5-2 Surface Water Field Measurements

Notes:

 $\mu$ S/cm = microSiemens per centimeter

gpm = gallons per minute

mV = millivolts

NTU = nephelometric turbidity units

ORP = oxidation reduction potential

	100	
Crystal Spring 2	And and a state of the state of	
		SC-1
As 0.5U	COC	g/L
Cd 0.08U	As	6.6
	Cd	0.081
Pb         0.1U           Zn         5.0U	Cu	2.3
Crystal Spring 3     PH     5.6	Pb	0.92
	Zn	9.5
As 2.6	рН	5.5
Cd 0.08U		C-Trib
	COC	g/L
Pb 0.69 7a 5.00	As	13.2
Zn         5.0U           pH         5.7	Cd	0.32
	Cu	2.0
Pb 0.1U	Pb	1.1
	Zn	90.0
<u>рн</u> <u>5.5</u>	рH	5.6
		SC-2
	COC	g/L
	As	11.9
	Cd	0.37
	Cu	16.2
	Pb	5.1
Crystal Spring 4       COC     g/L	Zn pH	<b>51.5</b> 5.9
As 8.9	рн	5.9
Cd 0.2		
Cu 4.7		
Po 1.4		
Zn 23.8		<mark>l Mine Adi</mark>
рН 6.2		g/L
	As Cd	442 520
Crystal Spring 5	Cu	9,060
COC g/L	Pb	84.4
	Zn	40,90
Cd         0.93           Qu         2.7	pН	3.9
Pb 5.4		
Zn 105	and which it	
pH 5.9		SC-3
Аз 8.6 Сd 0.93 Сu 2.7 Рь 5.4 Zn 105 рH 5.9		g/L
e e e e e e e e e e e e e e e e e e e	As Cd	11.7 67.9
Nec.	Cu	938
	Pb	18
T T T T T T T T T T T T T T T T T T T	Zn	5,710
	pН	4.9
Unnamed Tributary	199	
	1 3 3	

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

#### Notes:

- Area of interest subject to change.
   2011 Imagery ArcGIS Streaming Map Service.
   Analytical results for Total Metals are in g/L.
   ND = Non Detect



Exhibit 5-7 Creek and Spring Sampling Locations and Analytical Results Crystal Mine OU5 ROD

The total concentrations of several metals and metalloids, major cations, and sulfate were determined using standard EPA methods. Results are displayed in Table 5-3.

Parameter	Screening/Cleanup Level	Collection Period	USC-1	USC-Trib	USC-2	Crystal Mine Adit	USC-3
AL (	87 <sup>1</sup>	Spring	41.8	16.4	58.9	7,630	741
Al (µg/L)	87-	Fall	58.1	16.3	53.4	6,080	663
A. (	-	Spring	6.6	13.2	11.9	442	11.7
As (µg/L)	5	Fall	9.4	12.5	12.7	241	19.4
	0.0073	Spring	0.08U	0.32	0.37	520	67.9
Cd (µg/L)	0.097ª	Fall	0.08U	0.37	0.24	554	61.5
		Spring	3,290	5,350	3,810	57,400	15,200
Ca (µg/L)	_	Fall	4,220	8,140	5,140	56,200	20,400
Cu (u = /l.)	2.053	Spring	2.3	2.0	16.2	9,060	938
Cu (µg/L)	2.85ª	Fall	2.8	1.6	6.3	6,630	707
	2003	Spring	174	20.0U	173	47,700	1,140
Fe (µg/L)	300ª	Fall	272	57.6	224	53,000	1,080
K (		Spring	287	335	324	1,470	694
Κ (μg/L)	—	Fall	424	588	500	1,510	900
		Spring	574	969	675	16,000	3,470
Mg (µg/L)	_	Fall	669	1480	878	15,600	4,250
	120	Spring	15.5	5.4	18.1	10,100	1,390
Mn (μg/L)	120	Fall	27.3	9.9	22.6	11,900	1,260
		Spring	1,980	1,700	1,880	3,320	2,240
Na (µg/L)	_	Fall	2,300	2,120	2,410	3,550	2,740
	46.43	Spring	0.5U	0.5U	1.6	34.3	5.1
Ni (µg/L)	16.1ª	Fall	0.5U	0.5U	0.78	33.0	5.1
	0.553	Spring	0.92	1.1	5.1	84.4	18.0
Pb (µg/L)	0.55ª	Fall	2.8	0.9	3.8	90.2	18.2
	_	Spring	0.5U	0.5U	0.5U	1.1	0.5U
Se (µg/L)	5	Fall	0.5U	0.5U	0.5U	0.72	0.5U
	5.0	Spring	0.5U	0.5U	0.64	5.0	1.2
Sb (µg/L)	5.6	Fall	0.5U	0.5U	0.58	3.2	1.4
	0.5=2	Spring	0.5U	0.5U	0.5U	0.5U	0.5U
Ag (µg/L)	0.37ª	Fall	0.5U	0.5U	0.5U	0.5U	0.5U

TABLE 5-3 Total Elemental Levels (µg/L) in Surface Waters, SO4 (mg/L)

Parameter	Screening/Cleanup Level	Collection Period	USC-1	USC-Trib	USC-2	Crystal Mine Adit	USC-3
Ti (ug/l)	0.24	Spring	0.1U	0.1U	0.1U	0.1U	0.1U
Ti (μg/L)	0.24	Fall	0.1U	0.1U	0.1U	0.1U	0.1U
70 (40 (1)	37ª	Spring	9.5	90.0	51.5	40,900	5,710
Zn (µg/L)		Fall	13.2	125	48.4	37,000	5,280
50 (mg/l)		Spring	5.0U	5.0U	5.0U	461	72.2
SO₄ (mg/L)	_	Fall	5.0U	5.0U	5.0U	475	79.2

#### TABLE 5-3 Total Elemental Levels (ug/L) in Surface Waters SO4 (mg/L)

Notes:

Shaded cells indicate value is greater than the screening level.

<sup>1</sup>EPA Freshwater Screen Benchmarks. Available at <u>http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fw/screenbench.htm</u>. (Table 5-6) <sup>a</sup>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 a hardness of 25 mg/L. 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)

U indicates reported value < method detection limit.

Concentrations of many elements exceeded conservative screening benchmarks shown in Table 5-3. These same patterns were demonstrated in the dissolved elemental concentrations. These data may be found in the RI report.

USG Creek is a gaining reach from Station USC-1 through Station USC-3.

An unnamed tributary and the Crystal Mine adit discharge accounts for approximately one-third of the increase of flow recorded at downstream Station USC-3. Water quality above the confluence with the mine adit discharge was better than that recorded from stations located downstream of the mine. The degree of the change varies with the contaminant, ranging from one to several orders of magnitude difference. This pattern of degradation is consistent with sampling performed in 1994 and 1995 (MBMG/USFS Abandoned Mines Inventory). Water quality in USG Creek above the Site and at the confluence with the unnamed tributary are similar. Degradation occurs at the mine adit and continues at station USC-3. This is shown graphically for representative contaminants copper, arsenic and zinc in Exhibits 5-8, 5-9 and 5-10, respectively. Note that the vertical axes are log scale.

### EXHIBIT 5-8



### Total Arsenic (µg/L) in Uncle Sam Gulch Creek Waters

### EXHIBIT 5-9 Total Copper (µg/L) in Uncle Sam Creek Waters



#### EXHIBIT 5-10 Total Zinc (µg/L) in Uncle Sam Gulch Waters



Seasonal variations in concentration of total arsenic (As), copper (Cu) and zinc (Zn) at most sampling locations were generally greater in the fall for arsenic and mixed for copper and zinc compared to levels found during the spring sampling. Concentrations were lowest in USC-1 and at the USC-unnamed tributary, slightly greater at the USC-2 station, and then greatly elevated in waters emanating from the adit. The downgradient location USC-3 revealed water quality still influenced by the adit water. These same patterns were demonstrated in the dissolved elemental concentrations. This data is described further in the RI.

The lower adit at the Crystal Mine has a perennial discharge. The discharge varies on a seasonal basis with the highest flows occurring in the May/June timeframe, which coincides with snowmelt and periods of highest rainfall. The lowest flow occurs in late fall and winter (December). The seasonal pattern to the adit drainage was initially documented by the USGS in 1993, and again during the demonstration project performed by MSE from 1994 to 1996. From 2003 through 2010, the USGS sampled the adit discharge and estimated its flow on a quarterly basis. Discharge during this period ranged from a high of approximately 50 gpm to a low of 4 gpm,

again showing a seasonal flow regime. The significance of the seasonal flow regime is that it shows that the adit discharge flow rate is driven by surface water infiltrating and migrating down through the soil and bedrock fractures and intercepting the lower mine workings. This seasonal recharge activity perpetuates the production of AMD in the mine, as the water moves across the exposed rock surfaces, collects along the floor of the adit, and flows to the mouth where it eventually discharges to USG Creek. Based on the existing discharge hydrograph, this cycle is seasonal and may have a recharge travel time of less than 3 months.

Using adit discharge data collected by USGS in 1993 and comparing it with USGS data collected between 2003 and 2010, it appears that the backfilling and lining of the Crystal trench, completed by the EPA TCRA in 2002, reduced discharge from the lower adit by approximately 25 percent. This provides credibility to the hypothesis that the open trench and underlying bedrock fractures were acting as a conduit for snowmelt and precipitation to migrate into the lower workings of the mine. Furthermore, the MBMG collected water samples from the adit discharge in 2010 through 2012, analyzed them for oxygen and hydrogen isotopes, and compared them to regional meteoric water quality data. Findings indicated that "the residence time of the water was not sufficient for oxygen isotopes to equilibrate between water and subsurface minerals and that the water is representative of recent precipitation/recharge events" (MBMG, 2011 and 2014).

### 5.8.2 Spring Inventory and Sampling Results

A baseline spring inventory was performed in the vicinity of the Site in late June 2010. The purpose of the spring inventory was to assess their location, flow rate, water quality and seasonality. This information represents a baseline condition before any remedial action and may provide important insight about the linkage between historic mining at the Crystal Mine and discharge at the springs. The field crew located all visible springs within one-quarter-mile radius of the mine with a primary interest in those downgradient of the Crystal Mine (see Exhibit 5-6). A total of five springs were located, and waters were sampled and analyzed in early summer and again in the fall. Determinations of field characteristics as well as laboratory measurements of total and dissolved analytes were made. Field measurements are presented in Table 5-4. Total elemental levels of selected contaminants are presented in Table 5-5.

Site	Period	Flow (gpm)	рН	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	Temp. (C°)	ORP (mV)	Turbidity (NTU)
Spring 1	Spring	1.00	5.5	0	10.1	12.6	157	7
	Fall	2.00	5.8	12.7	8.32	8.4	204	6.6
Spring 2	Spring	0.00	5.6	0	8.5	14.3	169	0
	Fall		6.1	4.4	8.64	4.1	199	0
Spring 3	Spring	0.00	5.7	0	10.3	11.6	155	0
	Fall	0.25	6.2	4.3	8.86	7.7	207	5
Spring 4	Spring	0.50	6.2	0	12.5	12.2	126	0
	Fall	0.50	6.3	8.3	9.31	15.5	137	4.4
Spring 5	Spring	0.50	5.9	0	6.4	15.2	72	0
	Fall	1.00	6.1	48.5	11.03	12.4	174	0

### TABLE 5-4

### Field Measurements in Waters from Springs

Notes:

 $\mu$ S/cm = microSiemens per centimeter

gpm = gallons per minute

mV = millivolts

NTU = nephelometric turbidity units

ORP = oxidation reduction potential

Parameter	Screening/ Cleanup Level	Collection Period	Spring 1	Spring 2	Spring 3	Spring 4	Spring 5
Al	87 <sup>1</sup>	Spring	9.1	10.8	207	36.0	306
(µg/L)		Fall	9.8	21.9	247	52.9	19.8
As	F	Spring	ND	ND	2.6	8.9	8.6
(µg/L)	5	Fall	ND	ND	2.6	10.3	3.2
Cd	0.097 <sup>2</sup>	Spring	ND	ND	ND	0.2	0.93
(µg/L)	0.037	Fall	ND	ND	0.19	0.26	0.83
Cu	2.85 <sup>2</sup>	Spring	ND	ND	3.2	4.7	2.7
(µg/L)	2.85-	Fall	ND	ND	6.2	5.5	0.6
Fe	300 <sup>2</sup>	Spring	ND	ND	149	ND	344
(µg/L)		Fall	ND	ND	182	67	ND
Pb	0.55 <sup>2</sup>	Spring	ND	ND	0.69	1.4	5.4
(μg/L)	0.55-	Fall	0.16	0.18	0.44	2.0	0.34
Sb	5.6	Spring	ND	ND	ND	2.3	0.52
(µg/L)	5.0	Fall	ND	ND	ND	2.5	ND
Zn	37 <sup>2</sup>	Spring	ND	ND	ND	23.8	105
(μg/L)	3/-	Fall	ND	ND	10.0	40.2	83.7
SO <sub>4</sub>		Spring	ND	ND	ND	ND	135
(mg/L)	—	Fall	ND	ND	ND	ND	182

#### TABLE 5-5

Total Elemental Levels (µg/L) in Waters Collected from Springs, Sulfate in mg/L

Notes:

Shaded cells indicate value is greater than the screening level.

<sup>1</sup>EPA Freshwater Screen Benchmarks. Available at http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fw/screenbench.htm. (Table 5-6)

<sup>2</sup>The freshwater criterion for this metal is expressed as a function of hardness in the water column. The value given here corresponds to a hardness of 25 mg/L. 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) U indicates reported value  $\leq$  method detection limit.

Springs located north of the mine in USG (Spring 1 and Spring 2) exhibited very good water quality. Spring 3, located in a wetlands area north of the St. Lawrence mining claim, exhibited some natural metals enrichment (see Table 5-6). Water quality was slightly better than that of a similar sample collected from the St. Lawrence Pit by Reclamation in 2001.

These springs are essentially upgradient of the historic mining activity. Springs 4 and 5 are topographically downgradient of the disturbed mine lands and show more of a mineralized signature with metal concentrations slightly elevated.

### 5.8.3 Comparison with Water Quality Standards

Surface water standards have been established by the EPA in accordance with the Clean Water Act (CWA). Numerical values for some elements vary with water hardness and are often referred to as aquatic life standards. Circular DEQ-7 Montana Numeric Water Quality Standards are equal to, or more restrictive than, federal standards. The primary MCLs and acute and chronic aquatic life standards for the COPCs, as listed in State of Montana Circular DEQ-7 Numeric Water Quality Standards (MDEQ, 2012), are presented in Table 5-6. Although these water quality standards are waived under this interim ROD, they are provided here for comparison purposes.

#### TABLE 5-6

#### Surface Water and Ground Water Standards and Screening Benchmarks (mg/l)

			ana Standards <sup>2</sup>		National Re	commended		
	Human Heal	th Standards	Aquat	ic Life		ity Criteria – c Life <sup>3,c</sup>	EPA Surface Water <sup>1</sup>	
Analyte	Surface Water	Ground Water	Acute	Chronic	Acute	Chronic		
Aluminum	-	_	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 <sup>a</sup>	0.005	0.005	0.00052	0.000097	0.0020ª	0.00025ª	0.00025	
Copper <sup>a</sup>	1.3	1.3	0.00379	0.00285	0.013ª	0.0090ª	0.009	
Iron <sup>a</sup>	_	_	_	1	_	_	0.3	
Lead <sup>a</sup>	0.015	0.015	0.01398	0.000545	0.065ª	0.0025ª	0.0025	
Manganese	_	_	_	_	_	_	0.12	
Nickel <sup>a</sup>	0.1	0.1	0.145	0.0161	0.47ª	0.052ª	0.052	
Selenium <sup>b</sup>	0.05	0.05	0.02	0.005	_	0.0050 <sup>b</sup>	0.001	
Silver <sup>a</sup>	0.1	0.1	0.000374	_	0.0032ª	_	0.0032	
Thallium	0.00024	0.002	_	_	_	_	0.0008	
Zinc <sup>a</sup>	2	2	0.037	0.037	0.12 <sup>a</sup>	0.12 <sup>a</sup>	0.12	

Notes:

<sup>1</sup> EPA Freshwater Screen Benchmarks (mg/L). Available at

http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fw/screenbench.htm

<sup>2</sup> DEQ-7 Montana Numeric Water Quality Standards (October 2012)

<sup>3</sup> Freshwater standards from the EPA. 2009a. *National Recommended Water Quality Criteria for Priority Pollutants*. EPA Office of Water. Office of Science and Technology (4304T). Available at https://www.epa.gov/waterscience/criteria/wqcriteria.html. Updated December 2, 2009; Acute Criteria and Chronic Criteria.

<sup>a</sup> 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 a hardness of 25 mg/L. Criteria values for other hardness may be calculated from the following: CMC (dissolved) = exp(mA[In(hardness)]+bA) (CF), or CCC (dissolved) exp (mC[In(hardness)] + bC) (CF]

<sup>b</sup> 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

<sup>c</sup> Metals are stated as dissolved unless otherwise specified

Units are all reported in mg/L = milligram per liter (to covert to microgram per liter [ $\mu$ g/L] divide by 1000)

The best background representation for surface water quality was obtained from Springs 1 and 2 located north of the mine in the USG drainage (see Table 5-3). Water quality showed no indication of degradation by arsenic or metals. In general, COPC concentrations were greatest, and the pH lowest, in the adit discharge, followed by Station USC-3 located immediately downstream from the confluence of the adit discharge with the USG Creek. Arsenic concentrations exceeded human health MCLs during both sampling episodes (July and September) in the adit discharge, Crystal Spring 4, USG Creek Stations 2 and 3, and the USG Creek tributary. Cadmium concentrations exceeded in the adit discharge, while lead and zinc concentrations consistently exceeded in the adit discharge and at Station USC-3.

This interim ROD waives the surface water quality standards until implementation of the final remedy for the Basin Watershed OU2; they are presented here for relative comparison. A goal of the Basin Watershed OU2 ROD is to meet surface water standards.

### 5.9 Soil and Waste Rock Investigations

As noted in Section 5.6, soils and waste rock in the vicinity of the Site were evaluated by several previous investigations, all with the intent of assessing the impact of the mining activity relative to human and ecological exposures and risk. Significant previous findings and the 2010 sampling results are presented in the following subsections. The combination of previous findings and 2010 sampling demonstrates the long-term, consistent, degraded condition of the Site over the period of record.

The 2010 samples of waste rock and soils were collected from 40 test pits within the Site. A field XRF instrument was used to quantify concentrations of antimony, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver and zinc in these areas so that the lateral and vertical extent of contamination could be estimated. Surface (0- to 2-inch depth) materials as well as materials as deep as approximately 216 inches (18 feet) were obtained. A total of 201 samples were collected for elemental analysis. Samples were also collected from a nearby, but offsite, location that did not appear to be influenced by mining activities. A subset of the soil samples was sent to an analytical laboratory to confirm the concentrations of the elements generated by the XRF. Statistical analyses (paired t-test and linear regression) comparing the field and laboratory data indicated close correspondence between data sets (refer to Section 3.4.14 of the RI). Exhibit 5-11 shows the locations of the soil pits and the COPC concentrations based on the XRF results.

Representative metals and arsenic concentrations in Site soils and waste rock are presented in Table 5-7. The data are arranged by soil depth increment, number of samples collected from each increment, and mean, maximum, and minimum concentrations of arsenic, copper, lead and zinc. Almost all of the cadmium data were reported as less than the detection limit. The complete soils XRF and laboratory data sets can be found in Appendix B of the Crystal RI. These elemental data are similar to data reported in the 2005 RI for the Basin Watershed OU2.

Soil			(mg/kg) Ir Arsenic	i ci ysta	ivinc 5	Copper			Lead	. Dutaj	Zinc		
Depth	No.		Arsenie			Copper			LCau			2000	
(feet)	Samples	Mean	Max	Min.	Mean	Max	Min.	Mean	Max	Min.	Mean	Max	Min.
0.17	37	1,789	6,087	53	226	676	31	1,393	6,563	79	487	1,223	67
0.58	18	6,909	42,648	16	691	3,626	88	739	4,067	23	473	1,074	32
1	31	2,083	16,779	61	232	594	25	1,068	4,266	35	500	1,214	59
1.5	10	2,088	7,842	86	382	2,023	91	841	1,626	73	503	1,043	224
2	33	1,977	9,890	11	277	1,150	30	978	4,769	19	679	3,122	90
2.5	12	3,189	10,648	54	307	739	99	667	2,535	26	571	1,394	220
3	19	2,578	13,553	10	337	902	37	1,568	5,538	31	570	1,417	46
3.5	2	1,550	2,723	337	234	340	127	504	862	145	439	473	405
4	15	2,694	16,090	14	226	833	39	963	8,563	30	679	1,372	86
5	7	4,816	19,635	24	446	686	27	2,076	7,443	22	879	1,613	307
6	4	1,729	3,427	420	129	249	60	939	2,519	27	661	1,567	32
7	3	880	2,515	60	201	427	83	1,020	2,727	116	557	635	509
8	4	983	1,517	14	140	262	48	661	1,567	32	401	593	212
10	2	4,530	6,269	2,790	749	965	529	3,825	5,924	1,226	544	549	538
18	4	6,297	10,694	2,391	549	826	289	5,709	8,122	241	1,067	2,481	502

#### TABLE 5-7 Metal and Arsenic Levels (mg/kg) in Crystal Mine Site Soils and Waste Rock (Field XRF Data)\*

Notes:

\* Almost all cadmium concentrations were reported as less that the XRF detection limit

Virtual set production of the set production of	Crystal Tes           Depth         As           0 - 2"         892           1         411           1.5         2.372           2         1,241           3         2.79           Depth         As           0 - 2"         3,526           0.5         9,250           1.5         7,842           2.0         9,880           2.3         10,642           0 - 2"         6,066           0 - 2"         6,066           0 - 2"         6,087           1         7,6441           3         13,553           4         16,090           5'         19,632
Image: constraint of the set Pt 28 product of the set Pt 23 product of the set Pt 24 produ	Crystal Test           Depth         As           0 - 2'         493         4 - 6'         399           10 - 12''         296         385         26 - 28''         3,472           Crystal Test           Depth         As           0 - 2''         1,648         1''         3,124           2''         2,61,107         3,55''         3,77'           Crystal Test           Depth         As           0 - 2''         1,923         3,923           Crystal Test           Depth         As           0 - 2''         1,920         3,923           Crystal Test           Depth         As           0 - 2''         1,580         20'' - 22''         549           Ze - 30'' 4611           Crystal Test           Depth         As           0 - 2''         4,077         1''         2,047           1'         2''
Crystal Test Pli 2 Crystal Test Pli 1 Crystal Test Pli 1 <t< td=""><td>1.5         1.932           2.5         900           3         2.381           3' DUP         2.351           Crystal Test         Depth           0.5         4.375           1.5'         1.964           2.0'         2.311           2.0'         2.371           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.031           6 - 8''         898           9 - 11'         248           14 - 16''         221           26 - 29''         392           Crystal Test         Depth           As         0 - 2'         1.905           1'         2.944         2'           2'         5.717         3'           3'         2.46</td></t<>	1.5         1.932           2.5         900           3         2.381           3' DUP         2.351           Crystal Test         Depth           0.5         4.375           1.5'         1.964           2.0'         2.311           2.0'         2.371           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.311           2.0'         2.031           6 - 8''         898           9 - 11'         248           14 - 16''         221           26 - 29''         392           Crystal Test         Depth           As         0 - 2'         1.905           1'         2.944         2'           2'         5.717         3'           3'         2.46
$\frac{\frac{4}{6} - \frac{252}{14} - \frac{216}{16}}{\frac{7}{7} - \frac{64}{4} - \frac{118}{116}}$ $\frac{\frac{1}{17} - \frac{1}{164} - \frac{1}{116}}{\frac{1}{7} - \frac{1}{164} - \frac{1}{116}}$ $\frac{\frac{1}{16} - \frac{1}{164} - 1$	4'         512           4'         DP           Crystal Test           Depth         As           0 - 2'         2.981           6 - 8''         42,476           6 - 8''         42,477           10 - 13''         16,777           17 - 19''         6,055           7- 8'' DUP         5,984           Crystal Test         Depth           0 - 2''         3,402           10 - 12''         5,729           28 - 32'''         6,132           Depth         As           0 - 2''         3,402           10 - 12''         5,729           28 - 32''''         6,132           Depth         As           0 - 2'''         1,614           2''         2,238           8'''         1,51'''           15''         2,351           18'''         10,634

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-		-
Test P	it 4	
s		20
92 11	568	2
11 372	306 1,082	
372 241	1,082 1,009	1.0
241 79	250	
Test P	it 6	
<b>s</b> 526	Pb	
526 250	1,059	1.00
250 342	506 398	
390 648	398 376 367	
648	367	
lest P	it 5	
<b>S</b>	Pb	
	6 563	0.75
	6,438 4,266	12
541 553 090	4,092 8,563	
090	8,563 1,542	12
635	and the second s	
est Pi		
<b>\s</b> 93	Pb	
	427 344	
98	224	
85	235	1
472	391	100
Test P	it 7	
s	Pb	
548 124	1,339 1,724	
115	1,395	
307 77	118	13
	145	
'est Pi	t 39	
s	Pb	1
923 08	2,154	100
08 580	176 502	39
580 49	99	12.1
61	62	-0.1
Test P	it 9	
<b>15</b> 077 047	Pb	3.5
)47	3,703 1,539	
932	1,298	
00	453 1,458	0
381 351	1,458 1,470	
-	the second s	
est Pi	t 10	
\S	PD	13.
375	1,382 4,067	
964	1,582	2
371 390	583 1,407	
590	1,407	-
est Pl	t 38 Pb	
<b>\s</b> 031	рр 1,443	5
98	604	10
48	145 73	195
21 92	122	
est Pi		
est Pi ls	t 14 Pb	
905 944	981	
717	1,397 1,541	
346 12	245	
21	226	
est Pi		
s	Pb	
981 476	1 400	
	2,175	
470 648 779	1,301	
)55	2,326 2,351	
184	2,351	
est Pi	t 36	
iest Pi As 402	Pb	5-2
402	2,672 3,764	
729 132	4,742	
est Pi	6.16	34
est Pi s		24
514	937	
238	4,769	
517 351	740	
351 694	2,421 7,699	



### LEGEND Test Pit Sample Location

Notes:

- Analytical values are mg\kg
   LOD = Level of Detection
   2009 NAIP Orthophoto



Exhibit 5-11 Soil Pits with Samples Analyzed by XRF Crystal Mine OU5 ROD
Acidity in the 2010 samples was determined by measuring pH. Data were transformed to hydrogen ion concentrations so that statistical calculations of mean values could be correctly determined. Mean pH levels indicate acidic soil and 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 oxidation of pyrite is the source of the acidity in this material.

Elevated metal concentrations coupled with high acidity (low pH) results in enhanced metal mobility and availability to the environment (surface, vadose zone and ground water), and ecological receptors (vegetation and aquatic biota). In 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.

In contrast to the Site soils, background soil concentrations of the contaminants were much less: As = 7.6 to 162 mg/kg, Cu = 6.8 to 52 mg/kg, lead (Pb) = 9.9 to 189 mg/kg, cadmium (Cd) = 0.30 mg/kg and Zn = 17.3 to 311 mg/kg. The pH of background soils was 6.7. Because the Site is located in a natural mineralized zone, greater concentrations of these contaminants are expected.

The vertical extent of contamination by arsenic, copper, lead and zinc in the soils and waste rock is displayed in Exhibits 5-12 through 5-15. Mean concentrations for each sample increment are shown in these exhibits, as well as concentrations found in the background soils. Very elevated levels were found as deep into the soil as 18 feet. 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. This same pattern is found for mean levels of lead as a function of soil depth. Concentrations of copper and zinc in the soil profile are variable, with little pattern in terms of mean concentrations. The concentrations of copper and zinc are generally less than those of arsenic and lead.

#### EXHIBIT 5-12



#### Mean Soil Arsenic (mg/kg) and Soil Depth (Inches)

#### EXHIBIT 5-13 Soil Lead (mg/kg) and Soil Depth (Inches)



EXHIBIT 5-14



#### EXHIBIT 5-15 Soil Zinc (mg/kg) and Soil Depth (Inches)



#### 5.9.1 Soil Concentrations and Ecological and Human Benchmark Values

Mean and maximum concentrations of arsenic, copper, lead and zinc (see Table 5-1) exceed their respective ecological benchmark values. For example, the mean and maximum concentrations of arsenic in Site surface soils (0-2 inch depth; 1,789 mg/kg and 6,087 mg/kg, respectively) are three to four orders of magnitude greater than the ecological benchmark of 0.36 mg/kg. Maximum and mean arsenic concentrations throughout the soil profile exceed this ecological benchmark. The ecological benchmarks for lead (11 mg/kg), cadmium (0.36 mg/kg) and zinc (160 mg/kg) are also exceeded in many samples, with mean and maximum concentrations up to two orders of magnitude greater than the benchmark value. Table 5-2 summarizes soil and sediment screening benchmarks.

Comparisons of soil and waste rock concentrations in samples collected in 2010 to human health residential benchmark screening values (see Table 5-8) indicate that contaminated soil and waste rock values for arsenic, copper, lead and zinc exceed those considered to be protective of human health.

The Crystal Mine is located in a naturally mineralized zone and greater concentrations of these elements are expected. Arsenic levels in soils collected from the background sites range from 7.6 to 162 mg/kg with an integrated average for all depths of 36.9 mg/kg. The mean and maximum concentrations in the surface soil and underlying wastes exceed the background concentration for arsenic and other elements. This same pattern is repeated for copper, lead and zinc.

#### TABLE 5-8 Soil and Sediment Screening Benchmarks

			So	bil				Sedir	nent	
	Human Health	h Soil Screening I	Levels (mg/kg)	Ecological So	oil Screening Lev	vels (mg/kg) <sup>b</sup>	EPA Region 3 (mg/kg) <sup>c</sup>	NOAA SQuiRTs (mg/kg) <sup>d</sup>	Ecological Soil Sc (mg/k	•
Analyte	Background	Occupational	Residential <sup>a</sup>	Plants	Avian	Mammalian		ARCS	Avian	Mammalian
Aluminum	11,165	110,000	7,700	_	_	_	_	25,500	_	_
Antimony	0.4	7	3.1	_	_	0.27	2	—	NA	0.27
Arsenic	8.3	3.0	0.67	18	43	46	9.8	—	43	46
Cadmium	0.3	98	7	32	0.77	0.36	0.99	—	0.77	0.36
Copper	12.2	4,700	310	70	28	49	31.6	—	28	49
Iron	9,045	82,000	5,500	_	_	_	20,000	—	_	_
Lead	24.6	800	400	120	11	56	35.8	—	11	56
Manganese	212	2,600	180	220	4,300	4,000	460	—	4,300	4,000
Nickel	4.4	-	_	38	210	130	22.7	—	210	130
Selenium	0.78	580	39	0.52	1.2	0.63	2	—	1.2	0.63
Silver	0.39U	580	39	560	4.2	14	1	-	4.2	14
Thallium	0.79U	1.2	0.078	_	_	_	—	-	_	-
Zinc	83.2	35,000	2,300	160	46	79	121	—	46	79

Notes:

mg/kg = milligrams per kilogram

<sup>a</sup> Residential soil screening levels from the EPA (2012a). *Regional Screening Levels for Chemical Contaminants at Superfund Sites*. (Carcinogenic effect TR = 10<sup>-6</sup>, Noncarcinogenic effect HQ = 0.1). Although residential scenarios are not expected onsite, these levels serve as conservative screening values.

<sup>b</sup> Eco soil screening levels from the EPA EcoSSL guidance serve as conservative estimates of minimum detection limits. *Guidance for Developing Ecological Soil Screening Levels (EcoSSLs)* (EPA, 2005).

<sup>c</sup> Sediment screening levels are from the EPA Region 3 Freshwater Sediment Screening Benchmarks. Available at:

http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm.

<sup>d</sup> National Oceanic and Atmospheric Association (NOAA). 2008. Screening Quick Reference Tables (SQuiRTs).

ARCS = assessment and remediation of contaminated sediments. PNEC = predicted no-effect concentration

U = non-detect

#### **Bioavailability of Arsenic and Lead in Soils**

A Crystal Mine Site-specific bioavailability study was conducted to provide a better understanding of the bioavailability of arsenic and lead in selected Site soils. This information was used to more accurately assess the potential risk to human and ecological receptors. The InVitro Bioaccessibility Procedure used an *in vitro* test to measure the fraction of a chemical solubilized from a soil sample under simulated mammalian gastrointestinal conditions. A detailed description of the analytical methods and test procedures is provided in Section 3.6.4 of the RI. The Mine-specific mean bioavailability factors of 6 percent for arsenic and 12 percent for lead provide a realistic assessment of risk to receptors at the Site.

#### 5.9.2 Mine Waste Volumes and Locations

Surface disturbance at the Site consists of access roads, a former surface trench, waste rock piles and dumps from mining activity, and disturbed areas around mine structures. Four locations have been delineated as primary contaminated soil and waste rock areas. They consist of the Crystal Dump (Exhibit 5-16), Twin Ore Bins and Dump (Exhibit 5-17), Mammoth Road (Exhibit 5-18), and Mammoth Dump areas (Exhibit 5-19).

EXHIBIT 5-16 Crystal Mine Dump



EXHIBIT 5-17 Twin Ore Bins and Dump



EXHIBIT 5-18 Mammoth Road



EXHIBIT 5-19 Mammoth Dump Area



A combination of photographs, test pit information and the Site topography (surveyed in 2009) was used to determine the perimeter for the four areas that were analyzed. For purposes of volume estimation, it was assumed that all material determined to be waste rock overburden and contaminated soils will be removed, exposing the natural, uncontaminated soils below.

Contaminated waste rock and soil volume estimates are shown in Table 5-9 for each of the four designated dump areas. A total volume of 59,151 cubic yards was calculated. The actual volume of material that will eventually be removed may be slightly more or less.

#### TABLE 5-9

**Contaminated Waste Rock and Soils Volume Estimates** 

Designated Waste Rock/Soil Area	Calculated Volume (cubic yards)
Crystal Dump	24,000
Twin Ore Bins and Dump	13,950
Mammoth Road Dump	833
Mammoth Dump	20,268
Total	59,151

#### 5.9.3 Sediment Concentration in Uncle Sam Gulch Creek

Sediment samples were collected as part of historic investigations in the Basin Watershed OU2 RI (CDM, 2005a and 2005b). In 2001, in-stream sediment samples were collected and analyzed as either minus 10-mesh, minus 80-mesh, or minus 260-mesh particles. The greatest COPCs concentrations were detected in the 260-mesh particle size. In Cataract Creek, the greatest COPC concentrations occurred in sediments from USG Creek. Arsenic, cadmium, copper, lead and zinc significantly exceeded ecological and human health benchmarks (CDM, 2005b). USG Creek was the largest source of contaminated sediment to Cataract Creek. Historic sediment data and data collected during the Basin Watershed OU 2 RI relevant to the Crystal Mine and USG Creek are presented in Table 5-10.

Collection		То	tal Concentration	(mg/kg – dry weig	ht)	
location	As	Cd	Cu	Hg	Pb	Zn
		Hi	storic Sediment Da	ita		
54S USG	39	ND	36	ND	34	161
22-073-SE1 Crystal USG	434	8.1	27.4	0.05	513	111
22-073-SE2 Crystal USG	1,900	1	203	0.06	999	487
55S USG	3,600	7	560	ND	1,900*	920
17B USG	825	30	1,253	ND	378	1,812
16B USG	3,942*	27	3,971	ND	1,025*	1,291
56S USG	3,900*	ND	220	ND	ND	2,700
57S USG	1,300	39	2,300	ND	920	3,800
		Minus 10-	Mesh Sediment Da	ata (2001)		
S020 USG	568	27	1,340	0.07U	333	1,700
		Minus 80-	Mesh Sediment Da	ata (2001)		
S020 USG	1,190	49.3	3,190	0.06	795	4,030
		Minus 260	-Mesh Sediment D	ata (2001)		
S020 USG	1,500	72.6	4,810	0.11	1,030*	6,080

#### TABLE 5-10 Metal and Arsenic Concentrations in Uncle Sam Gulch Creek from Historic and 2005 RI/FS Reports

Notes:

Data are from Basin Watershed OU2 RI and FS (CDM, 2005a; CDM, 2005b); Table 7.4-1

USG = Uncle Sam Gulch

ND = no data

Highlighted values exceed either human health or ecological benchmark values. See Table 5-1.

\* - exceeds both ecological and human health benchmarks

U = not detected, with reported detection limit

No actions to clean up USG Creek have been implemented since these data were collected. However, to assess current conditions, stream channel sediment samples were collected in 2012. The 2012 stream sediment samples were collected at the same locations as the 2010 water quality and benthic macroinvertebrate sampling, plus one additional sample at the mouth of USG Creek. Sediment samples were collected from the top 10 centimeters of sediment deposits and sieved through 10 mesh, 80 mesh and 230 mesh screens for comparison with previous results. Sediment samples were

analyzed for aluminum, antimony, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, thallium and zinc. Exhibit 5-20 shows the 2012 sediment sample locations and analytical results. Table 5-11 presents the results of the 2012 sediment sampling.



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#### LEGEND

- ▲ 2012 Sediment Data
- Mine Adit
- NHD Stream

#### Notes:

- Area of interest subject to change.
  2011 Imagery ArcGIS Streaming Map Service.
  Analytical results are in mg/kg.
  ND = Non-Detect



Exhibit 5-20 2012 RI/FS Sediment Monitoring **Locations and Analytical Results** Crystal Mine OU5 ROD

TABLE 5-11	
Summary of Sediment Results (Dry Weight) in mg/kg	

		110	G-01-SD			_	USG-02-	50					USG-02-FD			_		USG-03-SD		
Analyte	USG-01-SD 10 MESH 7/24/2012	U	USG-01-SD USG-01-SD 80 MESH 2/24/2012	USG-01-SD 23 MESH 7/24/2012	 USG-02-5 10 MESF 7/24/201	1	USG-02-S 80 MESH 7/24/201	D	USG-02-SI 230 MESH 7/24/2012	1	USG-02-FD-MS 10 MESH 7/24/201	Í	USG-02-FL USG-02-FL MS/MSL 80 MESH 7/24/201	)- 	USG-02-FD MS/MSD 230 MESH 7/24/2012	1	USG-03-SD 10 MESH 7/24/2012	USG-03-SD 80 MESH 7/24/2012	USG-03-SD 230 MESH 7/24/2012	Freshwater Sediment Screening Benchmarks
Aluminum	1,300	J 2,3	340	5,190	1,530		1,390		5,260		964		1,630		5,510		1,520	2,370	4,680	25,500
Antimony	1.7	J 20	0.9	28.1	26.9		20.3		55.9		9.7	J	49.6	J	65.3	J	4	23	42.5	0.27
Arsenic	193	J 5	46	1,360	317		735	J	3,800		317		1,870	J	3,830		80.5	1,300	2,470	9.8
Cadmium	3	1 8	3.9	21.2	6.2		16.8		71.6		8.7		32		67.9		2.9	21.7	37.3	0.36
Copper	21.2	63	3.7	113	84.7	J	196		755		260	J	269	J	817		44.3	129	270	28
Iron	3,400	5,2	110	12,800	4,880	J	13,300		43,900		10,400	J	17,300		33,700		4,040	8,060	17,200	20,000
Lead	77.8	J 2	55	753	268		527	J	2,110		316		1,160	J	2,160		82.7	408	1,100	11
Manganese	108	J 3	24	765	105	J	723		2,310		618	J	891	J	2,220		253	762	1,050	460
Nickel	0.67	1	2	3.3	0.84		0.99		3.6		0.63		1.2		3.5		1.3	1.6	2.9	23
Selenium	0.22	0.	.57	1.1	0.31		0.78		2.2		1.3		1.8		4.1		0.16	0.84	1.1	0.6
Silver	0.58	J 2	2.2	4.9	3.5	l	1.6	J	12.4		0.69	J	4.5	J	11.8		0.055	4.6	7.7	1.0
Thallium	0.16	0.	.29	0.75	0.15		1.4		4		1.5		2.2		4.5		0.15	0.73	0.76	NA
Zinc	43.3	1	12	281	168	J	450		1,360		412	J	580	J	1,460		188	453	747	46

			USG-04-SD					USG-04-	FD				CC-01-SD				CC-02-SD		
	USG-04-SD 10 MESH		USG-04-SD 80 MESH	,	USG-04-SD 230 MESH	USG-04-I 10 MES		USG-04-F 80 MESH		USG-04-FD 230 MESH	CC-01-SI 10 MESI		CC-01-SD 80 MESH		CC-01-SD 230 MESH	CC-02-SD 10 MESH	CC-02-SD 80 MESH	CC-02-SD 230 MESH	Freshwater Sediment Screening
Analyte	7/24/2012		7/24/2012		7/24/2012	7/24/20	12	7/24/201	L <b>2</b>	7/24/2012	7/24/201	12	7/24/2012	2	7/24/2012	7/24/2012	7/24/2012	7/24/2012	Benchmarks
Aluminum	2,320		3,180		6,650	1,420		2,610		5,130	3,340	J	3,840		5,170	1,800	2,340	6,680	25,500
Antimony	4.3		11.4		25.6	5.5		11.1		22.4	42.8		12	J	21.8	137	8.7	26.2	0.27
Arsenic	386		466		1,030	238		420		824	73.8	J	561		783	113	405	1020	9.8
Cadmium	18.5		20.4		32	11.6		17.7		27.8	4.8		21.1		25.7	8.2	16.7	31.8	0.36
Copper	337		429		654	224		376		567	79	J	381	J	461	121	268	632	28
Iron	16,600	J	13,400		23,000	1,170		11,800		19,400	6,480		14,600		18,900	4,610	7,550	21,200	20,000
Lead	1,030	J	315		687	5,190	J	324		544	315	J	265	J	603	96.9	177	635	11
Manganese	771		1,610		1,580	207	J	1,170		1,560	333		1,390		1,290	438	1,340	1,820	460
Nickel	1.8		2.6		4.1	1.5		2.3		3.6	2.4		2.9		3.3	1.3	2.2	4.3	23
Selenium	0.99		1.7		2	1.3		1.1		1.4	0.89		1.8		2	0.27	1.3	2.1	0.6
Silver	2.8	J	1.9		4.8	0.82	J	1.9		5.1	4	J	2.2		6.4	4.7	1	3.6	1.0
Thallium	1.3		0.68		1.1	0.83		0.53		0.85	0.16		0.75		1.1	0.15	0.72	1.7	NA
Zinc	493		787		1,200	359		600		1,040	253	J	736		926	298	577	1,360	46

Sediment values in Table 5-11 that exceeded the ecological benchmark criteria are in **bold**. The highest concentrations were generally observed in the smallest-size fraction (silt/clay) sized particles. However, for each sample, the smallest-size fraction represents the smallest percentage by weight of the sample. The concentrations of most analytes increase downstream from USG Station 1 to USG Station 4. Concentrations of antimony, arsenic, cadmium, copper, lead, manganese, selenium, silver and zinc all exceeded freshwater sediment screening benchmarks. Exhibits 5-21 through 5-24 show downstream trends of arsenic, lead, copper and zinc.

The results of the sediment sampling confirm findings from the previous Basin Watershed OU2 RI (CDM, 2005b) that enriched metalloid and trace metal concentrations in stream sediments are present in USG from the Crystal Mine to its confluence with Cataract Creek.

EXHIBIT 5-21



#### Arsenic Concentrations in Sediments, USG Creek

#### EXHIBIT 5-22



#### ES042314162509BOI

### EXHIBIT 5-23





#### EXHIBIT 5-24 Zinc Concentrations in Sediments, USG Creek



#### 5.9.4 Aquatic Resource Investigation

A benthic macroinvertebrate inventory (BMI) was conducted on USG Creek in late August to early September 2010 to assess the relative health of aquatic biota along the Crystal Mine reach. Five collection stations were sited—three along USG Creek, one in Cataract Creek, and one below the confluence of these two streams. Sample location USG-1 was above the Site. Sample location USG-2 was adjacent to the Site. The mine adit discharges directly to the stream about 50 meters below this sampling location. Sample location USG-3 was below the Site, while CC-4 was located in a depositional area below the confluence. Sampling location CC-5 was on Cataract Creek above the confluence (see Exhibit 5-25).

Organisms were collected in a rectangular net and preserved in 95 percent ethanol. In the laboratory, ethanol was rinsed and organisms were identified to the lowest level (genus or species) and enumerated. The following metrics were determined and they describe the status of the benthic macroinvertebrate community: taxa richness, density, composition and relative abundance. In addition, the percentages of stoneflies and mayflies were calculated. Comparisons of these metrics among the six collection stations were completed.

Monitoring locations in the Cataract Creek drainage supported relatively few macroinvertebrates.

Density estimates ranged from 3 to 600 organisms per square meter, with community density greatest above the Crystal Mine (USG-1) and declined to near zero below the mine (USG-3). In Cataract Creek, macroinvertebrate community density was higher above the USG confluence (CC-5) than below CC-4 (Exhibit 5-26).



### EXHIBIT 5-26



#### Notes:

Area of interest subject to change.
 2011 Imagery - ArcGIS Streaming Map Service

#### LEGEND

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





Exhibit 5-25 **Benthic Macro-Invertebrate Monitoring Locations** Crystal Mine OU5 ROD



A total of 53 macroinvertebrate taxa were identified from the monitoring locations. For all samples combined, individual locations yielded from 2 to 35 taxa. Mayflies, stoneflies and caddisflies (collectively EPT) accounted for 70 percent of the taxa collected. EPT richness was significantly higher in Cataract Creek above USG (CC-5) than at other monitoring locations (see Exhibit 5-27). Community composition analysis indicated that mayflies and stoneflies dominated the macroinvertebrate fauna at each monitoring location; species differences were found at the different collection locations.

#### EXHIBIT 5-27



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 size (area) of each sample, macroinvertebrates were sufficiently rare to preclude the standard, 300-organism risk-based prioritization (RBP) assessment used in Montana (MDEQ, 2006).

Nevertheless, these data clearly show impacts from mine tailings and toxic pollutants originating from the Site. 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 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 site approximately 80 meters upstream (CC-5).

## 5.10 Geology and Ground Water Investigations

Several investigations were conducted to gather subsurface information and provide basic geologic and hydrogeologic data to assist in evaluating remedial alternatives to reduce AMD.

#### 5.10.1 2010 Investigation

In order to characterize the geologic conditions and hydrogeologic regime, the 2010 investigation included drilling and logging a vertical deep boring to intercept the lower workings and video-logging this boring to evaluate conditions of the lower workings. Horizontal borings to drain the plugged lower adit were also drilled and logged to evaluate subsurface conditions and rock mass characteristics.

#### 5.10.2 2011-2012 Investigations

- A 2011 ground water source area investigation in the northwest wetland area included excavating test pits and installing piezometers at the soil/bedrock interface, and constructing three shallow to medium-depth piezometers in the bedrock aquifer under the wetland.
- A 2012 supplementary investigation included installation of deep bedrock monitoring wells to characterize the deep ground water aquifer. Ground water samples were collected, and geophysical mapping of preferential ground water flow paths was performed using Willowstick<sup>®</sup> Technology.
   Willowstick establishes an electric circuit in ground water through the area of interest and monitors from ground surface the resulting electro-magnetic field generated by the circuit. The magnitude and pattern of the readings through a defined survey area indicates potential ground water flow paths.

#### 2010 Rock Core Boreholes

The initial drilling and geologic exploration was conducted in August 2010. Two lower adit borings were drilled to drain water impounded in the mine by the caved portions of the lower adit, and to assess host rock conditions in preparation for opening the adit portal. The lower adit borings were drilled slightly-above-horizontal (approximately 1 degree) and approximately 87 and 111.5 feet deep. The rock surrounding the adit consists primarily of medium- to coarse-grained, moderately to highly weathered granitic rock. When each of these borings intercepted the adit, a flow of approximately 150 gpm was measured discharging from the boreholes as the water drained out of the flooded lower adit. The discharge was directed into the existing settling ponds.

Rock core boring CM-B-3 was drilled vertically to a depth of approximately 300 feet to intercept the western end of the lower workings and characterize the rock mass in this vicinity. This boring indicated that the rock in the hanging wall of the Crystal vein consists of medium- to coarse-grained granitic rock with a greenish appearance, and ranged from fresh to slightly weathered to moderately to highly weathered granite that was largely reduced to fractured pieces and clayey rubble. A 3-inch steel casing was installed in this boring.

A downhole video survey was conducted in order to assess existing conditions in the lower workings and observe ground water inflow or mine flooding. Overall, the integrity of the mine workings appears not to be compromised in the vicinity of the boring. Ground water inflow of less than 1 gpm was observed dripping down the hole and falling past the camera. However, the lower mine workings were not flooded.

#### 2011 Wetland Investigation - Test Pits and Shallow Piezometers

**Test Pit Investigation**. The test pit investigation was conducted to evaluate ground water flow in the shallow subsurface and measure depth to solid bedrock to determine if the area was suitable for a surface water and shallow ground water collection/diversion system. Thirteen test pits were excavated to the surface of the hard, but fractured, granitic rock.

Test pit logs documented the lithology, depth of soil and weathered rock, and presence of ground water. In test pits where moisture or seepage was observed, 10-foot-long, 1-inch slotted polyvinyl chloride (PVC) pipe standpipe piezometers were installed to evaluate shallow ground water conditions.

The subsurface stratigraphy in the test pits generally consisted of surficial soils overlying a zone of fractured and weathered granite that overlies hard granitic bedrock between 2 and 6 feet deep. The upper weathered granite layer was decomposed into silty sand, clayey sand, and sandy clay, and exhibited relic crystalline rock texture and structure. The non-weathered granite was typically gray and hard but fractured near the surface.

Seepage from the test pit walls was typically observed between 4.5 and 7 feet below ground surface (bgs), and was most commonly discharging from stained fractures and loose sandy zones in the highly weathered granitic rock, rather than at the soil-bedrock interface. The test pit observations indicated that the shallow subsurface water in the wetland area was not perched in the uppermost surficial soils, but rather was discharging from fractures and weathered sandy zones within the bedrock.

**Drilling and Piezometer Construction**. The 2011 hydrogeologic exploration in the wetland area was conducted to evaluate the subsurface rock properties, presence of fractured and weathered saturated zones, and evaluate vertical ground water flow in the fractured bedrock aquifer. The borings were drilled to depths of 25, 80 and 138 feet. The piezometer casings and screens consisted of 1-inch-diameter, schedule 40 PVC with a 10-foot section of slotted screen. A sandpack was poured around each screen for a filter, and a bentonite seal was poured into the remainder of the annular space for a surface seal.

The boreholes for the piezometers were drilled open-hole. The borings indicated that the subsurface consists of weathered brownish-gray granite with clayey zones alternating with hard, gray granite with greenish mineral alteration and fractured quartz veins. The boreholes all produced water throughout their depth, suggesting that numerous water-bearing fractures and zones are present in the subsurface and that the subsurface is generally saturated in the upper 140 feet. Depth to ground water in each piezometer was measured after allowing full water level recovery following piezometer development. The highest ground water level elevation was measured in CWB-3, which had the deepest screened interval, with a static water level of 1.2 feet above the ground surface. This indicates that artesian conditions exist at depth. Piezometers CWB-2 and CWB-also exhibited artesian conditions.

The ground water elevations in the piezometers were used to calculate vertical ground water gradients. The data indicate an average upward vertical gradient of 0.02 foot per foot between wells CWB-3 and CWB-1. The upward vertical gradient indicates that the ground water flows upward through the subsurface through fractured zones in the rock. The presence of these artesian conditions in the upper 140 feet of the subsurface indicates a transmissive zone of ground water discharge fed by a larger higher-elevation recharge area.

## 2012 Wetland Investigation – Deep Monitoring Well Construction and Geophysical Ground water Mapping

Four deep ground water monitoring wells between 150 feet bgs and 300 feet bgs were installed and sampled in 2012. The monitoring well casing and screens consisted of 2-inch or 4-inch-diameter PVC with 20-foot screen sections. Exhibit 5-28 shows the monitoring well locations and the potentiometric surface contours.





#### LEGEND

- Mine Adit
- Piezometer Set in Test Pit
- + Intermediate Depth Piezometer
- Test Pit (No Piezometer)
- Horizontal Boring
- Vertical Boring
- Monitoring Well 2-inch Diameter
- Monitoring Well 4-inch Diameter
- Groundwater Elevation (ft msl) (Deep Monitoring Wells)
- Crystal Mine,1936 Map,
- 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

#### Notes:

- Area of interest subject to change.
  2011 Imagery ArcGIS Streaming Map Service.



Exhibit 5-28 Geologic Investigations: Test Pit, Borings, & Monitoring Well Locations Crystal Mine OU5 ROD

The depth to ground water at paired wells CMW-1 and CMW-2 shows that the vertical hydraulic gradients in the deep wells is downward, which is in contrast to the upward gradient observed in the shallower piezometers installed in the wetland in 2011.

During the development of each well, it was observed that recharge to these deep wells was very slow, which precluded constant-rate aquifer testing. The slow recharges indicated very low primary porosity and no apparent secondary (fracture) porosity in the bedrock in the screened interval. In order to evaluate the hydraulic conductivity of the deep fractured bedrock, water level recovery testing was conducted in two of the wells.

Estimated hydraulic conductivity values ranged from 1.62E-02 to 6.14E-02 foot/day. 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.

Permeable fractures were encountered at depths that produced large quantities of ground water from weathered/fractured zones. This confirms that the hydraulic conductivity can vary significantly over short distances at this Site, reflecting a large range of hydraulic conductivity and that ground water movement is occurring largely through discrete fractures and isolated fractured zones in the bedrock.

**Deep Monitoring Well Ground Water Sampling**. Each of the newly installed deep ground water monitoring wells was sampled for total metals, dissolved metals, chloride, sulfate and alkalinity. Table 5-12 summarizes the analytical results of the ground water sampling conducted at each well. Total and dissolved concentrations of arsenic and lead exceeded benchmark screening levels in CMW-3, which was drilled close to the Crystal vein. Concentrations of the other metals were also elevated in CMW-3 compared to the other wells.

#### TABLE 5-12 Crystal Mine Ground Water Quality Laboratory Results—Validated

	Date Sample					_	-		Tota	l Metals (	µg/L)					_						-	-	Dissolvec	Metals	(µg/L)					-	Ani (mį	ions g/L)	Alkali (mg	
Site	Collected	AI	Sb	As	Cd	Ca	Cu	Fe	Pb	Mg	Mn	Ni	к	Se	Ag	Na	ті	Zn	AI	Sb	As	Cd	Cu	Fe	Pb	Mn	Ni	Se	Ag	ті	Zn	CI	SO <sub>4</sub>	CaCO <sub>3</sub>	Total
CMW-1	9/11/2012	2520	2.1	5.6	0.05U	19,700	2	1,300	1.6	4,410	25.9	2.5U	3,560	0.77J	0.05U	44,900	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	14,200	0.93U	20.0U	0.5U	3,440	5.7	2.5U	8,20J	0.5U	0.05U	8,120	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	14,200	0.93U	20.0U	0.5U	3,450	7.1	2.5U	8,16J	0.5U	0.05U	9,960	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	37,400	1.4	20.9	0.24	29,200	21.6	16,200	43.6	10,400	298.0	9.4	6,980	2.2	0.22	20,900	0.5U	117.0	20,000	1.3	16.5	0.17	18.4	10,400	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	23,800	0.91J	14.2	0.18	35,800	57.7	12,600	32.2	8,900	336.0	8.0	6,350	1.8	0.15	20,400	0.5U	144.0	21,400	1.3	16.4	0.19	48.5	12,000	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	13,500	2.5	57	0.5U	3,490	17.3	2.5U	1,640	0.5U	0.05U	7,600	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
Montana D 7 WQ Stand (Human He MDEQ, (202	lards alth)		6.0	10	5		1,300		15.0			100		50	100		2	2,000		6.0	10	5	1,300		15		100	50	100	2	2,000				

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, with Revision 1993, Addendum)

ND = Not Detected at or above adjusted reporting limit

**Bolded Values** indicate an exceedance of ground water screening levels.

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

MS/MSD = matrix spike / matrix spike duplicate

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 = field duplicate

\*DEQ-7 standards specify that "Standards for metals (except aluminum) in surface water are based upon the analysis of samples following a "total recoverable" digestion procedure (EPA Method 200.2, Supplement I, Rev. 2.8, May, 1994)."

**Geophysical Ground Water Mapping.** Willowstick<sup>®</sup> Technology was used to geophysically map preferential ground water flow paths. Three surveys were conducted to target shallow, medium and deep profiles above the lower adit.

Four zones of potential infiltration into the lower adit were identified as a result of the investigation, based on preferential electric current flow and discrete or "channelized" flow in the shallow subsurface. The surveys also indicated where electric current (indicating ground water) possibly flows down and potentially intercepts the upper and lower adits.

In addition, the geophysical surveys indicated linear geologic structures interpreted to be faults or transmissive fractured zones that appear to influence ground water flow through the subsurface. These features are more pronounced in the shallow reaches, signifying that the subsurface is less fractured, less transmissive and more homogeneous with depth showing fewer ground water flow paths and less overall saturation. Thus, the shallower area is overall more saturated, and with depth the ground water flow becomes more concentrated into discrete fractures. This is consistent with the observations made during the drilling of the intermediate depth piezometers, and also the deep monitoring wells.

## 5.11 Hydrogeologic Findings

Ground water recharge in the vicinity of the Site originates from snowmelt and precipitation at topographic highs. Recharge is greatest in areas with higher hydraulic conductivity, such as zones of densely fractured rock and exploratory shafts, raises and pits. Ground water discharge occurs as numerous small springs and seeps in topographic lows, slope breaks, at lithology changes, and from the lower Crystal adit portal. Evidence for the meteoric influence on the Crystal adit discharge was previously discussed in detail in Section 5.8.1.

Study findings indicated that shallow ground water in the vicinity of the northwest wetland area occurs within discrete fractures and the weathered zones in granitic rock, rather than as diffuse seepage and flow through the unconsolidated soils at the soil/bedrock interface. Ground water discharges upward through the fractures in the weathered granite rather than infiltrating downward.

North and east of the Crystal trench, the depth to ground water in deeper monitoring wells shows a downward vertical gradient, in contrast to the upward vertical gradient observed in the shallower piezometers. These data illustrate the complexity of the local bedrock ground water system. Hydraulic conductivity values in the deeper aquifer are consistent with accepted and published values for slightly fractured, dense, competent crystalline rock.

However, the hydraulic conductivity can vary significantly over short distances at this Site, and ground water production is limited to specific fractures.

The investigation and geophysical modeling performed by Willowstick<sup>®</sup> Technology also showed that ground water flow was more diffuse and prominent in the shallow depth and is strongly controlled by fracture orientation and fracture permeability. The Willowstick<sup>®</sup> Technology findings indicated that the fractures are more pronounced in the shallow zone (5 to 150 feet bgs), implying that the subsurface becomes less fractured and thus less saturated overall with increasing depth, and ground water movement is confined to discrete fractures rather than throughout a large, highly fractured transmissive zone.

The shallower portion of the bedrock aquifer is more fractured and saturated, and discharges primarily upward in the vicinity of the wetland area. With depth, the ground water flow concentrates into fewer, more discrete, fractures. This is consistent with the observations made during the test pit excavations, drilling the intermediate depth piezometers and deep monitoring wells, and also confirmed by the geophysical mapping. The deep structural geologic features appear to create a potential hydraulic pathway in the vicinity of the western end of the lower workings. Furthermore, the complexity of the ground water system as described reinforces the difficulty of intercepting or controlling ground water that is seeping into the lower workings.

The potential for ground water from this Site to flow into a regional aquifer appears limited because of its remote location.

## 5.12 Crystal Mine Wetland Inventory

The wetlands at the Site were jurisdictionally delineated through the methods defined in the 1987 U.S. Army Corps of Engineers (USACE) Manual and the Regional Supplement for Western Mountains, Valleys, and Coast Region (USACE, 2010). The purpose of the mapping was to establish a baseline from which to help gauge the overall effect of remedial activities on the wetlands at the Site. Four wetland areas were evaluated with results provided in Table 5-13. Maps (Exhibits 3-23 and 3-24) delineating these areas are found in the RI.

**TABLE 5-13** 

Jurisdictional and Functional Wetlands Delineated by Area

Area Evaluated	Jurisdictional Wetlands (Acres)	Functional Wetland (Acres)
Large northwest wetland, north of road	8.6	17.4
Small northwest wetland, south of road	0.4	2.8
USG Creek	0.6	0.6
Lower seep area, south	0.3	0.3
Total	9.9	21.1

## 5.13 Riparian Wetland Health Assessment

A lotic wetlands (riparian) health assessment was performed on USG Creek in 2010. The assessment evaluated riparian health and vigor against pre-determined criteria and in comparison to other local representative, disturbed and undisturbed riparian areas. The findings are relevant as a means of assessing impacts resulting from the mining activity. The impacted portion of USG Creek was rated as "Nonfunctional or Unhealthy" using this evaluation system. A complete discussion of methods and results is found in Section 3.4.11 and Appendix H of the RI.

# Section 6. Current and Reasonably Anticipated Future Land and Resource Uses

This section describes the current and reasonably anticipated future land uses and current and potential beneficial surface water and ground water uses at or near the Site. Understanding these resource uses is important to the EPAs decision-making process because it helps ensure that the selected remedy is protective of human health and the environment, and is accepted by the community. Community and stakeholder input was acquired and considered during the process to identify current and future uses of these resources at or near the Site. The information presented in the following subsections form the basis for the risk characterization conclusions presented in Section 7.

## 6.1 Land Use

The majority of the land within the Basin watershed is managed by the USFS or BLM. The historic land use for claim properties in the watershed has been mining. The watershed is sparsely populated with limited residences located along the mainstem of Basin and Cataract Creeks, and the Town of Basin is located at the mouth of the watershed. The Site is located in the upper Basin watershed, is currently abandoned and unoccupied, and is typically covered with snow for about 8 months per year.

## 6.2 Human Land Uses

Human land uses within the vicinity of the Site include historical mining, and seasonal recreational use (for example, hiking, all-terrain vehicle [ATV] riding, camping and big game hunting). Motorized use (including ATV or motorcycle riding) at the Site is largely limited to the roadway as a result of steep terrain, boulders and woody debris. Given the present understanding of baseline conditions at the Site including its remote location, steep land slopes, high elevation, unreliable domestic water source, underground mine workings and unconsolidated material on which to build structure, residential use at the Site is improbable.

## 6.3 Ecological Land Uses

Habitat in the watershed is primarily forest land dominated by lodgepole pine and, to a lesser extent, by subalpine fir, Douglas fir, Engleman spruce, quaking aspen and common juniper. A large variety of grasses, shrubs and small trees, including some of those previously mentioned, are commonly found along creek banks and in isolated stands in open areas. Isolated wetland areas exist within the floodplains of the smaller tributaries in the upper (northern) portions of Cataract Creek. The mined areas where large mechanical disturbances occurred and where waste rock remains are largely devoid of vegetation.

Habitat at the Crystal Mine and within its surrounding area is sufficient to support a variety of wildlife species, including piscivorous birds, omnivorous birds, raptors, small burrowing mammals and large game species. Raptors found in the area include eagles and goshawks. Among the mammals potentially using the watershed are snowshoe hair, deer, elk, moose, black bear and small mammals (for example, mice). Current lists of endangered, threatened, proposed and candidate species obtained from USFWS, MDFWP and the MNHP suggest that the Canada lynx and grizzly bear have the potential of using habitats consistent with those found at the Site. However, both of these mammals are large carnivores with foraging areas significantly greater than the area occupied by the Site, so they would likely travel through the Site to better habitat.

## 6.4 Surface Water Use

USG Creek flows along the eastern boundary of the Site. USG Creek is expected to provide an aesthetic quality, support aquatic life typical of high-altitude first-order streams, and recharge downgradient streams. USG Creek flows into Cataract Creek approximately 2.8 miles downstream from the mine adit discharge. MDEQ classifies Cataract Creek and USG Creek as B-1. The B-1 classification states that the water quality of the stream must be sufficient to support recreational activities such as bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life and waterfowl and furbearers; agricultural and industrial water supply; and drinking, culinary and food processing purposes after conventional treatment. Water from Cataract Creek eventually recharges the Boulder River and shallow alluvial aquifers which are a source of drinking water for the Town of Basin.

## 6.5 Ground Water Use

There are no current or reasonably anticipated future uses of the limited ground water at the Site. The need to develop ground water resources at this remote high alpine site (approximately 8000 ft amsl) is unlikely due to its limited access, severe climate and being surrounded by federally owned lands (Beaverhead – Deerlodge National Forest). Ground water development may not be feasible because of unpredictable recharge from low permeability fractured bedrock. No drinking water wells are located within or adjacent to the Site. Therefore, ground water use is limited to the recharge of nearby surface water bodies (for example, USG and Cataract Creeks).

## Section 7. Summary of Site Risks

This section of the ROD summarizes the Site risks associated with residual contamination at the Site. Human health and ecological risk assessments (HHRA and ERA, respectively) were conducted to evaluate whether, in the absence of any remedial action, mining-related metals contamination at the Site poses an unacceptable risk to human or ecological receptors. Site risks provide the basis for taking action and identify the contaminants and exposure pathways that need to be addressed by remedial actions. A summary of the results of the HHRA and ERA is presented in the following subsections. More detailed information regarding the risk assessments is available in the RI (EPA, 2013).

## 7.1 Human Health Risk Assessment

The HHRA was conducted to estimate risk for potentially complete exposure pathways assuming no remedial action is taken. The purpose of the HHRA was to determine whether a potential for unacceptable risk to human health exists under current and reasonably anticipated future Site-use conditions. Data used in the HHRA were collected during the RI and were validated, evaluated, and determined to be representative of Site conditions and exposures, and of high enough quality to use in the HHRA. The results were used to identify the COCs that were the focus of the feasibility study and that require remedial action.

#### 7.1.1 Contaminants of Concern

Based on historical investigations in the Basin watershed and the conceptual site model, 13 contaminants were evaluated as COPCs at the Crystal Mine. Of the 13 COPCs, arsenic in soil and seep/spring water was identified as the only COC associated with human health for current recreational users (adult and adolescent) of the Site. Arsenic in soil was also identified as a COC for the hypothetical future industrial worker exposure scenario.

Potable use of ground water is currently not occurring at the Site. Total and dissolved concentrations of arsenic and lead did exceed benchmark screening levels (and DEQ-7 standards) in one monitoring well drilled close to the Crystal vein. Concentrations of the other metals were also elevated compared to the other wells.

#### 7.1.2 Exposure Assessment

The exposure assessment component of the HHRA identified the populations that could be exposed, the routes by which these individuals could become exposed, and the magnitude, frequency and duration of potential exposures. Human health effects associated with exposure to the contaminants of potential concern were estimated through the development of several current and hypothetical future exposure pathways. The exposure pathways were developed using the conceptual site model and reflect the potential for exposure to hazardous substances based on the present and reasonably anticipated future land and water uses (see Section 6) of the Site. The potential pathways for human health exposure are depicted on the conceptual exposure model, presented in Exhibit 7-1 and described in Section 6 of the RI (EPA, 2013).



Notes: C = Potentially complete pathway; quantitatively evaluated in the risk assessment

-- = Incomplete pathway

I = Potentially complete pathway; considered insignificat and not quatitatively evaluated in the risk assessment

		Potent	ial Rec	eptors		
Current and Future Recreational Users (Adolescent and Adult)	Future Intermittent Worker	Future Excavation Worker	Hypothetical Industrial Worker	Terrestrial Wildlife (birds and mammals)	Vegetation (upland plants)	Aquatic Biota (fish and invertebrates)
		С				
		C I				
					 C	
	С	С	С	C		
C   		  	  	 C	 C 	
	Ι				C 	
    C	  			 C		
    C	I  C			 C I		
    C	I  C	  C		 C		   
    C	I  C	  C	  C	 C I		
    C	I  C	  C	  C	 C I		
  C C 	I C	 C	  C	 C I C		
I  I C C  	I  C  	 C	 C  	 C I 		
    C   C	I  C  	 C	 C  	 C I   C		   
I  I C C  	I  C  	 C	 C  	 C I 		

EXHIBIT 7-1 CRYSTAL MINE CONCEPTUAL EXPOSURE MODEL FOR POTENTIAL HUMAN HEALTH AND ECOLOGICAL RECEPTORS Crystal Mine OU5 ROD

The Site and nearby lands are currently used mainly for recreation and it is reasonably anticipated that land use will remain recreational in the future. The Site is of potential human health concern to EPA because historical mining activities have resulted in the release of contaminants to soil, surface water, ground water and sediment, and excessive human exposure to mining-related contaminants can lead to adverse health effects. The most plausible current or future human receptor populations that were evaluated for the Site include the following:

- ✓ Future intermittent workers (for example, road maintenance, environmental sampling, Forest Service workers).
- ✓ Future adult and adolescent recreational users (for example, hikers, ATV riders or hunters).
- ✓ Future excavation workers (for example, excavation during remedial actions).

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 (at springs/seeps and in USG Creek) by recreational users.

As described in Section 6, the Site conditions preclude residential use and it is also unlikely that standard occupational worker scenarios would occur at the area of interest in the future. However, to provide a comparative perspective for decision making, conservative risk estimates for a hypothetical occupational worker scenario were considered in the HHRA. Although the Basin watershed may also be used for fishing, USG Creek near the mine Site is characterized as a high-altitude, small (both narrow and shallow), first-order stream not capable of supporting fish sizable enough for human consumption. Therefore, angler exposure scenarios were not considered.

#### 7.1.3 Toxicity Assessment

The toxicity assessment component of the HHRA evaluated the relationship between the magnitude of exposure to a chemical at the Site and the likelihood of adverse health effects to potentially exposed populations. This assessment provided a numerical estimate of the increased likelihood of adverse effects associated with chemical exposure. Arsenic toxicity data used in the toxicity assessment are presented in Table 7-4 since arsenic was the only COC in soil identified in the HHRA. The toxicity assessment contained two steps, hazard characterization and dose-response evaluation. MDEQ compares ground water and surface water directly to the Circular DEQ-7 Numeric Water Quality Standards, and considers any exceedance of the human health standards to be a risk.

#### 7.1.4 Risk Characterization

In the risk characterization component of the HHRA process, quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values identified in the toxicity assessment) to provide numerical estimates of potential health effects. The quantification approach differs for potential noncancer and cancer effects. The evaluation of cancer risk and noncancer risk for all contaminants of potential concern are presented in the HHRA chapter of the RI (EPA, 2013). This section of the ROD focuses on the exposure scenarios and contaminants identified as posing unacceptable risk in the HHRA.
Although this HHRA produces numerical estimates of risk, it should be recognized that these numbers might not predict actual health outcomes because they are based largely on hypothetical assumptions. Their purpose is to provide a frame of reference for risk-management decision-making. Any actual risks are likely to be lower than these estimates. Interpretation of the risk estimates provided should consider the nature and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding them. The potential for unacceptable human health risk at the Crystal Mine was identified using the following risk thresholds:

- In interpreting estimates of excess lifetime cancer risks, the EPA under the Superfund program generally considers action to be warranted when the multi-chemical aggregate cancer risk for all exposure routes within a specific exposure scenario exceeds the  $1 \times 10^{-4}$  risk range. The NCP directs that the "point of departure" for contaminants that do not have an ARAR should be  $1 \times 10^{-6}$ . Action generally is not required for risks falling within  $1 \times 10^{-6}$  and  $1 \times 10^{-4}$ ; however, this is judged on a case-by-case basis. Under state guidance, MDEQ considers a cancer risk exceeding  $1 \times 10^{-5}$  as unacceptable risk.
- Under the EPA and MDEQ guidance, a hazard index (HI) (the ratio of chemical intake to the RfD for all constituents) greater than 1 indicates that some potential exists for adverse noncancer health effects associated with exposure to the COPCs (EPA, 1991).

#### **Cancer Risk Estimation Method**

The potential for cancer effects is evaluated by estimating lifetime cancer risk (ELCR). This risk is the incremental increase in the probability of developing cancer during one's lifetime in addition to the background probability of developing cancer (that is, if no exposure to Site constituents occurs). For example, a  $2 \times 10^{-6}$  ELCR means that, for every 1 million people exposed to the carcinogen throughout their lifetimes, the average incidence of cancer may increase by 2 cases of cancer. In the U.S., the background probability of developing cancer for men is a little less than one in two, and for women a little more than one in three (American Cancer Society, 2003). Although synergistic or antagonistic interactions might occur between cancer-causing constituents and other constituents, information is generally lacking in the toxicological literature to predict quantitatively the effects of these potential interactions. Therefore, cancer risks are treated as additive within an exposure route in this assessment. This is consistent with the EPA guidance regarding risk assessment of chemical mixtures (EPA, 1986).

#### Noncancer Risk Estimation

For noncancer effects exposures, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular constituent with the highest level of exposure that is considered protective. The ratio of the chronic daily intake divided by RfD (or RfC) is termed the hazard quotient (HQ). Oral, dermal and inhalation HQs are summed to provide the total HQ for an individual COPC. When the HQ for a COPC exceeds one (that is, exposure exceeds RfD or RfC), there is a concern for potential noncancer health effects. To assess the potential for noncancer effects posed by exposure to multiple constituents, a HI approach was used according to the EPA guidance (EPA, 1989). This approach assumes that the noncancer hazard associated with exposure to more than one constituent is additive; therefore, synergistic or antagonistic interactions between constituents are not accounted for. The HI may exceed 1 even if all the individual HQs are less than 1. In this case, the constituents may be segregated by similar mechanisms of toxicity and toxicological effects. Separate HIs may then be derived based on mechanism and effect.

#### Summary of Risk Estimates by Exposure Scenario

The evaluation of cancer risk and noncancer risk are described, but risk estimates are only summarized for the media, contaminant (for example, arsenic) and the exposure scenarios for which unacceptable risk was identified. The risk estimates for these are provided in Table 7-1. More details regarding the risk estimates calculated for the other media, COPCs and exposure scenarios are provided in Section 6 (for example, the HHRA) of the RI (EPA, 2013).

#### Uncertainties in the Human Health Risk Assessment

Full characterization of risks to human health requires that the numerical estimates of risk presented in the risk assessments be accompanied by a discussion of the uncertainties inherent in the assumptions used to estimate those risks. Considering this, the risk results are themselves uncertain, and it is important for risk managers and the public to keep this in mind when interpreting the results of a risk assessment. Uncertainties in risk assessment methods may result either in understating or in overstating the risks, although the latter is likely the case because health-conservative assumptions are used to characterize risk. Several key uncertainties are described below:

- The degree to which sample collection and analyses reflect real exposure concentrations will influence the reliability of the risk estimates. Because the Site investigations have generally focused on sampling close to suspected source areas at the mine, rather than at areas where exposure are most likely, exposure point concentrations used for the risk estimates may be biased high.
- The estimation of exposure in this risk assessment required many assumptions. There are uncertainties regarding the likelihood of exposure, the frequency of contact with contaminated media, the concentrations of chemicals at exposure points and the total duration of exposure. The human exposure assumptions used in the risk estimates are intended to be conservative and likely overestimate the actual risk or hazard.
- The risk estimates for the recreational users assume the use of ATVs and the exposures for this scenario are uncertain because the concentration of arsenic in air was not measured directly but was estimated using a screening-level soil-to-air transfer model. Additionally, dust levels during ATV use depends on a number of factors and is expected to be highly variable. However, the particulate emissions factor (PEF) used for the recreational user scenarios was derived from empirical data and is expected to provide a reasonable upper-end measure of exposure.
- Furthermore, current conditions at the Site (for example, large woody debris, steep slopes and boulders) reduce the likelihood that significant ATV use could occur. Thus, risk estimates for arsenic should be considered uncertain, and true risks are more likely to be smaller than the calculated risks.
- There is a relatively high level of uncertainty associated with the evaluation of exposure and risks to springs/seeps, since the results are based on a limited data set and the degree of attenuation of seep water is expected to be considerable upon discharging and mixing into the USG Creek. The risk assessment conservatively assumes these could be used intermittently as drinking water sources.
- Uncertainties in toxicological data can also influence the reliability of risk management decisions. The toxicity values used for quantifying risk in this risk assessment have varying levels of confidence that may affect the confidence in the resulting risk estimates. The general sources of toxicological uncertainty include the following:
  - Extrapolation of dose-response data derived from high-dose exposures to adverse health effects that may occur at the low levels seen in the environment.
  - Extrapolation of dose-response data derived from short-term tests to predict effects of chronic exposures.
  - Extrapolation of dose-response data derived from animal studies to predict effects on humans.
  - Extrapolation of dose-response data from homogeneous populations to predict effects on the general population.

#### TABLE 7-1

#### Summary of Human Health Risks Above Appropriate Risk Levels

Receptor	Media	Pathway	Chemical of Concern	EPC Soil (mg/kg)/ Water (ug/L)	RME Cancer Risk	RME Non-Cancer Hazard (HQ)	CTE Cancer Risk	CTE Non-Cancer Hazard (HQ)	
Future Intermittent	Surface Soil*	Ingestion	Arsenic	2,256	9E-06	0.3	4E-06	0.3	
Worker	(0-2 inches bgs)	Inhalation	Arsenic	2,256	3E-08	0.01	4E-09	<0.01	
Future Recreational	Surface Soil*	Ingestion	Arsenic	2,256	4E-05	0.2	2E-06	0.03	
User - Adult	(0-2 inches bgs)	Inhalation	Arsenic	2,256	1E-04	5	6E-06	0.6	
-	Surface Water	Ingestion	Arsenic	19.4	3E-05	0.2	1E-05	0.05	
-	Springs/Seeps	Ingestion	Arsenic	10.3	2E-05	0.08	6E-06	0.03	
Future Recreational	Surface Soil*	Ingestion	Arsenic	2,256	3E-05	0.9	2E-06	0.1	
User - Adolescent	(0-2 inches bgs)	Inhalation	Arsenic	2,256	3E-05	5	2E-06 2E-06	0.6	
	Surface Water	Ingestion	Arsenic	19.4	9E-06	0.05	3E-06	0.01	
-	Springs/Seeps	Ingestion	Arsenic	10.3	5E-06	0.03	1E-06	<0.01	
Excavation Worker	Subsurface Soil	Ingestion	Arsenic	3,685	3E-05	0.7	2E-06	0.4	
	(0-10 feet bgs)	Inhalation	Arsenic	3,685	2E-08	<0.01	2E-09	<0.01	
Hypothetical Industrial	Surface Soil*	Ingestion	Arsenic	2,256	9E-05	0.6	1E-05	0.3	
Worker	(0-2 inches bgs)	Inhalation	Arsenic	2,256	3E-07	0.01	8E-08	0.01	

Notes:

**Bold** represents an exceedance a cancer risk of 10<sup>-5</sup> or hazard quotient greater than 1.

\* Note: MDEQ considers 0-2 feet bgs to be surface soil.

### 7.2 Ecological Risk Assessment

An ERA was conducted to estimate risk for potentially complete exposure pathways assuming no remedial action is taken. The ERA provides an assessment of the potential for adverse impacts of past releases to soil, sediment and surface water on aquatic resources and wildlife users in the vicinity of the Site (Note: MDEQ compares surface water directly to the Circular DEQ-7 Numeric Water Quality Standards, and does not conduct a separate risk assessment). The overall objective of the ERA was to quantitatively and qualitatively evaluate baseline or existing exposure and risks to ecological receptors, and to provide risk managers with information needed to achieve their ecological management goals and help determine remedial decisions, as necessary.

The ERA characterized the ecological communities at and in the vicinity of the Site, identified complete ecological exposure routes, identified contaminants of ecological concern and determined whether ecological exposures are high enough to pose unacceptable risks. The ERA used multiple lines of evidence to determine whether any releases at the Site could pose unacceptable risk to these ecological receptors.

The ERA followed the eight-step approach recommended by EPA (1997). More information on the process can be found in the risk assessment section of the RI.

The Crystal Mine ERA and its findings are summarized in the following sections. More detail can be found in the RI (EPA, 2013).

The following were identified in the screening level ecological risk assessment (SLERA) as contaminants (chemicals) of potential ecological concern (COPECs) for their respective exposures:

- Soil (plants)—aluminum, antimony, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, zinc
- **Soil** (wildlife)—aluminum, antimony, arsenic, cadmium, copper, iron, lead, nickel, selenium, silver, zinc
- Surface Water (aquatic organisms)—aluminum, arsenic, cadmium, copper, iron, lead, manganese, nickel, zinc
- **Sediment** (benthic infauna)—antimony, arsenic, cadmium, copper, iron, lead, manganese, selenium, silver, thallium, zinc

#### 7.2.1 Baseline Ecological Risk Assessment (BERA) Problem Formulation

Upon completion of the SLERA, several metals/metalloids were identified as COPECs and were carried forward for additional evaluation in the baseline ecological risk assessment (BERA) problem formulation. The BERA begins with a refinement of the COPECs, in which the conservative assumptions used in the SLERA are refined and risk estimates are calculated with exposure models that allow use of more site-specific assumptions. This ROD focuses on the ecological risk estimates for the media, contaminants and exposure scenarios for which unacceptable risk was identified. More detail information is available in the risk assessment (Section 6) of the RI (EPA, 2013).

A summary of the risk results is provided in the following sections separately for plants, aquatic resources, benthic infauna and wildlife (mammals and birds).

**Risk Characterization for Plants.** These terrestrial plant screening benchmarks for COPECs are summarized in Table 7-7. The results indicate that concentrations for the following eight COPECs exceeded benchmarks and levels measured at background locations: antimony, arsenic, cadmium, copper, lead, manganese, selenium and zinc.

Exceedances occur in both surface and subsurface soils, with the greatest factors of exceedances being from antimony and arsenic. Antimony and arsenic COPECs were also greater than 10 times above background levels. These results indicate that soil concentrations at the Site exceed levels known to pose a risk to vegetation and the levels of the COPECs at the Site are above measured background levels.

**Risk Characterization for Aquatic Resources.** To provide confidence in any decision making regarding aquatic resources in the USG Creek and downgradient streams, potential effects on aquatic communities are assessed using an approach that considers multiple lines of evidence collectively.

A summary of COPEC concentrations detected in surface water compared with surface water benchmarks is provided in Table 7-2. The results indicate that acute water quality criteria (WQC) were exceeded for dissolved aluminum, dissolved cadmium, dissolved copper and dissolved zinc. Chronic WQC were exceeded for dissolved aluminum, dissolved cadmium, dissolved copper, dissolved lead and dissolved zinc. Additionally, the pH of surface water (in USG Creek) adjacent to and immediately downgradient of the Site ranged from 4.9 to 5.9, which is below the chronic WQC range of 6.5 to 9.0. Metals concentrations were significantly elevated immediately below the influence of the adit discharge when compared with the upstream reference location.

Overall, 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. 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 additional evidence in support of this conclusion.

**Risk Characterization for Benthic Infauna.** Similar to the approach used to address risks to freshwater aquatic resources, potential effects on benthic communities are assessed using an approach that considers collective lines of evidence.

#### TABLE 7-2 Summary of Ecological Risk Hazard Quotients for Plants, Aquatic Organisms, and Benthic Infauna

	Sediment – Benthic Infauna (mg/kg)						Soil – Plant	s (mg/kg)		Surface Water – Aquatic Organisms (ug/L)					
COCª	Upper Effects Concentrations	CC-01	CC-02	USG- 01	USG- 02	USG- 03	Plant Screening Levels	Range of Soil Background Levels	Surface Soil EPC	Subsurface Soil EPC	Acute WQC*	*Chronic WQC	USG-1	USG- 2	USG- 3
Aluminum	_	_	-	_	_	_	_	_	-	_	750	87	37.2	39.2	391
Antimony	3	21.8	26.2	28.1	55.9	42.5	5	0.38U to 0.4	148	186	_	_	_	_	_
Arsenic	120	783	1,020	1,360	3,800	2470	18	7.6 to 162	3,904	3,685	_	_	_	_	—
Cadmium	5.4	25.7	31.8	21.2	71.6	37.3	32	0.22 to 0.38	35	33	0.52	0.097	<0.08	0.38	72.4
Copper	_	_	_	_	_	_	70	6.8 to 52	344	359		3.8	2.4	15.7	925
Iron	40,000	18,900	21,200	12,800	43,900	17,200	_	_	_	_		1,000	_	1	_
Lead	>1,300	603	635	753	2,110	1100	120	9.9 to 189	1,321	1,629	13.98	0.545	1.1	1.5	3.3
Manganese	1,100	1290	1,820	765	2,310	1,050	220	NA	829	898		_	_	1	—
Silver	1.7	6.4	3.6	4.9	12.4	7.7	_	_	_	_		_	_	1	—
Selenium	-	_	_	_	_	_	0.52	0.58U to 0.98	2.7	2.9		_	_	_	_
Zinc	_	_	_	_	_	_	160	17.3 to 185	574	661	37	37	10.5	51	6,110

Notes:

mg/kg = milligram per kilogram

ug/L - micrograms per liter

Bold indicates concentration exceeded screening levels and background (or upstream) locations

<sup>a</sup> Results are only provided for COCs in each media and as identified during the risk assessment

\* Hardness value upon which these DEQ-7 standards are based is 25 mg/l

COCs (for example, copper and zinc in sediment) may have been identified as such based on the wildlife risk results

COC = contaminant of concern

CC = Cataract Creek

WQC = water quality criteria

USG = Uncle Sam Gulch Creek

EPC = exposure point concentration

Comparisons of COPEC concentrations detected in sediment with probable (upper) effects benchmarks are provided in Table 7-7. These represent levels above which significant benchic macroinvertebrate impairment would be likely. The following conclusions can be drawn from the benchmark comparisons:

- Probable effects benchmarks were exceeded for antimony, arsenic, cadmium, lead, manganese and silver at sample locations adjacent to or downgradient of the Site. Arsenic had the highest levels of exceedance with levels 30 times above the screening level in the smallest size fractions.
- Because the COPCs are naturally occurring constituents and potentially influenced by upstream sources, further understanding of the background contributions is also important. The results indicated that levels downstream of influence of the Site are significantly elevated.

An additional line of evidence supporting the ecological risk characterization for sediment consists of a Sitespecific benthic macroinvertebrate investigation conducted in 2010. The methodology and results are provided in Appendix G of the RI (EPA, 2013). The study found that a sparse but diverse macroinvertebrate community occurs in USG Creek above the Site, and few organisms are living downstream of the mine. The study clearly showed significant impairment of benthic macroinvertebrate populations downstream of the Site. Measurable impacts extended beyond the confluence of USG Creek and Cataract Creek, which is approximately 1 mile downstream of the mine.

Geographic trends between COPEC concentrations in sediment and corresponding benthic macroinvertebrate survey results also support the ecological risk characterization. The relationship between COPEC concentrations in sediment and benthic macroinvertebrate health metrics (abundance and taxa richness) was explored. Limited data existed to provide a meaningful statistical evaluation between these measures. However, macroinvertebrate populations are significantly impaired at locations where COPEC concentrations are highest. No habitat differences (for example, differing flow rates or substrate) were identified that would confound the interpretation of the macroinvertebrate survey results.

Considered collectively, these lines of evidence provide 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.

**Risk Quantification for Wildlife.** Risks posed to mammalian and avian species that may use the Site were determined for mammalian and avian receptors.

Exposure was assumed to occur to COPECs in soil, sediment and surface water collectively. The HQ results are provided in Table 7-8. COPECs resulting in LOAEL-based ecological HQs exceeding 1 are as follows:

- Deer mouse—aluminum, antimony, arsenic, cadmium, copper, lead, selenium
- Mule deer—arsenic
- Raccoon—aluminum, antimony, arsenic
- Northern goshawk arsenic, lead
- Dusky flycatcher—arsenic, cadmium, copper, lead, zinc Spruce Grouse lead

A comparison of surface soil exposure point concentrations (EPCs) with the range of COPEC concentrations measured at background locations was also provided in the ERA and, for those COPECs identified with ecological HQs exceeding 1, surface soil EPCs for all are above background levels with the exception of aluminum.

Overall, the risk evaluation of mammalian and avian wildlife indicated that the combined exposures to measured levels of COPECs in surface soil, sediment and water are high enough to pose a significant risk to wildlife should they forage at the Site. The risks are greatest for individuals with smaller foraging areas (for example, deer mouse and dusky flycatcher).

#### Uncertainties in the Ecological Risk Assessment

Full characterization of ecological risks requires that the numerical estimates of risk presented in the risk assessments be accompanied by a discussion of the uncertainties inherent in the assumptions used to estimate those risks. Uncertainties in risk assessment methods may result either in understating or in overstating the risks. The latter is likely the case when health-conservative assumptions are used to characterize risk. Several key uncertainties are discussed below:

- The degree to which sample collection and analyses reflect real exposure concentrations will influence the reliability of the risk estimates. Because the Site investigations have generally focused on sampling close to suspected source areas at the mine, rather than at areas where exposure are most likely (for example, vegetated areas for wildlife), exposure point concentrations used for the risk estimates may be biased high for some receptors.
- Uncertainty in exposure estimation is introduced if a constituent occurring in soil is in a form that is
  more or less bioavailable than the form used to determine the COPECs toxicity in a laboratory study (as
  reported in literature) used to derive a toxicity reference value (TRV). For the ERA, bioavailability was
  assumed to be equal to the form used in the toxicity study reported in the literature. Because metals are
  primary contributors to the risk estimates for birds and mammals and because the available toxicity
  studies are generally conducted using very bioavailable constituent forms, the use of TRVs based on
  these more available forms may overestimate risk to wildlife.
- In the development of exposure estimates, exposure assumptions relating to wildlife diet are expected to overestimate risk. This is because the species' selected as endpoints are mobile and most are not likely to forage at the Site 100 percent of the time when higher quality habitat is available in nearby locations.
- Maximum sediment concentrations were used for the food chain calculations, which likely results in an overestimation of actual risk to most wildlife. The ERA assumes that each endpoint species receives at least a portion of their drinking water from the mine area. This assumption may overestimate exposure because, for some species, most or all water intake comes from food items.
- Uncertainties in toxicological data can also influence the reliability of risk management decisions. The toxicity values used for quantifying risk in this risk assessment have varying levels of confidence that may affect the confidence in the resulting risk estimates.
- Because the COPECs in Site media occur naturally, it is important when interpreting risks to consider the relative level of potential risk posed by naturally occurring levels.

### 7.3 Basis for Action

Table 7-3 summarizes the basis for action at the Site and a brief description is provided below.

Contaminants in soil and seeps/springs represent a threat to human health. The primary risk to human health from exposure to arsenic documented in the HHRA was for exposure of adolescent and adult recreational users (primarily to potential ATV users) to Site soils at the Site, although the levels at the Site would also pose a risk to residential or commercial users. Additionally, arsenic levels emanating from seeps/springs contains levels high enough to pose an unacceptable risk to recreational users that could use these as sources of drinking water.

The ERA indicates unacceptable risks to fish and benthic organisms exposed to USG Creek and Cataract Creek surface water and sediment. Levels of several COCs in USG Creek surface water exceed Montana water quality standards and surface water toxicity tests show significant fish mortality. Levels of several COCs in USG Creek sediments exceed benchmarks and population surveys indicate reduced abundance and diversity of benthic macroinvertebrates. The ERA also indicates levels of several COCs (primarily in soil and sediment) pose unacceptable risks to plants, birds and mammals. Due to the poor quality habitat on Site (large area of physical disturbance, limited vegetation and limited food sources), and the abundance of quality habitat adjacent to the Site, current risk to bird or mammal populations is likely low.

EPA has concluded that the remedial actions selected in this interim ROD are necessary to protect human health and the environment from actual or threatened releases of hazardous contaminants.

#### TABLE 7-3

#### **Basis for Action**

Receptor	Media	Reasonably Anticipated Future Land Use	Contaminant of Concern Requiring Action	Basis for Action	
Surface soil		Future intermittent worker	No unacceptable risks	Not applicable	
		Current and future recreational users (adolescents and adults)	Arsenic	Cancer risk > 1x10 <sup>-5</sup>	
Human		Current and future adult recreational user	Arsenic	Cancer risk > 1x10 <sup>-5</sup>	
Health		Hypothetical future industrial worker	Arsenic	Cancer risk > 1x10 <sup>-5</sup>	
	Subsurface soil	Future excavation worker	Arsenic	Cancer risk > 1x10 <sup>-5</sup>	
	Surface water Current and future recreational users (adults)		Arsenic	Cancer risk > 1x10 <sup>-5</sup> and HQ > 1	
	Seep/Springs*	Current and future recreational users (adults)	Arsenic	Cancer risk > $1 \times 10^{-5}$ and HQ > 1	
	Surface soil	Habitat supporting birds, and mammals	Antimony, arsenic, cadmium, copper, lead, zinc	LOAEL-based HQ >1	
	Subsurface soil	Supporting plants	Antimony, arsenic, cadmium, copper, lead, manganese, selenium, zinc	LOAEL-based HQ >1	
	Surface water**	Habitat supporting aquatic organisms, birds, and mammals	Aluminum, cadmium, copper, lead, zinc	Exceedances of WQS	
	Sediment	Habitat supporting benthic infauna, birds, and mammals	Antimony, arsenic, cadmium, copper, lead, manganese, silver, zinc	LOAEL-based HQ >1	

Notes:

HQ = hazard quotient

WQS = water quality standards

\*MDEQ compares surface water to the DEQ-7 human health standards in order to determine whether a risk to human health exists

\*\* MDEQ compares surface water to chronic aquatic DEQ-7 standards to determine whether a contaminant poses an ecological risk.

# Section 8. Remedial Action Objectives and Remedial Goals

### 8.1 Remedial Action Objectives and Remedial Goals

Remedial action objectives (RAOs) were developed by the EPA to address Site conditions. Remedial objectives are based on reasonably anticipated future land, water and ground water uses, and the findings of the risk assessment, presented in Sections 6 and 7, respectively.

#### 8.1.1 Surface Water RAOs

Water quality in Cataract Creek is classified by MDEQ as a B-1 stream. USG Creek is a tributary to Cataract Creek. Cataract Creek appears on MDEQ's Clean Water Act section 303(d) list for water quality standard exceedances of arsenic, cadmium, copper, lead, mercury and zinc. In addition, the amount of sedimentation/siltation exceeds acceptable levels. USG Creek is not currently listed on the Montana section 303(d) list but will be listed for the same constituents as a significant tributary. TMDLs for these creeks were developed by MDEQ and approved by the EPA in December 2012. The EPA does not propose to meet these standards with this interim ROD, but believes the remedy will contribute to achieving the TMDLs within the Basin Watershed OU2. A goal of the final remedy for OU2 is to meet surface water quality standards. Therefore, the surface water RAOs proposed for USG Creek are:

- 1. Reduce or prevent surface water infiltration and migration into the underground mine workings in an effort to reduce the volume of AMD discharging to USG Creek.
- 2. Reduce or prevent the release of COCs to surface waters that result in unacceptable risks to terrestrial and aquatic species.
- 3. Reduce or prevent the release of COCs to surface waters that result in exceedances of the Circular DEQ-7 Numeric Water Quality chronic aquatic standards.

#### 8.1.2 Ground Water RAOs

Ground water infiltrates through the bedrock fractures into the underground workings and discharges from the lower adit as AMD. This discharge presently intercepts and degrades USG Creek, which flows into Cataract Creek and eventually the Boulder River. Formal ground water quality objectives will be determined by the Basin Watershed OU2 remedy. In the interim, Montana ground water quality standards will be used for comparison purposes to guide the development of this interim remedy.

Proposed RAOs for ground water are as follows:

- 1. Reduce or prevent surface water infiltration and migration into the underground mine workings in an effort to reduce the volume of AMD.
- 2. Prevent or minimize ground water discharge containing COCs that contribute to TMDL exceedances in Cataract Creek.
- 3. Prevent or minimize human exposure to ground water contaminated with COCs above the Circular DEQ-7 Numeric Water Quality Standards.

### 8.1.3 Soil RAOs

The nature and extent of mine waste and impacted soils are described in the RI. Waste rock and associated soils are contaminated with significant concentrations of COCs. The RAOs for Site soils are as follows:

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

#### 8.1.4 Stream Sediment RAOs

The nature and extent of contaminated sediments in USG Creek is explained in the RI. With reconstruction of the creek channel adjacent to the Site (approximately 1,100 feet) proposed, remediation of stream sediments will rely on annual spring runoff and local thunderstorms to mitigate residual sediment contamination by natural recovery (burial and mixing) after the adit discharge is remediated. Annual monitoring of stream sediment deposits, approximately one-half mile downstream of the southern claim boundary where the USFS road facilitates access to the stream channel, will track the success of this natural recovery process above its confluence with Cataract Creek. The RAOs for sediments are as follows:

- 1. Prevent or minimize unacceptable risk to ecological systems (including aquatic and terrestrial) degraded by contaminated sediment containing elevated levels of metals (antimony, arsenic, cadmium, lead, manganese and silver).
- 2. Prevent or minimize further migration of contaminated source materials or discharges in close proximity to USG Creek.

### 8.2 Remediation Goals

The remediation goals (RGs) represent the concentration below which a contaminant is not considered an unacceptable risk. RGs are developed for both the protection of human health and for the protection of ecological receptors.

The Risk Assessment section of the RI report identified aluminum, cadmium, copper, lead and zinc in surface water and ground water as COCs. Because this is an interim action, the EPA has waived the surface and ground water quality standards until a final action is taken for the Basin Watershed OU2. The final remedy for the Basin Watershed OU2 will meet all surface and ground water quality standards. However, the interim action will improve water quality and the numerical values set forth in the DEQ-7 standards for acute and chronic aquatic and human health will be used for comparison purposes for the Site (see Table 8-1).

Contaminant	Human Health	Acute <sup>b</sup>	Chronic <sup>a</sup>	
Aluminum	-	0.75	0.087	
Antimony	0.0056	_	_	
Arsenic	0.01	0.34	0.15	
Cadmium	0.005	0.00052	0.000097	
Copper	1.3	0.00379	0.00285	
Iron	_	_	1	
Lead	0.015	0.0139	0.000545	
Manganese	-	-	_	
Nickel	0.1	0.145	0.0161	
Selenium	0.05	0.02	0.005	
Silver	0.1	0.000374	_	
Thallium	0.0002	_	_	
Zinc	2	0.037	0.037	

#### TABLE 8-1

DEQ-7 Surface and Ground Water Standards the EPA Will Address with the Basin Watershed OU2 ROD

Notes:

Values in mg/l

<sup>a</sup> Circular DEQ-7 (MDEQ, 2012), based on 25 mg/L hardness

<sup>b</sup> Circular DEQ-7 (MDEQ, 2012) acute standard

The only soil contaminant that exceeded a human health risk threshold was arsenic, and only for recreational users (ATV riders and hikers). Therefore, the EPA established a human health remedial action level (RAL) for soil arsenic. The RAL for arsenic is based on potential risks derived for the adolescent recreational user (1,243 mg/kg). Potential exposure is highest in the vicinity of the existing waste rock dumps and material. Antimony, aluminum, arsenic, cadmium, copper, lead, selenium and zinc were identified as ecological contaminants of concern in soils. Potential ecological exposure in soils occurs in barren erosion-prone areas, and for wildlife species that may burrow or consume food items on or below the soil surface.

The preliminary remediation goals (PRGs) for contaminants in stream sediments in USG Creek address potential risks to benthic infaunal communities, and are derived from the more restrictive of probable effects threshold concentrations (PEC) for protection of sediment infauna and wildlife (see Table 8-2). PEC represents the concentration above which adverse effects would frequently occur.

Monitored natural recovery is proposed as the remedial cleanup approach to achieve the stream sediment PRGs. As explained under the RAOs, the sediment quality is expected to improve through natural recovery after remedial actions for the contaminant source (treatment of mine adit discharge into USG Creek and remediation of the channel adjacent to the mine). Progress of the natural recovery will be monitored on an appropriate sampling schedule to judge improvement downstream. The monitoring point will be at the first road-accessible sampling location downstream of the Crystal Mine claim boundary (approximately one-half mile).

#### TABLE 8-2

#### Stream Sediment PRGs in mg/kg<sup>a</sup>

Contaminant	Probable Effects Concentration/Cleanup Screening Level
Antimony	3.0 <sup>b</sup>
Arsenic	33.0
Cadmium	4.98
Copper	149
Iron	40,000 <sup>b</sup>
Lead	128
Nickel	48.6
Silver	4.5 <sup>b</sup>
Zinc	459

Notes:

<sup>a</sup> Dry Weight. Source: D.D. McDonald; C.G. Ingersoll; T.A. Berger. *Development and Evaluation of Consensus Based Sediment Quality Guidelines for Freshwater Ecosystems*. Arch. Environ. Toxicol. 39, 20-31 (2000)

<sup>b</sup> Upper Effects Thresholds (UETs) from the NOAA SQuiRT tables (Buchman, 2008).

# Section 9. Description of Alternatives

The remedial alternatives assessed and evaluated in the feasibility study (FS) are briefly presented in this section. The EPA considered a wide range of alternatives to reduce Site risks and achieve RAOs. The assessment evaluated these alternatives for nine NCP criteria including: overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility or volume through treatment; short-term effectiveness; technical feasibility; administrative feasibility; availability of services and materials; and cost. Nine remedial alternatives passed the technology screen process for remediating waste rock and AMD. Three alternatives for waste rock remediation and six alternatives for ground water remediation of AMD were identified. The FS screened out active ground water source control and surface water treatment alternatives prior to the detailed analysis of the nine remaining alternatives. The EPA's preference is to address sources of contamination – waste rock/contaminated soil on the Site and AMD emanating from the lower mine adit. Institutional controls to preserve and protect the remedy and to prevent development that poses a risk to human health are common to all alternatives except the No Further Action alternative.

### 9.1 No Further Action Alternative

The No Further Action alternative would involve no further remedial action or land use controls at the Site beyond those currently in place or already undertaken. This alternative provides the baseline condition against which the other remedial action alternatives are compared. This alternative includes completed and ongoing actions at the mine Site including periodic monitoring of water quality.

### 9.2 Waste Rock/Soil Alternatives

Areas of exposed waste rock would be removed or capped as part of any selected remedy. Where waste rock (WR) removals intercepts/overlays stream banks, the banks would be reconstructed, stabilized and revegetated. Stream banks without impacted soils and with woody vegetation would be slated for no action, or for best management practices (BMPs). The following three waste rock alternatives were retained:

- WR alternative 1 waste rock capping
- WR alternative 2 excavation and disposal at the Luttrell Repository
- WR alternative 3 excavation and disposal at repository constructed onsite

### 9.3 Ground Water Alternatives (GW)

Ground water alternatives would either block the flow of AMD from the adit, or control or treat the flow before it enters USG Creek, while engaging in some form of source water control to prevent or limit water from entering the mine workings, where possible. Two alternatives were considered for blocking the flow of AMD. Both involve sealing the mine adit with a concrete 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. Three treatment options were also evaluated. All would control the flow of mine water by blocking the adit and piping the water to a treatment facility. Treatment options vary from an active, fully staffed plant to an unstaffed passive system.

- GW alternative 1 mine plugging
- GW alternative 2 remote mine plugging through borings from the surface
- GW alternative 3 active treatment of AMD

- GW alternative 4 semi-active treatment of AMD (quicklime injections system)
- GW alternative 5 semi-passive treatment (SPT) of AMD (with bulkhead and sulfate reducing biochemical reactor [SRBR])
- GW alternative 6 SPT of AMD (SRBR, aeration systems, oxidation/settling ponds, wetlands and discharge)

Brief descriptions of remedial features and approach, estimated cost (net present worth) and common elements of the alternatives considered for the remedy are presented in the following section.

TABLE 9-1

Alternative	Summary of Remedial Alternatives
No Further Action Alternative	No further remedial action or institutional controls at the Crystal Mine. This alternative provides the baseline conditions against which the other remedial action alternatives are compared. No additional active remediation work would occur at the Crystal Mine. This applies to all media. Any ongoing long-term biological and surface water monitoring conducted by the MBMG, the USFS (Region One), the State of Montana, and USGS is assumed to continue in accordance with the existing basin-wide plan. <u>Costs:</u> Capital: \$0
	30-year Operation and Maintenance (O&M): \$231,000 Total: \$231,000
WR Alternative 1 – Waste Rock Capping	This 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 capping of the waste rock. Overly steep slopes would most likely require regrading or terracing to allow installation of both liner and cover material.
	<u>Costs:</u> Capital: \$4,328,000
	30-year O&M: \$427,703
	Total: \$4,801,000
WR Alternative 2 – Excavation and Disposal at Luttrell Repository	<ul> <li>This alternative would remove approximately 59,500 cubic yards of contaminated soil/waste rock on approximately 6 acres of the Site. Soil would be removed to 12 inches below the bottom of the waste rock to ensure removal of all mining contaminated soils. Removal areas and specific action include:</li> <li>Excavation of the Crystal dump, Twin Ore Bins and Dump area, Mammoth road area and Mammoth</li> </ul>
	<ul> <li>dump area.</li> <li>Import of approximately 10,000 cubic yards of replacement soils from offsite soil borrow areas for revegetation of all excavated areas. Excavated material would be placed in the local Luttrell Repository. The chosen haul route (after consideration of haul distance, truck size, anticipated road improvements and maintenance, and public safety) is Jack Creek/Basin Creek Road (21 miles round trip).</li> </ul>
	<u>Costs:</u>
	Capital: \$7,098,000
	30-year O&M: \$472,703
	Total: \$7,571,000

#### TABLE 9-1 Description of Primary Alternatives

Alternative	Summary of Remedial Alternatives
WR Alternative 3 – Excavation and Onsite Disposal	This alternative is similar to WR Alternative 2 except that an onsite repository would be constructed for soil disposal. The repository would be designed with adequate capacity to handle waste rock and soils from the onsite waste dumps and source areas. Contaminated wood, metal or plastic debris would be hauled to the Luttrell Repository. An onsite loop road would be upgraded and used to transport the soil and waste rock to the onsite repository. The repository would be capped with an impermeable liner and covered with 24 inches of cover and top soil, and revegetated. Replacement soil, approximately 11,000 cubic yards from a clean borrow source, would be required to cover all excavated waste rock areas. The Crystal dump would be removed to the onsite repository and the remaining hillside would be terraced and capped with approximately 4,200 cubic yards of replacement soil and revegetated. Approximately 7,500 cubic yards of replacement soil (12 inches deep) would be required to cover all excavated areas. Costs: Capital: \$4,687,000 30-year O&M: \$472,703 Total: \$5,460,000
GW Alternative 1 – Mine Plugging	This alternative would employ the construction of a plug within the lower adit (tunnel) to seal mine water within the mine. The resulting flooding behind the plug would prevent air from entering the mine through the adit, potentially reducing oxidation and generation of AMD. After the mine adit is sealed, the surrounding area would be monitored to determine if new ground water discharge points have developed or if significant changes to the local ground water flow occur. Several monitoring wells would be located downgradient from the mine plug. Ground water monitoring upgradient of the mine would provide background data for comparison. Additionally, surface water both downgradient and upgradient of the Site would be routinely monitored to determine effectiveness of the plug. Costs: Capital: \$6,534,000 30-year O&M: \$1,164,000 Total: \$7,698,000
GW Alternative 2 – Remote Mine Plugging Through Borings from the Surface	A second alternative for mine plugging would be implemented by drilling down from the surface to collapse a targeted section of the mine tunnel and fill voids in the collapsed section through high-pressure grouting to complete an impervious plug. This approach provides the advantage of not having to reopen the mine adit to gain physical access to the section of interest. The disadvantage is the technical difficulty of accomplishing this task and completing a competent seal that would hold back mine water. As with alternative GW-1, periodic reconnaissance for new seeps and ground water monitoring downgradient of the mine would be implemented upon completion of the hydraulic plug to ensure that the plug is working and contaminated ground water is not escaping from the mine. Several monitoring wells would be located downgradient from the mine plug. Ground water monitoring upgradient of the mine would be routinely monitored to determine effectiveness of the plug. <b>Costs:</b> Capital: \$11,409,000 30-year O&M: \$818,583 Total: \$12,228,000

#### TABLE 9-1

<b>Description of Prima</b>	ry Alternatives

Alternative	Summary of Remedial Alternatives
GW Alternative 3 – Active Treatment of AMD	Alternative GW-3 would consist of an active treatment process to treat AMD at the Site. A high-density sludge (HDS) plant, a standard technology for treating AMD, would be designed and constructed. 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 ground water discharge. Chemically-resistant pipes running through the plug would transmit a constant volume of the AMD to the HDS plant. During periods of high ground water discharge, the plug would act like a dam, storing the AMD within the mine until it could be treated. Only adit discharge would be collected and diverted to the treatment plant. Construction of the HDS plant would require that a permanent source of electrical power be provided to the Site, resulting in the installation of aboveground transmission lines running to the mine sites. The HDS plant would require year-round operation by a part-time operator. Upgraded access roads would be needed to provide Site 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. Costs: Costs: Capital: \$4,781,000 30-year O&M: \$2,874,000
	Total: \$7,655,000
GW Alternative 4 – Semi-Active Treatment of AMD (Quicklime Injection System)	Alternative GW-4 would consist of a semi-active AMD treatment process. Mine discharge from the lower adit would be blocked by an adit bulkhead, collected and piped to the quicklime injection system where a 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 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. As necessary, 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. 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. <u>Costs:</u> Capital: \$3,315,000 30-year O&M: \$1,681,000
	Total: \$4,996,000

#### TABLE 9-1 Description of Primary Alternatives

Alternative	Summary of Remedial Alternatives
GW Alternative 5 – Semi-Passive Treatment of AMD with bulkhead and SRBR	Alternative GW-5 would be a three-stage semi-passive system utilizing a pH adjustment cell, a sulfate reducing biochemical reactor, and a clarification pond. As with alternatives GW-3 and GW-4, an adit bulkhead would be installed to control flow through a 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. Only adit discharge would be collected and diverted to the treatment system. The three stages of the treatment process are as follows:
	<ul> <li>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 described in depth in the FS.</li> <li>SRBR (Stage 2). The SRBR consists of a series of horizontal flow-through cells where sulfate concentrations are reduced by sulfate-reducing bacteria. Proper pH and mine water retention time within each cell are critical to the success on this stage. Conceptual design details of the cells are described in the FS.</li> </ul>
	• Clarification (Stage 3). The clarification pond represents the third stage of treatment and would allow settling of sludges and organic materials formed in the prior two stages. Effluent from the SRBR cells would be discharged into the 6-foot-deep end of the pond which offers storage for settling sludges. At the shallow end of the pond, native aquatic vegetation would provide biological filtering. 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.
	<u>Costs:</u>
	Capital: \$3,296,000
	30-year O&M: \$1,053,000
	Total: \$4,349,000
GW Alternative 6 - SPT of AMD without bulkhead (SRBR, Aeration System, Oxidation/Settling	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. GW-6 incorporates a slightly different semi-passive design by omitting a separate pH adjustment cell. Unlike alternatives GW-3 through GW-5, an adit bulkhead would not be installed to control flow through a pipe and control valve. Discharge from the adit would be captured and flow through a pipe, but would be allowed to flow freely out of the mine throughout the year.
Ponds,	• SRBR (Stage 1). The SRBR would be constructed similar to the description in GW-5.
Wetlands and Discharge)	<ul> <li>Aeration System (Stage 2). A series of short cascades would run from the SRBR to several aeration ponds to promote oxygen transfer to water increasing dissolved oxygen (DO) and oxidation reduction potential (ORP).</li> </ul>
	<ul> <li>Oxidation/Settling Ponds (Stage 3). These ponds would facilitate the precipitation and settling of iron oxide sludges from the SRBR cells and aeration channels.</li> </ul>
	• Wetland (Stage 4). A wetland area would be constructed to provide for suspended solids polishing.
	• Discharge to USG Creek (Stage 5). Discharge from the wetland pond would be directed to USG Creek through an open riprap lined channel.
	<u>Costs:</u>
	Capital: \$2,570,000
	30-year O&M: \$1,170,000
	Total: \$3,740,000

#### 9.3.1 Common Elements

Common remedial activities shared by alternatives include several pre-remedial actions to facilitate general Site access and equipment staging. These include road improvement and Site preparation. The successful treatment and discharge of mine water is also fundamental to implementation of GW alternatives 3 through 6. Surface water controls to convey potential source water (in the form of runoff) offsite and away from underground workings is common to all alternatives. Institutional controls that would protect the integrity of the remedy by preventing development, limit access to remedial features, and prevent use of contaminated surface or ground water for potable use would be common to all alternatives. Contaminated materials and waste generated during the opening of the collapsed portal and construction of the remedy would be removed and disposed of at the local Luttrell Repository.

Containment of mine waters as a remedy is common to GW alternatives 1 and 2. Containment of mine waters (utilizing mine bulkhead and piping) to regulate flow into treatment alternatives is a common element of GW alternatives 3 through 5.

Treatment of mine waters will occur as part of GW alternatives 3, 4, 5 and 6. Although the means of treatment will vary, common activities will include Site preparation, in some cases (alternatives 3 and 4) application of lime, and all water treatment alternatives will require periodic collection of sludges and biological media at the Luttrell Repository.

Replacement soil cover and vegetation is common to all waste rock alternatives. All alternatives will employ some form of monitoring. For instance:

- Monitoring effectiveness of erosion control, establishment of desirable vegetation and weed control.
- Monitoring of waste-left-in-place that limits Site use will require 5-year reviews to ascertain whether the remedial actions remain protective and functional.
- Monitoring of water levels in the mine, operational conditions (influent and effluent water quality) and functional conditions that represent sustainable treatment conditions.

Common remedial activities shared by the alternatives are presented in the following table.

#### TABLE 9-2

#### **Common Elements in Remedial Alternatives**

	Nia				Rem	edial Alterr	natives			
Remedial Component	No Action	WR-1	WR-2	WR-3	GW-1	GW-2	GW-3	GW-4	GW-5	GW=6
Pre-Remedial Activities:										
Improve access and Site roads		О	ο	0	О	0	0	0	0	0
Identify cover soil resource		0	0	0						
Sediment pond removal through TCRA action in 2014	0	0	0	0	0	0	0	0	0	0
Construct surface water controls		0	0	0	О	0	0	0	0	0
Construct erosion control		0	0	0						
Disposal of Wastes:										
Waste disposal in Luttrell Repository			0				0	0	0	0
Remedial Cover:										
Install liner over waste material		о		0						
Cap waste materials or waste removal areas with amended top soil		0	0	0						
Vegetation establishment		0	0	0						
Remedial Containment:										
Re-open mine adit— construct adit plug or bulkhead					0		0	0	0	
Drill and inject grout curtain around plugs					о	0				
Remedial Treatment										
Construct treatment system or chemical dispensing facility							0	0	0	0
Construct lined settling ponds								0	О	о
Construct treatment cells							0	0	0	0
Periodic sampling and analysis of treatment plant influent and effluent							0	0	0	0

#### TABLE 9-2

#### **Common Elements in Remedial Alternatives**

	No	Remedial Alternatives								
Remedial Component	Action	WR-1	WR-2	WR-3	GW-1	GW-2	GW-3	GW-4	GW-5	GW=6
Periodic collection and disposal of treatment system sludges at Luttrell Repository							0	0	ο	ο
Monitoring	Monitoring									
Periodic monitoring of Site (operational, functional, 5-year reviews)	0	0	0	0	0	0	0	0	0	0
Institutional Controls										
Prevent development; prevent use of water; limit access to remedial features and protect remedy		0	0	0	0	0	0	0	0	0

Notes:

No Action alternative

WR alternative 1 – Waste Rock Capping

WR alternative 2 – Excavation and Local Disposal

WR alternative 3 – Excavation and Onsite Disposal

GW alternative 1 – Mine Plugging through Reopened Mine Adit

GW alternative 2 – Remote Mine Plugging Through Borings from the Surface

GW alternative 3 – Active Treatment of AMD

GW alternative 4 - Semi-Active Treatment of AMD (Quicklime Injection System)

GW alternative 5 - Semi-Passive Treatment of AMD (SRBR)

GW alternative 6 - Semi-Passive Treatment of AMD (SRBR, aeration systems, oxidation/settling ponds, wetlands and discharge)

### **10.1 Comparative Analysis of Alternatives**

The Superfund law and regulations require that the EPA, in consultation with MDEQ, evaluate and compare the remedial cleanup alternatives based on the nine NCP criteria. These nine criteria are contained in the Superfund law, especially section 121 of CERCLA, 42 U.S.C. §9621, and are promulgated in the NCP at 40 CFR §300.430(e)(9)(iii). **Exhibit 10-1** describes the nine criteria, and Tables 10-1 and 10-2 present relative ranking of alternatives by each criteria for waste rock alternatives and ground water alternatives, respectively.

Any selected remedy must meet the **threshold criteria** of "overall protectiveness of human health and the environment" and "compliance with ARARs or appropriate justification for use of the CERCLA ARAR waivers." Only those alternatives that meet these criteria are considered further by the EPA. The **balancing criteria** of long-term effectiveness and permanence; reduction of toxicity, mobility or volume through treatment; short-term effectiveness; implementability; and cost are used by the EPA to identify and consider major trade-offs among the alternatives. Two of these criteria—long-term effectiveness and permanence, and reduction in toxicity, mobility, or volume through treatment—are emphasized by the NCP and EPA guidance. The **modifying criteria** represent state acceptance and community acceptance.

#### EXHIBIT 10-1 EPA's Evaluation Criteria

#### **EPA'S Evaluation Criteria**

#### Threshold Criteria—Must be Addressed

- 1. Overall protection of human health and the environment—*must be protective of human health and the environment.*
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)—includes state and federal regulations; where ARARs cannot be met, a justification for a waiver is required

#### Balancing Criteria—Must be Considered

- 1. Long-term effectiveness and permanence
- 2. Reduction of toxicity, mobility and volume
- 3. Short-term effectiveness
- 4. Implementability
- 5. Cost

#### Modifying Criteria—Must be Considered

- 1. State acceptance
- 2. Community acceptance

The EPA evaluated these criteria in detail in both the "Detailed Analysis" and the "Comparative Analysis of Alternatives" sections of the FS. The EPA, in consultation with MDEQ, formally evaluated these nine alternatives using the threshold and balancing criteria. A summary of the comparative analysis of the individual waste rock alternatives is provided in the following text.

#### **10.1.1 Summary of Comparative Analysis of Waste Rock Alternatives** Threshold Criteria

#### **Overall Protection of Human Health and the Environment**

The No Action alternative will leave existing conditions at the Site unchanged. This alternative does not address or mitigate the identified baseline risks to human or ecological receptors and is not protective of human health and the environment.

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 and erosion, or damage from other sources. Because of wastes left in place, this alternative would also require periodic monitoring and maintenance. Alternatives WR-2 and WR-3 are similar in that mine wastes would be removed and placed in either an onsite repository (WR-3) or in the Luttrell Repository (WR-2). Both of the alternatives would provide a high degree of protection to human health and the environment. Like WR-1, the onsite repository (WR-3) would require periodic monitoring and maintenance. 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.

#### TABLE 10-1

Relative Ranking of Waste Rock Alternatives after Comparison Analysis

Criterion	No Action	WR-1 Capping	WR-2 Excavate & Local Disposal	WR-3 Excavate & Onsite Disposal			
Threshold Criteria							
Human health and environment	1	3	4	4			
Compliance with ARARs	-	+	+	+			
Primary Balancing Criteria							
Long-term effectiveness	1	3	5	4			
Reduction of toxicity, mobility, volume	1	3	4	4			
Short-term effectiveness	2	4	2	4			
Implementability							
Technical	5	4	4	4			
Administrative	5	4	4	4			
Availability of service and materials	5	3	4	4			
Present worth cost	5	4	3	4			
Modifying Criteria							
Community Acceptance				Yes*			
State Acceptance				Yes*			

Notes:

Scale of Score = 1 is low; 5 is high (most favorable)

+ Indicates the alternative promotes ARAR compliance in the Basin watershed

- Indicates no promotion of ARAR compliance

\* Only the preferred alternative was evaluated for state and community acceptance

Yellow Indicates preferred alternative

#### **Compliance with ARARs**

Section 121(d) of CERCLA and NCP §300.430(f)(1)(ii)(B) require that remedial actions at CERCLA sites at least attain legally applicable or relevant and appropriate federal and state requirements, standards, criteria, and limitations which are collectively referred to as ARARs, unless ARARs are waived under CERCLA Section 121(d)(4). A listing of Site ARARs is presented in Table 10-2. A more comprehensive presentation of ARARs is included as Appendix A to this interim ROD. That appendix contains appropriate definitions and descriptions of terms relevant to the ARAR identification and compliance analysis for this Site.

ARARs are chemical, location or action specific. The remedial compliance implication of each designation is described as follows:

• Chemical-Specific ARARs – Chemical-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. This category includes Montana surface water standards (MDEQ, 2012) and the ability of each alternative to achieve these water quality standards, and sustain compliance with water quality standards. The Montana ground water standards are included in this category.

- Location-Specific ARARs 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. This category includes Montana's solid waste and floodplain management standards and ARARs for protected resources.
- Action-Specific ARARs 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. Mine reclamation standards that specify requirements for re-establishing remediated areas were examined, along with solid waste and floodplain requirements.
- Waived ARARs Because the EPA is selecting an alternative at the Crystal Mine OU5 as an interim measure, EPA has waived compliance with surface and ground water ARARs until the remedy for the Basin Watershed OU2 is developed. MDEQ has identified DEQ-7 Standards for ground water and chronic aquatic life standards for surface water as ARARs. The EPA will monitor water quality approximately one-half mile below the Site (where the road approaches the creek) and compare those values to the DEQ-7 standards. The final remedial action for the Basin Watershed OU2 will meet all ARARs, including the DEQ-7 standards for ground water and surface water.

All alternatives, with the exception of no action, have common ARARs.

**TABLE 10-2** 

#### Listing of Site ARARs (Federal and State of Montana)

The following is a list of the federal statutes, regulations, standards or requirements considered for the remedy at OU5 (as outlined in Appendix A):							
National Historic Preservation Act and regulations	Migratory Bird Treaty Act	Archaeological Resources Protection Act					
Archeological and Historic Preservation Act and regulations	Bald Eagle Protection Act	Resource Conservation and Recovery Act, Subtitles C and D					
Fish and Wildlife Coordination Act and regulations	Endangered Species Act and regulations	Clean Water Act					
The following is a list of the Montana state statutes, regulations, standards or requirements considered for the remedy at OU5 (as outlined in Appendix A):							
Ground water protection rules	Montana Floodplain and Floodway Management Act and regulations	Noxious Weeds					
Montana Water Quality Act and regulations (for example, Circular DEQ-7 Numeric Water Quality Standards)	Montana Natural Streambed and Land Preservation Act and regulations	Montana Human Skeletal Remains and Burial Site Protection Act					
Montana Mine Reclamation Statute and Regulations	Substantive MPDES permit requirements	State of Montana Solid Waste requirements					
Stormwater Runoff Control requirements	Montana Ambient Air Quality Regulations	Montana Strip and Underground Mine Reclamation Act					
Montana Metal Mining Act	Fugitive Dust Emission Regulations	Montana Hazardous Waste Act and implementing regulations					

#### **Primary Balancing Criteria**

#### 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.

#### 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.

#### 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 a common concern of these alternatives. Alternative WR-2 requires the removal of over 69,000 cubic yards of contaminated materials and transport to the site of 10,000 cubic yards of clean material. Alternative WR-3 would relocate approximately 60,000 cubic yards onsite. Alternative WR-1 requires transport to the site of 20,000 cubic yards 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.

#### Implementability

Implementability includes the evaluation of technical and administrative feasibility as well as the local availability of goods and services to successfully implement the chosen alternative.

- Technical Feasibility—Alternatives 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 implementability.
- 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.

#### Cost

Proposed alternative costs for this interim ROD consist of direct and indirect capital costs and long-term (30-year) O&M costs. Direct capital costs pertain to construction, materials, land, transportation, and analysis of samples for proposed alternatives. Indirect capital costs pertain to design, legal fees and permits. O&M costs pertain to maintenance and long-term monitoring and are presented as a net present worth value. Ranked by cost, the action alternatives, from most to least costly, are No Action alternative (\$0), alternative WR-1 (\$4.8 million), alternative WR-3 (\$5.2 million) and WR-2 alternative 5 (\$7.6 million).

#### **Modifying Criteria**

#### **Community Acceptance**

The community of Jefferson County and towns of Basin and Boulder, Montana, support the selected remedy, as described in Section 12. No objections were verbally stated by the community during the public meeting, nor received in writing during the public comment period.

#### State Acceptance

This is an Interim ROD to address a significant source of metal and arsenic contaminant loading to Uncle Sam Gulch Creek, a tributary to Cataract Creek. The Basin Watershed ROD (OU2) will detail the final determination regarding the need for and extent of any additional remedial actions necessary at OU5. DEQ supports the sequenced implementation of the Crystal Interim ROD as follows: (1) construction of the on-site repository and placement of impacted materials in the repository; (2) detailed evaluation and control, to the extent feasible, of surface water impacts and ground water impacts on the mine workings; (3) design and construction of the AMD water treatment system needed to reduce metal and arsenic loading to Uncle Sam Gulch C reek to acceptable levels; and (4) EPA's commitment to operate and maintain the AMD treatment system in accordance with 40 CFR §300.435. DEQ's determination that a waiver of the Circular DEQ-7 Montana Numeric Water Quality Standards for ground water and surface water is justified based on EPA's commitment that the final remedy for OU2 will meet all Circular DEQ-7 Montana Numeric Water and chronic aquatic surface water standards.

#### 10.1.2 Summary of Comparative Analysis of Ground Water Alternatives

Table 10-3 presents relative ranking of alternatives by each of the EPA's criteria for ground water alternatives.

#### **Threshold Criteria**

#### **Overall Protection of Human Health and the Environment**

Alternatives GW-1 and GW-2 would attempt to control the exposure risks by capturing the ground water flow within the mine complex and preventing it from discharging. If successful, these mine plugging 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. There is potential for plug failure, seepage around the plug, and allowing new contaminated seeps to emerge through host rock fractures and expressions in surface water. 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 (Active Treatment of AMD) 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.

### TABLE 10-3

Relative Ranking of Acid Mine Drainage Alternatives after Comparison Analysis
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	No Further Action	GW-1	GW-2	GW-3	GW-4	GW-5	GW-6	
Threshold Criteria								
Human health and environment	1	3	2	5	4	3	3	
Compliance with ARARs	-	+	+	+	+	+	+	
Primary Balancing Crite	Primary Balancing Criteria							
Long-term effectiveness	1	3	2	5	4	3	3	
Reduction of toxicity, mobility, volume	1	3	3	5	4	3	3	
Short-term effectiveness	2	3	4	2	4	4	4	
Implementability								
Technical	5	3	2	2	4	4	4	
Administrative	5	4	4	4	4	4	4	
Availability of service and materials	5	5	4	3	3	4	4	
Present worth cost	5	2	1	2	3	4	4	
Modifying Criteria								
Community Acceptance*							Yes*	
State Acceptance*							Yes*	

Notes:

Scale of Score = 1 is low; 5 is high (most favorable)

+ indicates the alternative promotes ARAR compliance in the Basin watershed

- Indicates no promotion of ARAR compliance

\* Only the preferred alternative was evaluated for state and community acceptance

Yellow Indicates preferred alternative

Alternative GW-4 (Semi-Active Treatment) 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 are both semi-passive with SRBRs, with GW-6 having additional water treatment by oxygen and polishing through a constructed wetland. The alternatives would be less protective than either alternative GW-3 or alternative GW-4 as they rely on natural chemical and biological processes. The settling and polishing ponds are open and their effectiveness would be subject to variability caused by capacity, influenced by seasonal variations in temperature and precipitation.

#### **Compliance with ARARs**

Refer to Section 10.1.1 above and Table 10-2.

#### **Balancing Criteria**

#### Long-Term Effectiveness and Permanence

The long-term effectiveness of mine plugging alternatives GW-1 and GW-2 would potentially range from as low as 25 percent to as high as 90 percent depending on 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.

Ground water seeps around and through the grout curtain in GW-2 can occur over time. 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 metal-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. 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 O&M 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 8 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. As sludge precipitates 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 operation and maintenance of 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. Scaling, a 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 is less of an issue for GW-6, but sludge formation will require periodic disposal. Proper operation and maintenance for the treatment ponds/cells and process would contribute significantly to the permanence of this treatment alternative.

#### Reduction of Toxicity, Mobility or Volume through Treatment

Alternatives GW-3, GW-4, GW-5 and GW-6 all offer treatment, while alternatives 1, GW-1 and GW-2 do not, thereby receiving a lower score than the treatment alternatives. The predicted treatment efficiencies of each alternative (ability to reduce toxicity, mobility and volumes of contaminants in the AMD) 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

All treatment alternatives would produce metal-containing sludges which would require proper disposal in a local repository.

#### **Short-Term Effectiveness**

Mine plugging alternatives GW-1 and GW-2 would initially carry some short-term safety risk because of the transport and operation of construction equipment. 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.

Active treatment 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. 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 Site and the local population. Unlike alternative GW-3, when construction is complete, several years may be required before these systems meet their optimal treatment efficiencies.

#### Implementability

#### **Technical Feasibility**

Alternative GW-1 would require specialized services to re-open the two mine portals and construct safe entry points into the mines. Assessment and inspection of the adits for evaluation of seepage, recharge and strategic placement of mine plugs would require special mining expertise and equipment. Alternative GW-2 would require specialized services to place underground explosives. Drilling and injecting of the grout curtain around the adit plugs is also a technically feasible but challenging consideration associated with alternative GW-2. Alternatives GW-1 and GW-2 are equivalent in technical feasibility.

Technical feasibility constraints associated with active treatment alternative GW-3 would be the construction and operation of the treatment plant, and providing power to the Site. Since these constraints are dependent on hiring regionally available contractors, Alternative GW-3 is considered more technically feasible than all of the other GW alternatives, and therefore scored highest.

Technical feasibility challenges associated with treatment alternatives GW-4, GW-5 and GW-6 are installing the treatment ponds/cells, installation of liners and collection of contaminated ground water. These alternatives are considered equivalent in technical feasibility, below alternative GW-3 and above alternative GW-1 and GW-2.

#### **Administrative Feasibility**

All of the ground water 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-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; 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 ground water alternatives in availability of services and materials.

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.

#### Cost

The No Action alternative is the lowest-cost alternative at \$231,000. The cost for the ground water alternatives (from least to most costly) are \$3.8 million for alternative GW-6 (Semi-Passive Treatment without bulkhead), \$4.4 million for alternative GW-5 (Semi-Passive Treatment), \$5.1 million for alternative GW-4 (Semi-Active Treatment), \$7.7 million for alternative GW-3 (Active Treatment), \$7.8 million for alternative GW-1 (Mine Sealing through Reopened Adit) and \$12.3 million for alternative GW-2 (Mine Sealing by Remote Means).

#### **Modifying Criteria**

#### **Community Acceptance**

The community of Jefferson County and the towns of Basin and Boulder, Montana, support the selected remedy for contaminated ground water at the Site, as described in Section 12. No objections were verbally stated by the community during the public meeting, nor received in writing during the public comment period.

#### State Acceptance

This is an Interim ROD to address a significant source of metal and arsenic contaminant loading to USG Creek, a tributary to Cataract Creek. The Basin Watershed ROD will detail the final determination regarding the need for and extent of any additional remedial actions necessary at OU5. MDEQ supports the sequenced implementation of the Crystal Interim ROD as follows: (1) construction of the onsite repository and placement of impacted materials in the repository; (2) detailed evaluation and control, to the extent feasible, of surface water impacts and ground water impacts on the mine workings; (3) design and construction of the AMD water treatment system needed to reduce metal and arsenic loading to USG Creek to acceptable levels; and (4) the EPA's commitment to operate and maintain the AMD treatment system in accordance with 40 CFR §300.435. MDEQ's determination that a waiver of the State of Montana's Circular DEQ-7 numeric water quality standards for ground water and surface water is justified based on the EPA's commitment that the final remedy for OU2 will meet all the State of Montana's Circular DEQ-7 numeric water quality standards for ground water and surface water standards.

### **11.1 Principal Threat Determination**

Principal threat wastes are source materials considered to be highly toxic or highly mobile that generally cannot be contained in a reliable manner or present a significant risk to human health or the environment should exposure occur. The NCP establishes an expectation that the EPA will use treatment to address principal threats posed by a site wherever practicable (NCP at CFR 40 § 300.430(a)(1)(iii)(A)), but recognizes that treatment is not always possible. A source material is one that includes or contains hazardous substances, pollutants, or contaminants that act as a reservoir for migration of contamination to ground water, surface water, or air, or acts as a source for direct exposure.

Perennial discharge from the lower adit, characterized by low pH, high arsenic and metals concentrations, is the major principal threat waste at the Crystal Mine. The source of contamination is the interaction of ground water with mineralized materials within the geologic formation exposed by historic mining. The mine adit discharge contributes high concentrations of dissolved aluminum, cadmium, copper and zinc to USG Creek and downstream tributaries. Mine water infiltrating into adjacent soils can also form soluble metal salts through evaporative processes (Exhibit 11-1). The metals in solution, and salts that dissolve and move into the creek during rain events, are highly toxic to aquatic life. These sources and pathways present acute and chronic risks to aquatic life in the creek.

#### EXHIBIT 11-1

Metal Salt Crystals Formed Adjacent to Lower Mine Adit Discharge



Arsenic in waste rock and soils, although considered a contaminant of concern for human health, has been determined to be a non-principal threat waste at the Site. However, if people were to live or recreate on four wheelers in areas where they have repeated, daily contact with the waste rock and soils, risks from arsenic could be in the range of concern for both noncancer and cancer (EPA, 2013).

Contaminated wastes are present throughout the Site and are commonly toxic to terrestrial plants. Acidic runoff from the exposed waste rock contributes to high concentrations of metals in USG Creek. This source of contaminants represents an acute risk to aquatic life in the Creek. Sources of concern include contaminated waste rock dumps, hillsides, and stream banks adjacent to the mine that lack vegetation. During normal snowmelt and precipitation events, these areas erode large amounts of metal-laden sediment into the aquatic system, and promote localized geomorphic instability along USG Creek.

The metal contamination and related acid generation from these wastes results in a lack of hillside and floodplain vegetation. Other impacts include the following:

- Accelerated hillside/streambank erosion, causing unacceptable chronic risks to aquatic life, as well as land management problems.
- Vulnerability of floodplain to destabilization.
- Potential and actual environmental hazards to terrestrial and aquatic life, especially from high-intensity precipitation and flood events.
- Degraded ground water quality.
- Degraded surface water quality as a result of metals, arsenic and sediments loading.

40 CFR §300.430(a)(1)(iii)(A) of the NCP states that principal threat wastes will be addressed where practicable with "treatment." For the contaminated adit discharge flowing into the creek, treatment is required to remediate the quality of the water. EPA has therefore selected an aggressive alternative to treat this principal threat waste. For waste rock and soils adjacent to the creek, removal and permanent disposal outside of the floodplain in a lined repository was selected. This remedy also addresses areas that are not considered principal threat wastes but represent unacceptable risk conditions, such as the steep, barren and disturbed areas. These areas will be will be mitigated by the application of new cover material, vegetation, and BMPs. Finally, surface water conveyance features will be constructed to move precipitation and snowmelt away from the underground mine.

## Section 12. Selected Interim Remedy

The EPA's selected interim remedy for the Site, as presented in the proposed plan, is a combination of a waste rock alternative (WR-3, removal and disposal in an onsite repository), and a ground water alternative (GW-6, semi-passive treatment of AMD). Based on consideration of the CERCLA requirements, the detailed analysis of viable remedial alternatives, and state and public comments, the EPA has determined that the combination of remedial alternatives WR-3 and GW-6 is an appropriate remedy for the Site.

Note: The EPA has decided to conduct part of the remedy presented in the proposed plan as a removal effort. Because accelerated erosion has compromised the integrity of the earthen berms supporting the sediment ponds, the EPA decided to conduct a TCRA in 2014. The removal effort will dewater both ponds, consolidate and remove contaminated sludge and synthetic liners, and transport this material to the Luttrell Repository for disposal. Mine water discharge from the lower adit will be rerouted directly into USG Creek until the semipassive water treatment portion of the remedy is constructed.

### 12.1 Short Description of the Selected Remedy

The remedy, consisting of remedial alternatives WR-3 and GW-6, will be implemented in phases to accommodate the short construction season at this high-altitude site. The cleanup strategy includes the following actions:

#### Contaminated Waste Rock/Soils Removal:

- ✓ An onsite repository will be designed and constructed over a portion of the Crystal Mine trench area.
- ✓ Contaminated mine structures will be dismantled and transported to the Luttrell Repository for disposal.
- ✓ Contaminated waste rock and soils from dumps, mine areas, and the USG Creek flood plain will be excavated, hauled and deposited in the onsite repository. When waste removal is complete, the repository will be capped with an impervious liner, covered with 18 to 24 inches of topsoil, and planted with native vegetation. Large rock and woody debris will be scattered throughout the repository surface to discourage ATV disturbance and minimize erosion.
- ✓ After removal of the mine wastes, the disturbed areas will be regraded, capped with topsoil and revegetated.
- ✓ Streambank reclamation actions will use removal and recontouring, along with BMPs, channel reconstruction and the planting of native woody and herbaceous vegetation to secure the banks.
- ✓ Surface water influence on ground water (source water control) will be evaluated and actions taken to intercept and convey surface water away from mine workings.

#### **Ground Water Remediation:**

- ✓ A semi-passive treatment system (SPTS) to remediate AMD from the lower adit will be designed and constructed.
- ✓ The lower adit portal will be re-opened and stabilized to facilitate the free flow of water from the mine adit where it will be conveyed into the treatment system. A secure portal entrance will be constructed to facilitate mine drainage while preventing access into the mine adit by recreationists. If appropriate, and recommended by MDFWP or USFWS experts, the gate structure will facilitate access by certain wildlife, such as bats.
- ✓ The SPTS will be constructed as described under GW-6 (the five stages of GW-6 are SRBR, aeration system, oxidation/settling ponds, wetlands and discharge to USG Creek).
#### **Operation, Monitoring and Maintenance:**

- Periodic replacement of the pH adjustment cell and SRBR media will be required. Sludge that settles in the deep end of the clarification pond will also require removal, drying and disposal at the Luttrell Repository. If appropriate, sludge removal may include injection into fabric tubes to facilitate dewatering and transport to the repository. Facilities to accommodate this activity will be incorporated into a remedial design (for example, using 20 yard dumpster bags to remove the sludge tubes).
- ✓ ICs to prohibit residential use, prevent installation of drinking water wells and to protect the remedy will be developed. ICs refer to administrative land management methods necessary to maintain the effectiveness of the remedy and protect human health by preventing exposure to contaminated soil and ground water that creates an unacceptable risk to human health. ICs will be tailored to the size, location and complexity of the area.
- ✓ The EPA and MDEQ will work with adjacent landowner agencies (primarily USFS) on the specific application of this remedy.
- Construction and post-construction monitoring of water quality and other environmental parameters will be performed.
- ✓ An operation, maintenance and monitoring (OMM) plan will be developed by MDEQ and the EPA that addresses all parameters that must be monitored, monitoring locations, frequency of monitoring, and the response actions to be taken based on monitoring data, to assure successful remedy implementation and protectiveness.

# 12.2 Rationale for the Selected Interim Remedy

The selected interim remedy meets the mandatory threshold criteria requirements of protection of human health and the environment and compliance with ARARs, or justification of a waiver of an ARAR. It successfully addresses the needs and tradeoffs of the five balancing criteria, reduces environmental risk from remaining contaminants, and promotes the long-term protectiveness of previous removal actions, as well as the current remedial action.

The selected interim remedy will protect human health by removing AMD contaminants discharging into USG Creek, preventing consumption of ground water at the Site through an IC, and breaking the exposure pathway to soil contaminants by removal and disposal of waste rock and soils, covering excavated areas with clean soil, and vegetating disturbed areas to stabilize slopes and erosion-prone areas.

The selected interim remedy will protect the environment by reducing the transport and loading of contaminants from the mine into USG Creek and Cataract Creek. Treatment of the mine water will reduce the exposure of fish and other aquatic receptors downstream of the mine to contaminants, and will contribute to meeting State water quality ARARs for the long-term protection of aquatic life in the Basin Watershed OU2. Semi-passive treatment was selected over more conventional treatment because of the remote Site location and difficult access during the winter. It also offered the best balance between cost effectiveness, implementability and protectiveness.

The selected interim remedy addresses contaminated sediment by reducing the primary source, the untreated mine discharge, and the ancillary sources of exposed waste rock and soils. The remedy does not include physical removal of sediment beyond the southern boundary of the Mammoth mine claim. Contaminated sediments beyond this point will decrease through natural mixing and transport processes of annual runoff and storm flow (monitored natural recovery).

The remedy does not address ground water beyond the discharge of mine water from the adit. The Site is located in an area of highly mineralized rock. Natural interaction between ground water and the mineralized veins in the bedrock occurs and results in isolated areas of contaminated ground water. Because this is an interim ROD, it is beyond the scope of this action to address all of the sources of ground water contamination in the watershed. However, the selected remedy is expected to improve ground water quality at the Site by continuously treating adit discharge, and removing waste rock and soils as a source of contamination. A goal of the final remedy for the OU2 Watershed is to meet all surface and ground water ARARs.

Monitoring, long-term O&M, and ICs will promote the long-term protectiveness of the selected remedy.

# 12.3 Detailed Description of the Selected Interim Remedy

A detailed description of the selected interim remedy is presented in this section. Minor changes to the remedy may occur during RD and remedial action to adapt the system to its location and optimize its treatment output, as long as changes to the RD and remedial action remain protective and comply with ARARs. Exhibits 12-1 to 12-3 provide a conceptual design of the selected remedial alternative.

### 12.3.1 Site Access

From the intersection of Basin Creek Road with Jack Creek Road, up through the Bullion Mine Site and over the summit to the Crystal Mine, approximately 5.6 miles of existing USFS road will be improved as an initial step to facilitate the safe movement of equipment and construction materials to and from the Site.

The EPA removal program will remove two sediment ponds located near the lower adit portal in 2014 as a TCRA to prevent an uncontrolled release of contaminated mine water and sludge should the existing berms holding the ponds fail. The removal program will discharge the pond water directly into USG Creek and consolidate the pond sludge and liner for transport and disposal at the Luttrell Repository.

# 12.3.2 Onsite Repository and Waste Rock Removal

An onsite mine waste repository will be designed and constructed over the west end of the Crystal trench. The repository will be designed with adequate capacity to handle waste rock and contaminated soils from the onsite waste dumps and source areas (approximately 60,000 cubic yards). An onsite loop road will be upgraded and used to transport the material to the onsite repository. The repository will be capped with an impermeable liner, covered with 24 inches of cover and top soil, and revegetated. Removal areas will be regraded for stability, covered with soil from a clean borrow source, and vegetated. Large rock and woody debris will be scattered throughout the repository surface and removal areas to discourage ATV disturbance and minimize erosion. Approximately 1,100 lineal feet of impacted streambanks along USG Creek will be remediated through removal and recontouring, along with BMPs, channel reconstruction and the planting of native woody and herbaceous vegetation to secure the banks.

## 12.3.3 Source Water Assessment and Control

The source water assessment and control effort will be comprised of a series of steps performed to determine if the flow of ground water into the mine workings (recharge) can be reduced. The specific steps to this process will be refined during remedial design, and will include the following:

#### Step 1

- Review existing information and look for additional information on the extent of the mine workings. Identify mine features not observed during the RI that may have a surface expression that would allow water to enter the workings.
- Perform a final Site reconnaissance to locate areas that could act as a conduit for surface water into the mine.

- Investigate and evaluate ground water inflow and contaminant release locations.
- Identify strategic locations for surface water control features to capture and convey snowmelt and rainfall away from areas above the underground workings.

#### Step 2

- Design seals for mine features identified in Step 1.
- Design water control features for conveyance away from areas above the underground workings and into adjacent drainages to limit ponding and infiltration.

#### Step 3

- Construct surface and ground water seals and water control and conveyance features.
- Continue to monitor lower adit discharge to gage impact on flow.

#### Step 4

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

### 12.3.4 Semi-Passive Water Treatment System

Alternative GW-6 will be a five-stage SPTS utilizing (1) an SRBR, (2) aeration system, (3) oxidation/settling ponds, (4) wetland, and (5) discharge to USG Creek. To incorporate desirable sustainability concepts into the design, the treatment process will function by gravity flow, utilize natural treatment chemistry, incorporate low operational and maintenance requirements, and sustain its effectiveness through seasonal changes at this remote Site. Adit flow will be collected outside the adit portal and conveyed through HDPE pipe to the constructed SPTS. Two treatment trains will be installed in parallel, consisting of the first three stages. Piping will be designed to allow for one treatment train at a time to be taken out of service for maintenance. Only one wetland and discharge point will need to be constructed to serve either treatment train. The five stages of the treatment process are further described in the following text (see Exhibits 12-1 through 12-4). Table 12-1 provides conceptual design parameters for this alternative.

#### TABLE 12-1

#### Alternative GW-6 Design Parameters

Feature	Crystal Mine			
Estimated flow rate <sup>a</sup>	45 gallons per minute			
Ground water collection	Direct piping from adit			
SRBR cells <sup>c</sup>	2 PVC-wrapped cells with 5-foot-thick soil cover for insulation, 6,200 cubic yards each			
Aeration channels	2 stepped channels lined with HDPE and riprap			
Oxidation/settling ponds <sup>b,d</sup>	2 HDPE-lined, 6.5-foot-deep ponds, 292 cubic yards each			
Clarification pond <sup>d</sup>	1 HDPE-lined, 6-foot-deep pond, 3,000 cubic yards			
Rock-lined channel	Treated effluent discharges to USG Creek			

Notes:

<sup>a</sup> See Appendix D of the FS for determination of design flow rates.

<sup>b</sup> Size of settling ponds based on available space.

<sup>c</sup> SRBR cell size based on 2-day retention time

<sup>d</sup> Pond design is based on sludge formation, storage needs, total suspended solids (TSS) retention, and to facilitate cleanout.









DEM Generated 5 Meter Contour (Displayed Elevation in Feet)





EXHIBIT 12-1 **GW-6 SEMI-PASSIVE** TREATMENT AREA (PLAN VIEW) Crystal Mine OU5 ROD



#### LEGEND:

EXHIBIT 12-2 PROCESS FLOW DIAGRAM Crystal Mine OU5 ROD







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

- The top layer will be a 2- to 3-foot geotextile and vegetated soil cover to prevent freezing.
- Below the top layer will be a water layer (mine discharge water) that will be 3 feet thick and consist of porous material.
- The next layer will 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 will be sized to provide approximately 2 days retention time.
- Below the limestone/compost layer will be a 3-foot-thick layer of limestone drain-rock with 6-inchdiameter perforated collector pipes running through the layer. The upper layer and this layer will be separated by a geotextile fabric, which will act as a filter keeping the limestone/compost out of the drain rock.
- The final layer will be a cushioning/protection layer for the line which will consist of a 6-inch-layer of sand.
- Water from the SRBR will then flow to the aeration system.

**Stage 2, Aeration System.** Two short series of cascades (riprapped channels) will 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 dissolved oxygen and ORP.
- The distal end of the open channels will be constructed with 6-inch-diameter perforated collection pipes running near the bottom to divert flow into the next oxidation/settling ponds.

**Stage 3, Oxidation/Settling Ponds**. The precipitation/settling ponds (two in series) will 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) will 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 will provide biological filtering and removal of total suspended solids (TSS). Overflow from this pond will be directed to the wetland (Stage 4).
- Periodically, sludge that settles in the deep end of the ponds will be excavated or slurried, and dried on drying beds or pumped into sediment tubes, which will drain into the ponds.
- The dried waste will 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 will need to be identified. For the purpose of this interim ROD, it is assumed that dried sludge will go to the Luttrell Repository for disposal.

Wetland (Stage 4). The wetland pond will allow for suspended solid polishing. It is assumed that discharge from the adit will 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 will consist of 2 feet of soil for the plants to develop roots.
- The second layer will be the water layer that is 2 to 3 feet thick (variable).

**Discharge to USG Creek (Stage 5).** Discharge from the wetlands pond will be conveyed to USG Creek by an open riprap-lined channel.

### 12.3.5 Institutional and Engineering Controls

ICs will consist of a combination of legal and administrative controls, access controls (physical controls), and community awareness activities to restrict access and use of contaminated areas and provide awareness of risks from exposure. The ICs will be tailored to the property to provide protection of human health and to maintain the integrity of the remedy to the extent possible.

As described in the preferred remedy, ICs are important, supplementary parts of the selected remedy. Presented here is a general description of the ICs that the EPA deems necessary for the remedy.

- Educational efforts for recreational users concerning the need to prevent incidental intake or ingestion of surface water in the vicinity of the Site. The EPA plans to work with local and county officials for implementation of this program.
- Prevention of ground water use for domestic consumption or activities that may spread ground water contamination at the operable unit. Several mechanisms could be used to implement this IC including local and county ordinances, or specific deed restrictions or easements on contaminated land.
- Restrictions that protect the remedy and promote the appropriate management of revegetated areas so that recreational use of these areas can occur, while the important revegetation efforts are protected, comply with ARARs and are sustained over time.
- Restrictions that prevent residential or commercial use, because the soil cleanup level is based upon recreational exposure (for example, deed restrictions).
- Fencing (an engineering control) may be needed to discourage public access to the SPTS and the mine portal. Access by large wildlife (deer, elk and moose) would also be discouraged by a fence of appropriate size. Vigilance through annual inspections of dikes and berms will be required to prevent damage by small burrowing rodents.
- The EPA and MDEQ will work with adjacent landowner agencies (primarily USFS) on the specific application of this remedy. The agencies will work to ensure that ICs are protective of human health and compatible with existing and reasonably anticipated future land use in the area.

### 12.3.6 Post-Remedy Construction Operation, Monitoring and Maintenance

In order to track and measure progress toward achieving cleanup goals at the Site, a monitoring program that includes physical, chemical and biological components is essential. Therefore, the EPA and MDEQ will develop a Site-wide OMM plan (including ongoing operation, maintenance and monitoring requirements for all remedy components) when remedial actions are complete. Because waste is proposed to be left onsite, 5-year reviews will be a component of post-remedy construction activities.

Anticipated activities include periodic inspection of the Site remedy, maintenance of surface water channels and trenches, monitoring and maintenance of soil cover and revegetated areas to ensure the vegetative cover is adequate to maintain protectiveness and control erosion, maintenance of engineered structures associated with the SPTS, and monitoring and enforcement of the institutional controls.

Operation and maintenance of the SPTS will include ongoing water quality monitoring at the discharge point and at the mine claim boundary, system inspection and review, periodic cell maintenance and sludge removal/disposal, and periodic excavation, disposal and replacement of biochemical reactor media. Frequency of maintenance will be refined during remedial design and initial operations. Emphasis will be placed on operation and maintenance considerations of the SPTS during design because of the remote, high elevation location of the system, the difficult access during the winter months, and the need to sustain a high level of function throughout the year. Maintenance activities need to be easily executed, sustaining, and cost effective.

# 12.4 Estimated Cost of the Selected Interim Remedy

The costs for the selected interim remedy presented in this section are estimates, with an accuracy expectation of +50 percent to -30 percent. The estimates will be refined as the remedy is designed and implemented. Even after the remedial action is constructed, the total project costs will be reported as an estimate due to the uncertainty associated with the OMM expenditures. Periodic costs are those costs that occur only once every few years or expenditures that occur only once during the entire OMM period or remedial time frame (for example, Site closeout or remedial feature replacement due to chemical or physical degradation). These costs may be either capital or OMM costs. Because of the duration of the cost evaluation for this interim ROD (30 years), periodic costs were primarily associated with OMM and the 5-year reviews. As an interim ROD, it is believed that a 30-year cost evaluation is justified, since the ROD for the Basin Watershed OU2 will likely occur during this period and re-evaluate the adequacy of this interim remedy. Table 12-2 presents a breakdown of the cost estimate for the selected remedy, including net present value (NPV) analysis on a year-by-year basis (discounted by 5 percent per year).

Costs for alternative WR-3 are summarized in the following points.

- 1) The NPV cost for alternative 3 is approximately \$5,252,000. The individual components of this cost are:
  - a) Estimated total capital costs: \$4,687,000
  - b) Estimated total O&M costs (first 30 years): \$565,000
  - c) Estimated construction time: Two field seasons

#### TABLE 12-2

Description	Quantity	Unit	Unit Cost	Cost	Assumptions	
Capital Costs						
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	СҮ	\$6.91	\$169,295	Crystal Dump excavation	
Waste Rock Excavation	35,500	СҮ	\$6.91	\$245,305		
Contaminated Soil Over Excavation	7,500	СҮ	\$5.33	\$39,975		

#### Cost Breakdown of Selected Remedy (Waste Rock Alternative)

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Replacement Soil	7,500	СҮ	\$2.79	\$20,925	
Cover Soil on Liner	11,000	СҮ	\$34.39	\$378,290	
Cap Soil	4,200	СҮ	\$34.39	\$144,438	
Waste Rock Hauling	24,500	СҮ	\$2.35	\$57,575	Crystal Dump hauled to repository
Waste Rock Hauling	35,500	СҮ	\$2.35	\$83,425	
Dust Control	15	day	\$1,684.6 7	\$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	Run-on - Runoff Control
Stream Bank 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					
Miscellaneous Equipment and Supplies	1	LS/YR	\$500	\$500	
5-Year Reviews	1	LS/YR	\$4,000	\$4,000	\$20k per 5-year review
Monitoring	1	LS/YR	\$20,000	\$20,000	Monthly sampling of streams and quarterly sampling of monitoring wells
Subtotal O & M Costs				\$24,500	
Contingencies (50%)				\$12,250	
Net Present Value of O&M Costs				\$564,938	Assumes 5% discount rate for 30 years
Alternative WR-3 Total Present Worth Costs				\$5,252,000	

#### TABLE 12-2

Cost Breakdown of Selected Remedy (Waste Rock Alternative)

Costs for alternative GW-6 are summarized in the following points.

2) The NPV cost for alternative 6 is approximately \$3,832,000. The individual components of this cost are:

- a) Estimated total capital costs: \$2,570,000
- b) Estimated total O&M costs (first 30 years): \$1,262,000
- c) Estimated construction time: Two field seasons

#### **TABLE 12-3**

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Capital Costs					
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		\$870,692*	
Excavation	12,448	CY	\$11.08	\$137,924	Common, no rock ex
Liner	32,000	FT <sup>2</sup>	\$0.97	\$31,040	40 ml HDPE
Sand Layer	331	CY	\$21.09	\$6,981	Single 6-inch lift, light compaction
Limestone Layer	2,432	CY	\$62.69	\$152,462	2 18-inch lifts, light compaction
Reactive Layer	2,764	CY	\$38.69	\$106,939	2 18-inch lifts, light compaction
Oxidation/Settling Ponds	2	EA		\$19,149*	
Excavation	584	CY	\$11.08	\$6,471	Common, no rock ex
Liner	3,200	FT <sup>2</sup>	\$0.97	\$3,104	40 ml HDPE
Aeration Channels	2	EA		\$4,317*	
Excavation	67	CY	\$8.38	\$561	
Rip Rap	30	CY	\$53.24	\$1,597	12 inches +/-
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-foot spacing, no land costs
Common Elements				\$999,000	
Surface Water Control		LS		\$101,000	Run-on - Runoff Control
Stream Bank Reconstruction		LS		\$639,000	Reconstruction of 1,000 ft of USG Creel

#### TABLE 12-3

Breakdown of the Selected Remedy – GW Alternative 6

Description	Quantity	Unit	Unit Cost	Cost	Assumptions
Removal/Disposal of Ponds and Structures		LS		\$259,000	2 ponds and mine structures
Subtotal Capital Costs				\$2,079,119	
Contingencies (50%)		\$1,039,559	Contingencies at 50% due to Site uncertainties		
Engineering and SDC (15%)				\$155,934	
Subtotal Capital Costs				\$3,275,000	
Operations and Maintenance					
Labor (Operators)	100	HR/YR	\$50	\$5,000	Assume 6 hrs/mo plus 28 hrs/yr for miscellaneous O&M
Rototilling of pH Adjustment Cell	1	LS/YR	\$250	\$250	Assume \$500 every 2 years
Periodic Replacement of pH Adjustment Cell	1	LS/YR	\$5,500	\$5,500	Assume \$33,000 to replace media every 6 years
Periodic Replacement of SRBR Beds	1	LS/YR	\$13,000	\$13,000	Assume \$200,000 to reconstruct SRBR cells every 15 years
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
5-Year Reviews	1	LS/YR	\$4,000	\$4,000	\$20k per 5-year review
Monitoring	1	LS/YR	\$19,000	\$19,000	Monthly sampling of streams and processes
Subtotal O&M Costs				\$54,750	
Contingencies (50%)		\$27,375			
Net Present Value of O& M Costs				\$1,262,463	Assumes 5% discount rate for 30 years
Alternative GW-6 Total Present Worth Costs				\$4,537,000	
TOTAL PRESENT WORTH COSTS FOR REMEDY (WR-3 and GW-6 combined)				\$9,789,000	

Notes:

\* Includes dual cells to promote continuous operations during media replacement.

# 12.5 Expected Outcomes of the Selected Remedy

Removal of the sediment ponds as a TCRA action in 2014, prior to formal remedial action, is expected to eliminate the risk of an uncontrolled release of a large volume of contaminated water and sediment onto USFS land and Cataract Creek via the USG Creek tributary. The first step of the remedy, removing the debris from the portal area, will allow the mine water to flow freely, enable accurate gaging of the flow rate to facilitate design, and contribute to accurate sizing of a SPTS.

Completing a source water assessment and control effort is expected to reduce source water infiltrating into the mine workings, reducing the volume of AMD produced by the mine that will be treated in the SPTS.

Successful operation of a SPTS to control and treat the AMD is expected to reduce the loading of low pH water and metals to USG Creek. Water quality is expected to improve in USG Creek, reduce risks to aquatic life, and promote a healthier, more robust aquatic environment and riparian corridor. Water quality improvements will contribute to USG Creek attaining the state beneficial use designation of B-1.

As exposed areas of waste rock and soil contamination are removed to the repository, slopes are regraded, stabilized, covered with clean soil, and revegetated, erosion is expected to decrease, and exposure of terrestrial receptors will be greatly reduced.

As the mine discharge to USG Creek is remediated through treatment, and slope stability and vegetative cover are achieved on hill slopes and stream banks, sediment contamination in USG Creek is expected to diminish. Spring runoff and summer storms will promote the migration, mixing and dilution of contaminated sediment beyond Site boundaries. This action will contribute to an improved aquatic environment. The progress of improvement will be tracked by periodic monitoring, the frequency of which will be identified in the OMM plan.

# 12.6 Performance Standards

This section describes and discusses key performance standards for surface water, soils and sediment applicable to the Crystal Mine interim remedial action only. Performance standards are also presented in Appendix A – the description of ARARs.

Performance standards for soil were derived for arsenic—the only human health risk for recreational users (ATV riders and hikers). The cleanup level for arsenic (1,243 mg/kg) is based on potential risks (including bioavailability testing) derived for the adolescent recreational user. Potential exposure occurs in barren areas of waste rock and soil within the mine claim areas. To limit future exposure to contaminated soil, remedial action will consist of the removal of waste rock and contaminated soils, slope stabilization, and the addition of clean soil cover and vegetation. Careful placement of debris (wood and rock) will be implemented to discourage ATV use and associated erosion. The proposed recreational cleanup level is based upon the assumption that ICs will be placed on the Site, limiting residential and commercial use.

Performance standards were not developed for terrestrial receptors because the species at risk are mobile and most are not likely to forage at the Site 100 percent of the time when higher quality habitat is available nearby. As previously stated, areas of concern created by contaminated waste rock and soil will be remediated by removal, and application of clean cover soil with vegetation to greatly reduce exposure to any residual soil contamination. The risk assessment assumes that each endpoint species receives at least a portion of their drinking water from the mine area. This assumption may overestimate exposure because, for some species, most or all water intake comes from food items. Table 12-4 presents contaminant concentrations that are expected to be protective of ecological receptors. Protective levels for aquatic receptors exposed to surface water are based on MDEQ water quality and aquatic life standards, Circular DEQ-7 (MDEQ, 2012). These concentrations are provided for comparison purposes only. Because this is an interim action, the EPA has waived the surface and ground water quality standards until a final action is taken for the Basin Watershed OU2. The goal of the final action for OU2 will be to meet all ARARs, including DEQ-7 standards for surface water and ground water. However, the EPA expects that the interim action will improve water quality, and monitoring of Site waters will be compared to the concentrations in Table 12-4.

Contaminant	Human Health	Acute <sup>b</sup>	Chronic <sup>a</sup>
Aluminum	-	0.75	0.087
Antimony	0.0056	-	_
Arsenic	0.01	0.34	0.15
Cadmium	0.005	0.00052	0.000097
Copper	1.3	0.00379	0.00285
Iron	-	_	1
Lead	0.015	0.0139	0.000545
Manganese	-	_	_
Nickel	0.1	0.145	0.0161
Selenium	0.05	0.02	0.005
Silver	0.1	0.000374	_
Thallium	0.0002	_	_
Zinc	2	0.037	0.037

#### TABLE 12-4 Surface Water Targets in mg/L

Notes:

<sup>a</sup> Circular DEQ-7 (MDEQ, 2012), based on 25 mg/L hardness

<sup>b</sup> Circular DEQ-7 (MDEQ, 2012) acute standard

Cleanup levels were not established for aquatic receptors exposed to sediments because it was determined that sediment contamination will be addressed by reducing the source of sediments (through mine water treatment and contaminated waste rock, soil, and sediment removal within the mine boundaries) and natural recovery induced by runoff action in the channel. The progression of natural recovery will be monitored at a downstream point of compliance along USG Creek beyond the Site boundaries (approximately one-half mile below the Mammoth Mine Claim boundary). Specific monitoring locations and frequency of monitoring will be determined after remedial construction in the OMM plan.

# 12.6.1 Performance Evaluations for the Selected Interim Remedy

Following implementation of the selected remedy, the EPA will operate the PTS and demonstrate that the remedy is operational and functional, and protects human health and the environment. As provided in 40 CFR §300.435(f)(3), "[f]or Fund-financed remedial actions involving treatment or other measures to restore ground- or surface-water quality to a level that assures protection of human health and the environment, the operation of such treatment or other measures for a period of up to 10 years after the remedy becomes operational and functional will be considered part of the remedial action." The EPA and MDEQ will develop an OMM plan that will include evaluations of the remedy:

- Improvements in surface water quality by comparing pre-treatment baseline values to values obtained immediately below the confluence of the passive treatment system discharge and USG Creek. The EPA's goal for the interim remedy is to achieve a 90 percent or higher reduction in aluminum, arsenic, cadmium, copper, lead and zinc.
- Reduction of acute and chronic risks to aquatics as measured by BMI taxa richness and species diversity counts every 5 years. The EPA's goal for the interim remedy is to promote a robust aquatic environment that supports benthic macroinvertebrate taxa richness and species diversity counts equivalent to an appropriate reference stream reach.
- A measure of improvement in vegetation attributes of: cover, production, species richness and successional trend across the reconstructed soil cover equivalent to an appropriate reference area.
- A reduction of 90 percent in stream sediment metals concentrations for the following particle size classes: 10 mesh (medium to course sand), 80 mesh (very fine to fine sand), and 230 mesh (silt/clay size). Monitoring results will be compared to historic results for the same size classes to demonstrate reduction. Evaluation frequency to be determined after remedial construction.

Reviews will be performed every 5 years to assess the performance of the remedy and confirm that human and ecological health are not being jeopardized.

# 12.7 Safety Concerns

Conducting a cleanup in a safe manner is a primary concern. Safety will be stressed throughout all aspects of the project. The EPA's experience with other sites where treatment of AMD has been performed indicates this project can be conducted safely with careful planning.

A primary consideration at the Site is managing truck traffic safely. This includes planning to safely optimize truck traffic flows on major highways, primary local county roads and secondary-access USFS roads onto the Site. The EPA has consulted with construction specialists at the USFS and with the EPA's contractor, and believes the project can be designed and implemented in a safe manner. Other construction projects, such as road construction and logging operations, commonly pose traffic safety risks and yet are effectively planned and implemented.

The EPA will emphasize project safety in implementation. This particular project will require road improvements and some possible road widening. The EPA will strive to minimize public contact with the trucks and heavy equipment, and ensure wide and stable roads where that potential contact may occur. The remedy will retain responsibility for road upgrades and the EPA will work closely with local representatives. The EPA believes the remedy can be safely implemented through good planning and engineering practices.

# **13.1 Statutory Determinations**

Under CERCLA section 121 and the NCP, the EPA must select a remedy that is protective of human health and the environment that complies with or appropriately waives ARARs, is cost effective, and utilizes permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, CERCLA includes a preference for remedies that include treatment that permanently and significantly reduces the volume, toxicity or mobility of hazardous substances, pollutants or contaminants as a principal element. The following sections discuss how the selected remedy meets these statutory requirements.

## 13.1.1 Protection of Human Health and the Environment

The selected remedy (combination of waste rock removal to an onsite repository [alternative WR-3] and semi-passive treatment of AMD [alternative GW-6]) described in this interim ROD mitigates risk to human health and the environment by reducing human and environmental receptor exposure to Site contaminants through treatment, removal and ICs. The selected interim remedy will reduce metal concentrations in USG Creek. A monitoring station downstream of the Mammoth mine claim on USG Creek will be assessed for surface water quality and sediment contamination. Surface water conveyance structures will effectively route runoff (potential recharge source water) away from mine features and underground workings to reduce formation of AMD. Downstream wetlands and associated ecological habitat will be protected.

Removal of contaminated waste rock and soils to an onsite repository, and stabilization of exposed slopes with clean cover material and vegetation will prevent excessive Site erosion and break exposure pathways to residual soil contaminants for plants, birds, mammals and other organisms. Implementation of the selected remedy will not pose any unacceptable short-term risks nor cross-media impacts.

## 13.1.2 Compliance with ARARs

The ARARs that the selected remedy for this Site must comply with are identified in detail in Appendix A. Key ARAR requirements and other performance standards for the Site are described in section 12.6 of this interim ROD.

Other criteria, advisories or guidance to be considered during remedial design for this action are also identified in Appendix A.

The EPA invokes the ARAR waiver of section 121(d)(4) of CERCLA for this interim action, for surface and ground water quality ARARs after treatment. The basis for the waiver of those standards is explained in Appendix A, and described in Section 10.1.2 of this interim ROD. Appendix A also describes the EPA's recognition that the final surface and ground water quality standards will be met by the Basin Watershed OU2 ROD.

## 13.1.3 Cost Effectiveness

In the EPA's judgment, the selected remedy is cost-effective. In making this determination, the following definition was used: "...A remedy shall be cost-effective if its costs are proportional to its overall effectiveness." (NCP, 40 CFR § 300.430(f)(1)(ii)(D)). This was accomplished by evaluating the overall effectiveness of the selected remedy and comparing that effectiveness to the overall costs. Overall effectiveness was evaluated by examining how the selected remedy meets three of the balancing criteria in combination: long-term effectiveness and permanence; reduction in toxicity, mobility and volume; and short-term effectiveness. The relationship of the overall effectiveness of the selected remedy was determined to be proportional to its costs.

The remedy provides significant long-term effectiveness and permanence by removing, through semipassive treatment, the principal threat to USG Creek, its riparian corridor/floodplain and downstream tributaries. It also provides reductions in mobility and volume by removing the metals from the mine's discharge prior to its confluence with USG Creek and associated floodplain. The metals-laden sludge and spent media will be removed from the treatment system and disposed of at the Luttrell Repository on a routine schedule. Non-principal threat wastes (contaminated waste rock and soils) will be permanently removed to an onsite, lined repository. The remedy provides for assurances that surface water RAOs will be consistently met after remedial construction because it removes, through treatment, the principal threat from the watershed. The remedy does contain some short-term risks (for example, truck and equipment traffic during construction), which lowers its overall protectiveness. However, the EPA will work closely with all stakeholders (USFS, MDEQ, local residents and recreationists) to ensure that these risks are addressed and minimized to the extent practicable.

### 13.1.4 Utilization of Permanent Solutions and Alternative Treatment (or Resource Recovery) Technologies to the Maximum Extent Practicable

This section looks at whether the remedy provides the best balance of trade-offs among the alternative with respect to the balancing criteria set forth in NCP, with an emphasis on long-term effectiveness and permanence and reduction in toxicity, mobility and volume (see NCP, 40 CFR § 300.430(f)(1)(ii)(E)). Modifying criteria were also examined in making this finding. In other words, the finding of practicability for use of permanent solutions and alternative treatment technologies to the maximum extent practicable is determined by looking at the remedy selection criteria and weighing trade-offs among those criteria.

The EPA has determined that the remedy represents the maximum extent to which permanent solutions and alternative treatment technologies can be utilized in a practicable manner at the Site. Of those alternatives that are protective of human health and the environment and comply with ARARs or justify a waiver, the EPA has determined that the selected remedy provides the best balance of trade-offs in terms of the balancing criteria, while also considering the statutory preference for treatment as a principal element and bias against offsite treatment and considering state and community acceptance. The EPA's balancing of the criteria and consideration of the criteria is explained in Sections 10.2 and 12.2 of this interim ROD.

A permanent solution is employed in the remedy through implementation of a passive water treatment system with a low, proven maintenance demand, compared to other alternatives, and is necessitated by the Site's remote location. Removal of contaminated waste rock and soils to a repository (located out of the flood plain) that encapsulates the waste, stabilizes exposed slopes with a clean soil cover, and vegetates exposed areas completes the permanent solution.

## 13.1.5 Preference for Treatment as a Principal Element

The principal threat waste at the Site, the mine water discharged from the lower adit, is treated as part of the Site's remedy. Metals are removed from the discharge before it enters USG Creek and disposed of at an existing mine waste repository upstream of the Site and out of the floodplain (Luttrell Repository). This is appropriate because more traditional treatment methods were not found to be feasible or cost effective given the remote location of the Site, and the greater maintenance demands they carried.

## 13.1.6 5-Year Reviews

Because this remedy will result in contaminants remaining onsite above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within 5 years after initiation of the remedial action, and at a minimum every 5 years thereafter, to ensure that the remedy is, or will be, protective of human health and the environment.

# Section 14. Documentation of Significant Changes

The proposed plan for the Site was released for public comment on March 2, 2014. It identified alternatives WR-3 and GW-6 as the preferred combination of alternatives. The combined waste rock removal and ground water treatment remedial alternative is described herein as the selected interim remedy. The public comment period ran until April 21, 2014 (30 days beyond the public meeting), and no extension was requested. The EPA received no written comments during that comment period. The EPA's response to comments is typically set forth in Part 3 (Responsiveness Summary). One significant change to the proposed plan was made; the sediment retention ponds and the sludges they contained will be removed to the Luttrell Repository as a TCRA performed in 2014. These ponds were to be removed as part of the remedy under the proposed plan. However, due to the risk of the ponds failing and contaminated sludges flowing onto USFS land below, EPA decided early action was needed to remove the ponds.

Part 3 Responsiveness Summary

# **Responsiveness Summary**

The public comment period ended on April 21, 2014. The EPA's response to comments is typically set forth in Part 3 (Responsiveness Summary). However, no formal comments were received during the public comment period. Verbal comments during a public meeting held on March 19, 2014, were supportive of the selected remedy.

Part 4 Acronyms and Abbreviations, and References

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# Acronyms and Abbreviations

°F	degrees Fahrenheit
μg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
μS/cm	microSiemens per centimeter
Ag	Silver
Al	Aluminum
AMD	acid mine drainage
amsl	above mean sea level
ARARs	Applicable or Relevant and Appropriate Requirements
ARD	acid rock drainage
ARM	Administrative Rules of Montana
As	Arsenic
ATV	all-terrain vehicle
Basin Watershed OU2	Basin Mining Area Watershed Operable Unit 2
BERA	baseline ecological risk assessment
BF	bioavailability adjustment factor
bgs	below ground surface
BLM	U.S. Bureau of Land Management
BMI	benthic macroinvertebrate inventory
BMP	best management practices
CaCO <sub>3</sub>	calcium carbonate
CaCO₃ Cd	calcium carbonate Cadmium
Cd	Cadmium
Cd CDM	Cadmium CDM Federal Programs Corporation
Cd CDM CEM	Cadmium CDM Federal Programs Corporation conceptual exposure model
Cd CDM CEM CERCLA	Cadmium CDM Federal Programs Corporation conceptual exposure model Comprehensive Environmental Response, Compensation and Liability Act
Cd CDM CEM CERCLA CFR	Cadmium CDM Federal Programs Corporation conceptual exposure model Comprehensive Environmental Response, Compensation and Liability Act Code of Federal Regulations
Cd CDM CEM CERCLA CFR Cl	Cadmium CDM Federal Programs Corporation conceptual exposure model Comprehensive Environmental Response, Compensation and Liability Act Code of Federal Regulations Chlorine
Cd CDM CEM CERCLA CFR Cl Cl-	Cadmium CDM Federal Programs Corporation conceptual exposure model Comprehensive Environmental Response, Compensation and Liability Act Code of Federal Regulations Chlorine Chloride
Cd CDM CEM CERCLA CFR Cl Cl- Cl- CIP COC COI	Cadmium CDM Federal Programs Corporation conceptual exposure model Comprehensive Environmental Response, Compensation and Liability Act Code of Federal Regulations Chlorine Chloride community involvement plant contaminant (chemical) of concern contaminant (chemical) of interest
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EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
EPT	mayflies, stoneflies, and caddisflies (collectively)
ERA	ecological risk assessment
ESV	ecological screening value
FD	field duplicate
Fe	Iron
FS	feasibility study
ft	Feet
g	grams
Gl	gastrointestinal
gpm	gallons per minute
GW	ground water
HDPE	high-density polyethylene
HDS	high-density sludge
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
ICs	institutional controls
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
K	potassium
kg	kilograms
lb/day	pound per day
LOAEL	lowest observed adverse effect level
MBMG	Montana Bureau of Mines and Geology
MCLs	maximum contaminant levels
MDEQ	Montana Department of Environmental Quality
MDFWP	Montana Department of Fish, Wildlife & Parks
Mg	magnesium
m <sup>3</sup> /kg	cubic meters per kilogram
mg/day	milligrams per cubic meter
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg-day	milligrams per kilograms-body weight per day
mg/L	milligrams per liter
Mn	manganese
MNHP	Montana Natural Heritage Program
MS/MSD	matrix spike/matrix spike duplicate
MSE	MSE Technology Applications, Inc.
mV	millivolt
Na	sodium

NCP	National Oil and Hazardous Substances Pollution Contingency Plan
Ni	nickel
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
NP/AP	neutralization potential/acid potential
NPL	National Priority List
NPV	net present value
NTU	nephelometric turbidity units
0&M	operation and maintenance
OMM	operation, monitoring and maintenance
ORP	oxidation reduction potential
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
РА	preliminary assessment
Pb	Lead
PEC	probable effects threshold concentration
PEF	particulate emissions factor
PRG	preliminary remediation goal
PRP	potentially responsible party
PVC	polyvinyl chloride
QAPP	quality assurance project plan
RAL	remedial action level
RAOs	remedial action objective
RBP	risk-based prioritization
RD	remedial design
Reclamation	U.S. Bureau of Reclamation
RfC	reference concentration
RfD	reference dose
RG	remediation goal
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
ROD	Record of Decision
RTI	Renewable Technologies, Inc.
SAP	sampling and analysis plan
Sb	Antimony
SDWA	Safe Drinking Water Act
Se	Selenium
SI	site investigation
SLERA	screening level ecological risk assessment
SMDP	Scientific Management Decision Point
SO <sub>4</sub>	Sulfate
SPT	semi passive treatment
SPTS	semi-passive treatment system
	· · ·

SQuiRTs SRBR	Screening Quick Reference Tables sulfate reducing biochemical reactor
T&E	threatened and endangered
TCRA	Time Critical Removal Action
TI	thallium
TMDL	total maximum daily load
TRV	toxicity reference value
TSS	total suspended solids
UCL	upper confidence limit
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USFS	U.S. Forest Service
USG	Uncle Sam Gulch
USGS	U.S. Geological Survey
WQC	water quality criteria
WR	waste rock
XRF	x-ray fluorescence
Zn	Zinc

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Appendix A ARARs Requirements and Waivers

## Summary of 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. Section 9621(d), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (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 ARARs for remedial action to be conducted at the 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 applies to the activities to be conducted under this remedial action. Remedial action is needed to treat acid mine drainage (AMD), remove waste rock to an onsite repository, and remediate Uncle Sam Gulch Creek channel adjacent to the historic mine area. Institutional controls will be adopted. These will restrict future access and exposure, and control any earth work or building modifications on the site. Removal and discharge of mine water, diversion, collection, treatment, and discharge of ground water and surface water, and management of waste materials will 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 CFR § 300.400. 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 applicable or relevant and appropriate. 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 state in a timely manner and that are more stringent than federal requirements may be applicable.<sup>1</sup>

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 applicable to the hazardous substances, pollutants, contaminants, remedial actions, locations, or other

<sup>&</sup>lt;sup>1</sup> 40 CFR § 300.5.

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.<sup>2</sup>

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.<sup>3</sup>

ARARs are chemical, location, or action specific. Chemical specific requirements address chemical or physical characteristics of compounds or substances on sites. These values establish acceptable amounts or concentrations of chemicals that 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.

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 the 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. These final ARARs will be set forth as performance standards for any and all remedial design or remedial action work plans.

Also contained in this list are policies, guidance or other sources of information that are to be considered (TBC) in the implementation of the record of decision (ROD). TBCs are generally used to set protective cleanup levels or otherwise used to make the remedy protective. The TBCs for this action are described in the Feasibility Study (EPA, 2013). 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 Section 300.430(f)(1)(ii)(C)(1) provides:

<sup>&</sup>lt;sup>2</sup> 40 CFR § 300.5.

<sup>&</sup>lt;sup>3</sup> <u>CERCLA Compliance with Other Laws Manual</u>, Vol. I, OSWER Directive 9234.1-01, August 8, 1988, p. 1-11.

- (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:
- 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 with respect to surface and ground water ARARs. It will not result in final compliance with these ARARs. The EPA is therefore invoking the interim action waiver as provided in 40 CFR § 300.430(f)(1)(ii)(C)(1) with respect to all surface water and ground water quality ARARs at OU5. The EPA does expect that surface and ground water ARARs will be attained at the time of the final remedial action for Basin Watershed OU2. The EPA also expects that implementation of the ROD will result in compliance with all other ARARs for the Crystal Mine OU5 remedy.

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Federal ARARs and TBCs							
National Historic Preservation Act (NHPA)	16 United States Code (U.S.C.). § 470	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).	A cultural resource inventory of the site was prepared and submitted to the Montana SHPO. Findings indicated that the site did meet some favorable criteria but would not likely qualify for the National Register of Historic Places because of deteriorating conditions.		1	
National Register of Historic Places	36 Code of Federal Regulations (CFR) 60						
Determinations of eligibility for inclusion in the National	36 CFR § 63						
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 U.S.C. § 461, et seq.						

<sup>4</sup> All references are to statutes and regulations on the books in September 2014.

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Migratory Bird Treaty Act	16 U.S.C. 703, et seq.	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.		✓	
List of Migratory Birds	50 CFR 10.13						
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. Specific mitigative measures may be identified for compliance with this requirement.	If bald or golden eagles are identified within the areas identified for remediation, activities must be designed to conserve the species and their habitat.		V	
Clean Water Act (dredge and fill requirement)	33 U.S.C. § 404	Relevant and Appropriate	Regulates discharge of dredged or fill materials into jurisdictional wetlands or waters of the United States. Substantive requirements of portions of Nationwide Permit No. 38 (General and Specific Conditions) are applicable to the Crystal Mine OU5 site remedial activities conducted within waters of the United States and will be addressed during remedial design.	A portion of the Crystal Mine site to be remediated is located adjacent to USG Creek. The remedial design will address compliance with Section 404.		V	

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Federal RCRA Subtitle C Requirements	42 U.S.C. Section 6921, et seq.	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. Montana has an authorized hazardous waste program.	RCRA Subtitle C requirements will generally not be applicable for those wastes for which the 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 waste. Subtitle C Generator Requirements would be applicable.			~
	40 CFR § 261-263 40 CFR §-268 ARM 17.53.6			Also, these regulations may be potentially applicable to any unknown, potentially hazardous wastes encountered during excavation of contaminated soils (e.g., buried drums, etc.).			
STATE OF MONTANA ARARS a	nd TBCs						
Ground Water Protection	Administrative Rules of Montana (ARM) 17.30.1005	Applicable but Waived <sup>3</sup>	Explains the applicability and basis for the ground water standards in ARM 17.30.1006, which establish the maximum allowable changes in ground water quality and may limit discharges to ground water.	The ROD does address contaminated ground water. The interim remedy will aid in reducing further contamination of ground water.	~		

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Ground Water Protection (continued)	ARM 17.30.1006		Provides that ground water is classified I through IV based on its present and future most beneficial uses and also sets the standards for the different classes of ground water listed in department Circular DEQ-7. <sup>1</sup> Ground water is to be classified according to actual quality or use, whichever places the ground water in the higher class. Class I is the highest quality; class IV the lowest.				
Montana Water Quality Act and Regulations	Montana Code Annotated (MCA) 75-5-101, et seq.	Applicable but Waived <sup>3</sup>	The Montana Water Quality Act, MCA § 75-5-101, et seq., establishes requirements for restoring and maintaining the quality of surface and ground water. 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.	The OU addressed in the ROD does address contaminated ground water and surface water. Due to the proximity of remedial actions to surface waters, measures will be taken to prevent contamination of surface waters.	V		

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Water Quality Act and Regulations (continued)	ARM 17.30.610		Pursuant to this authority and the criteria established by Montana surface water quality regulations, ARM § 17.30.601, et seq., Montana has established the Water-Use Classification system. Under ARM § 17.30.610, tributaries to the Missouri River have been classified B-1. Cataract Creek and its tributaries are part of the Missouri River drainage, but not part of the Basin Creek drainage.				

Montana Water Quality Act	
and Regulations (continued)	

ARM 17.30.623

23 Applicable but Waived<sup>3</sup> Waters classified B-1 are, after conventional treatment 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 purposes. This section provides also that concentrations of carcinogenic, bioconcentrating, toxic, radioactive, nutrient or harmful parameters may not exceed the applicable standards set forth in department Circular DEQ-7. DEQ-7 provides that "whenever both Aquatic Life Standards and Human Health Standards exist for the same analyte, the more restrictive of these values will be used as the numeric Surface Water Quality Standard." This regulation also specifies water guality standards for waters classified B-1, which set limits on the allowable levels of pollutants and prohibit certain discharges to those waters. The B-1 standards contain limitations on the reduction of dissolved oxygen, variation of hydrogen ion concentration (pH), temperature increases, color increases, and increases in the turbidity, suspended sediment, settleable solids, oils, and floating solids.

The DEQ-7 standards are waived during this interim action. However, steps will be taken during remedial design to ensure that the remedy does not violate the other standards. In particular, the remedy must not result in an increase above naturally occurring turbidity or suspended sediment  $\checkmark$ 

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Water Quality Act and Regulations (continued)	ARM 17.30.637	Applicable but Waived <sup>3</sup>	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 75-5-303	Applicable but Waived <sup>3</sup>	This provision states that existing uses of state waters and the level of water quality necessary to protect the uses must be maintained and protected.		$\checkmark$		

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Water Quality Act and Regulations (continued)	MCA 75-5-605	Applicable but Waived <sup>3</sup>	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. Including but not limited to standards relating to change in temperature, taste, color, turbidity, or odor; or the discharge, seepage, drainage, infiltration, or flow of liquid, gaseous, solid, radioactive or other substance into state water that will or is likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, or welfare, to livestock, or to wild animals, birds, fish, or other wildlife. Section 75-5-101(30) (a), MCA. Also, it is unlawful to place or cause to be placed any wastes where they will cause pollution of any state waters				
	ARM 17.30.705 and 1011	Applicable but Waived <sup>3</sup>	Existing and anticipated uses of surface water and ground 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.		✓		

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
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 (NPDES) permits.	Treated discharge into waters of the State of Montana (USG Creek) is planned as part of the interim remedial action. This discharge will be made in consultation with the State of Montana. Measures must be taken to prevent any uncontrolled discharges. <sup>2</sup>			~

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Substantive MPDES Permit Requirements (continued)	ARM 17.30.1203 and 1344	Applicable	Provisions of 40 CFR Part 125 for criteria and standards for the imposition of technology-based treatment requirements are adopted and incorporated in MPDES permits. Although the permit requirement would not apply to on-site discharges, the substantive requirements of Part 125 are applicable, i.e., for toxic and nonconventional pollutants treatment must apply the best available technology economically achievable (BAT); for conventional pollutants, application of the best conventional pollutant control technology (BCT) is required. Where effluent limitations are not specified for the particular industry or industrial category at issue, BCT/BAT technology-based treatment requirements are determined on a case by case basis using best professional judgment (BPJ). See CERCLA Compliance with Other Laws Manual, Vol. 1, August 1988, p. 3-4 and 3-7 to 3-8.	The Site is an abandoned, not active mine. The pollutants are not conventional (BOD, fecal coliform, etc.). The EPA's BPJ is a passive treatment system as described in the ROD and in accordance with CERCLA.	1		
Stormwater Runoff Control Requirements	ARM 17.24.633	Relevant and Appropriate	All surface drainage from a disturbed area must be treated by the best technology currently available.	These requirements would be applicable to disturbed remedial areas.			$\checkmark$

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Stormwater Runoff Control Requirements (continued)	ARM 17.30.1341	Applicable	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 General Permit for Storm Water Discharge Associated with Construction Activity, Permit No. MTR100000 (January 1, 2013).	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.			1
Montana Ambient Air Quality Regulations	ARM 17.8.220	Applicable	Settled particulate matter shall not exceed a 30-day average of 10 grams per square meter.	The EPA expects that use of best management practices will result in compliance with these provisions. The EPA does not expect to monitor in connection with any of the substantive requirements listed here.			
	ARM 17.8.222	Applicable	Lead emissions to ambient air shall not exceed a 90-day average of 1.5 micrograms per cubic liter of air.				
	ARM 17.8.223	Applicable	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.				
	ARM 17.8.304(2)	Applicable	Emissions into the outdoor atmosphere shall not exhibit an opacity of 20 percent or greater averaged over 6 consecutive minutes.				

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Ambient Air Quality Regulations (continued)	ARM 17.8.308	Applicable	There shall be no production, handling, transportation, or storage of any material; use of any street, road, or parking lot; or operation of a construction site or demolition project unless reasonable precautions are taken to control emissions of airborne particles. The 20 percent opacity limit described above is also specified for these activities.				
	ARM 17.8.604(2)	Applicable	Lists material that may not be disposed of by open burning except as approved by the department.				
	ARM 17.8.221	Applicable	Concentrations of particulate matter in ambient air shall not exceed annual average scattering coefficient of particulate matter of 3 x 10-5 per meter.				
Montana Fugitive Dust Emissions	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.			V

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Strip and Underground Mine Reclamation Act, Section 82-4- 201, et seq., MCA	Section 82-4-231, MC	Relevant and Appropriate	Section 82-4-231, MCA Requires operators to reclaim and revegetate affected lands using most modern technology available. Operators must grade, backfill, topsoil, reduce high walls, stabilize subsidence, control water, minimize erosion, subsidence, land slides, and water pollution				✓
	Section 82-4-233, MCA	Relevant and Appropriate	Section 82-4-233, MCA, Operators must plant vegetation that will yield a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area and capable of self-regeneration.				~
Montana Metal Mining Act, Section 82-4-301, et seq., MCA	Section 82-4-336, MCA.	Relevant and Appropriate	Section 82-4-336, MCA. Disturbed areas must be reclaimed to utility and stability comparable to adjacent areas.				~
a F 1 1 S	General Backfilling and Grading Requirements, ARM 17.24.501	Relevant and Appropriate	General Backfilling and Grading Requirements, ARM 17.24.501. Requires backfill be placed so as to minimize sedimentation, erosion, and leaching of acid or toxic materials into waters, unless otherwise approved. Final grading must be to the approximate original contour of the land				V
	Monitoring for Settlement, ARM 17.24.519	Relevant and Appropriate	Monitoring for Settlement, ARM 17.24.519. Requires monitoring of settling of regraded areas				$\checkmark$

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Metal Mining Act, Section 82-4-301, et seq., MCA (continued)	General Hydrology Requirements, ARM 17.24.631(1), (2), (3)(a) and (b)	Relevant and Appropriate	General Hydrology Requirements, ARM 17.24.631(1), (2), (3)(a) and (b). Requires minimization of disturbances to the prevailing hydrologic balance. Changes in water quality and quantity, in the depth to ground water and in the location of surface water drainage channels should be minimized. Other pollution minimization devices must be used if appropriate, including stabilizing disturbed areas through land shaping, diverting runoff, planting quickly germinating and growing stands of temporary vegetation, regulating channel velocity of water, lining drainage channels with rock or vegetation, mulching, and control of acid-forming, and toxic-forming waste materials.				V

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Metal Mining Act, Section 82-4-301, et seq., MCA (continued)	Reclamation of Drainage Basins, ARM 17.24.634	Relevant and Appropriate	Reclamation of Drainage Basins, ARM 17.24.634. Requires disturbed drainages be restored to the approximate pre-disturbance configuration. Drainage design must emphasize channel and floodplain dimensions that approximate the premining configuration and that will blend with the undisturbed drainage above and below the area to be reclaimed. The average stream gradient must be maintained with a concave longitudinal profile. This regulation provides specific requirements for designing the reclaimed drainage to: (1) approximate an appropriate geomorphic habit or characteristic pattern; (2) remain in dynamic equilibrium with the system without the use of artificial structural controls; (3) improve unstable premining conditions; (4) provide for floods and for the long-term stability of the landscape; and (5) establish a premining diversity of aquatic habitats and riparian vegetation.				
17	Diversions, ARM 17.24.635 through 17.24.637	Relevant and Appropriate	Sets forth requirements for temporary and permanent diversions.				$\checkmark$

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Metal Mining Act, Section 82-4-301, et seq., MCA (continued)	Sediment Control Measures, ARM 17.24.638	Relevant and Appropriate	Sediment control measures utilizing BTCA must be implemented during operations.				
	Sedimentation Ponds and Other Treatment Facilities, ARM 17.24.639	Relevant and Appropriate	Sedimentation Ponds and Other Treatment Facilities, ARM 17.24.639. Sets forth requirements for construction and maintenance of sedimentation ponds, including that sedimentation ponds be located as near as possible to the disturbed area and out of any major stream courses.				
	Discharge Structures, ARM 17.24.640	Relevant and Appropriate	Discharge Structures, ARM 17.24.640. Requires discharges from sedimentation ponds, permanent and temporary impoundments, and diversions be controlled to reduce erosion, deepening or enlargement of stream channels and to minimize disturbance of the hydrologic balance.				V
	Acid- and Toxic- Forming Spoils, ARM 17.24.641	Relevant and Appropriate	Acid- and Toxic-Forming Spoils, ARM 17.24.641. Requires drainage from acid- and toxic-forming spoil into ground and surface water be avoided and establishes practices to avoid such drainage.				V
	Ground Water, ARM 17.24.643 through 17.24.646	Relevant and Appropriate	Ground water, ARM 17.24.643 through 17.24.646. Sets forth provisions for ground water protection, ground water recharge protection, and ground water and surface water monitoring.				✓

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Section 82-4-301, et seq., MCA and (continued) Subs ARM Esta Vege	Soil, ARM 17.24.701 and 17.24.702	Relevant and Appropriate	Soil, ARM 17.24.701 and 17.24.702. Sets forth requirements for redistributing and stockpiling of soil for reclamation. Also, outlines practices to prevent compaction, slippage, erosion, and deterioration of biological properties of soil.				~
	Substitute Materials, ARM 17.24.703	Relevant and Appropriate	Substitute Materials, ARM 17.24.703. When using materials other than, or along with, soil for final surfacing in reclamation, the operator must demonstrate that the material: (1) is at least as capable as the soil of supporting the approved vegetation and subsequent land use; and (2) is the best available in the area to support vegetation. Such substitutes must be used in a manner consistent with the requirements for redistribution of soil in ARM 17.24.701 and 17.24.702.				*
	Establishment of Vegetation, ARM 17.24.711	Relevant and Appropriate	Establishment of Vegetation, ARM 17.24.711. Requires that a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of land to be affected shall be established except on road surfaces and below the low water line of permanent impoundments.				1

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
0 0		Relevant and Appropriate	See also Section 82-4-233, MCA. Vegetative cover is considered of the same seasonal variety if it consists of a mixture of species of equal or superior utility when compared with the natural vegetation during each season of the year. This requirement may not be appropriate where other cover is more suitable for the particular land use or another cover is requested by the landowner.				~
	Timing of Seeding and Planting, ARM 17.24.713	Relevant and Appropriate	Timing of Seeding and Planting, ARM 17.24.713. Requires seeding and planting of disturbed areas to be conducted during the first appropriate period favorable for planting after final seedbed preparation.				V
	Practices, ARM	Relevant and Appropriate	Soil Stabilizing Practices, ARM 17.24.714. Requires mulch or cover crop, or both, be used until adequate permanent cover can be established				$\checkmark$

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Metal Mining Act, Section 82-4-301, et seq., MCA (continued)	Method of Revegetation, ARM 17.24.716	Relevant and Appropriate	Method of Revegetation, ARM 17.24.716. Requires revegetation be carried out in a manner that encourages prompt vegetation establishment, such as by drill or broadcast seeding, by seedling transplants or by establishing sod plugs, and in a manner that avoids the establishment of noxious weeds. Seeding must be done on the contour, whenever possible. Seed mixes should be free of weedy or other undesirable species.				~
	Planting of Trees and Shrubs, ARM 17.24.717	Relevant and Appropriate	Planting of Trees and Shrubs, ARM 17.24.717. Requires the planting of trees and other woody species if necessary, as provided in Section 82- 4-233, MCA, to establish a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the affected area and capable of self-regeneration and plant succession at least equal to the natural vegetation of the area. Introduced species may be used in the revegetation process where desirable and necessary to achieve the approved land use plan.				✓

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Metal Mining Act, Section 82-4-301, et seq., MCA (continued)	Soil Amendments, ARM 17.24.718	Relevant and Appropriate	Soil Amendments, ARM 17.24.718. Requires soil amendments, irrigation, management, fencing, or other measures, as necessary to establish a diverse and permanent vegetative cover.				~
	Eradication of Rills and Gullies, ARM 17.24.721	Relevant and Appropriate	Eradication of Rills and Gullies, ARM 17.24.721. Specifies that rills or gullies in reclaimed areas must be filled, graded or otherwise stabilized and the area reseeded or replanted if the rills and gullies are disrupting the reestablishment of the vegetative cover or causing or contributing to a violation of water quality standards for a receiving stream.				~
	Monitoring, ARM 17.24.723	Relevant and Appropriate	Monitoring, ARM 17.24.723. Requires operators to conduct approved periodic measurements of vegetation, soils, and wildlife, and if data indicate that corrective measures are necessary, propose and implement such measures.				V

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Section 82-4-301, et seq., MCA (continued) Veg Mea ARM Ana ARM Prot Enh Fish	Revegetation Success Criteria, ARM 17.24.724	Relevant and Appropriate	Revegetation Success Criteria, ARM 17.24.724. Specifies that revegetation success must be measured against approved technical standards or unmined reference areas. Reference areas and standards must be representative of vegetation and related site characteristics occurring on lands exhibiting good ecological integrity. Sets forth required management for reference areas.				~
	Vegetation Measurements, ARM 17.24.726.	Relevant and Appropriate	Vegetation Measurements, ARM 17.24.726. Requires standard and consistent field and laboratory methods to obtain and evaluate revegetated area data with reference area data and/or technical standards and sets forth the required methods for measuring productivity				~
	Analysis for Toxicity, ARM 17.24.731	Relevant and Appropriate	Analysis for Toxicity, ARM 17.24.731. If toxicity to plants or animals on the revegetated area or the reference area is suspected due to the effects of the disturbance, comparative chemical analyses may be required.				~
	Protection and Enhancement of Fish and Wildlife, ARM 17.24.751.	Relevant and Appropriate	Protection and Enhancement of Fish and Wildlife, ARM 17.24.751(e) only. Sets forth requirements to protect and enhance fish and wildlife habitat				~

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. ARM 36.15.602(5), 36.15.605, and 36.15.703 generally provide that obstructions cannot be placed within, nor can certain activities (e.g., solid and hazardous waste disposal and storage of toxic, flammable, hazardous, or explosive materials) take place within, floodplains or floodways. The permitting and variance provisions at ARM 36.15.218(1) allow actions within the floodplain or floodway under certain conditions:	Mine areas to be remediated are located adjacent to USG Creek. These standards are applicable to all actions within potential floodplain areas. The remedy may result in structures within a floodplain. The EPA, in consultation with DEQ, will evaluate the factors contained within the variance to determine whether a proposed use within the floodplain is eligible for the variance.	
			(a) the proposed use would not increase flood hazard either upstream or downstream in the area of insurable buildings;		
			(b) refusal of a variance would because of exceptional circumstances cause a unique or undue hardship on the applicant or community involved;		
			(c) the proposed use is adequately floodproofed; and		
			(d) reasonable alternative locations outside the designated floodplain are not available.		

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
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 future disturbances to the stream.	A portion of the Crystal Mine site interim remedial action is adjacent to USG Creek. The remedial actions will alter or affect the streambed and its banks. All stream channel design for reconstruction will be reviewed by MDEQ for compliance with state standards.		V	
	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.	One of the interim preliminary remedial goals is to prevent or minimize the release of contaminants to surface water. The interim remedial action will not adversely affect the fish or game habitat; it is intended to improve it.			~

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Human Skeletal Remains and Burial Site Protection Act	MCA 22-3-801	Applicable	The Human Skeletal Remains and Burial Site Protection Act is the result of years of work by Montana tribes, state agencies, and organizations interested in assuring that all graves within the State of Montana are adequately protected. The Human Skeletal Remains and Burial Site Protection Act prohibits purposefully or knowingly disturbing or destroying human skeletal remains or burial sites.	If human skeletal remains or burial site are encountered during remedial activities at the site, then these requirements will be applicable.		~	
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 hunting, fishing, or other recreation is permitted.				V
	ARM 17.50.523	Applicable	Specifies that solid waste must be transported in such a manner as to prevent its discharge, dumping, spilling or leaking from the transport vehicle.	Sludges will be periodically hauled to Luttrell Repository in compliance with this requirement.			✓

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Solid Waste Requirements (continued)	ARM 17.50.1009(1)(c)	Applicable	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.	The placement of the wastes from the remedial actions at the Crystal Mine will be consistent with these applicable requirements.			~
	ARM 17.50.1204	Applicable	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	Applicable	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 to collect and control at least the water volume resulting from a 24-hour, 25-year storm.				~

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Solid Waste Requirements (continued)	ARM 17.50.1403	Applicable	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 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.	These requirements apply to the onsite repository.			Ý
	ARM 17.50.1404	Applicable	Post closure care requires maintenance of the integrity and effectiveness of any final cover, including making repairs to the 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 ground water monitoring requirements found at ARM Title 17, chapter 50, subchapter 13.				V

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Solid Waste Requirements (continued)	MCA 75-10-206	Applicable	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.				1
	ARM 17.50.1110	Applicable	Prohibits any discharge of a pollutant from a solid waste facility to State waters, including wetlands, that violates any requirement of the Montana Water Quality Act. Prohibits any discharge from a solid waste facility of a nonpoint source of pollution to Waters of the U.S., including wetlands, that violates any requirement of an area-wide or statewide water quality management plan approved under the Federal Clean Water Act.				
	ARM 17.50.1111		Prohibits placement of bulk or noncharacterized waste into a solid waste facility, unless the waste is household waste other than septic liquid waste or leachate derived from and placed back into a facility with a composite liner and leachate collection and removal system.				

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Solid Waste Requirements (continued)	ARM 17.50.1004; ARM 17.50.1009(1)(h).		A solid waste facility located within the 100-year floodplain may not restrict the flow of the 100-year flood, reduce the temporary water storage capacity of the floodplain, or result in washout of solid waste that poses a hazard to human health or the environment. See also ARM 17.50.1009(1)(h).				
	Wetlands, ARM 17.50.1005.		A solid waste facility may not be located in a wetland, unless there is no demonstrable practicable alternative.				
	Fault Areas, ARM 17.50.1006.		A solid waste facility cannot be located within 200 feet (60 meters) of a fault that has had displacement in Holocene time without demonstration that an alternative setback will prevent damage to the structural integrity of the solid waste facility and will be protective of human health and the environment.				
	Seismic Areas, ARM 17.50.1007.		A solid waste facility may not be located in a seismic impact zone without demonstration, by a Montana licensed engineer, that the solid waste structure is designed to resist the maximum horizontal acceleration in lithified earth material for the site.				

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
Montana Solid Waste Requirements (continued)	Unstable Areas, ARM 17.50.1008.		A solid waste facility may not be located in an unstable area (determined by consideration of local soil conditions, local geographic or geomorphologic features, and local artificial features or events, both surface and subsurface) without demonstration, by a Montana licensed engineer, that the solid waste facility is designed to ensure that the integrity of the structural components will not be disrupted.				
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.			Ý

Statutes, Regulations, Standards or Requirements	Citations or References4	ARAR Determination	Description	Comment	Chemical- Specific	Location- Specific	Action- Specific
The Montana Hazardous Waste Act and implementing regulations	§§ 75-10-401 et seq., MCA, ARM 17.53.501, et seq.	Relevant and Appropriate	This Act and regulations establishes a regulatory structure for the generation, transportation, treatment, storage and disposal of hazardous wastes. These requirements are applicable to substances and actions at the site that involve listed and characteristic hazardous wastes, as well as used oil.	These requirements will generally not be applicable for those wastes for which the 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 not to be classified as hazardous waste. However, sludge from the water treatment system may be hazardous and covered under the Bevill exclusion; the generator, transportation, and disposal requirements would be relevant and required. Also these regulations may be potentially applicable to any unknown, potentially hazardous wastes encountered during excavation of contaminated soils (e.g., buried drums, etc.).			

<sup>1</sup>Montana Department of Environmental Quality, Water Quality Division, Circular DEQ-7, Montana Numeric Water Quality Standards (October 2012). <sup>2</sup>Montana's MPDES regulations are more stringent than the Federal NPDES regulations <sup>3</sup>40 CFR § 300.430(f)(1)(ii)(C)(1)

## Acronyms

ARAR ARM BTCA	Applicable or Relevant and Appropriate Requirements Administrative Rules of Montana 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, 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 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."*