Final Volume 1

Focused Remedial Investigation, Bullion Mine, OU6 Jefferson County, Montana

Prepared for

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

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Prepared by

CH2MHILL®
Boise, Idaho

Executive Summary

A focused remedial investigation (RI) was performed on the Bullion Mine Site (hereafter "the Site"), which is located within the Basin Mining Area NPL Site, near Basin, Montana. The U.S. Environmental Protection Agency (EPA) Region 8 authorized the RI report in accordance with Task 9 of the *Statement of Work/Work Plan for the Bullion Mine OU6 Remedial Investigation/Feasibility Study*, under EPA Contract Number EP-W-06-021.

The purpose of the RI is to characterize the nature and extent of contamination, describe the fate and transport of contaminants, and present the results of screening level risk assessment of risks to human health and the environment in sufficient detail to support the development, evaluation, and selection of appropriate remedial alternatives. The Bullion Mine Site OU6 was added to the National Priority List (NPL) in 1999 as part of the Basin Watershed OU2 NPL listing. The Site is located approximately 6 miles north of the town of Basin, within the Jill Creek subbasin of the Jack Creek tributary to the Basin Creek drainage.

The Site was previously part of a watershed-wide remedial investigation / feasibility study (RI/FS) process (Basin Watershed OU2), and the subject of historic sampling episodes (State of Montana, U.S. Forest Service (USFS), and U.S. Geological Survey). Findings of the risk assessment for the Basin Watershed OU2 identified arsenic, cadmium, copper, lead, and zinc as the primary contaminants of concern (COCs). These metals/metalloids were considered the drivers of toxicity concerns for human and ecological receptors. Contaminants (chemicals) of potential concern (COPCs) identified in the Basin Watershed OU2 RI provided a guide for a list of contaminants (chemicals) of interest (COIs) for the focused Bullion Mine RI and risk assessment.

A conceptual site model was prepared to help identify potential sources of COIs and probable pathways of movement of these contaminants from source material into soils, groundwater, and surface water. The primary sources are acid mine drainage (AMD), and acid rock drainage (ARD) from residual waste rock in the soil profile. Waste rock dumps were removed and reclaimed in a joint EPA-USFS removal action performed in 2001–2002. Successful revegetation has occurred through much of the Site although several small, barren areas associated with former dump footprints still remain. Some erosion of these sites is apparent, however they are located upgradient and some distance from Jill Creek.

Evidence of AMD and ARD can be seen in iron oxide staining (orange precipitate), which is commonly associated with groundwater or surface water flow paths from adit discharge or the numerous springs and seeps occurring along the lower third of the Site downgradient from the collapsed portal area of the lower adit.

Field sampling of soil, surface water, sediment, and groundwater was performed at various locations within the Site and samples were analyzed for the COI concentrations. All media sampled, exhibited high levels of contamination typical of abandoned mine sites. The most significant impacts were from the AMD into the surface water of Jill Creek, a tributary of Jack Creek.

A human health risk assessment and an ecological risk assessment were conducted in accordance with applicable EPA and Montana Department of Environmental Quality (MDEQ) guidance. Human health risks for arsenic were found to exceed acceptable levels for recreational users under the assumption that ATV activities occur at the Site and surface water is used for drinking water. The soil risk estimates are driven by the dust inhalation pathway and would overestimate the risk for other recreational users (for example, hikers). Considering this, risk estimates for the intermittent worker scenario, which do not exceed acceptable levels, are likely more representative of most recreationalists (for example, hikers). Ecological risks were also found to be unacceptable. Based on the results of the ecological risk assessment, the contaminants with the highest potential for wildlife exposure are (1) antimony, arsenic, cadmium, and lead, and to a lesser extent copper and lead in soil, and (2) antimony, arsenic, cadmium, copper, and lead in stream sediment. These contaminants are considered COCs because the potential ecological risks associated with exposures to them are significant. The receptors with the greatest risk include wildlife that forage over a smaller area (for example, deer, mice, and flycatchers) and those that burrow. Measured soil concentrations exceed published plant screening benchmarks and background levels for COPCs. The greatest risk to plants was found for exposure to antimony and arsenic in deeper rooted vegetation forms.

Risks to the aquatic and benthic community in Jill Creek were evaluated using multiple lines of evidence. Concentrations of aluminum, cadmium, copper, iron, lead, and zinc were detected in surface water collected from Jill Creek at concentrations exceeding levels protective of aquatic organisms. The greatest exceedances occurred for cadmium, copper, and zinc immediately downgradient from the influence of the adit discharge. Sediment concentrations of antimony, arsenic, cadmium, iron, and silver exceed published probable effects benchmarks for benthic macroinvertebrates. The greatest exceedances occurred for arsenic. Historic in-situ fish toxicity testing and macroinvertebrate community surveys support the conclusion that water quality is currently unsuitable for survival.

On the basis of the nature and extent of contamination, land and water uses, and site-specific risk assessment, the RI findings support the conclusion that an unacceptable level of risk exists to human and ecological receptors from mining-related wastes associated with the Site. Multiple investigators (USFS, U. S. Geological Survey, Montana Bureau of Mines and Geology, and MDEQ) consider the AMD from this mine to be the most significant contribution to water quality degradation in Jill Creek and the Jack Creek drainage. In its current condition, the Site presents a constant threat to the environment.

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

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Acronyms and Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	micrograms per liter
$µg/m^3$	micrograms per cubic meter
µg/mg	micrograms per milligram
µS/cm	microSiemens per centimeter
Ag	silver
Al	aluminum
ALM	Adult Lead Model
AMD	acid mine drainage
amsl	above mean sea level
ARCS	assessment and remediation of contaminated sediments
ARD	acid rock drainage
ARM	Administrative Rules of Montana
As	arsenic
ASTM	American Standards for Testing and Materials
AUF	area use factor (unitless)
Basin Watershed OU2	Basin Mining Area Watershed Operable Unit 2
BERA	baseline ecological risk assessment
BF	bioavailability adjustment factor
bgs	below ground surface
BLM	USDI Bureau of Land Management
bmp	below measuring point
$CaCO_3$	calcium carbonate
CCC	Criterion Continuous Concentration
Cd	cadmium
CDA	Coeur d'Alene
CDM	CDM Federal Programs Corporation
CEM	conceptual exposure model
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
Cl	chlorine
Cl-	chloride
CLP	Contract Laboratory Program
CMC	Criteria Maximum Concentration
COC	contaminant (chemical) of concern
COI	contaminant (chemical) of interest
COPC	contaminant (chemical) of potential concern
COPEC	contaminants (chemical) of potential ecological concern
CSL	cleanup screening level
CSM	conceptual site model
CTE	central tendency estimates
Cu	Copper
CWA	Clean Water Act

DQO	data quality objective
EcoSSL	Ecological Soil Screening Levels
EE/CA	engineering evaluation / cost analysis
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
EPT	mayflies, stoneflies, and caddisflies (collectively)
ERA	ecological risk assessment
ESV	ecological screening value
Fe	iron
FeS_2	pyrite
FS	feasibility study
g	grams
g/day	grams per day
GDP	Clark Fork River Governor's Demonstration Project
GI	gastrointestinal
gpm	gallons per minute
GPS	global positioning system
HCO_3	bicarbonate
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
ICP	inductively coupled plasma
IRIS	Integrated Risk Information System
IVBA	In Vitro Bioaccessibility Procedure
K	potassium
kg	kilograms
LAO	Lower Area One
lb/day	pound per day
LOAEL	lowest observed adverse effect level
Maxim	Maxim Technologies Inc.
MBMG	Montana Bureau of Mines and Geology
MCLs	maximum contaminant levels
MDEQ	Montana Department of Environmental Quality
Montana FWP	Montana Fish, Wildlife & Parks
mg	magnesium
m^3/kg	cubic meters per kilogram
mg/m^3	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	mass spectroscopy
mV	millivolt
Na	sodium
NHPA	National Historic Preservation Act
Ni	nickel
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
NPL	National Priority List
NRCS	National Resources Conservation Service (formerly Soil Conservation Service)
NRWQC	National Recommended Water Quality Criteria
NTU	nephelometric turbidity units
ORP	oxidation reduction potential
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
Pb	lead
PEF	particulate emissions factor
PNEC	predicted no-effect concentration
PPRTVs	Provisional Peer Reviewed Toxicity Values
PRAO	preliminary remedial action objective
PVC	polyvinyl chloride
QC	quality control
RAGS	Risk Assessment Guidance for Superfund
Reclamation	U.S. Bureau of Reclamation
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RME	“reasonable maximum” exposure
ROD	record of decision
RPD	relative percent difference
RSL	regional screening level
RTI	Renewable Technologies, Inc.
S/m	Siemens per meter
Sage	Sage Earth Science
SAP	sampling and analysis plan
Sb	antimony
SDWA	Safe Drinking Water Act
Se	selenium
SHPO	State Historic Preservation Office
SLERA	screening level ecological risk assessment
SMDP	Scientific Management Decision Point
SNOTEL	Snowpack Telemetry System
SO_4	sulfate
SQuiRTs	Screening Quick Reference Tables

T&E	threatened and endangered
Tl	thallium
TRV	toxicity reference value
UCL	upper confidence limit
USACE	U.S. Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USFS	U.S. Forest Service
USGS	United States Geological Survey
w/w	wet weight
XRF	x-ray fluorescence
Zn	zinc

1. Introduction

The Basin Mining Area was placed on Superfund's National Priorities List (NPL) on October 22, 1999, because of mining-waste related contamination created in the watershed and in the town of Basin. 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 Figures 1-1 and 1-2).

FIGURE 1-1
Site Location Map

Listing made the Site eligible for federal cleanup funds while the U.S. Environmental Protection Agency (EPA) seeks to recover costs from the parties responsible for the contamination, or to complete the work if no parties are found. The NPL designation also allows EPA to cooperate with other agencies (such as the U.S. Forest Service [USFS]) in the cleanup. Mine wastes impact Basin and Cataract Creek water quality. Contaminants are arsenic, cadmium, copper, lead, and other metals. Listing allows EPA to view the watersheds in a collaborative manner with other agencies and community groups. 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.

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

Approximately 300 abandoned mine sites exist in the 77-square-mile Basin Watershed. EPA completed a Remedial Investigation (RI) in the Watershed OU2 in 2005. While working on the RI, EPA determined that several removal actions should be performed at some of the most problematic mine sites. Therefore, in early 2000, working in partnership with the USFS, EPA initiated removals of some of the mining wastes at the Buckeye/Enterprise, Crystal, and Bullion Mines. The removal actions were completed in 2002. Funding was provided by each agency according to the ownership (federal or private). Wastes were disposed of in the Luttrell Repository under joint state and federal stewardship (EPA, State of Montana, USFS).

Although some initial cleanup work was performed at the Bullion Mine (the Site), it did not address the adit discharge. Because the Bullion and the Crystal Mines contribute the most to water quality degradation in the Basin Watershed OU2, EPA decided to focus its efforts on reducing these adit discharge sources. In 2009, EPA prepared a draft engineering evaluation/cost analysis (EE/CA) for additional cleanup work (CH2M HILL, 2009). In 2010, before completing the scoring of remedial alternatives in the EE/CA, EPA decided to pursue a focused remedial investigation/ feasibility study (RI/FS) and Interim ROD for both the Bullion and Crystal Mine Sites.

The focused RI of the Crystal and Bullion Mines began in summer 2010. Findings associated with each mine site will be presented in separate reports. **This report represents the findings of the RI for the Bullion Mine.** Historic information was gathered from a variety of sources to obtain insight on land ownership, geology, mining, water quality, local ecology, and other technical data relevant to the Site. Copies of this information are cited in Section 7, *References and Literature Cited*.

1.1 Purpose of Report

The purpose of this focused RI is to characterize the nature and extent of contamination, the fate and transport of contaminants, and present the results of screening level assessment of risks to human health and the environment in sufficient detail to support the development, evaluation, and selection of appropriate remedial alternatives for the Bullion Mine Site OU6.

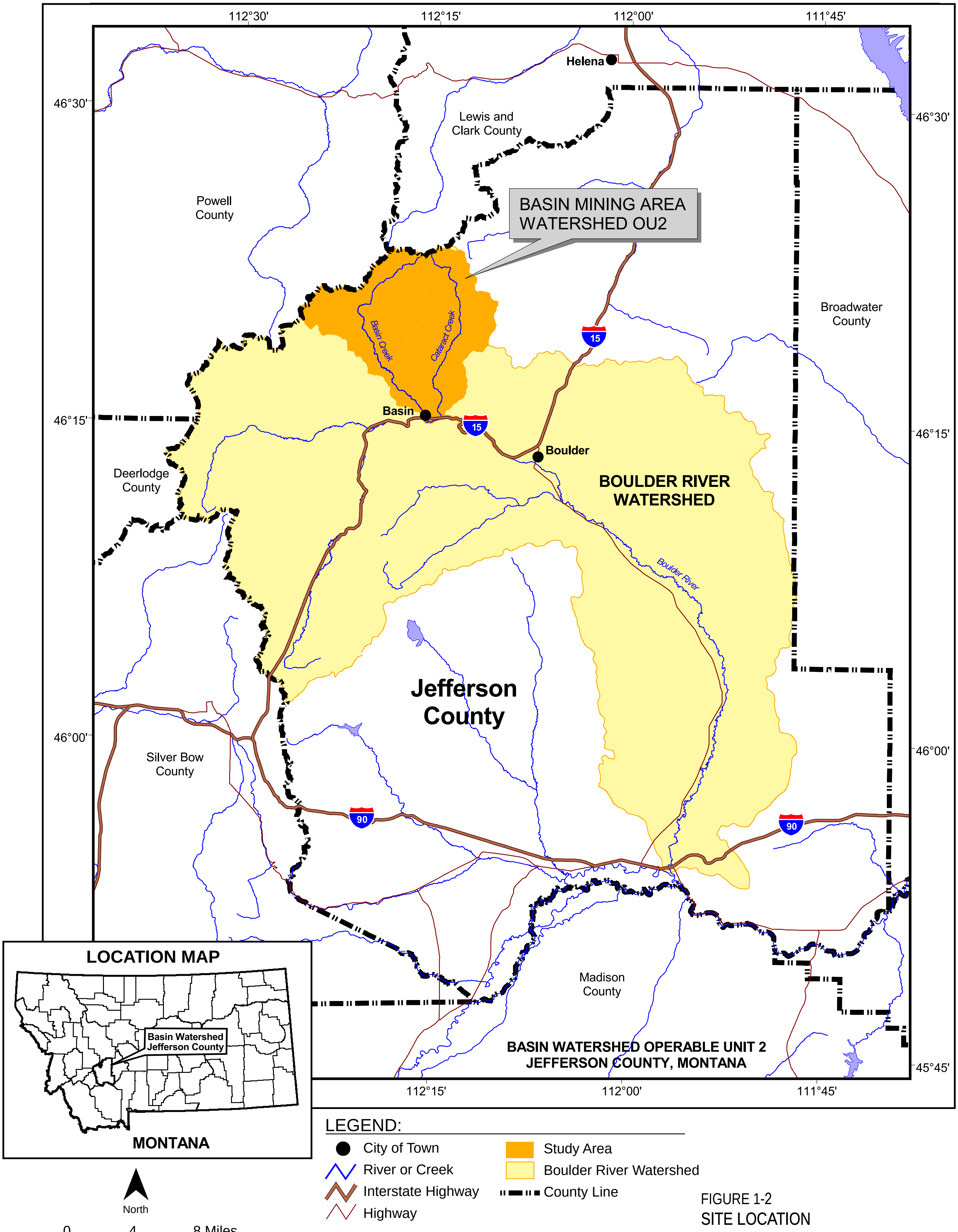
1.2 Report Organization

This report follows the format recommended by the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1989b). Section 1 describes the general setting and features of the Site, the Site history and significance of cultural resources, summary of previous investigations, and a discussion of proposed contaminants (chemicals) of interest (COIs). Section 2 presents a general discussion of the conceptual site model, potential sources of COIs, movements and behavior of COIs, and application of the conceptual model. Section 3 describes the site characterization with text describing data quality objectives (DQOs), previous Site actions, 2010–2012 contaminant source investigations, media, methods of analysis employed with field data and laboratory samples, and quality assurance/quality control. Sections 4 and 5 address the nature and extent of contamination at the Site. Section 6 presents the methodology and findings of the human health (HHRA) and ecological risk assessments (ERA). Section 7 presents a summary of the findings, proposed extent of remedial action, and recommendations. Section 7 also provides a description of proposed preliminary remedial objectives which will help guide consideration, assessment, and evaluation of remedial alternatives discussed in the feasibility study (FS) portion of the CERCLA process (FS, Volume 2).

1.3 Site Background and Regulatory Chronology

Approximately 300 abandoned hard rock mines exist within the Basin Watershed OU2, according to an RI conducted by CDM Federal Programs Corporation (CDM) for EPA (Basin Watershed OU2 RI) (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.Therefore, EPA has concluded that these two sites will be prioritized for cleanup and that Interim RODs will be developed for them prior to a ROD for the Basin Watershed OU2. Thus, each site requires an individual RI/FS to advance to the interim ROD and cleanup (remedial action).

The Bullion Mine is located in the upper part of the Jill Creek subbasin within the Jack Creek drainage, approximately 6 miles north of the town of Basin (9 miles by road). The Bullion Mine was worked periodically from 1897 to 1974. The ore was extracted from adits constructed at three different elevations that were connected by stopes and inclines. The Bullion vein consists of quartz, pyrite, tetrahedrite, galena, sphalerite, chalcopyrite, arsenopyrite, and siderite. The mine produced approximately 30,000 tons of gold, silver, copper, lead, and zinc ore between 1905 and 1955. The Bullion Mine Site (hereafter “the Site”) is now a significant source of AMD that is impacting water quality in Jill Creek, Jack Creek, and Basin Creek. The AMD leaving the Site is laden with arsenic and heavy metals—particularly aluminum, cadmium, copper, lead, manganese, and zinc. The principal source of AMD is discharge from the lower Bullion adit, plus springs and diffuse seepage from the surrounding slope in the vicinity of the lower adit. Springs, seeps, and adit drainage contribute to the total metal load in Jill Creek downstream of Bullion Mine. Jill Creek flows into Jack Creek approximately 1 mile downstream of its confluence with the Bullion Mine seepage.



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

FIGURE 1-2
SITE LOCATION
Bullion Mine OU6 Remedial Investigation

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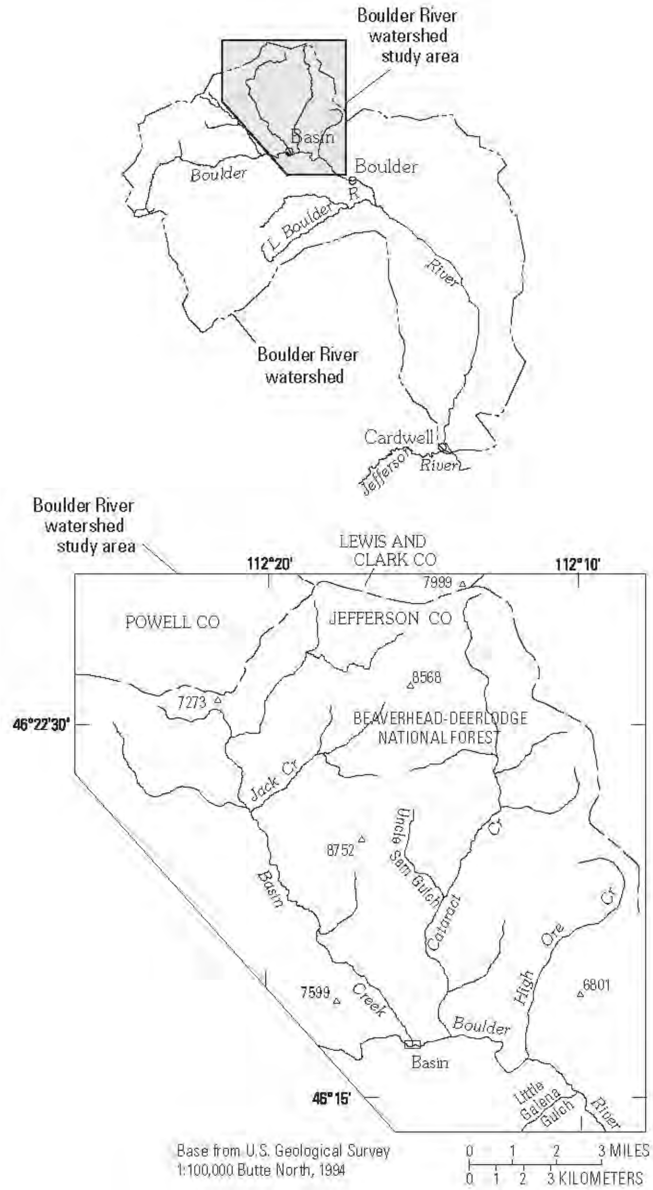
Regulatory and government interest in the site began in the 1990s. The following is a list of relevant investigations and associated regulatory activities that have occurred at the site. The site investigations are explained in more detail in Section 1.5.

- **(1897) Claim Surveyed.** The Bullion lode was discovered in 1888. The claim was surveyed in 1897 and registered to John Fischer and Fred Fischer.
- **(1891 to 1974) Mining Begin/Finish.** Mining on the Bullion Claim commenced with its survey in 1987. Primary production of gold, silver, copper lead and zinc occurred between 1901 and 1948. Inactivity with brief periods of cursory work occurred between 1949 and 1974.
- **(1994 to 2008) Site Investigations.**
  - **March 1994. Abandoned Hardrock Mine Priority Sites – Summary Report (Red Book). Prepared by Pioneer Technical services and Thomas, Dean, and Hoskins, Inc.** In 1993, the Montana Department of State Lands (Abandon Mines and Reclamation Bureau) identified and inventoried abandoned and inactive hard rock mine sites in Montana that exhibited severe environmental degradation to surface water and groundwater. Prospective sites on state and federal lands were visited to confirm locations and site conditions with respect to exposure pathways, and the severity and extent of their contamination (soils, surface waters, mine discharge). The Site ranked 32, or in the top 12 percent.
  - **April 1994. Abandoned-Inactive Mines Program Deerlodge National Forest, Basin Creek Drainage. Volume I, Basin Creek Drainage and Volume II, Cataract Creek Drainage. Prepared by Montana Bureau of Mines and Geology, Open files 321 and 344.** In 1992, the USFS, and MBMG entered into an agreement to inventory and perform 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. Water quality sampling results from a mine discharge with a depressed pH and local creek exceeded maximum contaminant levels (MCLs) for arsenic and numerous metals.
  - **2001. Sampling Activities Report: Basin Mining Area – Bullion Mine, Jefferson County, Montana. Prepared for the U.S. Environmental Protection Agency by URS Operating Services and TetraTech, Inc.** In August 2001, site sampling was implemented in response to task elements specified in a Region 8 Response Team 2 Superfund Technical Assessment by the EPA. The objective of this investigation was to characterize the soils and mine waste at and below the former mill area and in the adjacent adit discharge channel. Results of soils and mine waste sampling indicated elevated arsenic concentrations above State-wide background values.
  - **2001. Bullion Mine and Mill Site Investigation. Prepared for Beaverhead-Deer Lodge National Forest USDA Forest Service, Region 1 by Maxim Technologies Inc.** In 1999, Maxim Technologies Inc. performed an investigation of the Bullion Flotation Mill tailing site. The objective of the study was to: map the extent and thickness of tailing deposits in tailing impoundments along Jill Creek, determine volumes, chemical characteristics of the waste, and evaluate the physical characteristics. The data aided evaluation and planning of a potential removal action at the site.
  - **2003, 2004. Montana State University Investigations.** Montana State University performed several detailed investigations of the vegetation, soil, and water at the Bullion Mine site in 2003 and 2004 (Montana State University, 2003; Montana State University, 2004). The 2004 investigation also included stream flow data at Jill Creek both above and below the confluence with the Bullion Mine adit discharge, as well as groundwater infiltration into Jill Creek. Although not part of the formal RI, the results of the investigations, completed after the removal of mine wastes, confirmed the significant residual contamination of soils, shallow groundwater, and mine adit discharge.
  - **2004. Integrated Investigation of Environmental Effects of Historical Mining in the Basin and Boulder Mining Districts, Boulder River Watershed, Jefferson County, Montana. *U.S. Geological Survey Professional Paper 1652.*** In 1998, the United States Geological Survey (USGS) initiated a 5-year study in the Boulder River Basin to evaluate abandoned mines and issues related to AMD and its effects on the

environment (see Figure 1-2A). The study collected data at mine sites in Basin Creek tributary, including the Bullion Mine, on surface water quality and flow characteristics, impacts too soils/sediments, leaching potential of mine wastes, and geophysical surveys.

- **2005. Basin Watershed OU2 RI/FS Study. Prepared by CDM for EPA.** In 1991, a remedial investigation and feasibility study was initiated on the Basin Watershed (OU2) which included the Bullion Mine site (OU6). Soils, mine waste, and surface water were sampled. Concentrations of arsenic and metals were elevated and risks to Human and Ecological Health documented.
- **2008. Draft Final Reclaimed Mine Inspection Report for the Bullion Mine Site. Prepared by Pioneer Technical Services, Inc.** In 2008, Pioneer Technical Services completed a comprehensive post-reclamation inspection to evaluate the performance of reclamation activities at the Site implemented in 2001 and 2002. The evaluation, performed at the request of the USFS, determined that reclamation efforts were meeting revegetation performance criteria, as well as regulatory and risk-based cleanup goals. However other public safety concerns were raised with respect to site access, residual barren areas, and treatment of the mine adit discharge.

FIGURE 1-2A
Location of Boulder River Watershed and Study Area, Montana



Note:
Adapted from USGS Professional Paper 1652, 2004 Publication

- **1998-99. PA/SI.** EPA conducted a preliminary assessment (PA) and site investigation (SI) of the Basin Mining Area in 1998-99. 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 Bullion 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 OU6 occurred on April 12, 2000.
- **2001 to 2002. Time Critical Removal Activities.** In 2001 and 2002, a Time Critical Removal Action at the Bullion Mine was completed through a joint USFS and EPA initiative. Waste was removed from approximately 8 acres (approximately 27,238 cubic yards) from the upper, middle, and lower waste rock piles (below the three adits), and tailings from impoundments adjacent to Jill Creek. Waste materials were transported to the Luttrell Repository on the northern boundary of the watershed near the headwaters of Basin Creek.

- **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 EPA in 2010 and is represented in part by this document. The RI/FS should be completed in 2013.

Ongoing activities include preparation of a Proposed Plan (PP) and Record of Decision (ROD). After cleanup goals are set in the ROD, remedial design and remedial action activities will begin as the Site progresses into the remediation or clean-up phase.

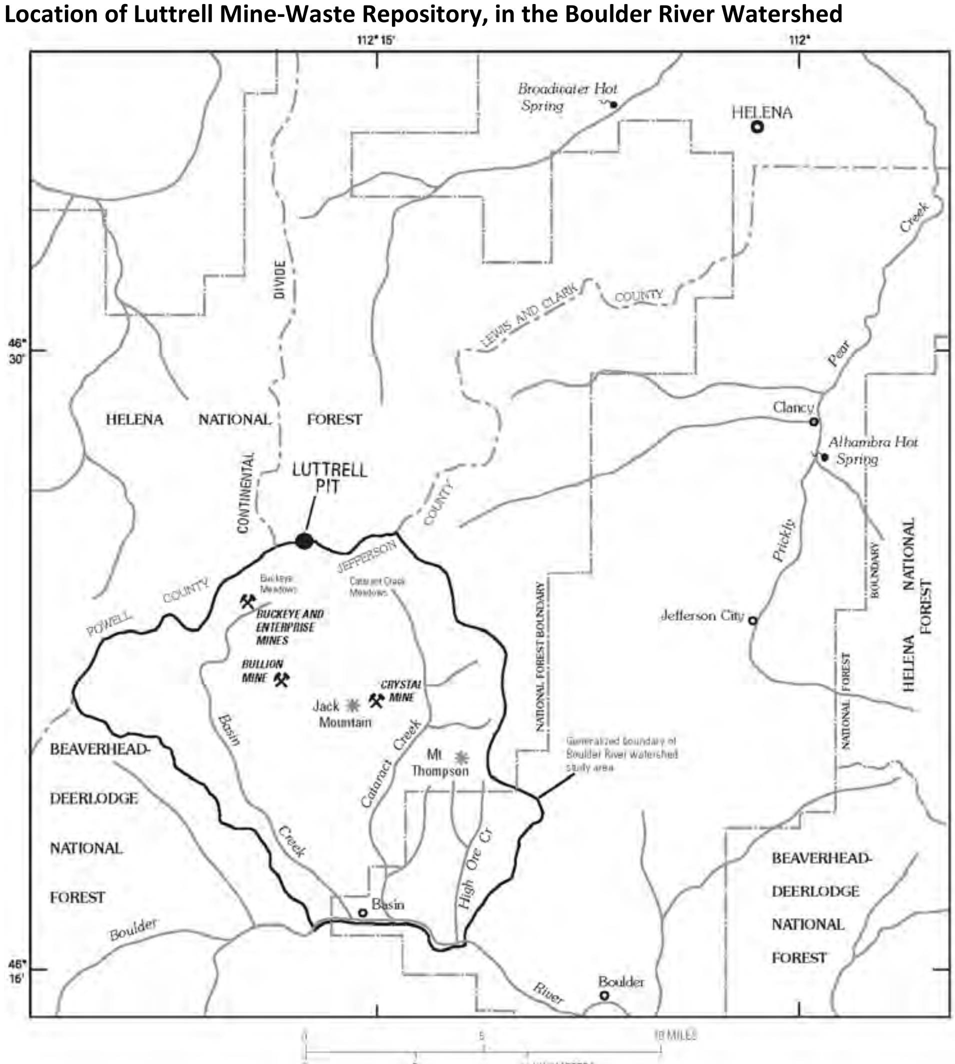
1.3.1 Site Description

The Basin Watershed OU2 covers 77 square miles within the Boulder River Watershed located in the Beaverhead-Deerlodge National Forest and in the northern portion of Jefferson County, Montana (see Figure 1-3). OU2 includes 8 miles of the Boulder River (along the southern boundary) and the entire Basin Creek and Cataract Creek Watersheds. Basin Watershed OU2 is mountainous with high and sharp relief, and contains successions of distinct mountain ranges and valleys (CDM, 2005b).

The Bullion Mine was the largest and most productive mine in the Basin Mining district. The mine is located in Sections 13 and 14, T7N, R6W. The Site and associated claims consists of approximately 40 acres and is within the Basin Creek drainage on the northwest slope of Jack Mountain. The Site is located north of the town of Basin and is accessed by traveling north on Basin Creek Road (USFS Road 172) to the Jack Creek Road (USFS Road 660), turning up Jack Creek for approximately 1 mile to USFS Road 8524. The Bullion Mine and Mill Site is located approximately 1 mile from the Jack Creek Road.

The Bullion Mine site includes dilapidated remnants of a log shop building, two log cabins, mess hall, a flotation cell from a mill site, and the short section of a portal associated with the lower adit. Previous waste rock dumps and tailings impoundments associated with the mine were removed from the Site in a joint removal action by EPA and the USFS (2001–2002) and disposed of in the Luttrell Repository OU3, a joint mine waste repository shared by the State of Montana, EPA, and the USFS. The Luttrell Repository is located at the top of the Basin Watershed, and also accepts mine waste from the Upper Tenmile Creek Mining Area Superfund site on the north side of the Continental Divide (see Figure 1-2B).

FIGURE 1-2B
Location of Luttrell Mine-Waste Repository, in the Boulder River Watershed



Note:
Base Modified from U.S. Geological Survey 1:250,000 Butte, 1947, and White Sulphur Springs, 1958.
Adapted from USGS Professional Paper 1652, 2004 Publication.

1.3.2 Surface Features

The Basin Watershed OU2 is located in the Northern Rocky Mountains Physiographic Province, a mountainous region with elevations ranging from nearly 5400 feet above mean sea level (amsl) at the town of Basin to 8752 feet amsl at Jack Mountain, the highest peak. The watershed is divided into two major drainages. The western portion drained by Basin Creek, and the eastern portion is drained by Cataract Creek. The Site is partially located within "unnamed" drainage, now commonly referred to as "Jill Creek drainage," a small tributary to Jack Creek and Basin Creek (see Figure 1-3). 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 spring (USDA NRCS, 2009).

The surface expression of the Bullion Mine resides on a predominantly steep, northwest-facing slope. Slopes across the Site range from less than 3 percent to as steep as 40 percent in a few localized areas. The overall Site gradient between the three adit portals is approximately 30 percent. The Jill Creek floodplain slopes approximately 3 percent to the northwest. Jill Creek intercepts the northern edge of the Site near its lowest elevation. Surface runoff from the Site flows north towards and into Jill Creek. Elevation at the Site ranges from approximately 7100 feet amsl along Jill Creek to 7800 feet amsl above the upper mine portal. One semi-improved dirt and gravel road provides access to the entire Site. This road approaches the mine from Jack Creek, intercepts the Site through a series of switchbacks, and eventually crosses over a ridge and saddle to the southeast and continues to the Crystal Mine Site.

1.3.3 Meteorology

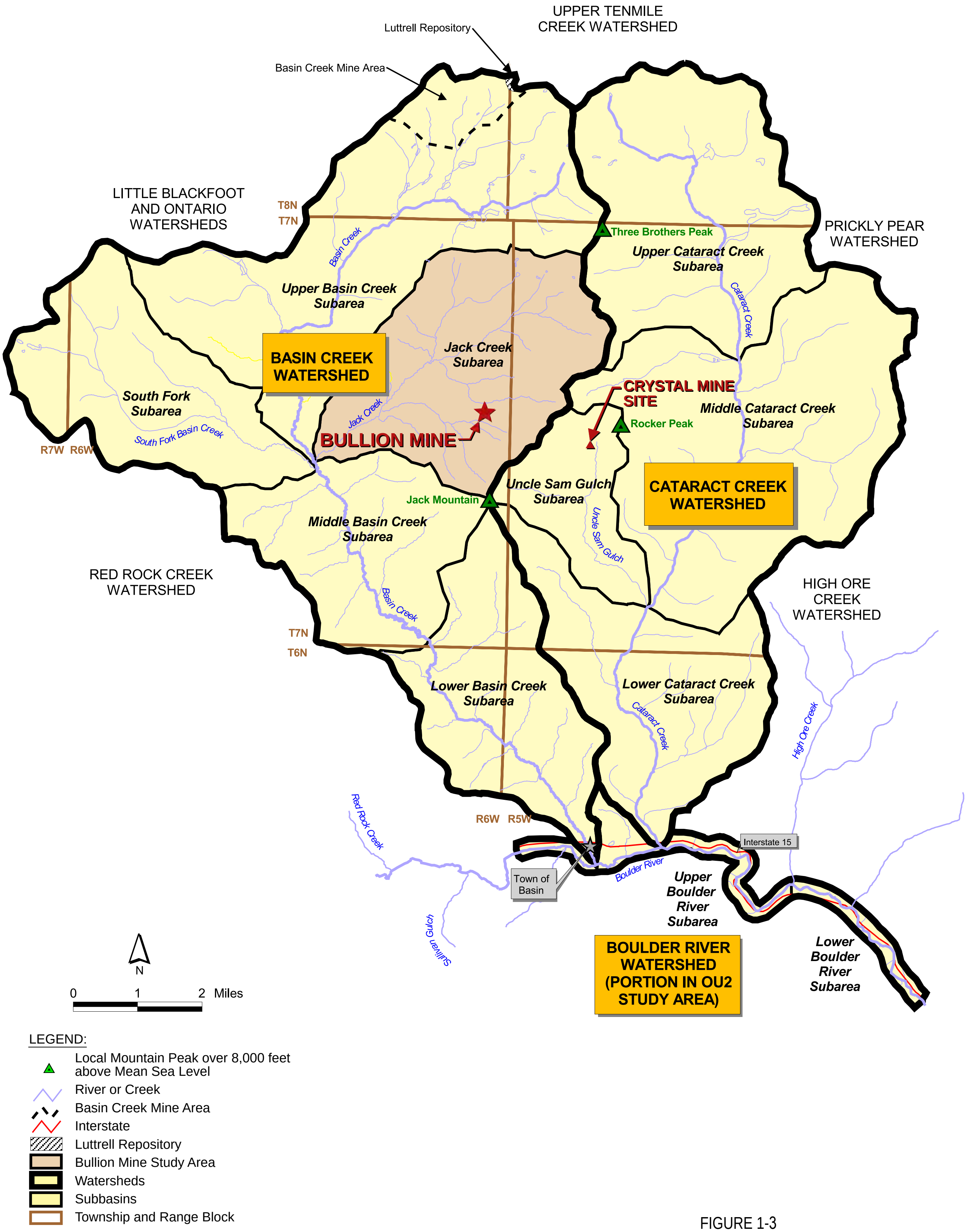
The Site receives an average annual precipitation of approximately 29 inches. The highest precipitation for the area generally occurs in May, June, and July (see Table 1-1). Temperature extremes for the Site range from highs near 85 degrees Fahrenheit (°F) in late summer to lows near -40°F in December and January. Snowfall accumulation typically occurs between October and March (Weather Underground, 2009).

TABLE 1-1
Weather Records for SNOTEL Sites Located Near the Bullion Mine

Location	Average Temperature	Average Monthly Low Temperature (Month) (°F)	Average Monthly High Temperature (Month) (°F)	Historic Low Temperature (Year) (°F)	Historic High Temperature (Year) (°F)	Annual Precipitation (inches)
Basin [a]	42.4	10 (Jan)	82 (Jul)	-42 (1990)	101 (2002)	11.5
Frohner Meadow [b]	37.5	8 (Jan)	84 (Jul)	-54 (1990)	90 (1990)	22.9
Rocker Peak [c]	32.8	-21 (Dec/Feb)	77 (Jul)	-42 (1990)	84 (2008)	29.1

Sources:
[a] The Weather Channel (2011)
[b] Natural Resources and Conservation Service (2011a)
[c] Natural Resources and Conservation Service (2011b) (located 0.4 mile from the Bullion Mine)

Note:
°F = degrees Fahrenheit



Note: Study area is within the Beaverhead-Deerlodge National Forest

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

FIGURE 1-3
BULLION MINE SITE
Bullion Mine OU6 Remedial Investigation

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Meteorological conditions in the upper Basin Creek Watershed are continuously monitored at three locations: Basin Creek Snow Telemetry (Snowpack Telemetry System [SNOTEL]) Station (7180 feet amsl), Frohner Meadow (6480 feet amsl), and Rocker Peak (8000 feet amsl). The Rocker Peak Station is the closest to the Site and is located approximately 1.7 miles east of Uncle Sam Gulch. The average temperatures at the Rocker Station during the coldest months of December and January are between 17°F and 23°F. July and August are the warmest months with average temperature in the low 50°F range (see Table 1-2). The month with the greatest precipitation is typically June, with averages around 4 inches (CDM, 2005b).

TABLE 1-2
Average Monthly Temperature and Precipitation for SNOTEL Sites Located Near the Bullion Mine

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°F)												
Basin [a]	22	27	33	41	50	58	65	64	54	44	30	23
Frohner Meadow [b]	23	23	28	34	42	49	58	57	48	38	29	22
Rocker Peak [c]	19	19	23	29	37	44	53	52	44	33	23	17
Precipitation (inches)												
Basin [a]	0.4	0.3	0.5	0.8	2.0	1.9	1.5	1.4	1.1	0.6	0.6	0.4
Frohner Meadow [b]	1.6	1.4	1.5	2.2	2.7	3.6	2.4	1.5	1.8	0.9	1.7	1.7
Rocker Peak [c]	2.2	1.9	2.3	3.2	3.5	4.2	2.7	1.7	2.0	1.0	2.1	2.3

Sources:
[a] The Weather Channel (2011)
[b] Natural Resources and Conservation Service (2011a)
[c] Natural Resources and Conservation Service (2011b) (located 0.4 Miles from the Bullion Mine)

1.3.4 Surface Water Hydrology

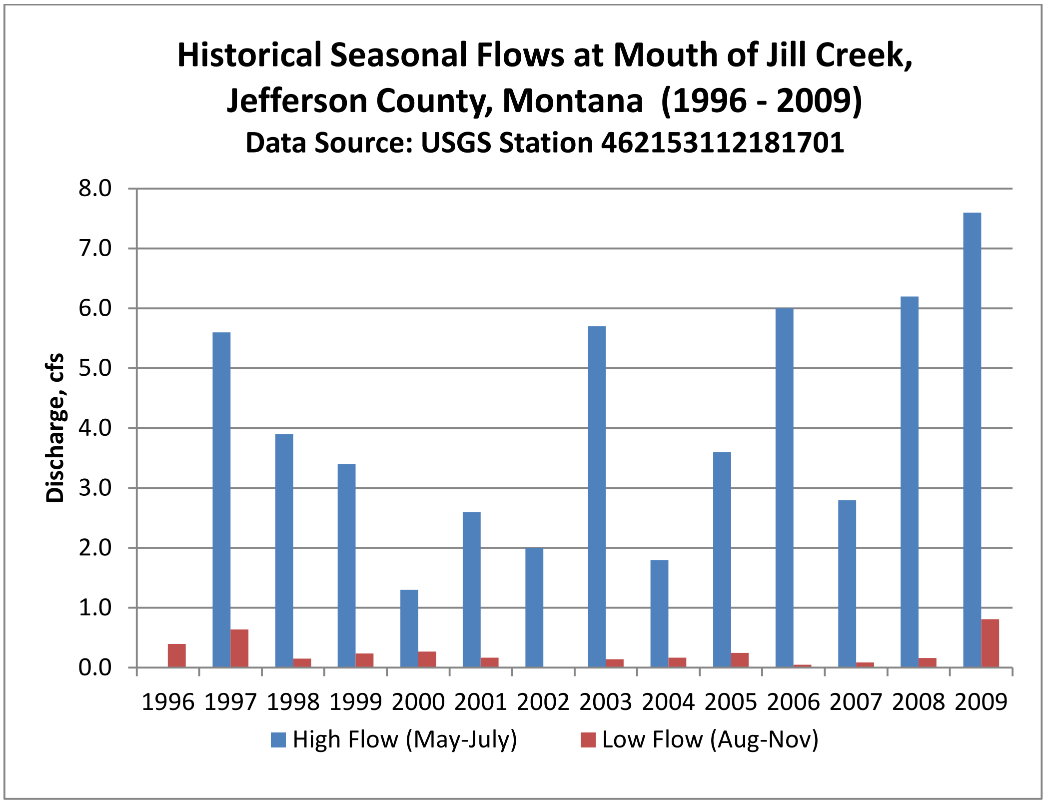
This section presents a discussion of the hydrology of the Basin Creek Watershed and tributaries relevant to the location of the Bullion Mine.

1.3.4.1 Surface Water Flow Regime

Drainage. In the Basin OU2 Watershed, surface water flow regimes respond to seasonal patterns with high flows occurring in the spring (May through June) in response to snowmelt. Low flows typically occur in early fall through late winter (October through February). Occasional summer thunderstorms do create temporary “flashy” peaks, but not on the order of a typical spring runoff. Surface water in the Basin Watershed OU2 flows south, collecting in either Basin Creek to the west or Cataract Creek to the east. It eventually reaches the Boulder River, which then flows 77 miles east to its confluence with the Jefferson River near Cardwell, Montana.

Bullion Mine Site. Surface water from the Site, including mine drainage, flows approximately 0.1 mile northwest to Jill Creek. Jill Creek flows east to west for approximately 1 mile to its confluence with Jack Creek. From there, Jack Creek flows southwest approximately 2 miles to its confluence with Basin Creek. The local creeks experience a seasonal flow pattern with high flows occurring in the spring because of snowmelt and low flows in the late summer through the winter months (see Figure 1-4).

FIGURE 1-4
Seasonal Flow Pattern in Jill Creek



Disturbed, barren, erosion-prone surfaces at the Site are minimal and limited to several former waste rock dump locations and the main access road. Most of the Site is revegetated—the result of a removal action performed by EPA and USFS in 2002. Overland flow, when generated by snowmelt and intense thunder storms, follows Site topography and drains toward the northwestern corner of the Site (see Figure 1-5).

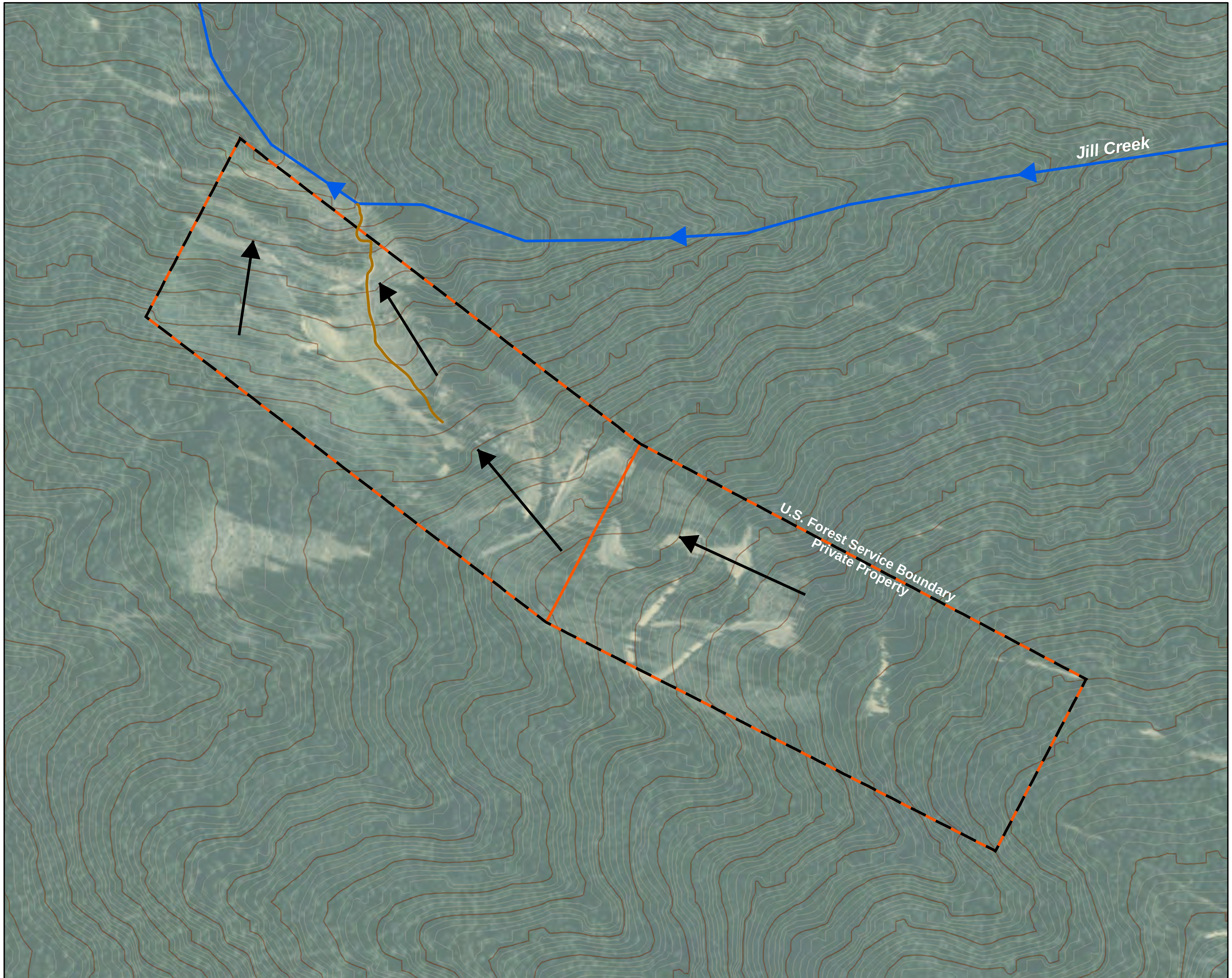
Jill Creek flows east to west for approximately 500 feet adjacent to the northwestern corner of the West Bullion Extension claim boundary and is the only perennial stream in the vicinity of the Site. A constructed channel from the mouth of the lower adit captures discharge from the mine and directs it approximately 700 feet to a confluence with Jill Creek. The adit discharge has been monitored at least quarterly by the USGS since 1999. A summary of adit discharge from 1999 through 2009 is presented in Table 1-3.

The lower third of the Site is wet, supporting a boggy wet meadow and numerous springs and seeps—all of which drain towards Jill Creek.

TABLE 1-3
Discharge Summary of the Bullion Mine Lower Adit (1999–2011)

Sample Location	Number of Observations	Maximum Flow (gpm)	Minimum Flow (gpm)	Mean Flow (gpm)
Bullion Mine lower adit discharge	40	14.33	1.8	4.92

Note:
gpm = gallons per minute



LEGEND

- Drainage
- Adit Discharge Channel
- Major Contour (10m)
- Minor Contour (2m)
- U.S. Forest Service Boundary
- Mine Claim Boundary

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

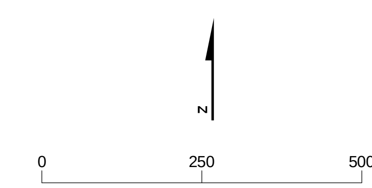


FIGURE 1-5
BULLION MINE MAP (DRAINAGE)
Bullion Mine OU6 Remedial Investigation

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1.3.4.2 Water Quality Classification

The Montana Department of Environmental Quality (MDEQ), under the Administrative Rules of Montana (ARM), classifies and assesses Montana surface waters with the intent of protecting human health and ecological degradation from water-borne contamination while maintaining beneficial use of the waters. Beneficial use classifications assigned to streams in each major drainage area within Montana are provided in ARM 17.30.606.

Jill Creek carries no specific classification, but the streams into which it flows do. The beneficial use classification for Jack Creek and Basin Creek is B-1. This classification states that the water quality of the stream must be sufficient to support recreational activities such as bathing and swimming; growth and propagation of salmonid fishes and associated aquatic life and other wildlife; agricultural and industrial water supply; and drinking and culinary purposes, after conventional treatment.

Basin Creek. MDEQ also conducts periodic assessments of each stream within the listed drainage areas to determine if the current water quality is consistent with water quality standards (MDEQ, 2004) and the stream's use classification. If the result of the assessment warrants improvements in water quality to meet standards, the stream is listed on the Montana 303(d) list in accordance with federal regulations under the Clean Water Act (CWA). The entire length of Basin Creek, from the headwater to the mouth at the confluence with the Boulder River, was first listed on the 1988 303(d) list. According to the 2012 assessment (MDEQ, 2012) based on 2010 sampling results, the water quality parameters that exceeded standards are aluminum, arsenic, cadmium, copper, lead, and zinc. In addition, the amount of sedimentation/siltation exceeded acceptable levels. Total maximum daily loads (TMDLs) for the metals have been developed according to the recommendations of the assessment and were approved by EPA in December 2012.

Jack Creek. Jack Creek is not currently listed on a Montana 303(d) list. However, the 2012 assessment based on 2010 sampling results concluded that Jack Creek is impaired and will be listed on the 2014 303(d) list. The water quality parameters that exceeded standards are aluminum, arsenic, cadmium, copper, lead, and zinc. TMDLs have been developed and approved by the EPA in December, 2012. According to historic information, Jill Creek, as a result of the Bullion Mine adit discharge, is a prime contributor to the degraded condition of Jack Creek.

1.3.5 Geology

1.3.5.1 Geologic Setting

The Bullion Mine vicinity is underlain by bedrock geologic units including granitic rocks and volcanic rocks, and unconsolidated surficial geologic units including colluvial, glacial, and alluvial deposits. The following section provides a summary of the geologic units in the vicinity of the Bullion Mine. The geology is described in greater detail in Section 3.4.3.

1.3.5.2 Bedrock Geologic Units

Bedrock geologic units in the Bullion Mine vicinity include extrusive volcanic rocks of the Middle Member of the Elkhorn Mountains Volcanics and intrusive rocks of the Butte Pluton. The Middle member of the Elkhorn Mountain Volcanics is described as "greenish-gray, gray, brownish-gray to reddish-gray, fine-grained, dacitic welded tuff, and also includes lapilli tuff, tuff breccias, and minor volcanic sandstone and conglomerate." This unit is between approximately 73 and 78 million years old and may be as much as 8,200 feet thick. The Elkhorn Mountains Volcanics are mapped near the upper portions of the Bullion Mine.

The rock that comprises the Butte Pluton of the Boulder Batholith classifies as granite or granodiorite. The Butte Pluton was emplaced between approximately 82 and 74 million years ago. This rock unit includes three textural phases—fine grained, medium- to coarse-grained, and the aplite and porphyry phase. The medium- to coarse-grained phase is described as light to dark gray, with potassium feldspar, plagioclase, hornblende, and biotite. This unit underlies as much as 90 percent of the Basin Creek area and numerous outcrops of this rock type were observed in the vicinity of the Bullion Mine. The fine-grained phase includes light and dark gray and pinkish gray varieties and is both porphyritic and equigranular. The aplite and porphyry unit is similar in texture to the fine-grained unit, but is distinguished by a very low mafic content. The aplite and porphyry units form tabular bodies and dikes throughout the area.

1.3.5.3 Surficial Geologic Units

Surficial geologic units in the Bullion Mine vicinity include Quaternary age (less than 1.6 million years) glacial till, alluvial deposits, and colluvial deposits. The glacial till deposits are the most extensive surficial deposits in the Basin Creek Watershed and consist primarily of morainal deposits that cover slopes and valley bottoms. The till is typically deeply weathered, and smaller clasts are poorly preserved and most have disintegrated into unsorted sand- and fine gravel-sized grains that now form the interstitial matrix for larger, less weathered boulders. At the Bullion Mine, the glacial till has been deposited downslope along the valley walls and bottom of Jill Creek and mantles the lower portion of the mine vicinity, primarily below the lower adit.

Other surficial deposits in the vicinity include alluvial deposits along Jill Creek that consist of (1) rounded sand, gravel and boulders; and (2) colluvium on slopes that consists of locally derived, weakly stratified silt, sand and gravel deposited by gravity processes.

1.3.5.4 Structural Geology

Geologic structures in the area consist of faults/shear zones, joints, fractures, and lineaments. The geologic structure is important because it influenced the orientation and location of the ore bodies and polymetallic quartz veins. The veins developed in east-trending fractures and shear zones formed by tectonic stresses that appear to be related to emplacement of the crystalline rocks. In addition, the orientation and density of geologic structure and fractures influences groundwater flow in the vicinity of the Bullion Mine.

The volcanic rocks typically underlie topographically higher areas above the Bullion Mine and are generally highly fractured. In contrast, the plutonic rocks have near-surface fracturing but the fracturing typically decreases with depth. The exposed portions of the Butte Pluton are cut by fracture systems that formed during cooling of the pluton (nondiastrophic fractures), and those that developed during emplacement of the batholith because of tectonic stresses (diastrophic fractures). The nondiastrophic fractures in the Butte Pluton include cross joints, longitudinal joints, and flat-lying joints. These joint systems are evident in granitic outcrops in the vicinity of the Bullion Mine.

The diastrophic factures are important because some are comprised of shear zones that contain quartz veins and polymetallic mineral deposits. The most important of these fracture systems, based on economic significance, is marked by east-trending shear zones as much as 6 miles long. The Bullion vein is formed in one of the most prominent east-trending shear zones. This vein is part of a major east-trending structural lineament known to extend more than 3.5 miles in length from the Bullion Mine on the west to the Eva May Mine on the east. The vein is offset in several places by north-trending cross faults and joint sets in the Butte Pluton.

1.3.6 Soils

1.3.6.1 Basin Creek Watershed

The majority of the soils found within the Basin Creek Watershed consist primarily of sandy loam with cobbles. Depth to bedrock varies because of erosion and deposition of glacial and alluvial materials, and colluvial cover. Areas of steep slope (35 to 60 percent) tend to have 12 to 18 inches of soil on top of bedrock. Valleys tend to have more than 60 inches of soil on top of fractured bedrock.

1.3.6.2 Bullion Mine Soils

The majority of the Site is underlain by Sig family and Roman family soils, and rock outcrop. The Sig and Roman soils are found in steep glaciated mountain slopes and formed in glacial till and moraines. Slopes are convex to linear and range from 10 to 35 percent. A typical soil profile for the Sig family consists of very stoney to cobbly sandy loam to 15 inches, underlain by granitic bedrock. A typical soil profile for the Roman family consists of very bouldery to gravelly loam to 19 inches, underlain by very gravelly loamy coarse sand in till derived from granite. These soils are well-drained to excessively drained and have a moderately high to high saturated hydraulic conductivity between 0.2 and 2 inches per hour.

The northwest portion of the Bullion Mine along Jill Creek is underlain by the Garlet-Worock-Waldbillig soils, which consist of soils formed in moderately steep, young glacial ground moraines. Slopes are linear and range from 10 to 35 percent. A typical soil profile for these soils consists of very cobbly to sandy loam and gravelly clay loam to a depth of greater than 60 inches. These soils are well-drained and have moderately high to high saturated hydraulic conductivity between 0.2 and 2 inches per hour.

Because of previous mining and reclamation activities, most the onsite soils within the mine claim have been highly disturbed over the years.

1.3.7 Hydrogeology

Two general aquifers exist in the Basin Creek Watershed: a shallow, unconfined alluvial aquifer found in stream alluvium and thick colluvial deposits, and a deeper aquifer within fractured bedrock. Groundwater recharge in the vicinity of the Bullion Mine occurs from the infiltration of snowmelt and precipitation at topographic highs. Infiltration is greatest in areas with higher hydraulic conductivity, such as zones of densely fractured rock and collapsed shafts and raises. Groundwater discharge occurs as numerous springs and seeps in topographic lows, slope breaks, at geologic contacts with changes in hydraulic conductivity, and where adits daylight. Typically, crystalline bedrock aquifers have low hydraulic conductivity, except where secondary fracture permeability exists, such as along fault zones, mineralized zones, and large fractures. The predominant east-west orientation of linear features may have a significant influence on structurally controlled shallow groundwater flow directions. The polymetallic vein systems are up to 50 feet wide, and, along with old mine workings, can act as groundwater conduits.

In the immediate vicinity of the Bullion Mine, it appears that groundwater inflow into the tunnels and adits comes primarily from (1) precipitation and snowmelt into the soil profile and its migration into underlying fractured bedrock, and (2) surface water runoff intercepting old collapsed shafts and trenches above the extensive mine workings. No groundwater discharge was emanating from the middle and upper Bullion adits during the 2010 investigations, but the lower Bullion adit was a primary point of groundwater discharge.

Numerous springs were observed and have been inventoried in the vicinity of the Sites lower adit, which indicates groundwater movement from the soil/bedrock interface or from exposed bedrock fractures. Seepage from the adit and springs drains into Jill Creek, which flows westward towards Jack Creek. Groundwater seeps and groundwater infiltration downgradient of the Site contribute to the total metal load in Jill Creek downstream of Bullion Mine. The local hydrogeologic conditions and groundwater levels are described in more detail below under "Subsurface Conditions."

1.3.8 Surrounding Land Use and Populations

The majority of the land within the Basin Creek Watershed is managed by the USFS or USDI Bureau of Land Management (BLM). The historic land use for claim properties in the watershed has been mining. Other land uses in the area consist of logging, grazing, recreation, and residential. Although the watershed is sparsely populated, a few residences are located along Basin and Jack Creeks, with the town of Basin at the mouth of the watershed. Water from these creeks recharges shallow alluvial aquifers which are a source of drinking water for many Basin residents and the represents the primary human health risk pathway. No known potable water supply wells are located within a 1-mile radius of the Site. Water from Basin Creek is also used for irrigation, supports impaired fisheries, and ultimately enters the Boulder River. Neighboring residential areas are the town of Boulder (approximately 7 miles east and downstream of Basin), the city of Butte (more than 22 miles southwest of Basin), and the city of Helena (more than 25 miles northeast of Basin).

1.3.9 Habitat Characterization and Delineation

The Basin Creek Watershed is primarily evergreen forest dominated by lodgepole pine, Douglas fir, spruce, aspen, and common juniper (CDM, 2005b). A variety of small trees, shrubs, and grasses are found in scattered open areas and along stream banks. Lower elevations of the watershed along the Boulder River are dominated by riparian areas consisting of willow, alder, conifer, cottonwood, and aspen. Biological surveys within the watershed are limited; however, the Montana Natural Heritage Program (MNHP) does not identify any special plant species of concern (Mincemoyer, 2005).

1.3.10 Aquatic Assessment

From its headwaters, Basin Creek flows approximately 17 miles to its confluence with the Boulder River. Basin Creek flows through the town of Basin. Of the 30 named and unnamed tributaries to Basin Creek, Jack Creek is fairly typical of the area and can be characterized as a relatively high gradient, cold water stream with abundant riffles, shallow pools and isolated wetlands (CDM RI Addendum, 2004). Wetlands commonly occur within the floodplains. Stream substrate consists of sand, gravel and cobbles. According to the USGS and previous RI/FS studies (CDM, 2004), Jill Creek, contributes approximately 65 to 68 percent of the flow in Jack Creek.

Loading of copper and zinc to Jill Creek from the Bullion Mine adit during base-flow conditions was estimated at 1.13 and 5.88 pounds per day (0.5 and 2.69 kilograms per day [kg/day]), respectively. The Bullion Mine discharge, contributing acidic and metal-rich water, is the principal contaminant source to the Jill Creek tributary of Jack Creek. During transport in Jill Creek, much of the iron and aluminum contributed by the mine is transformed from dissolved to colloidal phases through the interception of tributaries with near neutral pH. The colloidal material affects other metals that sorb to colloids. Deposition of this material provides a route for metals to enter the food web and create a condition of chronic toxicity for fish downstream. This source is likely to have the most impact on aquatic health in the Basin Creek drainage (Section D2, "Quantification of Metal Loading by Tracer Injection and Synoptic Sampling, 1997-1998." Professional Paper 1652, USGS, 2004).

A study published by the USGS (Nimick and Cleasby, 2000) reported that the survivability of juvenile cutthroat trout (hatchery-raised) at 96 hours was zero at several sites within Jill Creek and Uncle Sam Gulch (Cataract Creek drainage). The study concluded that metals are accumulating in biofilm, invertebrates, and fish in tributaries of concern including Jill Creek (Bullion Mine Site). The study also stated that it is unlikely that fish survival would increase unless COIs in surface water are reduced to 3 micrograms per liter (µg/L) for cadmium, 33 µg/L for copper, and 400 µg/L for zinc.

1.4 Site History

Mining within the Basin Mining District began in the mid to late 1800s and continued sporadically into the 1960s. The first mining consisted of placer mining activities concentrated on Basin and Cataract Creeks. The first lode deposits were discovered in the 1870s with the Eva May, Crystal, Uncle Sam, Hattie Ferguson, Bullion, and the Hope/Katie Mines (CDM, 2005b).

Mining was most active during the 1890s and early 20th century. Placer mining activity continued during the first half of the 20th century. Subsurface mining continued until the 1960s, when the Crystal Mine ended production. Between 1902 and 1957, the Basin Mining District produced minerals worth an estimated value of $11,700,309.

The Bullion Mine was most productive between 1901 and 1948. Inactivity mixed with brief periods of mining occurred from 1950 through 1974 (RTI, 2011). The smelter and a gravity concentrator were constructed in 1905. The smelter was located approximately 1 mile away, on another tributary to Jack Creek. In 1929, a flotation mill was constructed in the main development area. Total production was approximately 30,000 tons of ore containing 3,500 ounces of gold; 250,000 ounces of silver; 300 tons of copper; 1,000 tons of lead; and 1,000 tons of zinc.

Seven foundations from mining structures are scattered throughout the lower half of the Site. The majority of the foundations lie between the middle and lower adit. The Site contained several waste rock piles below the adits (these were removed in 2001), on which several buildings and ore bins were constructed. A mill with tailings and two breached tailings impoundments were also present prior to the removal action. The three adits, along with most of the former waste rock dumps and some of the tailings are on private land (patented mining claims).

The Bullion property includes the claims shown in Table 1-4 and Figure 1-6.

TABLE 1-4
Bullion Mine – Mining Claims

Mining Claim Name	Location Date	Mineral Survey Date	Area (acres)	Mineral Patent Number
Bullion	August 14, 1888	June 11,1897	20.29	5108
West Bullion Extension	September 30, 1917	November 19, 1920	20.35	782859
Sunset				(unpatented)

VICINITY MAP

LEGEND

- Adit Discharge Channel
- U.S. Forest Service Boundary
- Mine Claim Boundary

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

N

0 250 500
Feet

FIGURE 1-6
BULLION MINE CLAIM BOUNDARIES
Bullion Mine OU6 Remedial Investigation

\\OWL\PROJ\EPA\408158BULLIONMINE\GIS\MAPFILES\BULLIONCLAIMBOUNDARY.MXD JCARR3 7/29/2011 10:31:34

CH2MHILL

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In 1950, a representative of MBMG visited the Bullion Mine. The mine at the time was registered to Allan J. Bullock of Basin (RTI, 2011). At some point, Delbert Bullock, Allan's brother, and Keith P. Johnson and Donald W. Johnson were included in the ownership, The Bullock brothers operated the Bullion (and the Crystal) Mine on a small scale between 1969 and 1984. In October 1997, the Johnsons (both deceased now) conveyed their undivided half interest in the Bullion Mine to Bay Horse Inc., a Montana Corporation.

On June 15, 2007, Delbert M. Bullock transferred his property interests in the Crystal and Bullion mines to his son, Chris D. Bullock. Chris D. Bullock and Allan J. Bullock each currently own an undivided one-third interest in the Crystal Mine and an undivided one-quarter interest in the Bullion Mine. Bay Horse, Inc. currently owns an undivided one-third interest in the Crystal Mine and an undivided half interest in the Bullion Mine.

1.4.1 Cultural Resources

Cultural and historic resources within the Bullion Mine OU were characterized during this RI. The National Historic Preservation Act (NHPA) of 1966 established a process by which federal agencies must incorporate historic resource issues into their planning process. Section 106 of the NHPA requires the head of a federal agency with jurisdiction over a federal, federally assisted, or federally licensed undertaking to take into account the effects of that agency's undertakings on properties included in or eligible for the National Registry of Historic Places. The state agency responsible for documenting, recording, and investigating cultural resources is the Montana State Historical Preservation Office (SHPO). Under this task, existing public information concerning cultural resources associated with the Bullion Site were searched. Potentially significant historical, cultural, and archeological sites were identified from SHPO file search.

As part of the planning effort for completing the RI and eventually initiating a Site cleanup, EPA notified SHPO of the Superfund project. Although the Bullion Mine had been recorded as a historic site in 1995 and the site form updated in 1998, SHPO regarded the Site information as dated. The office also preferred that new guidance (Godfrey, 2003), produced since the original site recordation, be consulted in a re-examination.

EPA contracted Renewable Technologies, Inc. (RTI) to perform an updated inventory of the Site (RTI, 2011), note any changes that might have occurred since 1998 (RTI, 1999), and reconsider Site eligibility in light of the 2003 guidance. RTI was familiar with the property because their staff originally documented it as an historic entity (24JF1311). This summary is largely taken from the RTI report on the updated survey (Rosillon, 2011).When GCM Services first examined the Bullion in 1995, its crew found that the surface workings of the mine covered portions of three mining claims—the Bullion, West Bullion Extension, and the unpatented Sunset. GCM Service's investigation noted that the remains at the Bullion Mine date mainly to the early twentieth century up to about World War II. Sixteen features at the Site at the time included collapsed mine openings, mill ruins, and a small residential complex (Anderson et al., 1995). RTI's report following its 1998 revisit did not add substantially to the record, concentrating mainly on providing details to enhance earlier feature descriptions (Rossillon and Haynes, 1999).

As part of the original Site recordation, GCM Services staff determined that the Bullion Mine was not eligible for listing in the National Register of Historic Places. However, 3 years later, RTI found the property eligible under Criteria A and C. More specifically, it found the Site to be a contributing element to "the discontiguous Bullion Mine and Ore Processing historic district which encompasses the Bullion Mine." Subsequent to those evaluations, the EPA and USFS sponsored significant reclamation work at the Bullion. In 2001–2002, contracted work involved removal of two large waste rock dumps, mill tailings, and associated ore storage, loading, and processing features. A stream channel through the Site that more or less originates at one of the adits was channelized. Finally, as part of a cultural resource mitigation program, a log shop was moved to a new location away from reclamation activities and flotation cells were relocated to the former upper mill floor.

On August 6, 2011, RTI historic archaeologist Mitzi Rossillon revisited the Bullion Mine. She examined all of the previously recorded features, comparing their current condition with that reported previously. Because the Site is changed from its last reported appearance, RTI remapped the Site using global positioning system (GPS) technology. Only features which had changed significantly since 1998 were evaluated. Finally, RTI revisited its 1998 National Register evaluation.

RTI found in 2011 that the Site had not only changed as a result of the 2001–2002 reclamation work but also had been damaged by natural deterioration since last reported 13 years ago. The majority of remaining buildings and structures at the Bullion Mine are concentrated in what was once a residential area. Relatively few mining and milling features are left. Therefore, RTI now believes the Bullion Mine is not eligible for the National Register. A citation for RTI's report detailing additional information may be found in Section 8, *References and Literature Cited*.

1.5 Previous Investigations

Interest in the Basin Mining area (including the Bullion Mine), its legacy of hard rock mining, and the impacts on local aquatic resources extends back to 1992, the result of water quality studies initiated by the USGS and the Montana Bureau of Mines and Geology (MBMG). Several studies documented water quality in the Boulder River, Basin Creek, and Cataract Creek. Previous sampling, risk assessments, and response actions have been undertaken in the Basin Watershed OU2. Mine sites designated as operable units within OU2, such as the Bullion Mine, were included in these activities, many of the results and conclusions from this previous work are pertinent to this investigation of the OU6 Site. Therefore, relevant information from these studies has been incorporated into this RI and is described in greater detail under specific media in Section 3.

The findings from these studies and investigations are summarized in Appendix A with specific reports referenced in Section 8.

1.6 Selection of Contaminants of Interest and Remedial Investigation Data Interpretation

Contaminants of interest (COIs) for this focused RI are summarized in this section. Traditionally, the RI identifies COIs based on defined contaminant sources. The risk assessment process then refines these to contaminants (chemicals) of potential concern (COPCs) and concludes with the identification of the primary COCs, around which remedial options and alternatives are then proposed to mitigate risks (feasibility study process). As previously stated in this document, the Site was evaluated as part of a watershed-wide RI/FS process (Basin Watershed OU2), and a risk assessment was performed. As such, COPCs were already evaluated for the Site through a baseline ecological risk assessment (BERA) for the Basin Watershed OU2 (CDM, 2002). The risk assessment identified the primary COCs that drive the risk to human health and the environment at the Site as arsenic, cadmium, copper, lead, and zinc (EPA, 2000b).

1.6.1 Contaminant of Interest Selection Summary

Using the previous Basin Watershed OU2 risk assessment findings, site-specific historic investigation findings, and the knowledge that the Site has been inactive since those findings, the focused RI prepared a list of metals and metalloids (COIs) to evaluate for nature and extent of contamination at the Bullion Mine (see Table 1-6). Mercury was not included based on historic and current sampling results indicating its presence typically at or below detection levels in samples from the Bullion Mine discharge and Jill/Jack Creeks (CDM, 2005b, Tables 6.3-1, 6.4-1; USGS, 2011). Media sampling results were screened for exceedance of conservative human health and ecological benchmarks. Screening benchmarks are presented in Tables 1-5, 1-6, 1-7, and 1-8.

TABLE 1-5

List of Contaminants of Interest and Associated Media Sampled, Bullion Mine OU6 RI (2010–2012)

Analytes		Groundwater	Surface Water	Sediments	Soil
Aluminum	Al	X	X	X	X*
Antimony	Sb	X	X	X	X
Arsenic	As	X	X	X	X
Cadmium	Cd	X	X	X	X
Copper	Cu	X	X	X	X
Iron	Fe	X	X	X	X
Lead	Pb	X	X	X	X
Manganese	Mn	X	X	X	X
Nickel	Ni	X	X	X	X
Selenium	Se	X	X	X	X
Silver	Ag	X	X	X	X
Thallium	Ti	X	X	X	X*
Zinc	Zn	X	X	X	X

Note:
* Soil sample analytes aluminum and thallium were limited by x-ray fluorescence (XRF) detection capabilities

TABLE 1-6

Surface Water and Groundwater Screening Benchmarks

	State of Montana Standards [2]				National Recommended Water Quality Criteria – Aquatic Life[3,c]		
	Human Health Standards		Aquatic Life				
Analyte	Surface Water	Groundwater	Acute	Chronic	Acute	Chronic	EPA Surface Water[1]
Aluminum	---	---	0.75	0.087	---	---	0.087
Antimony	0.0056	0.006	---	---	---	---	0.03
Arsenic	0.01	0.01	0.34	0.15	0.34	0.15	0.005
Cadmium	0.005	0.005	0.00052	0.000097	0.0020[a]	0.00025[a]	0.00025
Copper	1.3	1.3	0.00379	0.00285	0.013[a]	0.0090[a]	0.009
Iron	---	---	---	1	---	---	0.3
Lead	0.015	0.015	0.01398	0.000545	0.065[a]	0.0025[a]	0.0025
Manganese	---	---	---	---	---	---	0.12
Nickel	0.1	0.1	0.145	0.0161	0.47[a]	0.052[a]	0.052
Selenium	0.05	0.05	0.02	0.005	---	0.0050[b]	0.001
Silver	0.1	0.1	0.000374	---	0.0032[a]	---	0.0032
Thallium	0.00024	0.002	---	---	---	---	0.0008
Zinc	2	2	0.037	0.037	0.12[a]	0.12[a]	0.12

Notes:
[1] EPA Freshwater Screen Benchmarks (milligrams per liter [mg/L]). Available at http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fw/screenbench.htm.
[2] Circular DEQ-7 Montana Numeric Water Quality Standards (MDEQ, 2012)
[3] Freshwater standards from EPA (2009b), *National Recommended Water Quality Criteria (NRWQC) for Priority Pollutants*.
[a] The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a hardness of 100 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)

[b] This recommended water quality criterion for selenium is expressed in terms of total recoverable metal in the water column. It is scientifically acceptable to use the conversion factor (0.996 – CMC or 0.922 – CCC) that was used in the GLI (60 FR 15393-15399, March 23, 1995; 40 CFR 132 Appendix A) to convert this to a value that is expressed in terms of dissolved metal.
[c] Metals are stated as dissolved unless otherwise specified.
Units are all reported in mg/L = milligram per liter

TABLE 1-7
Soil and Sediment Screening Benchmarks

	Soil					Sediment			
	Human Health Soil Screening Levels (mg/kg)[a]		Ecological Soil Screening Levels (mg/kg)[b]			EPA Region 3 (mg/kg)[c]	NOAA SQuiRTs (mg/kg)[d]	Ecological Soil Screening Levels (mg/kg)[b]	
Analyte	Occupational	Residential	Plants	Avian	Mammalian		ARCS	Avian	Mammalian
Aluminum	99,000	7,700	---	---	---	---	25,500	---	---
Antimony	41	3.1	---	---	0.27	2	---	NA	0.27
Arsenic	1.6	0.39	18	43	46	9.8	---	43	46
Cadmium	80	7	32	0.77	0.36	0.99	---	0.77	0.36
Copper	4,100	310	70	28	49	31.6	---	28	49
Iron	72,000	5,500	---	---	---	20,000	---	---	---
Lead	800	400	120	11	56	35.8	---	11	56
Manganese	2,300	180	220	4,300	4,000	460	---	4,300	4,000
Nickel	2,000	150	38	210	130	22.7	---	210	130
Selenium	510	39	0.52	1.2	0.63	2	---	1.2	0.63
Silver	510	39	560	4.2	14	1	---	4.2	14
Thallium	1	0.078	---	---	---	---	---	---	---
Zinc	31,000	2,300	160	46	79	121	---	46	79

Notes:
mg/kg = milligrams per kilogram
[a] Residential soil screening levels from EPA (2012). *Regional Screening Levels for Chemical Contaminants at Superfund Sites*. (Carcinogenic effect TR = 10^{-6}, Noncarcinogenic effect HQ = 0.1). Although residential scenarios are not expected on-Site, these levels serve as conservative screening values.
[b] Eco soil screening levels from EPA Eco SSL guidance serve as conservative estimates of minimum detection limits. EPA (2005), *Guidance for Developing Ecological Soil Screening Levels (EcoSSLs)*.
[c] Sediment screening levels are from EPA Region 3 – Freshwater Sediment Screening Benchmarks. Available at: http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm.
[d] U.S. National Oceanic and Atmospheric Association (NOAA). 2008. Screening Quick Reference Tables (SQuiRTs). NOAA, 2008).
ARCS = assessment and remediation of contaminated sediments. PNEC = Predicted No-Effect Concentration

TABLE 1-8
Summary of Conservative Screening Benchmarks by Media*

Analyte	Soil Screening Value (mg/kg)	Surface Water Screening Value (mg/L)	Sediment Screening Value (mg/kg)	Groundwater Screening Value (mg/L)
Aluminum	7,700	0.087	25,500	---
Antimony	0.27	0.0056	0.27	0.006
Arsenic	0.39	0.005	9.8	0.01
Cadmium	0.36	0.000097	0.36	0.005
Copper	28	0.00285	28	1.3
Iron	5,500	0.3	20,000	---
Lead	11	0.000545	11	0.015
Manganese	180	0.12	460	NA
Nickel	38	0.0161	23	0.1
Selenium	0.5	0.001	0.6	0.05
Silver	4.2	0.000374	1.0	0.1
Thallium	0.08	0.00024	NA	0.002
Zinc	46	0.037	46	2.0

Notes:
Derived from Tables 1-6 and 1-7
*Screening benchmarks are intentionally conservative—not intended for assessment of risk

1.6.2 Data Interpretation Approach

The discussions presented in this document are based primarily on 2010 and 2012 RI sample results. When possible, historic data (maximum, minimum, average, and median) were used to supplement the most recent data. The limited data for this focused RI are considered representative of Site conditions at a particular location and, when combined with other historic data, do provide sufficient evidence to support risk management decisions.

Existing data from other investigations and agencies were collected, formatted, assembled, and rigorously evaluated by the Basin Watershed OU2 RI (CDM, 2002) with respect to their use and comparability. All data deemed acceptable for unrestricted use or screening level were used with data collected from 2010 to 2012.

All 2010–2012 RI sample results were validated and evaluated for usability in the RI (see Section 3.4.1.4). No data were qualified as rejected. All data were considered to be valid and acceptable, including those analytes qualified as estimated. For data interpretation, all detected values were used. For nondetected results, the laboratory reporting values were used. In these cases, the value of the reporting limit was used as the concentration value.

Dissolved metals concentrations detected in aqueous media were compared against ecological screening benchmarks, while total metals concentrations were compared against human health screening benchmarks. For solid media, detected concentrations (total concentrations) were compared against human health and ecological screening benchmarks.

1.6.3 Background Evaluation

A number of background soil and surface water samples were collected during the 2010 Bullion Mine RI. Soil background samples were collected at locations where little or no evidence of mining existed, or from locations where minimal historic mining occurred. Surface water was sampled upstream of the mine influence and groundwater was sampled from springs located outside the mined area. Sample locations, and the samples collected, represent natural background conditions and should be adequate to differentiate from mining influenced conditions. However, natural mineralized zones do exist on and near the Site and throughout the Basin Creek Watershed in general.

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2. Conceptual Site Model Description

Section 2 describes the conceptual site model and its individual parts as a frame of reference for the presentation of site characterization data described in Section 3, *Site Characterization*, and interpreted in Section 4, *Nature and Extent of Contamination*, of this report. The description presented here is general in nature and covers the entire Site. More detailed descriptions of individual parts of the model are described in Section 4, as well as the relative importance of the individual components of the model. Section 3, *Site Characterization*, presents the chemical and physical attributes of the Site by media type as defined by the conceptual model. Section 4, *Nature and Extent of Contamination*, and Section 5, *Contaminant Fate and Transport*, examine relationships between environmental variables within the conceptual model and describe the relative significance of each of the sources and pathways identified. Section 6, *Risk Assessment*, presents the assessment of both human health and ecological risks inherent to the Site.

A conceptual model for the Site was prepared to help with (1) identification of potential sources of metals and arsenic; (2) probable pathways of movement of these contaminants from source material into soils, groundwater, 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, 1989c). The model for the Bullion Mine OU6 Site was developed from existing data (previous sampling and Basin Watershed OU2 RI) and information obtained from RI field activities performed in 2010 and 2012. Prominent Site features are presented in Figure 2-1.

2.1 General Site Setting

In the high elevations associated with the Site, groundwater is present in shallow, unconsolidated glacial till and alluvial deposits as well as the fractured and weathered bedrock. Shallow groundwater flow generally follows surface topography and infiltrates downward through fractures and weathered zones in the altered vein rock. Groundwater is not a potable drinking water source at, or near, the Site. However, domestic wells are in use along Basin Creek and the installation of a well was observed during the summer of 2010 at a residence near the intersection of Jack Creek and the Bullion Mine road (USFS Road 8524) approximately 2 miles from the Site. Snowmelt and runoff water is believed to infiltrate the shallow soils, migrate through fractured bedrock, and intercept the underground mine workings. This water moves laterally and vertically through the workings, discharges from the lower adit at an average rate of approximately 5 gpm, flows down the constructed drainage channel, and discharges into Jill Creek approximately 235 yards downstream from the adit portal. Discharge from the adit is highest in the late summer, responding to snowmelt and runoff and travel time through the rock and mine workings. In addition, numerous springs discharge on the slope above and below the adit portal and contribute to the flow of Jill Creek. Figures 2-2 and 2-3 present an illustration of a conceptual site model.

2.2 Potential Contaminant Sources

2.2.1 Waste Rock and Soils

Accumulations of waste rock, host rock, and mineralized overburden extracted during mining of the Bullion claims were removed and transported to the Luttrell Repository during a removal action performed in 2001–2002 (see Section 3.3). The Site retains minor surface expressions of historic dump locations and tailings impoundments, a significant improvement over its historic condition. However, under the thin veneer of imported cover and top soil, residual mine wastes extend across the Site, and, in exposed or lightly vegetated areas, may represent a source of arsenic and metals. It is important to remember that the geologic zone of interest for mining consisted of vein minerals of crystalline quartz and fine-grained pyrite. Natural lenses of sulfide minerals occur within portions of the vein and contribute to the acid-generating potential of the waste material. 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 appeared in the higher-grade veins.

The depth of cover soil varies across the Site from a few inches on steep hillsides to several feet in former waste rock dump and tailings areas (Maxim, 2003). Soil test pits were used to assess depth of cover and contaminant concentrations across the Site (see Section 3).

2.2.2 Adit Discharge

The portal to the lower workings adit is in the southeast part of the Bullion Expansion Claim, at an elevation of approximately 7300 feet amsl. The lower adit portal is presently collapsed with its only surface expression being dilapidated head set timbers and a small discharge of acidic mine water. While the mine was being worked, waste rock and ore were transported out of the lower workings of the mine through this adit. Over time, through disuse and lack of general maintenance, several sections of the adit collapsed making direct entry into the adit impossible. Groundwater has pooled behind these natural plugs. The pressure from the pooled groundwater has eroded a small outlet through the collapsed debris resulting in a sustained perennial discharge from the mine (Photograph 2-1). During USFS and EPA removal action in 2001–2002, a sump was installed to capture a diffuse discharge source from the adit and direct it into a more controllable point source. Exposure of the mineralized rock within the mine's underground workings to groundwater and bacteria have resulted in a constant discharge of acidic groundwater from the mouth of the adit and ultimately into Jill Creek. This discharge represents the primary and most serious source of arsenic and metals at the Site.

PHOTOGRAPH 2-1. **Acidic Discharge from Collapsed Adit Section**

2.3 Movement and Behavior of Contaminants of Concern

This section presents a brief, introduction of geochemical changes that can occur during the movement of metals from source materials to potential receptors. A more site-specific discussion of fate and transport mechanisms will be presented in Section 5.0.

2.3.1 Geochemical Processes

The basic ingredients involved in the weathering of metal sulfides are oxygen, water, temperature, and time. Geochemical changes that result from the weathering of metals-laden sulfide minerals include the release of free metal ions and acidity, and the precipitation, coprecipitation, and absorptive processes that change free metal ions to less mobile forms. Bacteria are involved in catalyzing the reaction under certain conditions.

Oxidation of metal sulfides produces acidity (hydrogen ions), free metal ions, and sulfate. An important role in metals mobility is commonly attributed to pH because acidic conditions increase the mobility of most metals, whereas alkaline environments inhibit metal mobility. Arsenic, however, is not a metal and may become more mobile in high pH environments.

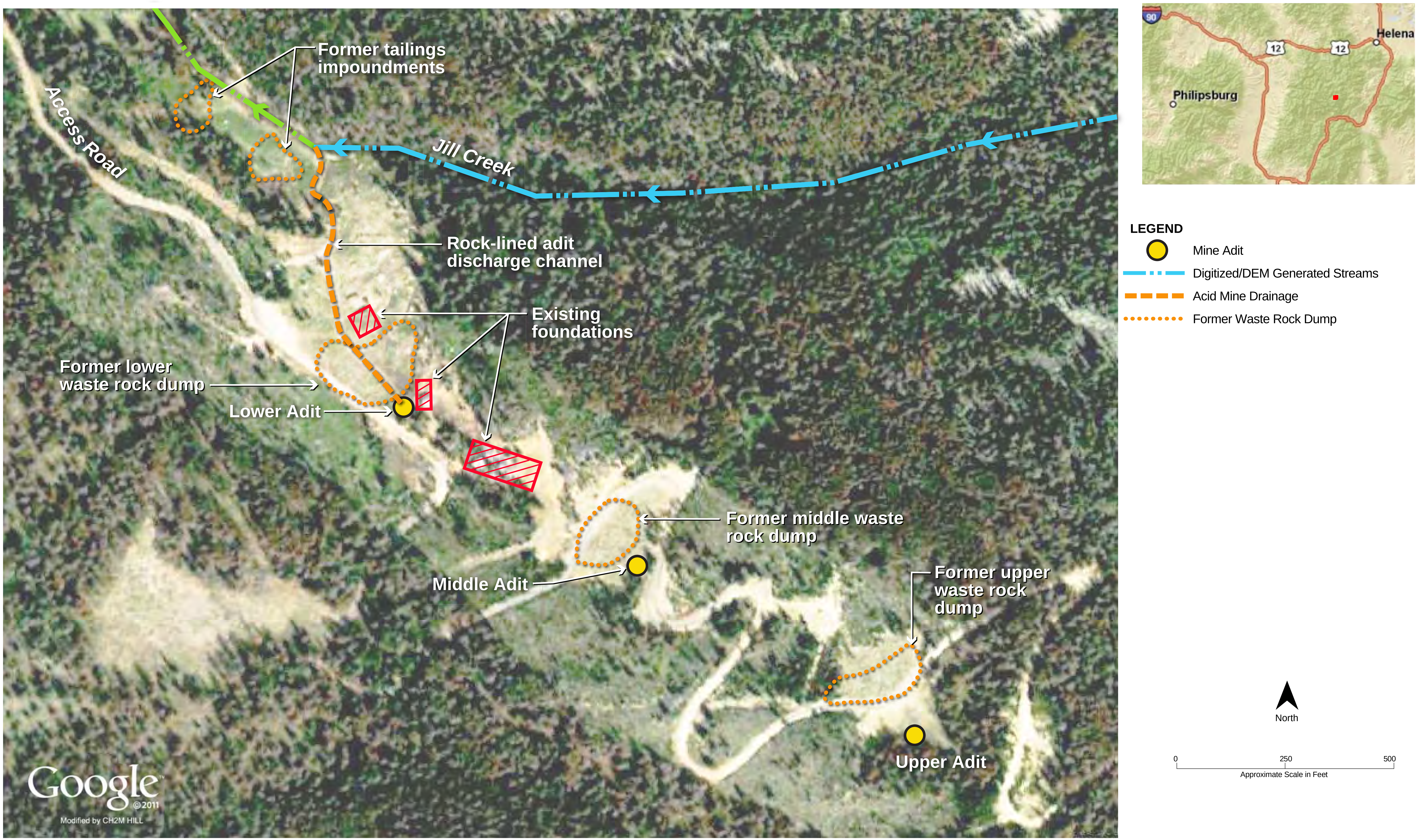

FIGURE 2-1
BULLION MINE PROMINENT SITE FEATURES
Bullion Mine OU6 Remedial Investigation

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FIGURE 2-2
BULLION MINE CONCEPTUAL SITE PLAN
Bullion Mine OU6 Remedial Investigation

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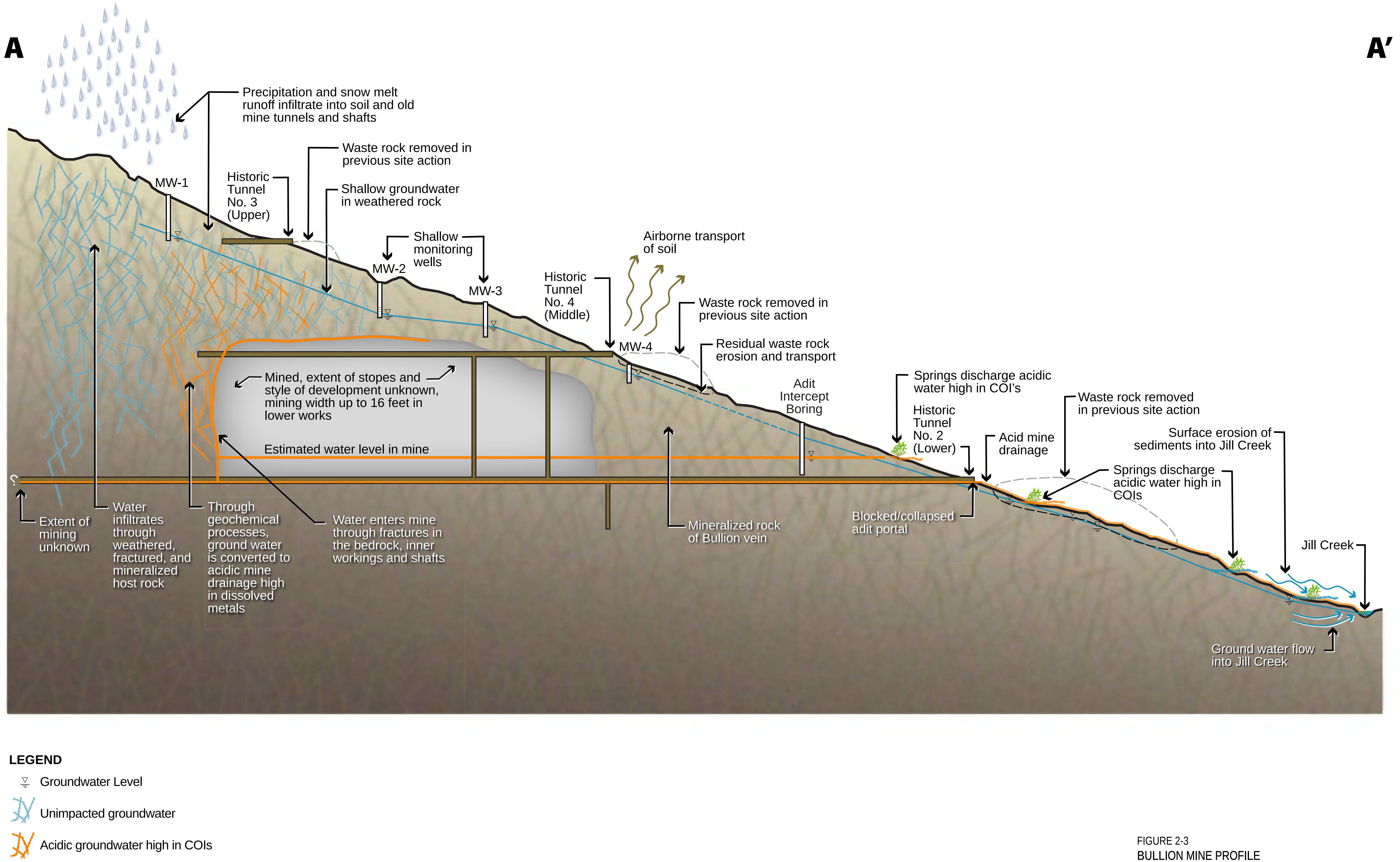

FIGURE 2-3
BULLION MINE PROFILE
Bullion Mine OU6 Remedial Investigation

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Where oxygen is limited, reducing conditions are present in which sulfides are much less likely to weather, such as where soils are constantly saturated. Under reducing conditions, precipitation, coprecipitation, and adsorptive processes contribute to the removal of metal ions from solution. Where organic compounds are present, such as buried soil, oxygen is low and metals tend to bind with organic materials through chemical and physical mechanisms. Buffering of acidic water also tends to reduce the mobility of metals. In soils that contain excess alkalinity, often in the form of calcium carbonate, precipitation and coprecipitation of metals may occur. If waters become excessively alkaline, arsenic may become more mobile at the higher pH levels, as it desorbs from amorphous ferric hydroxides.

As free metal ions move into the groundwater or surface water, geochemical reactions can occur to enhance or inhibit mobility. Reduction/oxidation potential (ORP) and pH strongly influence metal mobility in water. Dissolution/precipitation and adsorption are the primary reactions that occur in groundwater and surface water. Dissolution is the process of metals moving from a solid mineral phase into solution. This occurs when the solution is under-saturated with respect to the mineral, or when oxidation potential and pH change sufficiently to make the mineral phase unstable. In contrast, precipitation is when the metal ion phase is unstable resulting in the formation of oxides and hydroxides. Adsorption is the accumulation of metals in the boundary region of solid-liquid interfaces. Adsorption of metals is influenced by surface area, pH, complexing organics, and the concentration of absorbates.

Because the reactions influencing form and mobility of metals and arsenic in groundwater 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 groundwater and surface water are important to note.

2.3.2 Mobilization Mechanisms and Pathways

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

- Soil and groundwater
- Stream sediment and surface water
- Soil and vegetation
- Surface water and groundwater
- 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 Section 6, Figure 6-1.

PHOTOGRAPH 2-2. **Example of Runoff Induced Erosion Still Occurring on Site**

2.3.3 Erosion and Runoff

Erosion and runoff move source materials directly to surface water (see Photograph 2-2) and were historically important transport mechanisms of COIs at the Site. Overland flow over mine disturbed areas triggered by precipitation or snowmelt runoff may entrain and transport metallic particles. This pathway has been mostly mitigated by waste rock removal, soil capping, and revegetation that occurred as part of a removal action in 2001-2002. Stream bank erosion, especially during high flows, may cause stream bank materials containing arsenic and metals to erode directly into the stream. Animals and humans may also cause source materials to erode directly into the stream at locations where soil stability is compromised as a result of physical disturbance. The degree to which materials may be transported may be 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. Vegetation reduces surface water runoff, consumes water in the root zone, promotes infiltration, and reduces influx to groundwater.

2.3.4 Infiltration and Vadose Zone Transport

Although the soils and associated vadose zone at the Site are not very thick, infiltration is a significant transport mechanism for the residual waste rock material and underlying soils. Infiltration of water from the surface down to the soil-bedrock interface is another method by which COIs may move. This process is most likely to occur during precipitation events and snowmelt. Soluble metals of concern in source material may be leached by infiltrating water and carried into underlying soil and shallow groundwater. Conditions influencing the degree to which metals become mobile by this process include: (1) duration and intensity of rainfall or snowmelt; (2) proximity of waste rock and impacted soils to groundwater or surface water; (3) topography; (4) permeability of soil and waste rock materials; and (5) the geochemistry of the specific waste rock, soil, and pore water system. Adsorption, precipitation, coprecipitation, complexing with organic matter and desorption, solubilization, and remobilization all affect the mobility of metal ions in pore water.

2.3.5 Groundwater Inflow into the Fluvial System

Shallow groundwater contributing to base flow of Jill Creek is another conceptual transport mechanism for potential COIs at the Site. In the mixing zone between groundwater and surface water, precipitation, cementation, or dissolution of metals in streambed sediments may occur. Transport of metals by this mechanism would most likely occur during low stream flow conditions or during the decline of the annual stream flow peak, as water that had previously infiltrated into the banks at high stage (bank storage) drains back to the creek as the stage drops.

PHOTOGRAPH 2-3. **Acid Mine Drainage from Lower Adit Portal**

Groundwater 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. Groundwater seeping down adit (tunnel) walls, ceilings, and floors changes geochemically through exposure to sulfide minerals, oxygen, and bacteria. Changes may include the release of free metal ions and acidity into the groundwater, altering its quality as it moves along the adit to its discharge point at the adit portal (see Photograph 2-3). Retention time within the adit can exacerbate these changes depending upon the availability of oxygen and other Site conditions. Once the groundwater discharges from the portal, exposure to the atmosphere may result in precipitation, coprecipitation, 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 Jill Creek in the case of the Site.

2.3.6 Physical Transport of Sediments

Sediment transport by moving water is another mechanism of contaminant transport. 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. This transport mechanism is covered extensively in the Basin Watershed OU2 RI (CDM, 2005b).

2.3.7 Surface Water Flow to Groundwater

Surface water may transport contaminants into groundwater along stream reaches that lose water into shallow alluvial aquifers. This method of transport would likely occur during periods of spring runoff when the stream stage is high and is referred to as “bank storage.” This is an ephemeral condition with the water and contaminants moving back into the stream as conditions return to base flow or as the stream loses elevation.

2.3.8 Airborne Transport

COIs 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 nonvegetated source material. Entrainment of particles would most likely occur under dry, windy conditions. Entrainment can be increased when source material is physically disturbed (by recreational vehicles) under such conditions. However, because this Site is revegetated and large boulders and woody debris were scattered across the Site during the removal action, it does not accommodate recreational vehicle use. Therefore, airborne transport is minimal.

2.4 Conceptual Model Application

Section 2 described potential components of a conceptual site model for the Bullion Mine. Sections 3 and 4 present Site data and its evaluation relative to human and ecological risk. This information is then evaluated in the framework of the CEM under the screening level risk assessment in Section 6 of this report.

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3. Site Characterization

Section 3 presents the chemical and physical characterization of the Site by media. This section begins with a brief discussion of relevant project and data quality objectives (DQOs). Previous removal activities and interim remedial planning activities are also cited and explained in this section. Field methods and results for the 2010 media field investigation subsections are presented. This section concludes with a discussion of data validation methods and results.

3.1 Investigation Objectives

Although a significant amount of site characterization data has been generated and removal actions have occurred, the Bullion Mine remains a major contributor to local downstream surface water and sediment contamination and impact to aquatic receptors. Of major concern is the poor water quality of the discharging mine adit and springs. This focused RI is intended to accomplish the following objectives:

- Assess the competence of underground mine workings and the condition of host rock by drilling into the workings at strategic locations.
- Detect and observe the occurrence and volume of water within, and discharge from, the adit. Obtain water samples.
- Evaluate shallow hydrogeologic conditions and obtain groundwater samples.
- Identify and inventory springs in the immediate vicinity of the mine. Evaluate those potentially impacted by mine water by collecting and analyzing water samples to quantify concentrations of COIs.
- Assess and quantify potential mine-related impacts to Jill Creek (water and sediment sampling to assess the most current risk to aquatic and benthic receptors quality).
- Define the vertical thickness of cover soil and the appearance of subsurface residual mine waste and mixed soil contamination throughout the Site. Sample surface soils to evaluate the bioavailability of arsenic and lead at the Site (most likely human health risk factors).
- Inventory and delineate wetlands.
- Assess the status of revegetation establishment that has occurred since the 2001-2002 time critical removal action by the USFS and EPA.
- Identify endangered and threatened species.
- Perform a survey of the benthic community in Jill Creek.

Information gathered during the 2010–2012 field seasons supplement historic information and contribute to a screening-level risk assessment. It also facilitates consideration of remedial alternatives for the feasibility study, and allows development of preliminary remedial action objectives and goals for remediation of the Site. This focused RI fills data gaps in the site characterization and conceptual site model (CSM), facilitates assessment of site-specific risks (human health and ecological), and will ultimately help guide a timely cleanup of this Site.

3.2 Data Quality Objectives

3.2.1 Data Quality Objective Process

DQOs were presented, explained, and approved by EPA in the Sampling and Analysis Plan (SAP) for field investigations for the Site (CH2M HILL, 2010). DQOs were developed in accordance with EPA's seven step process (EPA, 2006). The following is the problem statement from the DQOs that guided the data collection and characterization of the Bullion Mine site, "Characterization of mining-related wastes is required to complete a focused RI for the Bullion Mine operable unit. The nature and extent of contamination requires further definition to determine if mine wastes and impacted waters pose unacceptable risk to human health and the environment, and to obtain the information necessary to complete the FS." Additional information on DQO's is provided in the SAP (CH2M HILL, 2010).

3.2.2 Investigation Boundaries

The physical boundaries for the Site include the mine workings (see mine claim boundaries shown in Figure 1-6), the surrounding disturbed landscape in the vicinity of the mine, seeps/springs emanating from above and below the mine workings, and Jill Creek upstream and downstream of the Site. The temporal boundaries are field seasons in which potential human and ecological receptors are exposed to Site contaminants. The findings from these studies and investigations are summarized in Appendix A with specific reports referenced in Section 8.

3.3 Previous Site Removal Actions

In 2001–2002, a time critical removal action at the Bullion Mine was completed through a joint USFS and EPA initiative. The goal of the agencies was to reduce risks to human and environmental health from metal contamination associated with soil erosion and sedimentation (Maxim, 2003). The removal action (removal of 27,000 cubic yards of waste rock and tailings, soil capping/revegetation of disturbed areas, consolidation of adit discharge into a channel to Jill Creek, and reconstruction of the Jill Creek channel) provides a new baseline condition for the Site with respect to wind and runoff generated erosion and direct exposure from contaminated waste rock and soils. The findings from this investigation and removal action are summarized in Appendix A with specific reports referenced in Section 8.

3.4 2010–2012 Field Investigation Activities

Field investigation focused on the acquisition of data to characterize and define human and ecological risk associated with arsenic and metals concentrations in soils, surface water and groundwater, and to obtain the information necessary to complete the Feasibility Study.

3.4.1 2010 Field Activities

Primary field data collection activities consisted of the following:

- Conducted a drilling program to locate and characterize the lower adit, including installed four shallow monitoring wells. This effort also included the installation of six piezometers in the northwestern portion of the Site.
- Performed a geophysical survey along a series of transects across the Site to map the bedrock surface.
- Implemented excavation and sampling of soil test pits and determining COI concentrations using field (XRF) instrumentation and conventional laboratory analyses to characterize surface and subsurface soils.
- Gauged and sampled synoptic flow for Jill Creek, and collected and submitted water samples to an analytical laboratory for determination of COI levels and other parameters.
- Performed a survey and inventory of seeps and springs to sample in the vicinity of the Bullion Mine (including upgradient and downgradient). Recorded flow and collected samples in the summer and again in the fall. Water samples were submitted to an analytical laboratory for determination of COI levels and other parameters. Sampled and monitored the lower adit discharge.
- Implemented an onsite wetland survey to delineate existing wetlands within the mining claim boundaries or adjacent to the Site.
- Performed a threatened and endangered species literature search for the area using current Montana Fish Wildlife & Parks and USFS (Beaverhead and Deerlodge National Forests) information and data.
- Performed a benthic macro-invertebrate survey of Jill Creek to assess direct impacts of contaminants on aquatic biota.

3.4.2 2011 Field Activities

Primary field data collection activities consisted of the following:

- Static water levels were monitored in the four wells and six piezometers that were installed in 2010.

3.4.3 2012 Field Activities

Primary field data collection activities consisted of the following:

- Static water levels were monitored in the four wells and six piezometers.
- Stream sediments were sampled at six locations including upstream and downstream of the Bullion Mine and extended to the confluence of Jill Creek and Jack Creek.
- Surface soil samples were collected at eight locations and analyzed for bioavailability of arsenic and lead.

Several ancillary field activities spanning all three field seasons (flume installation on the discharging adit; continuous flow monitoring, and adit discharge sampling, including age and source determination) were also performed by MBMG personnel under a MDEQ agreement.

3.5 Surface Water Investigations

Water quality samples were collected from stations on Jill Creek and at numerous spring locations identified during the field inventory. Surface water sampling locations at the Site are presented in Figure 3-1.

3.5.1 Synoptic Sampling of Jill Creek

The purpose of a synoptic sampling of Jill Creek was to identify and document, if possible, seasonal changes in flow and water quality in the target reach of Jill Creek. Synoptic sampling was performed twice during the 2010 field season, in the early summer and in the fall during the low flow time of the year. Sampling was performed at four locations (above the mine, JC-1; just above the confluence of the adit drainage channel, JC-2; below the confluence of the adit drainage channel, JC-3; and below the furthest downstream spring discharge approximately 1,000 feet below the disturbed mine, JC-4). Discharge from the lower Bullion adit, above its confluence with Jill Creek, was also sampled as part of this investigation.

Sampling locations were field staked and surveyed to identify sampling stations (Table 3-1 and Figure 3-1). Stream discharge was measured using a Marsh-McBirney meter. Water samples were analyzed for major ions and total and dissolved COIs. Field parameters were also measured (pH, dissolve oxygen, specific conductivity, temperature, and turbidity) at each designated station (see Table 3-2). Field methods describing the collection of hydrologic data and water quality sampling are presented as standard operating procedures in the sampling and analysis plan (SAP) (CH2M HILL, 2010).

TABLE 3-1
GPS Location of Adit Discharge and Jill Creek Sampling Locations

Station Name	Latitude (°N)	Longitude (°W)
Bullion Lower Adit	46.357258102	-112.295927293
JC-1	46.357289555	-112.295131811
JC-2	46.357259963	-112.295885356
JC-3	46.357343519	-112.296091796
JC-4	46.360224586	-112.297931019

TABLE 3-2
Summary of Surface Water Field Parameters

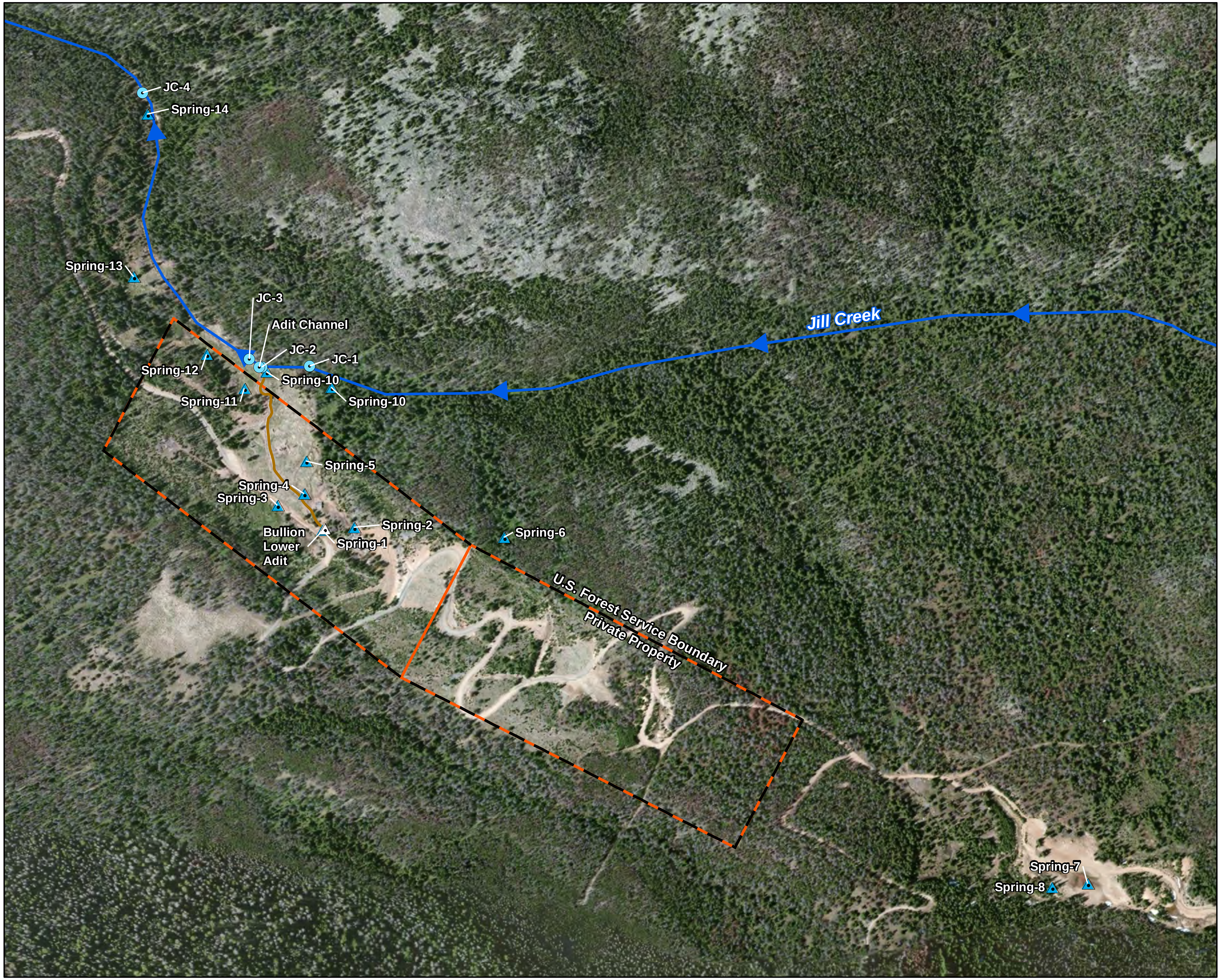
Site	Date	Flow (gpm)	pH	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Temperature (°C)	ORP (mV)	Turbidity (NTU)
Bullion Lower ADIT	7/27/2010	6.4	2.5	3.25	10.5	5.7	392	7.0
	9/21/2010	3.2	2.88	0.19	3.55	6.2	410	7.4
JC-1	7/27/2010	449.3	5.62	0.07	8.6	14.4	277	18
	9/21/2010	142	6.06	7.4	11.55	4.5	173	0.0
JC-2	7/27/2010	460.5	6.39	0.076	9.13	13.4	170	0.0
	9/21/2010	107.1	6.25	7.8	11.84	4.7	168	0.0
JC-3	7/27/2010	461.4	4.38	0.155	5.77	21.4	321	32
	9/21/2010	120.1	5.13	17	11.93	5.4	258	15.2
JC-4	7/27/2010	412.6	4.6	0.164	6.07	25.3	258	14
	9/21/2010	142.5	5.68	17.8	11.76	6.2	168	13.6

Notes:
---- Data not available
µS/cm = microSiemens per centimeter
gpm = gallons per minute
mV = millivolts
NTU = nephelometric turbidity units
ORP = oxidation reduction potential

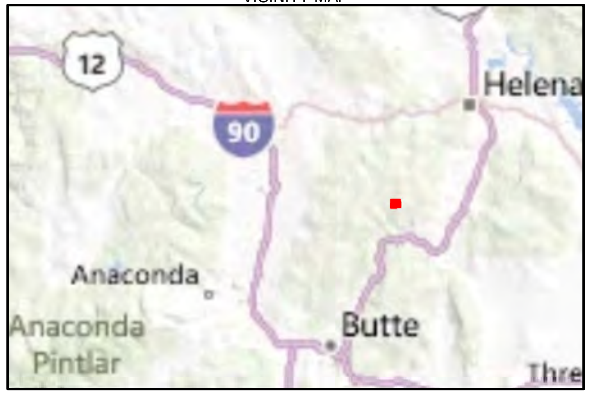
It is recognized that diel fluctuations in dissolved metal concentrations have been observed in mountain watersheds (both large and small) under varying flow conditions (Nimick et al., 2003). The pattern of diel fluctuation for divalent metals (such as cadmium, copper, and zinc) is generally that concentrations are highest in the early morning and decrease throughout the day to a minimum concentration in the late afternoon/early evening. Concentrations increase over the night to the maximum again in early morning. Diel fluctuations in arsenic levels follow an inverse temporal pattern. Geochemical mechanisms such as sorption, driven by pH and temperature changes, have been suggested as the main processes involved in these fluctuations (Nimick et al., 2003). Because of the limited stream reach being sampled and the ability to collect samples at all stations within a short period of time, the RI data do not account for diel fluctuations.

Jill Creek water quality sampling stations were located upstream and downstream of the confluence with the lower adit discharge. In 2010 synoptic flow measurements indicated a static condition from Station JC-1 through JC-4. This is somewhat contrary to conditions the USGS observed in 1998 (USGS, 2004) in which the creek was found to be slightly gaining through this reach. Water quality above the confluence with the mine adit discharge is superior to that recorded at downstream stations. The degree of change in water quality varies by element, ranging from one to several orders of magnitude difference downstream of the confluence of the lower adit discharge with Jill Creek. This pattern of degradation is consistent with sampling performed in 1998 (USGS, 2004) which demonstrated an adverse impact downstream of Jill Creek's confluence with Jack Creek.

COI concentrations at surface water Stations JC-1 and JC-2, above the confluence with the mine discharge, remained relatively stable for both the July and September sampling episodes. At stations JC-3 and 4, analyses for total aluminum, arsenic, cadmium, copper, iron, lead, and zinc concentrations were lower in the September sampling. This was true for dissolved values of aluminum, arsenic, cadmium, copper, iron, lead, and zinc concentrations at station JC-4 as well. The pattern of degradation imposed by the lower adit discharge on Jill Creek water quality remained consistent throughout the year (see Table 3-3a and 3-3b). Results of selected COIs from the 2010 field and analytical samples are plotted on Figure 3-2 (field parameters), Figure 3-3 (total analysis), and Figure 3-4 (dissolved).



VICINITY MAP



LEGEND

- Bullion Lower Adit
- Stream Sample Location
- Spring Sample Location
- Adit Discharge Channel
- U.S. Forest Service Boundary
- Mine Claim Boundary

Notes:
1. Area of interest subject to change.
2. 2011 Imagery - ArcGIS Streaming Map Service.

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FIGURE 3-1
SURFACE WATER SAMPLING LOCATIONS
Bullion Mine OU6 Remedial Investigation

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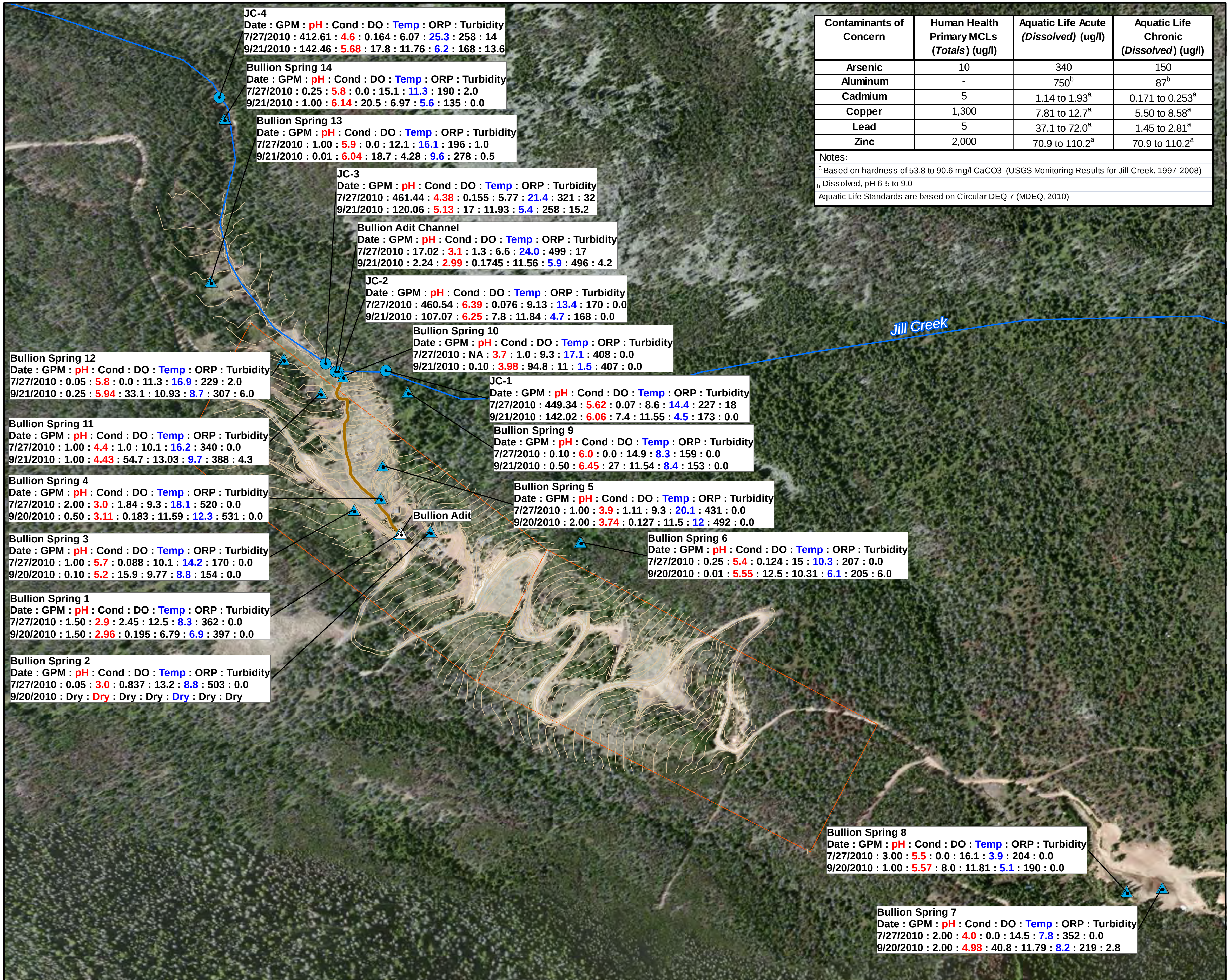

Contaminants of Concern	Human Health Primary MCLs (*Totals*) (ug/l)	Aquatic Life Acute (*Dissolved*) (ug/l)	Aquatic Life Chronic (*Dissolved*) (ug/l)
Arsenic	10	340	150
Aluminum	-	750[b]	87[b]
Cadmium	5	1.14 to 1.93[a]	0.171 to 0.253[a]
Copper	1,300	7.81 to 12.7[a]	5.50 to 8.58[a]
Lead	5	37.1 to 72.0[a]	1.45 to 2.81[a]
Zinc	2,000	70.9 to 110.2[a]	70.9 to 110.2[a]

Notes:
[a] Based on hardness of 53.8 to 90.6 mg/l CaCO3 (USGS Monitoring Results for Jill Creek, 1997-2008)
[b] Dissolved, pH 6-5 to 9.0
Aquatic Life Standards are based on Circular DEQ-7 (MDEQ, 2010)

VICINITY MAP

LEGEND

- Bullion Lower Adit
- Spring Sample Location
- Stream Sample Location
- AditChannel
- Topographic Survey
- Mine Claim Boundary

Notes:
1. Analytical values are ug/L
2. July Dissolved Oxygen (DO) values are unreliable
3. 2011 Imagery - ArcGIS Streaming Map Service

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FIGURE 3-2
Bullion Mine Spring/Stream Sampling Field Parameters
Bullion Mine OU6 Remedial Investigation

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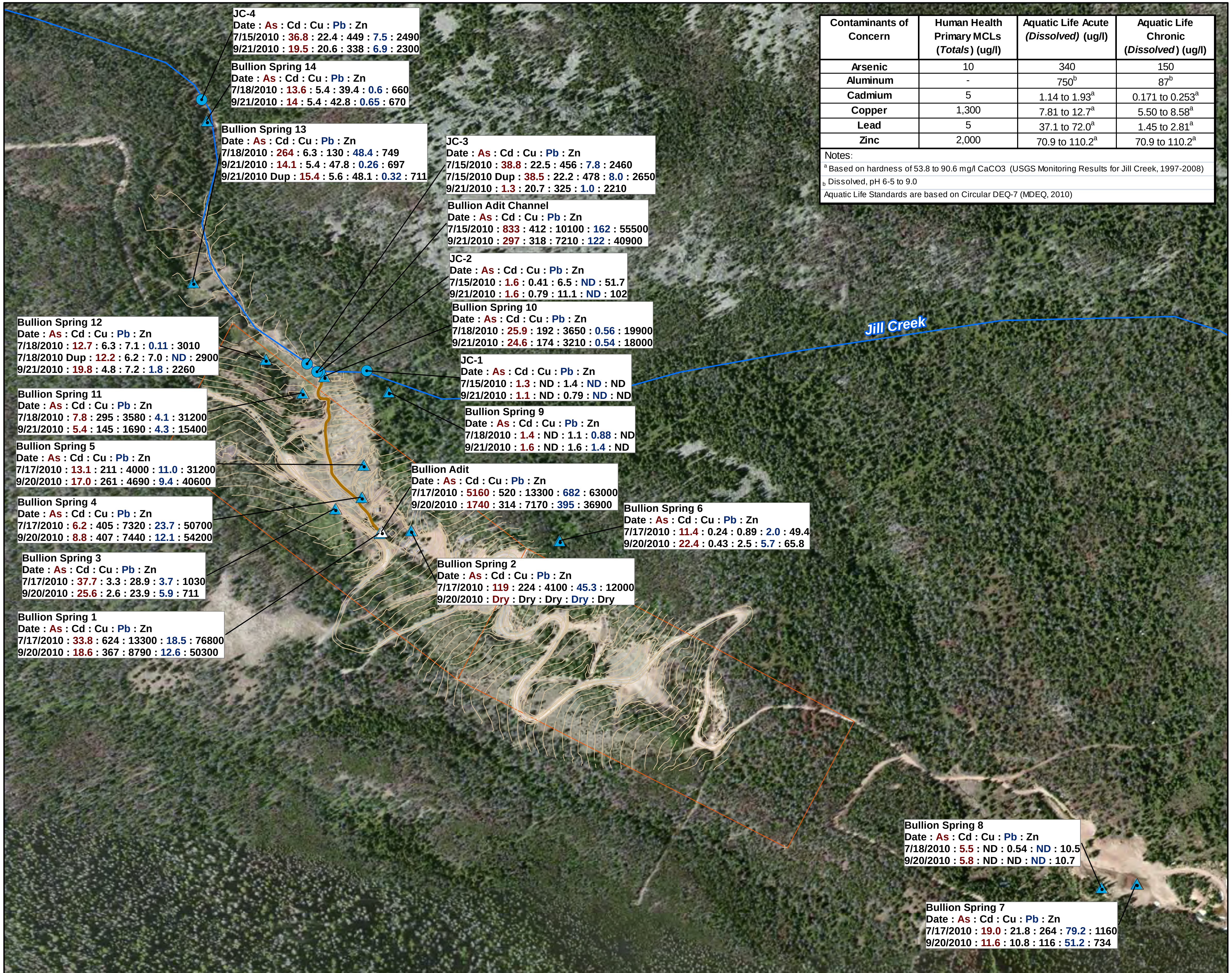

Contaminants of Concern	Human Health Primary MCLs (*Totals*) (ug/l)	Aquatic Life Acute (*Dissolved*) (ug/l)	Aquatic Life Chronic (*Dissolved*) (ug/l)
Arsenic	10	340	150
Aluminum	-	750[b]	87[b]
Cadmium	5	1.14 to 1.93[a]	0.171 to 0.253[a]
Copper	1,300	7.81 to 12.7[a]	5.50 to 8.58[a]
Lead	5	37.1 to 72.0[a]	1.45 to 2.81[a]
Zinc	2,000	70.9 to 110.2[a]	70.9 to 110.2[a]

Notes:
[a] Based on hardness of 53.8 to 90.6 mg/l CaCO3 (USGS Monitoring Results for Jill Creek, 1997-2008)
[b] Dissolved, pH 6-5 to 9.0
Aquatic Life Standards are based on Circular DEQ-7 (MDEQ, 2010)

VICINITY MAP

LEGEND
- Bullion Lower Adit
- Spring Sample Location
- Stream Sample Location
- Adit Discharge Channel
- Topographic Survey
- Mine Claim Boundary

Notes:
1. Analytical values are ug/L
2. 2011 Imagery - ArcGIS Streaming Map Service

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Feet

FIGURE 3-3
Bullion Mine Spring\Stream Sampling Water Quality Total Metals
Bullion Mine OU6 Remedial Investigation

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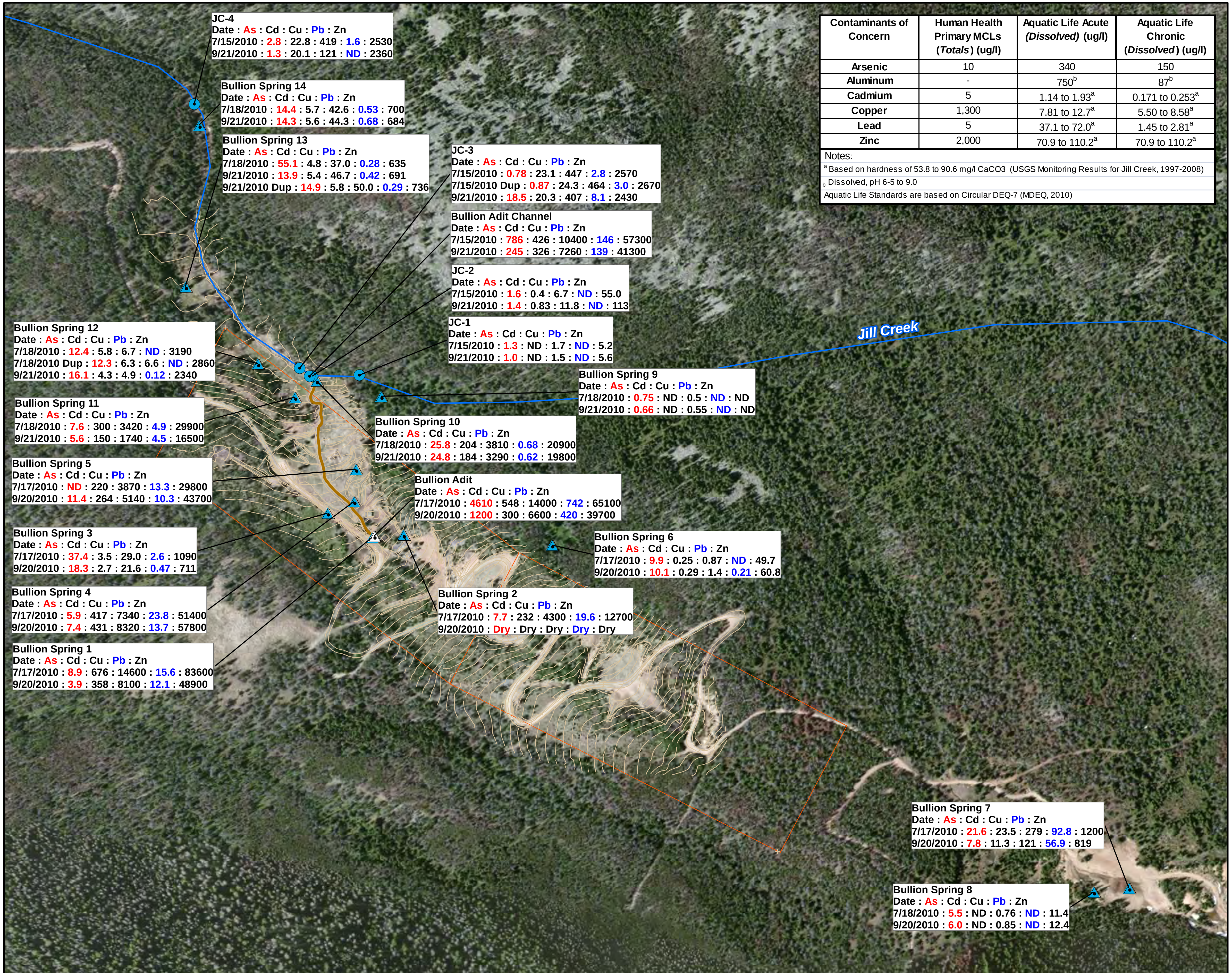

Contaminants of Concern	Human Health Primary MCLs (*Totals*) (ug/l)	Aquatic Life Acute (*Dissolved*) (ug/l)	Aquatic Life Chronic (*Dissolved*) (ug/l)
Arsenic	10	340	150
Aluminum	-	750[b]	87[b]
Cadmium	5	1.14 to 1.93[a]	0.171 to 0.253[a]
Copper	1,300	7.81 to 12.7[a]	5.50 to 8.58[a]
Lead	5	37.1 to 72.0[a]	1.45 to 2.81[a]
Zinc	2,000	70.9 to 110.2[a]	70.9 to 110.2[a]

Notes:
[a] Based on hardness of 53.8 to 90.6 mg/l CaCO3 (USGS Monitoring Results for Jill Creek, 1997-2008)
[b] Dissolved, pH 6-5 to 9.0
Aquatic Life Standards are based on Circular DEQ-7 (MDEQ, 2010)

VICINITY MAP

LEGEND
- Bullion Lower Adit
- Spring Sample Location
- Stream Sample Location
- Adit Discharge Channel
- Topographic Survey
- Mine Claim Boundary

Notes:
1. Analytical values are ug/L
2. July Dissolved Oxygen (DO) values are unreliable
3. 2011 Imagery - ArcGIS Streaming Map Service

N

0 100 200 400
Feet

FIGURE 3-4
Bullion Mine Spring\Stream Sampling Water Quality Dissolved Metals
Bullion Mine OU6 Remedial Investigation

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The lower adit at the Bullion Mine has a perennial discharge. The discharge varies seasonally, with the highest flows occurring in the May to June time frame—coinciding with snowmelt and periods of highest rainfall. The lowest flow typically occurs in December. The seasonal pattern of the adit drainage was initially documented in 1993 and has been observed annually by USGS quarterly monitoring through 2011. Based on their data, discharge during this period ranged from a maximum of approximately 14 gpm to a low of less than 1 gpm with a mean of about 5 gpm—again showing a seasonal flow regime. A similar pattern was observed by MBMG field staff recording daily flume measurements from June 2010 to November 2012. The seasonal flow regime is driven by surface water infiltrating and migrating downward through the soil and bedrock fractures, and intercepting the lower mine workings. This seasonal recharge activity appears to drive seasonal variations in contaminant concentrations in acid mine drainage as the groundwater moves across the exposed rock surfaces, collects along the floor of the adit, and flows to the partially plugged portal opening where it eventually discharges to Jill Creek. A difference in water quality was observed between the July and September sampling. July concentrations for COIs were elevated compared to the September sampling episode, reflecting a seasonal difference.

Contaminant loading into Jill Creek from adit discharge was calculated for several representative COIs based on observed discharge in the adit channel, which was higher in July (17 gpm) than in September (2.2 gpm). The loading for July and September sampling, respectively (pounds per day) was as follows: arsenic (0.17, 0.01); cadmium (0.08, 0.01); copper (2.06, 0.19); lead (0.03, 0.003); and zinc (11.3, 1.1).

3.5.2 2010 Spring Inventory and Sampling Results

The purpose of the spring/seep inventory in the vicinity of the Site was to document spring/seep locations, flow rates, water quality, and to document any seasonal changes in flow and chemistry. This information represents a baseline condition for the benefit of planning any future remedial actions and may provide important insight about the linkage between groundwater inflow at the Bullion Mine and discharge at the springs.

A baseline spring inventory was performed in the vicinity of the Bullion Mine in mid July 2010. Existing geologic and hydrogeologic information gathered by the USGS in the area was reviewed prior to the start of field work. Field personnel performed the inventory in early summer to take advantage of snowmelt runoff that might contribute recharge to both ephemeral and perennial springs. The field crew searched for springs within a 0.25-mile radius of the mine, recorded GPS coordinates of each spring/seep (see Table 3-4), photographed the springs, measured the discharge of each spring/seep, and sampled the spring/seep for total and dissolved COIs and field parameters (pH, temperature, specific conductivity, dissolved oxygen, oxidation reduction potential, and turbidity). Fourteen springs were located and sampled in early summer (see Table 3-4 and Figures 3-1, 3-3, and 3-4). Seven of the springs are within the mine boundaries. Seven of the springs (Springs 6 to 10, 13, and 14) are located outside of the mine boundaries, along Jill Creek. Three of the springs are located upgradient of the Bullion Mine. The remaining 11 are downgradient.

A second field sampling event was performed in the early fall (September) to document changes in spring discharge and collect additional water quality samples. Thirteen of the springs remained flowing during the fall sampling period. The flow rate of each spring was either measured in the field or estimated, if it was not possible to obtain a direct value for flow rate. Samples were collected using a peristaltic pump.

The total cumulative spring discharge was estimated to be 13.2 gpm in the early summer, and approximately 10 gpm in the early fall (25 percent reduction). The diffuse nature of a spring's discharge makes flow estimates very rough at best. However, a seasonal reduction in flow was apparent. Six of the springs exhibited flow decreases from July to September, five of the springs increased in flow, and three of the springs remained the same. In general, the springs in the vicinity of the adit decreased in discharge over the summer. Springs lower down on the slope in the vicinity of Jill Creek increased in discharge over the summer.

As previously discussed, the discharge from the adit itself fluctuates annually between spring runoff and early winter freeze-up (on the basis of MBMG weir data). When directly measured by field staff in 2010, discharge in the channel below the adit decreased steadily from a high of 17 gpm in July to 2.24 gpm in September. Later in the year, the overall decrease in spring flow and flow in the channel is consistent with less precipitation/runoff and the overall depletion of source water as soils within the Site drain.

PHOTOGRAPH 3-1. **Spring 7 – Historic Mining Disturbance**

Note the lack of vegetation and the mineralized spring area.

Water field parameters measured from the Bullion Mine springs, and the adit discharge are summarized in Table 3-5. Water quality analytical results are presented in Table 3-3.

Springs 6, 9, and 8 (located north, northwest, and east of the Site, respectively) represent background conditions. Springs 1 through 5 and 10 through 14 are topographically downgradient of the lower adit portal area or are within the disturbed mine land footprint and show more of a mineralized signature. COI concentrations are elevated with depressed pH. Spring 7 (located east and topographically upgradient of the Site) represents another mineralized area which has been recently remediated. This mineralized spring is the only surface expression of any historic mining activity (see Photograph 3-1). In general, COI concentrations were higher in the July sampling episode than during the September sampling. Mine-related impact on the quality of these springs is discussed in more detail in Section 3.4.4.

3.5.3 Comparison with Water Quality Standards

The SDWA directs EPA to develop standards for potable water. Some of these standards are mandatory (primary) and some are desired (secondary). The standards established under the SDWA are often referred to as primary and secondary MCLs. Similarly, the CWA directs EPA to develop acute and chronic water quality standards intended to protect aquatic organisms. Numerical values for some elements may vary with water hardness and are often referred to as Aquatic Life Standards. Montana Surface Water Quality Standards are equal to, or more restrictive than, federal standards. The primary MCLs and acute and chronic Aquatic Life Standards for the COIs, as listed in State of Montana Circular DEQ-7 (MDEQ, 2012), are presented in Table 3-6.

The best baseline representation for surface water quality was obtained from Spring 9, located northwest of the majority of the Site. Water quality showed no indication of enrichment by arsenic or other COIs. In general, COI concentrations in surface water were highest, and the pH lowest, in the Bullion Mine adit discharge, the adit channel, followed by surface water Station JC-3 located immediately downstream from the confluence of the adit discharge and the creek.

Table 3-7 illustrates where sample results indicate that MCLs and aquatic life standards are exceeded by a representative suite of COIs.

For the purpose of this report, the aquatic life standards are being used as a target for relative comparison. As described in the SAP and quality assurance project plan for this project, sampling consisted of grab samples, not the compositing of samples over a designated time period as is required under Circular DEQ-7 for a true comparison with acute and chronic aquatic life standards.

TABLE 3-3A
Summary of 2010 Surface Water Analytical Results—*Total Metals Analyses*

Site	Date Sample Collected	Total Metals (µg/L)																	Anions (mg/L)		Cations (mg/L)	
		Al	Sb	As	Cd	Ca	Cu	Fe	Pb	Mg	Mn	Ni	K	Se	Ag	Na	Tl	Zn	Cl^- [E]	SO_4^{2-} [E]	Total	$CaCO_3$
ADIT																						
Bullion adit channel	7/15/2010	**19,900**	4.6	**833**	**412**	75,600	**10,100**	**136,000**	**162**	28,200	**26,200**	**106**	2,100	**3.6**	0.50U	4,200	0.10U	**55,500**	7.2	1,030	5.0U	5.0U
Bullion adit channel	9/21/2010	**15,800**	3.2	**297**	**318**	81,100	**7,210**	**110,000**	**122**	29,600	**23,000**	**92.4**	2,350	**3.9**	---	5,410 [C,E]	0.20	**40,900**	1.0U	956	5.0U	5.0U
Bullion Mine adit	7/17/2010	**19,500**	**21.8**	**5,160**	**520**	74,400	13,300	**243,000**	**682**	30,800	**29,900**	**114**	3,030	**3.4**	**0.97**	5,030	**0.42**	**63,000**	1.0U	1,390	5.0U	5.0U
Bullion Mine adit	9/20/2010	**13,300**	**17.8**	**1,740**	**314**	73,800	7,170	**169,000**	**395**	28,900	**21,200**	**80.1**	2,880	**3.1**	---	5,010 [C,E]	0.19	**36,900**	1.0	1,120	5.0U	5.0U
SPRINGS																						
Spring 1	7/17/2010	**31,100**	1.3	**33.8**	**624**	102,000	**13,300**	**248,000**	**18.5**	38,900	**34,900**	**149**	3,350	**5.2**	0.50U	4,080	0.10U	**76,800**	2.6	1,640	5.0U	5.0U
Spring 1	9/20/2010	**18,200**	0.92	**18.6**	**367**	82,600	**8,790**	**167,000**	**12.6**	32,100	**26,100**	**114**	3,290	**4.4**	---	5,330 [C,E]	**0.44**	**50,300**	ND	1,240	5.0U	5.0U
Spring 2	7/17/2010	**12,900**	1.6	**119**	**224**	33,900	**4,100**	**5,470**	**45.3**	9,510	---	**49.2**	976	**3.4**	**1.9**	3,640	0.10U	**12,000**	1.5	314	5.0U	5.0U
Spring 2	9/20/2010	*Spring was dry*																				
Spring 3	7/17/2010	**99.2**	1.8	**37.7**	**3.3**	8,880	**28.9**	61.8	**3.7**	1,940	43.8	3.2	977	0.50U	0.50U	2,120	0.10U	**1,030**	1.0U	16.0	19.1	19.1
Spring 3	9/20/2010	**196**	1.9	**25.6**	**2.6**	10,800	**23.9**	253	**5.9**	2,460	92.4	2.6	1,290	0.50U	---	2,300 [C,E]	0.10U	**711**	1.0U	15.7	31.0	31.0
Spring 4	7/17/2010	**31,400**	0.5U	**6.2**	**405**	133,000	**7,320**	**16,600**	**23.7**	42,900	**31,200**	**155**	1,860	**5.7**	0.50U	7,160	0.10U	**50,700**	1.0U	1,010	5.0U	5.0U
Spring 4	9/20/2010	**35,600**	0.62	**8.8**	**407**	110,000	**7,440**	**14,900**	**12.1**	39,300	**34,200**	**135**	1,580	**8.4**	---	6,750 [C,E]	0.22	**54,200**	1.2	1,090	5.0U	5.0U
Spring 5	7/17/2010	**15,100**	0.5U	**13.1**	**211**	112,000	**4,000**	**998**	**11.0**	30,500	**20,300**	**107**	2,600	**3.8**	0.50U	5,370	0.10U	**31,200**	1.0U	686	5.0U	5.0U
Spring 5	9/20/2010	**19,400**	0.84	**17.0**	**261**	114,000	**4,690**	**1,980**	**9.4**	34,600	**28,800**	**131**	3,450	**6.6**	---	5,640 [C,E]	**0.29**	**40,600**	2.6	836	<5.0	<5.0
Spring 6	7/17/2010	53.9	0.61	**11.4**	**0.24**	8,610	0.89	57.7	2.0	2,570	4.8	0.55	1,580	0.50U	0.50U	3,720	0.10U	**49.4**	1.0U	28.0	12.5	12.5
Spring 6	9/20/2010	**239**	0.80	**22.4**	**0.43**	8,890	2.5	**391**	**5.7**	2,730	**2,730**	0.86	1,910	0.50U	---	4,490 [C,E]	0.10U	**65.8**	1.0U	31.9	14.2	14.2
Spring 7	7/17/2010	**3,030**	0.5U	**19.0**	**21.8**	7,060	**264**	**3,680**	**79.2**	1,950	**1,330**	8.2	1,320	0.50U	0.50U	1,860	0.10U	**1,160**	1.0U	62.3	5.0U	5.0U
Spring 7	9/20/2010	**2,000**	0.5U	**11.6**	**10.8**	8,390	**116**	**2,180**	**51.2**	2,340	**1,190**	8.6	1,680	0.62	---	2,320 [C,E]	0.10U	**734**	1.0U	57.6	5.0U	5.0U
Spring 8	7/18/2010	9.8	0.5U	**5.5**	0.08U	5,060	0.54	50.0U	0.1U	1,020	1.9	0.50U	826	0.50U	0.50U	1,810	0.10U	10.5	1.0U	5.0U	18.5	18.5
Spring 8	9/20/2010	5.6	0.5U	**5.8**	0.08U	5,470	0.50U	50.0U	0.10U	1,130	1.1	0.50U	881	0.50U	---	2,020 [C,E]	0.10U	10.7	1.0U	5.0U	23.1	23.1
Spring 9	7/18/2010	**124**	0.5U	1.4	0.08U	26,700	1.1	160	**0.88**	5,610	17.4	0.50U	1,490	0.50U	0.50U	2,810	0.10U	5.0U	1.0U	40.4	56.6	56.6
Spring 9	9/21/2010	**160**	0.5U	1.6	0.08U	29,200	1.6	217	**1.4**	5,930	29.6	0.50U	1,630	0.50U	---	2,990 [C,E]	0.10U	5.0U	1.0U	43.9	60.3	60.3
Spring 10	7/18/2010	**8,360**	1.2	**25.9**	**192**	78,600	**3,650**	211	**0.56**	20,900	**9,460**	**61.2**	2,790	**3.5**	0.50U	10,100	0.10U	**19,900**	1.5	437	5.0U	5.0U
Spring 10	9/21/2010	**8,030**	1.1	**24.6**	**174**	80,000	**3,210**	200	0.54	19,200	**8,790**	**55.6**	2,360	**3.9**	---	9,270 [C,E]	0.10U	**18,000**	1.6	487	5.0U	5.0U
Spring 11	7/18/2010	**1,870**	0.5U	**7.8**	**295**	71,800	**3,580**	50.0U	**4.1**	21,600	**10,300**	**68.3**	2,520	**1.2**	0.50U	5,640	0.10U	**31,200**	1.3	357	5.0U	5.0U
Spring 11	9/21/2010	**1,350**	0.5U	**5.4**	**145**	39,600	**1,690**	50.0U	**4.3**	10,900	**5,220**	**33.4**	1,570	0.56	---	3,980 [C,E]	0.10U	**15,400**	1.2	242	5.0U	5.0U
Spring 12	7/18/2010	11.4	3.2	**12.7**	**6.3**	31,200	**7.1**	50.0U	0.11	6,050	1.2	10.2	1,760	0.50U	0.50U	2,710	0.10U	**3,010**	1.0U	85.0	20.2	20.2
Spring 12 Dup	7/18/2010	8.7	3.0	**12.2**	**6.2**	30,100	**7.0**	50.0U	0.10U	6,160	1.3	10.4	1,780	0.50U	0.50U	2,850	0.10U	**2,900**	1.0U	84.4	20.3	20.3
Spring 12	9/21/2010	**141**	2.5	**19.8**	**4.8**	35,000	**7.2**	142	**1.8**	6,500	10.4	7.7	1,670	0.50U	---	2,760 [C,E]	0.10U	**2,260**	1.0U	96.0	33.0	33.0

TABLE 3-3A

Summary of 2010 Surface Water Analytical Results—*Total Metals Analyses*

Site	Date Sample Collected	Total Metals (µg/L)																	Anions (mg/L)		Cations (mg/L)	
		Al	**Sb**	**As**	**Cd**	**Ca**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**K**	**Se**	**Ag**	**Na**	**Tl**	**Zn**	**Cl^- E**	**SO_4^{2-} E**	**Total**	**$CaCO_3$**
Spring 13	7/18/2010	**722**	**7.7**	**264**	**6.3**	28,900	130	**1,650**	**48.4**	3,690	**153**	2.2	2,010	0.50U	**0.66**	2,410	0.10U	**749**	1.0U	34.2	50.2	50.2
Spring 13	9/21/2010	25.4	1.3	**14.1**	**5.4**	16,600	47.8	50.0U	0.26	3,260	30.0	1.9	1,130	0.50U	---	2,380 [C,E]	0.10U	**697**	1.0U	36.4	29.6	29.6
Spring 13 Dup	9/21/2010	26.5	1.3	**15.4**	**5.6**	16,700	48.1	50.0U	0.32	3,260	31.1	2.2	1,140	0.50U	---	2,420 [C,E]	0.10U	**711**	1.0U	37.0	29.6	29.6
Spring 14	7/18/2010	16.3	3.5	**13.6**	**5.4**	20,300	**39.4**	50.0U	**0.6**	4,210	1.7	1.4	1,290	0.50U	0.50U	2,570	0.10U	**660**	1.0U	52.4	24.5	24.5
Spring 14	9/21/2010	20.1	3.9	**14.0**	**5.4**	16,800	**42.8**	50.0U	**0.65**	3,560	2.1	1.5	1,160	0.50U	---	2,500 [C,E]	0.10U	**670**	1.0U	48.9	20.3	20.3
JILL CREEK																						
JC-1	7/15/2010	41.1	0.5U	1.3	0.08U	5,190	1.4	50.0U	0.10U	1,080	1.3	0.50U	746	0.50U	0.50U	2,110	0.10U	5.0U	1.0U	5.4	17.3	17.3
JC-1	9/21/2010	56.4	0.5U	1.1	0.08U	5,920	0.79	50.0U	0.10U	1,230	1.2	0.64	785	0.50U	---	2,180 [C,E]	0.10U	5.0U	1.0U	5.8	21.6	21.6
JC-2	7/15/2010	51.3	0.5U	1.6	**0.41**	5,500	**6.5**	50.0U	0.10U	1,140	18.5	0.50U	762	0.50U	0.50U	2,080	0.10U	**51.7**	1.0U	6.4	17.0	17.0
JC-2	9/21/2010	50.9	0.5U	1.6	**0.79**	6,580	**11.1**	50.0U	0.10U	1,360	40.0	0.63	791	0.50U	---	2,160 [C,E]	0.10U	**102**	1.0U	5.0U	21.6	21.6
JC-3	7/15/2010	**966**	0.5U	**38.8**	**22.5**	8,640	**456**	**6,110**	**7.8**	2,330	**1,240**	5.3	761	0.50U	0.50U	2,010	0.10U	**2,460**	1.0U	52.0	5.0U	5.0U
JC-3 Dup	7/15/2010	**1,010**	0.5U	**38.5**	**22.2**	8,850	**478**	**6,210**	**8.0**	2,440	**1,300**	6.0	840	0.50U	0.50U	2,240	0.10U	**2,650**	1.0U	58	5.0U	5.0U
JC-3	9/21/2010	**390**	0.5U	1.3	**20.7**	10,700	**325**	**1,490**	**1.0**	2,930	**1,300**	6.0	884	0.50U	---	2,410 [C,E]	0.10U	**2,210**	1.0U	58.4	5.0U	5.0U
JC-4	7/15/2010	**915**	0.5U	**36.8**	**22.4**	10,400	**449**	**5,580**	**7.5**	2,760	**1,130**	5.6	921	0.50U	0.50U	2,340	0.10U	**2,490**	1.0U	58.1	5.0U	5.0U
JC-4	9/21/2010	**840**	0.5U	**19.5**	**20.6**	12,400	**338**	**5,130**	**6.9**	3,300	**1,230**	6.0	928	0.50U	---	2,450 [C,E]	0.10U	**2,300**	1.0U	58.2	5.0U	5.0U
Screening Levels[g]		***87***	***5.6***	***5***	***0.097***	***---***	***2.85***	***300***	***0.55***	***---***	***120***	***16.1***	***---***	***1.0***	***0.37***	***---***	***0.24***	***37***				

Notes:

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

[a] Elevated levels of dissolved manganese in lab method blank and field blank

[b] Elevated level of dissolved lead in field blank

[c] Elevated level of total sodium in field blank

[d] Elevated level of dissolved aluminum in field blank

[e] No analytical limitations

[g]Screening Levels refer to Tables 1-10 through 1-12 (conservative risk based Screening Level Summary Table): **Bolded values indicate exceedance of screening levels.**

TABLE 3-3B
Summary of 2010 Surface Water Analytical Results—*Dissolved Metals Analyses*

Site	Date Sample Collected	Dissolved Metals (µg/L)												
		Al	Sb	As	Cd	Cu	Fe	Pb	Mn	Ni	Se	Ag	Tl	Zn
ADIT														
Bullion Channel	7/15/2010	**21,600**	4.4	**786**	**426**	**10,400**	**148,000**	**146**	**27,800**	**113**	**3.6**	0.50U	0.19	**57,300**
Bullion Channel	9/21/2010	**16,600**	3.1	**245**	**326**	**7,260**	**111,000**	**139**	**22,100**	**76.4**	---	---	0.21	**41,300**
Bullion Mine	7/17/2010	**20,200**	**20.3**	**4,610**	**548**	**14,000**	**268,000**	**742**	**31,900**	**118**	**3.3**	0.50U	**0.28**	**65,100**
Bullion Mine	9/20/2010	**13,800**	**15.9**	**1,200**	**300**	**6,600**	**169,000**	**420**	**21,300**	---	0.19	---	0.19	**39,700**
SPRINGS														
Spring 1	7/17/2010	**32,900**	0.94	**8.9**	**676**	**14,600**	**282,000**	**15.6**	**39,300**	**160**	**5.0**	0.50U	**0.51**	**83,600**
Spring 1	9/20/2010	**18,900**	0.55	3.9	**358**	**81,00**	**167,000**	**12.1**	**24,500**	---	**1.3**	---	**0.45**	**48,900**
Spring 2	7/17/2010	**12,800**	0.50U	**7.7**	**232**	**4,300**	**2,540**	**19.6**	**7,120**	**50.3**	**3.2**	**1.6**	0.10U	**12,700**
Spring 2	9/20/2010	*Spring was Dry*												
Spring 3	7/17/2010	35.6	2.0	**37.4**	**3.5**	**29.0**	50.0U	**2.6**	43.4	3.1	0.50U	0.50U	0.10U	**1,090**
Spring 3	9/20/2010	21.4 [d,e]	1.7	**18.3**	**2.7**	**21.6**	50.0U	0.47	91.0	---	0.50U	---	0.10U	**711**
Spring 4	7/17/2010	**31,000**	0.50U	**5.9**	**417**	**7,340**	**16,900**	**23.8**	**32,500**	**160**	**4.9**	0.50U	0.10U	**51,400**
Spring 4	9/20/2010	**40,000**	0.50U	**7.4**	**431**	**8,320**	**16,300**	**13.7**	**35,700**	---	**3.2**	---	0.10U	**57,800**
Spring 5	7/17/2010	**15,000**	---	0.50U	**220**	**3,870**	50.0U	**13.3**	**20,200**	---	0.50U	---	---	**29,800**
Spring 5	9/20/2010	**21,500**	<0.50	**11.4**	**264**	**5,140**	**2,080**	**10.3**	**30,500**	---	**2.3**	---	<0.10	**43,700**
Spring 6	7/17/2010	18.3	0.59	**9.9**	**0.25**	0.87	50.0U	0.10U	0.78	0.61	0.50U	0.50U	0.10U	**49.7**
Spring 6	9/20/2010	20 [d,e]	0.51	**10.1**	**0.29**	1.4	50.0U	0.21	3.5	---	0.50U	---	0.10U	**60.8**
Spring 7	7/17/2010	**3,060**	0.50U	**21.6**	**23.5**	**279**	**3,990**	**92.8**	**1,410**	8.2	0.50U	0.50U	0.10U	**1,200**
Spring 7	9/20/2010	**2,060**	0.50U	**7.8**	**11.3**	**121**	**2,080**	**56.9**	**1,350**	---	0.50U	---	0.10U	**819**
Spring 8	7/18/2010	6.8	0.50U	**5.5**	0.08U	0.76	50.0U	0.10U	0.6	0.50U	0.50U	0.50U	0.10U	11.4
Spring 8	9/20/2010	4.0U	0.50U	**6.0**	0.08U	0.85	50.0U	0.10U	1.3	---	0.50U	---	0.10U	12.4
Spring 9	7/18/2010	8.1	0.50U	0.75	0.08U	0.5	50.0U	0.10U	0.8 [a,e]	0.50U	0.50U	0.50U	0.10U	5.0U
Spring 9	9/21/2010	4 [d,e]	0.50U	0.66	0.08U	0.55	50.0U	0.10U	2.4	---	0.50U	---	0.10U	5.0U
Spring 10	7/18/2010	**8,490**	1.3	25.8	**204**	**3,810**	229	**0.68**	**10,200**	**63.7**	**3.0**	0.50U	0.10U	**20,900**
Spring 10	9/21/2010	**8,840**	1.1	24.8	**184**	**3,290**	214	**0.62**	**9,340**	---	**1.6**	---	0.10U	**19,800**

TABLE 3-3B

Summary of 2010 Surface Water Analytical Results—*Dissolved Metals Analyses*

Site	Date Sample Collected	Dissolved Metals (µg/L)												
		Al	Sb	As	Cd	Cu	Fe	Pb	Mn	Ni	Se	Ag	Tl	Zn
Spring 11	7/18/2010	**1,840**	0.50U	**7.6**	**300**	**3,420**	50.0U	**4.9**	**10,200**	**68.5**	0.91	0.50U	0.10U	**29,900**
Spring 11	9/21/2010	**1,490**	0.50U	**5.6**	**150**	**1,740**	50.0U	**4.5**	**5,500**	---	0.50U	---	0.10U	**16,500**
Spring 12	7/18/2010	4.0U	3.0	**12.4**	**5.8**	**6.7**	50.0U	0.10U	2.3 [a,e]	10.6	0.50U	0.50U	0.10U	**3,190**
Spring 12	9/21/2010	13.8 [d,e]	2.2	**16.1**	**4.3**	**4.9**	50.0U	0.12	4.0	7.8	0.50U	---	0.10U	**2,340**
Spring 13	7/18/2010	22.9	4.7	**55.1**	**4.8**	**37.0**	50.0U	0.28	47.8	1.8	0.50U	0.50U	0.10U	**635**
Spring 13	9/21/2010	30.1 [d,e]	1.3	**13.9**	**5.4**	**46.7**	50.0U	0.42	30.9	---	0.50U	---	0.10U	**691**
Spring 14	7/18/2010	16.9	3.8	**14.4**	**5.7**	**42.6**	50.0U	0.53	3.2 [a,e]	1.6	0.50U	0.50U	0.10U	**700**
Spring 14	9/21/2010	33.9	4.0	**14.3**	**5.6**	**44.3**	50.0U	**0.68**	2.9	---	0.50U	---	0.10U	**684**
JILL CREEK														
JC-1	7/15/2010	23.3	0.50U	1.3	0.08U	1.7	50.0U	0.10U	0.79 [a,e]	0.50U	0.50U	0.50U	0.10U	5.2
JC-1	9/21/2010	15.3 [d,e]	0.50U	1.0	0.08U	1.5	50.0U	0.10U	0.79	---	0.50U	---	0.10U	5.6
JC-2	7/15/2010	30.4	0.50U	1.6	**0.4**	**6.7**	50.0U	0.10U	18.9	0.50U	0.50U	0.50U	0.10U	**55.0**
JC-2	9/21/2010	39.8 [d,e]	0.50U	1.4	**0.83**	**11.8**	50.0U	0.10U	39.8	---	0.50U	---	0.10U	**113**
JC-3	7/15/2010	**830**	0.50U	0.78	**23.1**	**447**	**1,300**	**2.8**	**1,270**	0.50U	0.50U	0.50U	0.10U	**2,570**
JC-3	9/21/2010	**968**	0.50U	**18.5**	**20.3**	**407**	**6,190**	**8.1**	**1,270**	6.1	0.50U	---	0.10U	**2,430**
JC-4	7/15/2010	312	0.50U	2.8	**22.8**	**419**	**1,610**	**1.6**	**1,170**	5.9	0.50U	0.50U	0.10U	**2,530**
JC-4	9/21/2010	36.5 [d,e]	0.50U	1.3	**20.1**	**121**	**1,050**	0.10U	**1,170**	---	0.50U	---	0.10U	**2,360**
Screening Levels [g]		***87***	***5.6***	***5***	***0.097***	***2.85***	***300***	***0.545***	***120***	***16.1***	***1.0***	***0.37***	***0.24***	***37***

Notes:

[a] Elevated levels of dissolved manganese in lab method blank and field blank
[b] Elevated level of dissolved lead in field blank
[c] Elevated level of total sodium in field blank
[d] Elevated level of dissolved aluminum in field blank
[e] Highest Quality (Enforcement Quality) as defined by CFR SSI Data Management/Data Validation Plan (PTI 1992, and Revision, Addendum)
[f] No Analytical Limitations
[g] Screening Levels refer to Tables 1-10 through 1-12 (conservative risk based Screening Level Summary Table): **Bolded values indicate exceedance of screening levels.**
U = below detection limits

TABLE 3-4
GPS Locations of Inventoried and Sampled Springs

Station Name	Latitude (°N)	Longitude (°W)
Bullion Adit	46.355512023	-112.294804431
Spring 1	46.355496682	-112.294835932
Spring 2	46.355538202	-112.294335949
Spring 3	46.355750006	-112.295564437
Spring 4	46.355887734	-112.295147193
Spring 5	46.356246325	-112.295134455
Spring 6	46.355484644	-112.291950962
Spring 7	46.351915604	-112.282514507
Spring 8	46.351858971	-112.283075700
Spring 9	46.357063921	-112.294773526
Spring 10	46.357209060	-112.295813461
Spring 11	46.357018943	-112.296154269
Spring 12	46.357375886	-112.296765243
Spring 13	46.358199209	-112.297969451
Spring 14	46.359991745	-112.297843006

TABLE 3-5
Spring and Adit Field Parameters

Site	Date	Flow (gpm)	pH	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Temperature (°C)	ORP (mV)	Turbidity (NTU)
Bullion Mine ADIT	7/27/2010	6.4	2.5	3.25	10.5	5.7	392	7.0
	9/20/2010	3.2	2.88	0.19	3.55	6.2	410	7.4
Spring 1	7/27/2010	1.50	2.9	2.45	12.5	8.3	362	0.0
	9/20/2010	1.50	2.96	0.195	6.79	6.9	397	0.0
Spring 2	7/27/2010	0.05	3.0	0.837	13.2	8.8	503	0.0
	9/20/2010	Dry	Dry	Dry	Dry	Dry	Dry	Dry
Spring 3	7/27/2010	1.00	5.7	0.088	10.1	14.2	170	0.0
	9/20/2010	0.10	5.2	15.9	9.77	8.8	154	0.0
Spring 4	7/27/2010	2.00	3.0	1.84	9.3	18.1	520	0.0
	9/20/2010	0.50	3.11	0.183	11.59	12.3	531	0.0
Spring 5	7/27/2010	1.00	3.9	1.11	9.3	20.1	431	0.0
	9/20/2010	2.00	3.74	0.127	11.5	12	492	0.0
Spring 6	7/27/2010	0.25	5.4	0.124	15	10.3	207	0.0
	9/20/2010	0.01	5.55	12.5	10.31	6.1	205	0.0
Spring 7	7/27/2010	2.00	4.0	0.0	14.5	7.8	352	0.0
	9/20/2010	2.00	4.98	40.8	11.79	8.2	219	2.8

TABLE 3-5
Spring and Adit Field Parameters

Site	Date	Flow (gpm)	pH	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Temperature (°C)	ORP (mV)	Turbidity (NTU)
Spring 8	7/27/2010	3.00	5.5	0.0	16.1	3.9	204	0.0
	9/20/2010	1.00	5.57	8.0	11.81	5.1	190	0.0
Spring 9	7/27/2010	0.10	6.0	0.0	14.9	8.3	159	0.0
	9/21/2010	0.50	6.45	27	11.54	8.4	153	0.0
Spring 10	7/27/2010	0.00	3.7	1.0	9.3	17.1	408	0.0
	9/21/2010	0.10	3.98	94.8	11	1.5	407	0.0
Spring 11	7/27/2010	1.00	4.4	1.0	10.1	16.2	340	0.0
	9/21/2010	1.00	4.43	54.7	13.03	9.7	388	4.3
Spring 12	7/27/2010	0.05	5.8	0.0	11.3	16.9	229	2.0
	9/21/2010	0.25	5.94	33.1	10.93	8.7	307	6.0
Spring 13	7/27/2010	1.00	5.9	0.0	12.1	16.1	196	1.0
	9/21/2010	0.01	6.04	18.7	4.28	9.6	278	0.5
Spring 14	7/27/2010	0.25	5.8	0.0	15.1	11.3	190	2.0
	9/21/2010	1.00	6.14	20.5	6.97	5.6	135	0.0

Notes:
µS/cm = microSiemens per centimeter
gpm = gallons per minute
mV = millivolts
NTU = nephelometric turbidity units
ORP = oxidation reduction potential

TABLE 3-6
Surface Water and Groundwater Screening Benchmarks

Analyte	State of Montana Standards [2]				National Recommended Water Quality Criteria – Aquatic Life[3,c]		USEPA Surface Water[1]
	Human Health Standards		Aquatic Life				
	Surface Water	Groundwater	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	0.005	0.005	0.00052	0.000097	0.0020[a]	0.00025[a]	0.00025
Copper	1.3	1.3	0.00379	0.00285	0.013[a]	0.0090[a]	0.009
Iron	---	---	---	1	---	---	0.3
Lead	0.015	0.015	0.01398	0.000545	0.065[a]	0.0025[a]	0.0025
Manganese	---	---	---	---	---	---	0.12
Nickel	0.1	0.1	0.145	0.0161	0.47[a]	0.052[a]	0.052
Selenium	0.05	0.05	0.02	0.005	---	0.0050[b]	0.001
Silver	0.1	0.1	0.000374	---	0.0032[a]	---	0.0032
Thallium	0.00024	0.002	---	---	---	---	0.0008
Zinc	2	2	0.037	0.037	0.12[a]	0.12[a]	0.12

Notes:
[1] USEPA Freshwater Screen Benchmarks (mg/L). Available at http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fw/screenbench.htm.
[2] Circular DEQ-7 (2012) Montana Numeric Water Quality Standards
[3] Freshwater standards from USEPA. 2009. *National Recommended Water Quality Criteria (NRWQC) for Priority Pollutants*. USEPA 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 (CMC) and Chronic Criteria (CCC).
[a] The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a hardness of 100 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)
[b] This recommended water quality criterion for selenium is expressed in terms of total recoverable metal in the water column. It is scientifically acceptable to use the conversion factor (0.996 – CMC or 0.922 – CCC) that was used in the GLI (60 FR 15393-15399, March 23, 1995; 40 CFR 132 Appendix A) to convert this to a value that is expressed in terms of dissolved metal.
[c] Metals are stated as dissolved unless otherwise specified.
Units are all reported in mg/L = milligram per liter (to covert to microgram per Liter [μg/L] divide by 1000)

TABLE 3-7
Exceedance of Human Health MCLs (Totals) and Acute and Chronic Aquatic Life Standards (Dissolved) by Representative COIs at Specific Sampling Locations (see Figure 3-1)

Sample Location	Aluminum	Antimony	Arsenic	Cadmium	Copper	Lead	Nickel	Zinc
Adit								
Adit Discharge	AC	H	H,AC	H, AC	H, AC	H, AC	H, AC	H, AC
Adit Channel	AC		H,AC	H, AC	H, AC	H, AC	H,AC	H, AC
Jill Creek								
JC-1								
JC-2				AC				AC
JC-3	AC		H	H, AC	AC	AC		H, AC
JC-4	AC		H	H, AC	AC	AC		H, AC
Springs								
SP-1	AC		H	H, AC	H, AC	H, AC	AC	H, AC

TABLE 3-7
Exceedance of Human Health MCLs (Totals) and Acute and Chronic Aquatic Life Standards (Dissolved) by Representative COIs at Specific Sampling Locations (see Figure 3-1)

Sample Location	Aluminum	Antimony	Arsenic	Cadmium	Copper	Lead	Nickel	Zinc
Adit								
Sp-2	AC		H	H, AC	H, AC	H, AC	AC	H, AC
SP-3			H	AC	AC			AC
Sp-4	AC			H, AC	H, AC	H, AC	AC	H, AC
Sp-5	AC		H	H, AC	H, AC	AC		H, AC
Sp-6			H	AC				AC
Sp-7	AC		H	H, AC	AC	H, AC		AC
Sp-8								
Sp-9								
Sp-10	AC		H	H, AC	H, AC	AC	AC	H, AC
Sp-11	AC			H, AC	H, AC	AC	AC	H, AC
Sp-12			H	H, AC	AC			H, AC
Sp-13		H	H	H, AC	AC	H		AC
Sp-14			H	H, AC	AC	AC		AC

Notes:
AC = Dissolved Surface Water Results Exceed both Acute and Chronic Aquatic Life Standards
H = Total Surface Water Results exceed Human health MCLs

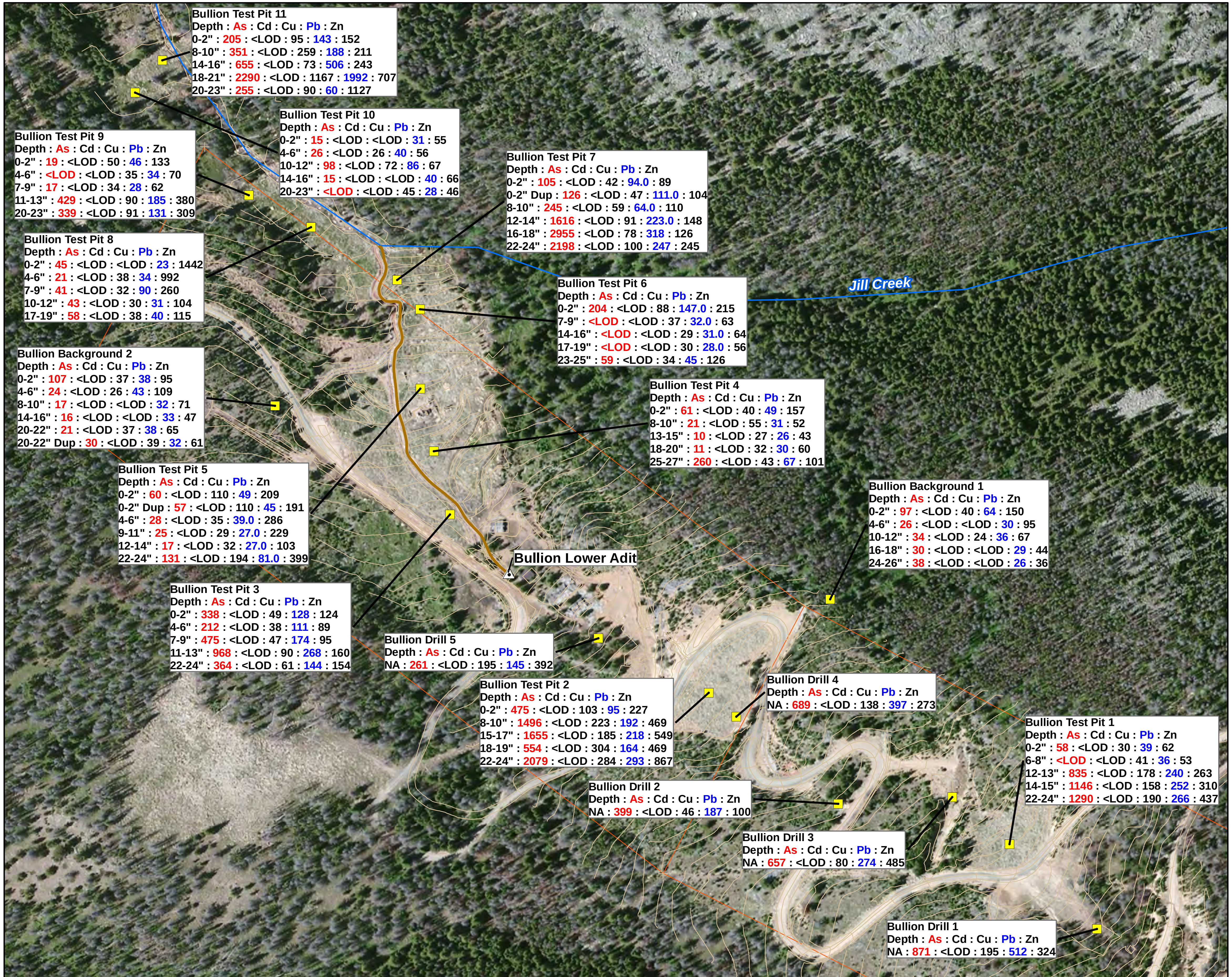
3.6 Soil Investigations

A soil investigation of the Site was performed to characterize surface and subsurface soil profiles relative to COIs. This information is intended to reflect current site conditions and contribute to a risk assessment approximately 10 years after implementation of a removal action. The following sections provide, in detail, the approach and subsequent results.

3.6.1 Soil Characterization

As previously mentioned in Section 3.3 and described in Appendix A, a joint effort by EPA and the USFS was initiated to remove mine waste and reclaim the Site. The agencies' goal was to reduce metal contamination associated with soil erosion and sedimentation and to reduce risks to human and environmental health (Maxim, 2003). Excavated waste and contaminated soils were transported to the Luttrell Repository. The newly exposed materials were amended with lime and phosphate. Approximately 18 inches of a cover soil, amended with composed manure and fertilizer, was applied to the Site and revegetated. These activities present a baseline condition reflected in the results of the soils investigation.

During this RI, samples of residual waste rock and soils were collected from 11 test pits within the project Site in 2010. Locations of these pits in relation to the mine workings are presented in Figures 3-5 and 3-5a. Surface samples were also collected from proposed monitoring well locations (designated in Figures as *Bullion Drill 1-5*) to assess contaminant concentrations that drillers might be exposed to while installing the wells. A field XRF instrument was used to quantify concentrations of antimony, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, and zinc in these materials so that the areal and vertical extent of contamination could be estimated. A total of 73 samples were collected for elemental analysis. Background samples were also collected from two locations assumed to be offsite and most likely not influenced by mining activities (see Table 3-8). A subset of the soil samples were sent to Pace Analytical Laboratory in Billings to confirm the concentrations of the elements identified by the XRF (see Table 3-9). Section 3.4.13 presents data and information regarding the relationships between XRF field data concentrations and those determined by standard laboratory techniques.



VICINITY MAP

LEGEND
- Bullion Lower Adit
- TestPit
- Adit Discharge Channel
- Topographic Survey
- Mine Claim Boundary

N

0 100 200
Feet

Notes:
1. Analytical values are mg\kg
2. LOD = Level of Detection
3. 2011 Imagery - ArcGIS Streaming Map Service.

FIGURE 3-5
Bullion Mine Soil Pit Sampling XRF Sampling Results
Bullion Mine OU6 Remedial Investigation

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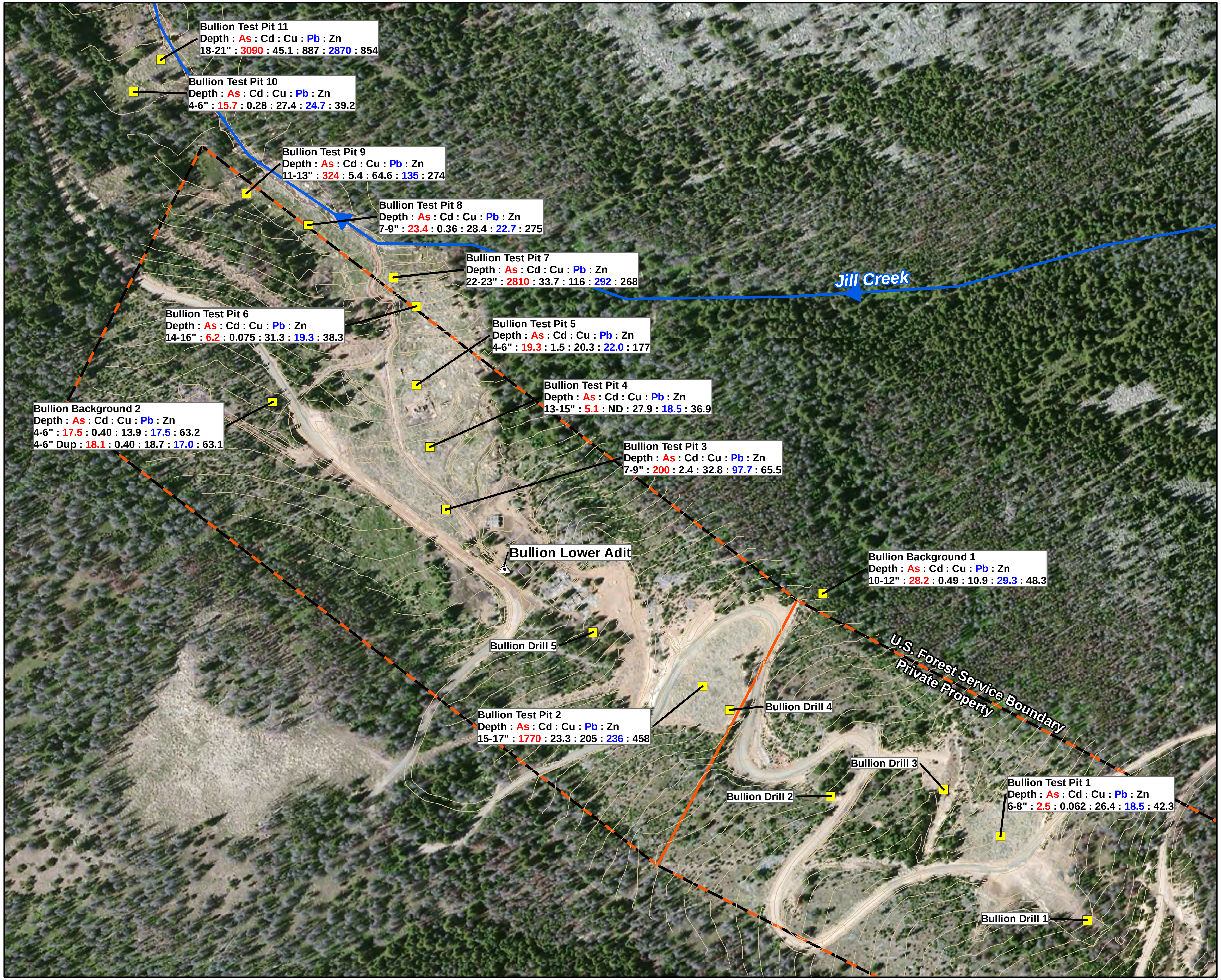
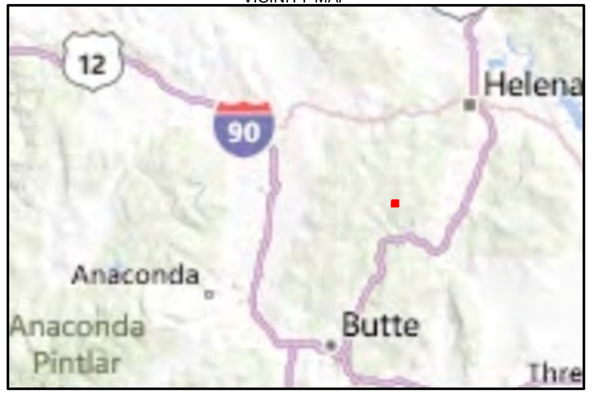


VICINITY MAP



LEGEND

- Bullion Lower Adit
- Test Pit
- Topographic Survey
- U.S. Forest Service Boundary
- Mine Claim Boundary

Notes:
1. Analytical values are mg\kg
2. 2011 Imagery - ArcGIS Streaming Map Service.

N

0 100 200
Feet

FIGURE 3-5A
SOIL SAMPLING RESULTS (ANALYTICAL)
Bullion Mine OU6 Remedial Investigation

BOI \\OWL\PROJ\EPA\408158BULLIONMINE\GIS\MAPFILES\ANALYTICALRESULTSSOIL_SOILSAMPLING.MXD JCARR3 2/20/2013 4:16:14 PM

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TABLE 3-8
2010 Bullion Mine XRF Sampling Results - DRAFT

Site	Date Sample Collected	Metals (mg/kg)										
		Sb	As	Cd	Cu	Fe	Pb	Mn	Ni	Se	Ag	Zn
Bullion Test Pit 1: 0 to 2 inches	8/7/2010	81U	58	45U	30	32,566	39	601	48U	6U	44U	62
Bullion Test Pit 1: 6 to 8 inches	8/7/2010	77U	16U	57U	41	31,103	36	579	74U	6U	33U	53
Bullion Test Pit 1: 12 to 13 inches	8/7/2010	92U	835	61U	178	36,522	240	718	49U	5U	33U	263
Bullion Test Pit 1: 14 to 15 inches	8/7/2010	92U	1,146	45U	158	39,338	252	900	89U	6U	37U	310
Bullion Test Pit 1: 22 to 24 inches	8/7/2010	82U	1,290	47U	190	45,944	266	1,340	64U	8U	42U	437
Bullion Test Pit 2: 0 to 2 inches	8/7/2010	77U	475	55U	103	35,495	95	682	64U	9U	33U	227
Bullion Test Pit 2: 8 to 10 inches	8/7/2010	95U	1,496	45U	223	46,336	192	1,213	66U	6U	34U	469
Bullion Test Pit 2: 15 to 17 inches	8/7/2010	115U	1,655	55U	185	48,019	218	1,243	74U	6U	55U	549
Bullion Test Pit 2: 18 to 19 inches	8/7/2010	117U	554	48U	304	31,800	164	1,264	85U	7U	33U	469
Bullion Test Pit 2: 22 to 24 inches	8/7/2010	143U	2,079	46U	284	46,364	293	1,809	56U	10U	34U	867
Bullion Test Pit 3: 0 to 2 inches	8/7/2010	78U	338	44U	49	27,189	128	512	61U	5U	54U	124
Bullion Test Pit 3: 4 to 6 inches	8/7/2010	84U	212	43U	38	28,622	111	461	70U	7U	38U	89
Bullion Test Pit 3: 7 to 9 inches	8/7/2010	77U	475	44U	47	30,263	174	1,153	64U	6	54U	95
Bullion Test Pit 3: 11 to 13 inches	8/7/2010	79U	968	46U	90	35,686	268	471	68U	7U	43U	160
Bullion Test Pit 3: 22 to 24 inches	8/7/2010	117U	364	46U	61	40,507	144	516	78U	9U	54U	154
Bullion Test Pit 4: 0 to 2 inches	8/7/2010	116U	61	42U	40	29,238	49	582	78U	5	32U	157
Bullion Test Pit 4: 8 to 10 inches	8/7/2010	97U	21	43U	55	29,525	31	508	46U	4U	33U	52
Bullion Test Pit 4: 13 to 15 inches	8/7/2010	79U	10	44U	27	23,539	26	356	49U	5	58U	43
Bullion Test Pit 4: 18 to 20 inches	8/7/2010	78U	11	44U	32	27,954	30	620	65U	4U	40U	60
Bullion Test Pit 4: 25 to 27 inches	8/7/2010	120U	260	44U	43	28,693	67	664	88U	5U	60U	101
Bullion Test Pit 5: 0 to 2 inches	8/7/2010	79U	60	53U	110	27,761	49	633	50U	5U	33U	209
Bullion Test Pit 5: 0 to 2 inches Dup	8/7/2010	75U	57	43U	110	27,254	45	594	46U	7U	32U	191
Bullion Test Pit 5: 4 to 6 inches	8/7/2010	75U	28	45U	35	25,461	39	1,032	70U	5U	38U	286
Bullion Test Pit 5: 9 to 11 inches	8/7/2010	73U	25	41U	29	22,146	27	663	52U	5U	31U	229
Bullion Test Pit 5: 12 to 14 inches	8/7/2010	97U	17	42U	32	18,022	27	459	60U	7U	31U	103
Bullion Test Pit 5: 22 to 24 inches	8/7/2010	77U	131	43U	194	25,968	81	511	91U	5U	33U	399

TABLE 3-8
2010 Bullion Mine XRF Sampling Results - DRAFT

Site	Date Sample Collected	Metals (mg/kg)										
		Sb	As	Cd	Cu	Fe	Pb	Mn	Ni	Se	Ag	Zn
Bullion Test Pit 6: 0 to 2 inches	8/7/2010	78U	204	45U	88	23,093	147	437	46U	4U	34U	215
Bullion Test Pit 6: 7 to 9 inches	8/7/2010	101U	18U	44U	37	29,898	32	425	47U	4U	48U	63
Bullion Test Pit 6: 14 to 16 inches	8/7/2010	77U	17U	44U	29	28,096	31	403	59U	4U	33U	64
Bullion Test Pit 6: 17 to 19 inches	8/7/2010	110U	19U	48U	30	25,694	28	492	45U	5U	32U	56
Bullion Test Pit 6: 23 to 25 inches	8/7/2010	100U	59	44U	34	26,432	45	474	65U	6U	44U	126
Bullion Test Pit 7: 0 to 2 inches	8/7/2010	108U	105	59U	42	78,652	94	1,575	108U	8U	37U	89
Bullion Test Pit 7: 0 to 2 inches Dup	8/7/2010	79U	126	44U	47	27,905	111	484	82U	4U	54U	104
Bullion Test Pit 7: 8 to 10 inches	8/7/2010	78U	245	42U	59	29,096	64	482	51U	5U	33U	110
Bullion Test Pit 7: 12 to 14 inches	8/7/2010	105U	1,616	45U	91	29,312	223	573	70U	7U	32U	148
Bullion Test Pit 7: 16 to 18 inches	8/7/2010	79U	2,955	45U	78	41,282	318	479	70U	7U	48U	126
Bullion Test Pit 7: 22 to 24 inches	8/7/2010	91U	2,198	45U	100	42,783	247	573	112U	13U	36U	245
Bullion Test Pit 8: 0 to 2 inches	8/7/2010	80	45	56U	36U	40,352	23	604	72U	7U	34U	1,442
Bullion Test Pit 8: 4 to 6 inches	8/7/2010	88U	21	51U	38	15,433	34	569	57U	3U	29U	992
Bullion Test Pit 8: 7 to 9 inches	8/7/2010	72U	41	41U	32	22,923	90	369	71U	6U	31U	260
Bullion Test Pit 8: 10 to 12 inches	8/7/2010	77U	43	60U	30	23,397	31	374	50U	3U	31U	104
Bullion Test Pit 8: 17 to 19 inches	8/7/2010	72U	58	64U	38	19,139	40	346	57U	6U	31U	115
Bullion Test Pit 9: 0 to 2 inches	8/7/2010	70U	19	44U	50	21,957	46	344	45U	5U	30U	133
Bullion Test Pit 9: 4 to 6 inches	8/7/2010	98U	20U	44U	35	30,093	34	594	62U	4U	35U	70
Bullion Test Pit 9: 7 to 9 inches	8/7/2010	77U	17	50U	34	28,759	28	460	54U	6U	33U	62
Bullion Test Pit 9: 11 to 13 inches	8/7/2010	83U	429	45U	90	31,607	185	462	63U	6U	33U	380
Bullion Test Pit 9: 20 to 23 inches	8/7/2010	128U	339	44U	91	35,816	131	367	65U	8U	33U	309
Bullion Test Pit 10: 0 to 2 inches	8/7/2010	90U	15	44U	46U	27,388	31	254	60U	5U	33U	55
Bullion Test Pit 10: 4 to 6 inches	8/7/2010	77U	26	42U	26	25,165	40	372	60U	7U	33U	56
Bullion Test Pit 10: 10 to 12 inches	8/7/2010	84U	98	57U	72	26,125	86	450	44U	4U	33U	67
Bullion Test Pit 10: 14 to 16 inches	8/7/2010	91U	15	44U	35U	23,347	40	469	66U	4U	34U	66
Bullion Test Pit 10: 20 to 23 inches	8/7/2010	78U	17U	44U	45	28,706	28	460	52	6U	36U	46

TABLE 3-8
2010 Bullion Mine XRF Sampling Results - DRAFT

Site	Date Sample Collected	Metals (mg/kg)										
		Sb	**As**	**Cd**	**Cu**	**Fe**	**Pb**	**Mn**	**Ni**	**Se**	**Ag**	**Zn**
Bullion Test Pit 11: 0 to 2 inches	8/7/2010	105U	205	59U	95	24,282	143	586	44U	4U	31U	152
Bullion Test Pit 11: 8 to 10 inches	8/7/2010	127U	351	44U	259	27,429	188	483	58U	6U	33U	211
Bullion Test Pit 11: 14 to 16 inches	8/7/2010	111U	655	55U	73	32,165	506	322	50U	9U	49U	243
Bullion Test Pit 11: 18 to 21 inches	8/7/2010	273	2,290	48U	1,167	14,138	1,992	239	48U	17	35U	707
Bullion Test Pit 11: 20 to 23 inches	8/7/2010	69U	255	40U	90	28,403	60	796	66U	6U	30U	1,127
Bullion Background-1: 0 to 2 inches	8/16/2010	110U	97	38U	40	12,877	64	1,658	34U	5U	28U	150
Bullion Background-1: 4 to 6 inches	8/16/2010	70U	26	40U	36U	17,761	30	341	51U	4U	30U	95
Bullion Background-1: 10 to 12 inches	8/16/2010	84U	34	43U	24	18,939	36	150	57U	6U	42U	67
Bullion Background-1: 16 to 18 inches	8/16/2010	119U	30	42U	42U	14,918	29	88	64U	4U	31U	44
Bullion Background-1: 24 to 26 inches	8/16/2010	72U	38	41U	31U	12,384	26	79	36U	7U	31U	36
Bullion Background-2: 0 to 2 inches	8/16/2010	64U	107	38U	37	17,543	38	387	37U	4U	29U	95
Bullion Background-2: 4 to 6 inches	8/16/2010	125U	24	40U	26	26,277	43	337	42U	4U	31U	109
Bullion Background-2: 8 to 10 inches	8/16/2010	76U	17	44U	46U	28,839	32	329	55U	7U	33U	71
Bullion Background-2: 14 to 16 inches	8/16/2010	112U	16	44U	45U	26,610	33	310	76U	6U	37U	47
Bullion Background-2: 20 to 22 inches	8/16/2010	77U	21	44U	37	32,367	38	300	79U	6U	40U	65
Bullion Background-2: 20 to 22 inches Dup	8/16/2010	99U	30	44U	39	30,769	32	297	48U	5U	35U	61
Bullion Well Boring 1	8/16/2010	125U	871	54U	195	21,582	512	545	42U	6U	32U	324
Bullion Well Boring 2	8/16/2010	114U	399	43U	46	24,820	187	414	64U	7U	60U	100
Bullion Well Boring 3	8/16/2010	77U	657	44U	80	31,921	274	1,037	57U	5U	33U	485
Bullion Well Boring 4	8/16/2010	85U	689	54U	138	31,619	397	736	68U	6	37U	273
Bullion Well Boring 5	8/16/2010	67U	261	46U	195	21,068	145	725	39U	6U	30U	392

TABLE 3-9
2010 Bullion Mine Soil Sampling Results (Analytical)

Site	Date Sample Collected	Metals (mg/kg)													pH
		Al	Sb	As	Cd	Cu	Fe	Pb	Mn	Ni	Se	Ag	Tl	Zn	
Bullion Test Pit 1: 6 to 8 inches	8/4/2010	15,000	0.50U	2.5	0.062	26.4	17,400J	18.5	363	8.1	0.99	0.50U	1.0U	42.3	7.5
Bullion Test Pit 2: 15 to 17 inches	8/4/2010	7,250	0.48U	1,770	23.3	205	30,000	236	1,100	7.1	0.48U	0.48U	0.95U	458	7.0
Bullion Test Pit 3: 7 to 9 inches	8/4/2010	13,800	0.50U	200	2.4	32.8	16,500J	97.7	316	7.7	0.75U	0.50U	1.0U	65.5	6.8
Bullion Test Pit 4: 13 to 15 inches	8/4/2010	16,200	0.48U	5.1	0.032	27.9	17,500J	18.5	312	8.3	0.72U	0.48U	0.96U	36.9	6.7
Bullion Test Pit 5: 4 to 6 inches	8/5/2010	16,500	0.47U	19.3	1.5	20.3	18,000J	22.0	624	6.5	1.5	0.47U	0.93U	177	7.1
Bullion Test Pit 6: 14 to 16 inches	8/5/2010	16,000	0.46U	6.2	0.075	31.3	18,100J	19.3	295	8.6	0.69U	0.46U	0.92U	38.3	7.2
Bullion Test Pit 7: 22 to 23 inches	8/5/2010	9,590	0.48U	2,810	33.7	116	35,400	292	620	6.0	0.71U	0.79	0.95U	268	7.2
Bullion Test Pit 8: 7 to 9 inches	8/5/2010	15,700	0.48U	23.4	0.36	28.4	16,400J	22.7	328	9.1	0.72U	0.48U	0.96U	275	7.5
Bullion Test Pit 9: 11 to 13 inches	8/5/2010	9,580	1	324	5.4	64.6	19,100J	135	253	6.9	0.71U	0.47U	0.96U	274	7.6
Bullion Test Pit 10: 4 to 6 inches	8/5/2010	14,300	0.46U	15.7	0.28	27.4	16,100J	24.7	333	7.6	0.69U	0.46U	0.93U	39.2	7.7
Bullion Test Pit 11: 18 to 21 inches	8/6/2010	6,560	141	3,090	45.1	887	17,200	2,870	199	11.4	0.69U	29.2	0.92U	854	4.2
Bullion Background-1: 10 to 12 inches	8/16/2010	11,100	0.43U	28.2	0.49	10.9	13,200	29.3	115	5.6	0.65U	0.43U	0.87U	48.3	6.9
Bullion Background-2: 4 to 6 inches	8/16/2010	17,600	0.35U	17.5	0.40	13.9	14,800J	17.5	170	8.3	0.53U	0.35U	0.70U	63.2	6.9
Bullion Background-2: 4 to 6 inches Dup	8/16/2010	16,200	0.45U	18.1	0.40	18.7	14,500J	17.0	160.0	7.9	0.67U	0.45U	0.89U	63.1	7.1

Notes:
J = results indicate the result is estimated.
U = below detection limits

Soil samples were collected at representative locations along the banks of Jill Creek and in areas where waste rock was removed and the soils reclaimed. Because of limited Site access for excavation equipment, and the shallow proposed depths, the test pits were hand-excavated using shovels and pry bars. The test pits ranged in depth from 19 to 24 inches, and were dug deep enough to penetrate through non-native fill and sample native materials.

Prior to excavation, all test pit locations were staked in an effort to achieve a representative Site sampling array. GPS coordinates were recorded for each test pit location using a Trimble GPS unit. GPS coordinates were recorded in a field notebook and then transferred to test pit logs (see Appendix B) that described total depth, thickness of waste rock, sampling intervals, presence of groundwater, and other relevant information. Upon completion of sampling, test pits were backfilled to grade with excavated materials.

As previously stated, the soil test pits extended to native ground surface to document the depth of cover soils, residual waste rock, tailings or mixed soils at each location. Because the test pits were all less than 27 inches deep, soil samples were collected by hand from test pit walls. The soil samples were collected using clean stainless steel or plastic trowels and placed into labeled, resealable plastic baggies (as described in the SAP). Assuming the majority of the sampling locations had an overburden of cover soil, general sampling intervals consisted of (1) the soil surface; (2) two samples between the soil surface and the underlying native soil; (3) a sample at the mine waste/top of the native soil interface; and (4) one sample from 1 foot below the top of the native soil. In general for XRF analysis, five soil depth intervals per pit were sampled for quantification of levels of the elements listed previously.

A summary of metal and arsenic concentrations (measured by field XRF) in Bullion Mine soils samples are presented in Table 3-10. The data are arranged by soil depth increment, number of samples collected from each increment, and mean, maximum, and minimum concentrations of several elements. Almost all of the antimony, cadmium, nickel, selenium, and silver data were reported as less than their respective detection limits. The complete soils XRF data set can be found in Appendix B. Metal and arsenic levels in soils reported by the analytical laboratory are summarized in Table 3-11, with mean, maximum, and minimum values for the each element. This table also contains pH data for the soils. Background soil concentrations are exhibited in Table 3-12. The interpretation of metal and arsenic concentrations in the soils is somewhat complicated because of the cover soil that was imported after excavation activities were completed in 2001. Mean levels of arsenic increase with sample depth, with a mean value of 860 mg/kg for samples collected from the 17- to 24-inch depth. This sample increment is assumed to be below the imported cover soil, and thereby represents residual soil contamination remaining after the excavation of wastes and contaminated soils. Maximum concentrations of arsenic (2,290 mg/kg), copper (1,167 mg/kg), lead (1,992 mg/kg) are also found in soils from this depth increment. These trends of increasing soil concentrations by depth are displayed in Figures 3-6, 3-7, 3-8, 3-9, and 3-10.

Soil elemental concentrations reported in the background soils (see Table 3-12) are comparable with minimum concentration of the Site soils, and in general they are less than the mean concentrations for Site soils (see Table 3-10). Recontamination of the imported cover soil may be occurring via three processes of elemental mobility: redeposition of contaminants from dusts and contaminated surface water (and snowmelt); erosion of the cover soil that exposes contaminated layers; and upper movement of waters containing a metal signature from the underlying wastes into the cover soil.

FIGURE 3-6
Soil Arsenic Concentrations as a Function of Soil Depth (XRF Data)

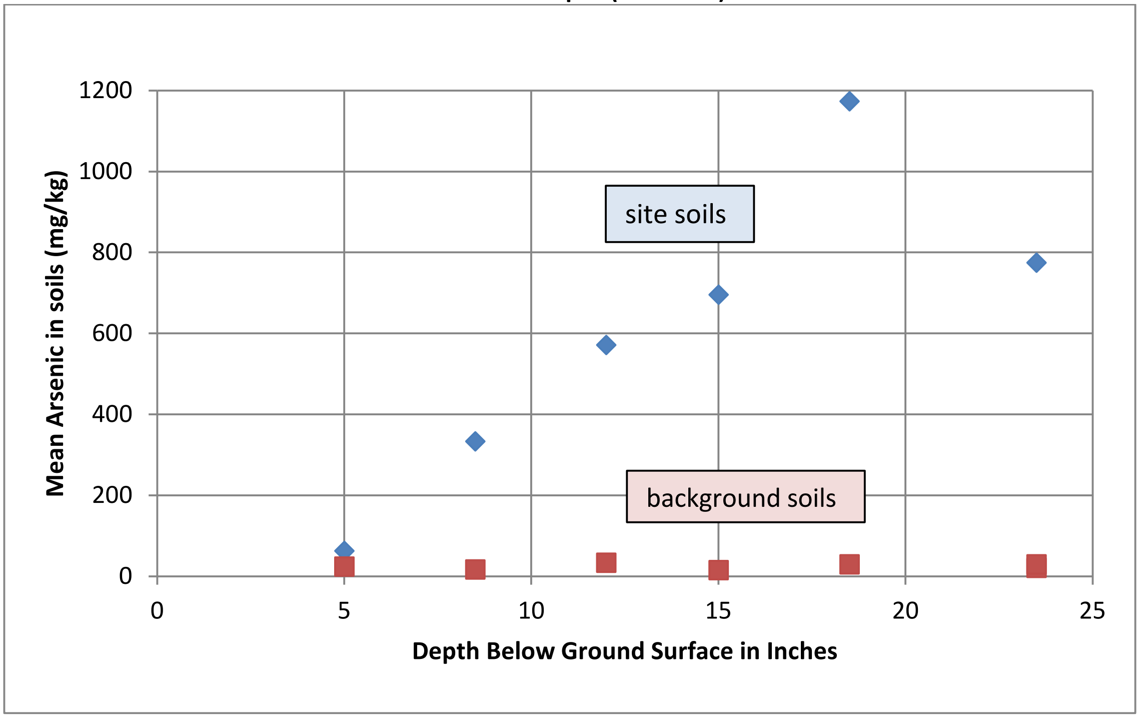

FIGURE 3-7
Soil Copper Concentrations as a function of Soil Depth (XRF Data)

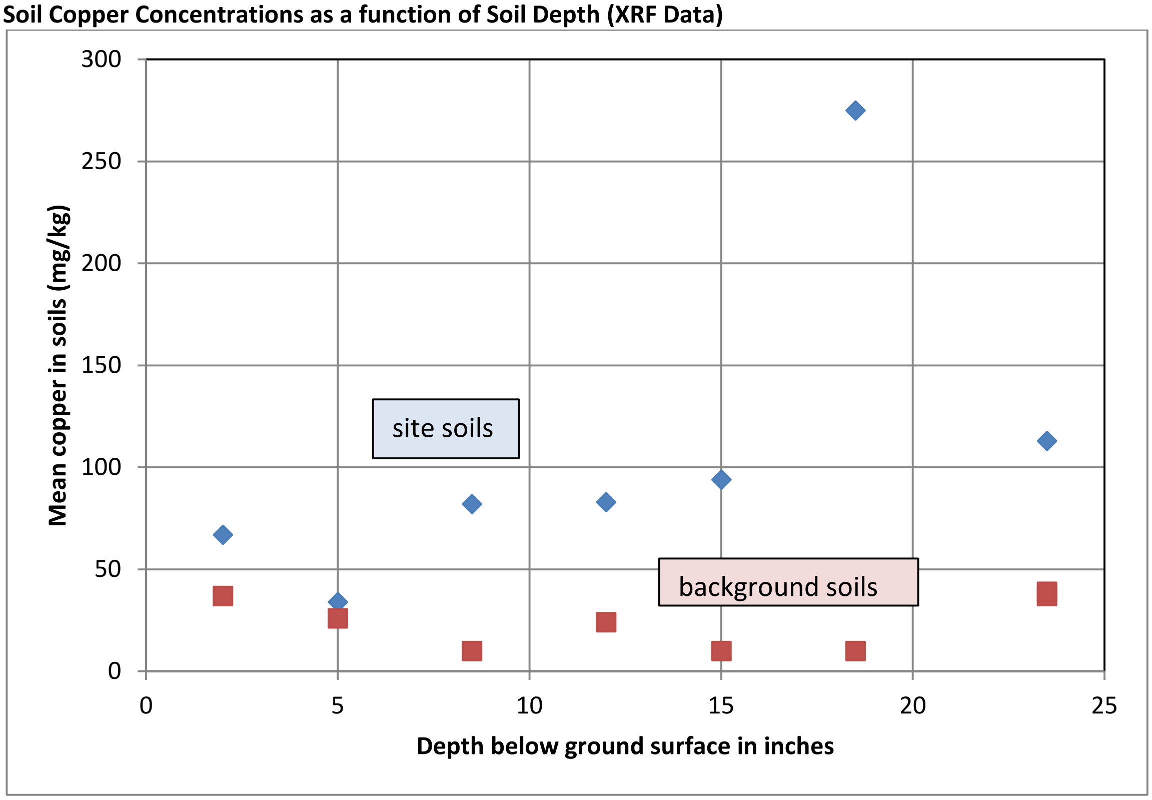

FIGURE 3-8
Soil Lead Concentrations as a Function of Soil Depth (XRF Data)

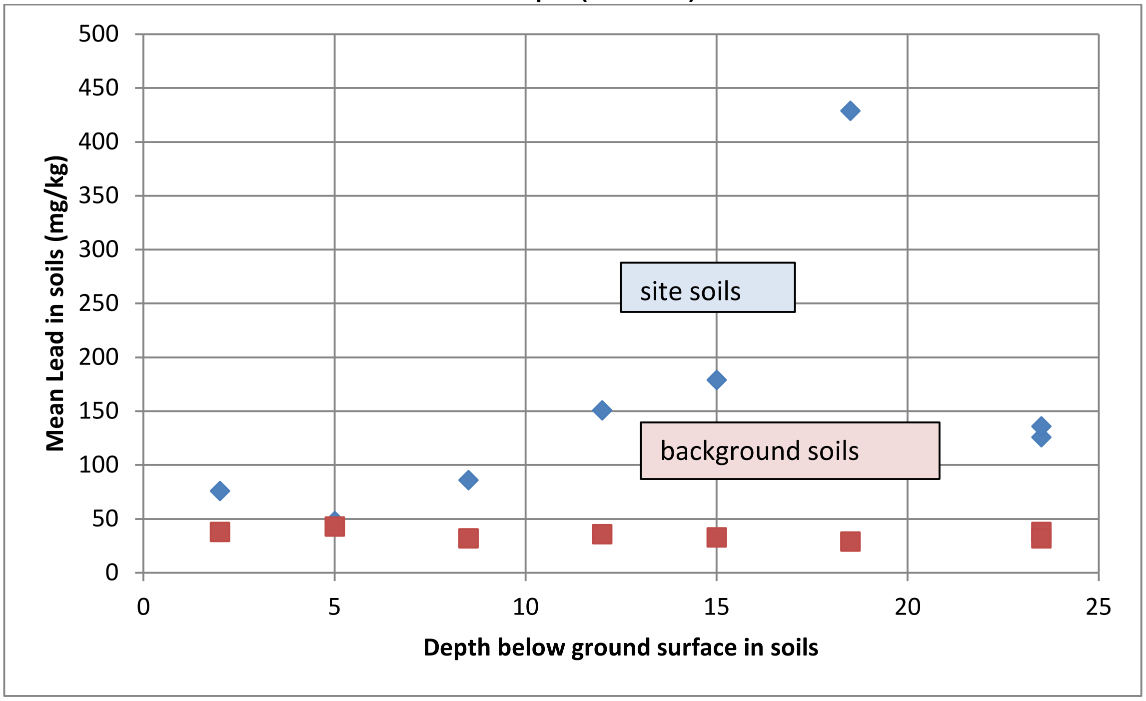

FIGURE 3-9
Soil Zinc Concentrations as a Function of Soil Depth (XRF Data)

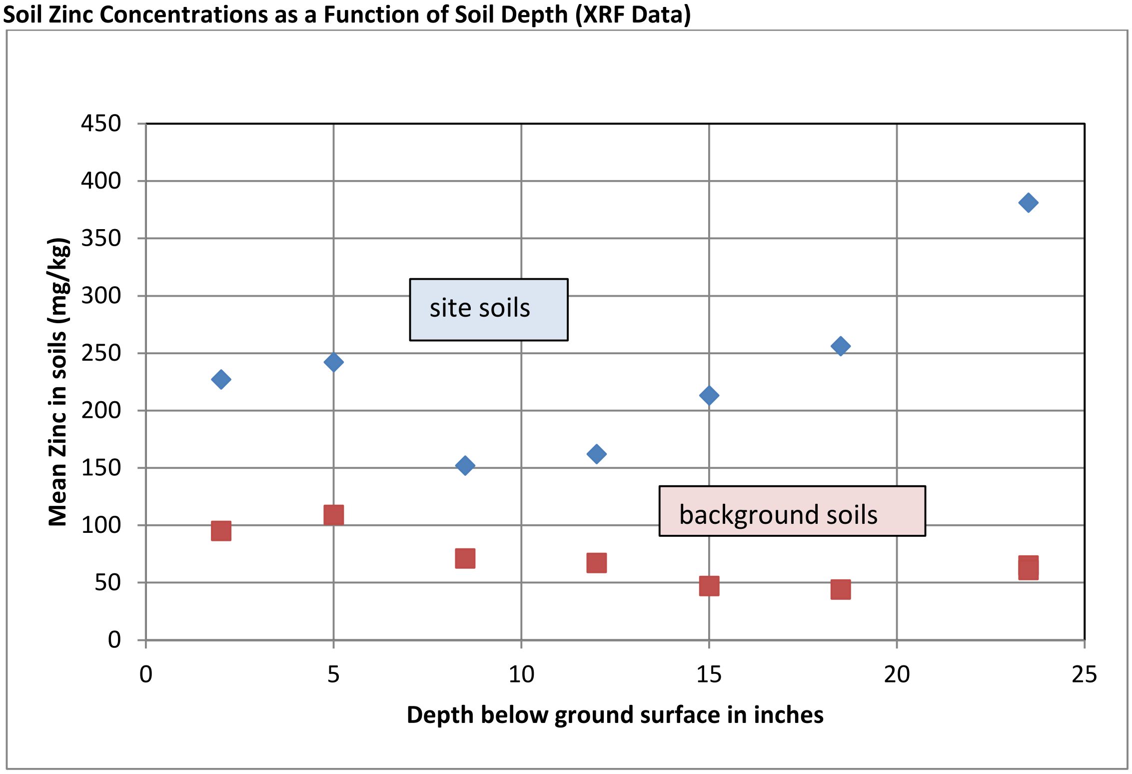

FIGURE 3-10
Soil Manganese Concentrations as a Function of Soil Depth (XRF Data)

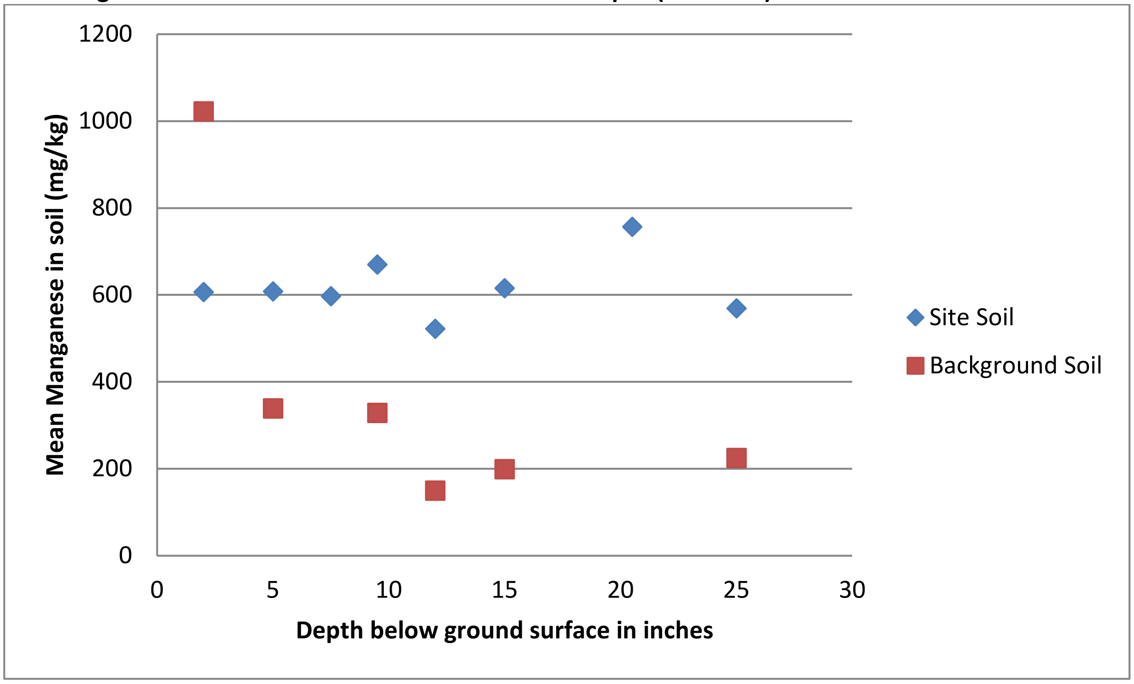

TABLE 3-10

Summary of Metal and Arsenic Levels (mg/kg) in Bullion Mine Site Soils and Waste Rock (XRF Data)*

Soil Depth (inches)	No. Samples	Antimony			Arsenic			Cadmium			Copper			Iron			Lead			Manganese			Nickel			Selenium			Silver			Zinc		
		Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
0-2	13	86U	116U	70U	136	475	15	49U	59U	42U	65	110	30	32,549	78,652	21,957	77	147	23	607	1,575	254	62U	108U	44U	6U	9U	4U	37U	54U	30U	243	1,442	55
4-6	5	84U	98U	75U	61	212	20U	45U	51U	42U	34	38	26	24,955	30,093	15,433	52	111	34	606	1,032	372	64U	70U	57U	5U	7U	3U	35U	38U	29U	299	992	56
6-9	5	81U	101U	72U	113	475	16U	47U	57U	41U	38	47	32	28,589	31,103	22,923	72	174	28	597	1,153	369	62U	74U	47U	6U	6U	4U	40U	54U	31U	107	260	53
8-11	5	94U	127	73U	428	1,496	21	43U	45U	41U	125	259	29	30,906	46,336	22,146	100	192	27	670	1,213	482	55U	66U	46U	5U	6U	4U	33U	34U	31U	214	469	52
10-14	6	90U	105U	79U	661	1,616	17	49U	61U	42U	92	178	32	29,546	36,522	18,022	172	268	27	522	718	450	59U	70U	44U	6U	7U	4U	34U	43U	31U	187	380	67
13-17	6	102U	160U	77U	583	1,655	10	48U	55U	44U	85	185	27	32,417	48,019	23,347	179	506	26	616	1,243	322	65U	89U	49U	6U	9U	4U	44U	58U	33U	213	549	43
17-24	11	113U	273	69U	860	2,290	11	47U	64U	40U	218	1,167	32	32,869	46,364	14,138	309	1,992	28	757	1,809	239	68U	112U	48U	9U	17	4U	37U	54U	30U	412	1,127	46
23-27	2	110U	120U	100U	160	260	59	44U	44U	44U	39	43	34	27,563	28,693	26,432	56	67	45	569	664	474	77U	88U	65U	5.5U	6U	5U	52U	60U	44U	114	126	101

Note:
*XRF Model used did not analyze for aluminum or thallium
U = concentration less than or equal to XRF detection.

TABLE 3-11

Metal and Arsenic Levels (mg/kg) in Bullion Mine Site Soils and Waste Rock (Laboratory Data)

Soil Depth (inches)	No. Samples	pH			Aluminum			Antimony			Arsenic			Cadmium			Copper			Iron			Lead			Manganese			Nickel			Selenium			Silver			Thallium			Zinc		
		Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
4-6	2	7.3	7.7	7.1	15,400	16,500	14,300	0.47U	0.47U	0.46U	17.5	19.3	15.7	0.9	1.5	0.28	23.9	27.4	20.3	17,050	18,000	16,100	23.4	24.7	22.0	479	624	333	7.1	7.6	6.5	1.1	1.5	0.69U	0.47U	<0.47	<0.46	<0.93	<0.93	<0.93	108	177	39.2
6-9	3	7.1	7.5	6.8	14,833	15,700	13,800	0.49U	0.50U	0.48U	75.3	200	2.5	0.94	2.4	0.06	29.2	32.8	26.4	16,767	17,400	16,400	46.3	97.7	18.5	336	363	316	8.3	9.1	7.7	0.8	1.0	0.72U	0.49U	<0.50	<0.48	<0.99	<1.00	<0.96	128	275	42.3
10-13	1	7.6			9,580			0.98U			324			5.4			64.6			19,100			135			253			6.9			0.71U			0.47U			<0.94			274		
13-17	3	6.9	7.2	6.7	13,150	16,200	7,250	0.47U	0.48U	0.46U	594	1,770	5.1	11.7	23.3	0.08	88.1	205	27.9	21,867	30,000	17,500	91.3	236	18.5	569	1,100	295	8.0	8.6	7.1	0.63U	0.72U	0.48U	0.47U	<0.48	<0.46	<0.94	<0.96	<0.92	178	458	36.9
18-23	2	4.5	7.2	4.2	8,075	9,590	6,560	70.7	141	0.48U	2,950	3,090	2,810	39.4	45.1	33.7	502	887	116	26,300	35,400	17,200	1,581	292	2,870	409.5	620	199	8.7	11.4	6.0	0.7	0.71	0.69	14.995	29.2	0.79	<0.94	<0.95	<0.92	561	854	268

TABLE 3-12

Metal and Arsenic Levels (mg/kg) in Background Soils collected near Bullion Mine Site[a] (XRF and Laboratory Data)

Soil Depth (inches)	No. Samples	pH			Aluminum[b]			Antimony			Arsenic			Cadmium			Copper			Iron			Lead			Manganese			Nickel			Selenium			Silver			Thallium***			Zinc		
		Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
0-2	2							87U	110U	64U	102	107	97	38U	38U	38U	39	40	37	15,210	17,543	12,877	51	64	38	1,023	1,658	387	36U	37U	34U	5U	5U	4U	29U	29U	28U				123	150	95
4-6	2							98U	125U	70U	25	26	24	40U	40U	40U	26	26	26	22,019	26,277	17,761	37	43	30	339	341	337	54U	57U	51U	5U	6U	4U	36U	42U	30U				102	109	95
8-10	1							76U			17			44U			46U			28,839			32			329			55U			7U			33U						71		
10-12	1							84U			34			43U			24			18,939			36			150			57U			6U			42U						67		
14-16	1							112U			16			44U			45U			26,610			33			310			76U			6U			37U						47		
16-18	1							119U			30			44U			42U			14,918			29			88			64U			4U			31U						44		
20--26	3							83U	99U	72U	30	38	21	43U	44U	41U	36U	39U	31U	25,173	32,367	12,384	32	38	26	225	300	79	54U	79U	36U	6U	7U	5U	35U	40U	31U				54	65	36
Laboratory Data																																											
4-6	*2*	*7.0*	*7.1*	*6.9*	*16,900*	*17,600*	*16,200*	*0.40U*	*0.45U*	*0.35U*	*17.8*	*18.1*	*17.5*	*0.4*	*0.4*	*0.4*	*16.3*	*18.7*	*13.9*	*14,650*	*14,800*	*14,500*	*17.3*	*17*	*17.5*	*165*	*170*	*160*	*8.1*	*8.3*	*7.9*	*0.60U*	*0.67U*	*0.53U*	*0.40U*	*0.45U*	*0.35U*	*0.80U*	*0.89U*	*0.70U*	*63.2*	*63.2*	*63.1*
10-12	*1*	*6.9*			*11,100*			*0.43U*			*28.2*			*0.49*			*10.9*			*13,200*			*29.3*			*115*			*5.6*			*0.65U*			*0.43U*			*0.87U*			*48.3*		

Notes:
[a] Field XRF data are in standard font. Laboratory data are in *blue font.*
[b]XRF Model used did not analyze for aluminum or thallium
U = concentration less than or equal to XRF detection.

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Mean and maximum concentrations of the arsenic, cadmium, copper, lead, iron, manganese, aluminum, nickel, and zinc exceed their respective ecological benchmark values (see Table 1-7). For example, the mean and maximum concentrations of arsenic in Site soils (452 mg/kg and 2,955 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. Comparisons of soil and waste rock concentrations in samples collected in 2010 to human health residential benchmark values (see Table 1-7) indicate that the cover soil and waste values of arsenic, cadmium, copper, lead, manganese, and zinc exceed those considered to be protective of human health.

The Bullion Mine is located in a natural mineralized zone and greater concentrations of these elements are expected. Arsenic levels in soils collected from the background sites range from 16 to 107 mg/kg (see Table 3-12), with a mean level of 40 mg/kg. Both the mean and maximum concentrations in cover soil and the underlying wastes exceed the background concentrations for arsenic and other elements. This same pattern is repeated for copper, lead, manganese, nickel, and zinc concentrations. Only the minimum concentrations for cover soil are similar to the background soil levels.

The vertical extent of contamination of arsenic, copper, lead, and zinc in the soils and waste rock is shown in Figures 3-6 through 3-10. Mean concentrations for each sample increment are also shown in these figures, as well as concentrations found in the background soils. Very elevated levels were found below the cover soil.

Acidity in these soils and waste rock samples was determined by measuring pH in the laboratory. Data were transformed to hydrogen ion concentrations so that statistical calculations of mean values could be correctly determined. Mean pH levels (see Table 3-10) indicate acidic soil/waste rock at a depth 18 to 23 inches deep in the soil profile. The source of the acidity in these materials is derived from the oxidation of pyrite in the Bullion ore body.

3.6.2 Bioavailability of Arsenic and Lead in Soil

As directed by EPA, a mine-specific bioavailability study was conducted to provide a better understanding of the bioavailability of arsenic and lead in selected Site soils. This information will be used to more accurately assess the potential risk to human and ecological receptors. In addition, the site-specific bioavailability data are expected to support decisions on the selection of appropriate cleanup levels. A representative subset of soils was culled from the larger number of soil samples collected during the 2010 sampling event. These soils had revealed varying concentrations of arsenic (range from 15 to 475 mg/kg) and lead (23 to 147 mg/kg). A background soil sample was also selected (see Table 3-13).

3.6.3 Analytical Methods for Bioavailability Tests

The laboratory analysis used to estimate the bioavailability of the arsenic and lead in soil was the In Vitro Bioaccessibility Procedure (IVBA) for arsenic and lead. These test procedures provide a tool to measure the fraction of a metal that is absorbed by an organism through specific routes of exposure (for example, incidental soil ingestion). The laboratory procedures for these analyses were provided in the Field SAP (CH2M HILL, August 22, 2012) as:

- **Attachment A.** Standard Operating Procedure *In Vitro* Bioaccessibility (IVBA) Procedure for Arsenic (June 2011).
- **Attachment B.** Standard Operating Procedure for an *In Vitro* Bioaccessibility Assay for Lead in Soil (April 2012).

The IVBA procedure used an in vitro test to measure the fraction of a chemical solubilized from a soil sample under simulated mammalian gastrointestinal conditions. The soil sample was first sieved through a 250-micron sieve. A portion of the soil that passes through the sieve was used to determine the total concentration of arsenic and lead. The in vitro test introduced an aqueous fluid into a portion of the soil sample that passed through the sieve. The chemical solubilized from the soil sample is representative of the fraction of arsenic and lead potentially absorbed by a mammal under physiologically relevant conditions simulating gastric pH, buffering, and temperature. Upon completion of this extraction, the filtered extract solution was analyzed for arsenic and lead.

TABLE 3-13

2010 Remedial Investigation Soil Sample Results (Surface Interval) and Locations

Sample Identifier	Arsenic Concentration [a] (mg/kg)	Lead Concentration [b] (mg/kg)	GPS [c] Northing (feet)	GPS [c] Easting (feet)	Laboratory Analysis
Bullion Background 1	97	67	780163.15	1263950.09	EPA 6010
Bullion Test Pit 1	58	39	779677.81	1264305.28	EPA 6010
Bullion Test Pit 2	475	95	779977.28	1263709.38	EPA 6010
Bullion Test Pit 3	338	128	780331.01	1263196.64	EPA 6010
Bullion Test Pit 5	60	49	780580.18	1263137.59	EPA 6010
Bullion Test Pit 6	204	147	780738.07	1263137.46	EPA 6010
Bullion Test Pit 8	45	23	780900.51	1262920.95	EPA 6010
Bullion Test Pit 10	15	31	781167.60	1262572.04	EPA 6010

Notes:

[a] This sample is selected because it is within the area of interest; its arsenic concentration is well-spaced between other samples being tested; and it has sufficient arsenic concentration for IVBA testing.

[b] This sample is selected because it is within the area of interest; its lead concentration is well-spaced between other samples being tested; and it has sufficient lead concentration for IVBA testing.

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

The mass of the arsenic and lead found in the filtered extract was compared to the mass introduced into the test. The fraction liberated into the aqueous phase is defined as the bioaccessable fraction of arsenic and lead in that soil sample and is presented in Table 3-14. The bioaccessable fraction determined in this in vitro test predicts the site-specific gastrointestinal bioavailability of metals in for the sample. The tests were completed at the University of Colorado's Laboratory for Environmental and Geologic Studies performed the sample analyses.

TABLE 3-14

Results of Arsenic and Lead Bioavailability Analyses

Sample Identifier	Lab ID	% Arsenic IVBA	% Lead IVBA	% Lead RBA Predicted [a]
Bullion TP 01	TL-18	6	9	8
Bullion TP 02	TL-14	33	13	11
Bullion TP 03	TL-8	26	20	18
Bullion TP 05	TL-5	22	23	20
Bullion TP 06	TL-4	17	14	12
Bullion TP 06 FD	TL-19	17	16	14
Bullion TP 08	TL-17	48	54	47
Bullion TP 10	TL-13	4	13	11
Bullion Background	TL-6	18	9	37
Minimum[b]		**4**	**9**	**8**
Maximum[b]		**48**	**54**	**47**
Mean[b]		**21.8**	**19.4**	**18.1**

Notes:

[a] % RBA Pb predicted value based on Drexler and Brattin (2007)

[b] Does not include FDs or background

FD = field duplicate

IVBA = in vitro bioaccessibility

RBA = relative bioavailability

3.6.4 Results of Soil Arsenic and Lead Bioavailability Tests

The last column in Table 3-14 provides predicted values for the *in vivo* (juvenile swine) relative bioavailability of lead in the soils. The predicted values are based on correlation studies ($r^2 = 0.924$, $p < 0.001$) in which the relative bioaccessibility in vitro procedure were compared to *in vivo* data (Drexler and Brattin, 2007).

The range of variability for arsenic and lead bioavailability is high. A 60 percent bioavailability default value was assumed for both arsenic and lead during the risk assessment prepared for the Basin Watershed OU2 RI. As shown in Table 3-14, sample specific bioavailability factors are below the default values at all selected Site soils. The Mine-specific mean bioavailability factors of approximately 22 and 19 percent for arsenic and lead, respectively, would be expected to provide a more realistic assessment of risk to receptors at the Site.

The results of bioavailability studies confirm the previous assertion that the relative amount of arsenic and lead available for potential adverse effects in humans and mammals is lower than assumptions used in the risk assessment prepared for the Basin Watershed OU2 RI. The HHRA and ERA should be revisited and results adjusted to account for this information. A data summary of the bioavailability of arsenic and lead in Bullion Mine soils is provided in Appendix C.

3.7 Sediment Investigations

3.7.1 Introduction

Stream sediment in Jill Creek was not sampled as part of the 2010 RI for the Site. The 2001 removal action, reclamation of approximately 500 linear feet of Jill Creek, and revegetation of the area, have greatly reduced the obvious erosion issues previously associated with the Site. Barren, eroding slopes no longer intercept Jill Creek as they did prior to 2001. The current condition represents a new baseline for the Bullion Mine reach of Jill Creek. In spite of the improvements, bank erosion and over land flow remain as natural processes that contribute sediment into the creek. Historic sediment concentrations and loads are summarized in and can be reviewed by consulting the Basin Watershed OU2 RI (CDM, 2005a).

In the Jack Creek drainage, the highest COI concentrations occurred in sediments from the Jill Creek tributary, with the Bullion Mine as the source. Arsenic, cadmium, copper, lead, and zinc significantly exceeded ecological and human health benchmarks (CDM, 2005b). As such, Jack Creek was the largest source of contaminated sediment to Basin Creek both historically and in the 2001 sampling. Today, the primary degradation of water quality, within the Jill Creek tributary to Jack Creek is the discharge of AMD from the Bullion Mine, which is the focus of this report.

Benthic macroinvertebrate community assessments in the streams (2010) revealed an adversely impacted aquatic environment. Agency review comments on the Bullion Mine draft RI suggested that stream sediment be added to the recently sampled media to help provide a more current assessment of risk to aquatic and benthic receptors. The 2012 stream sediment sampling locations were collocated with the previous water quality and benthic macroinvertebrate sampling sites collected during the 2010 RI effort. The 2012 sample data were used to more accurately assess the extent of the contamination and to provide additional lines of evidence to evaluate the potential risk to human and aquatic ecological receptors.

3.7.2 Sediment Sample Locations

Six sediment sampling sites were collocated with the previous 2010 RI macroinvertebrate survey sites. Figure 3-11 provides the coordinates for the sample locations for the 2012 sediment sampling along Jill and Jack Creeks. The field sampling methodology and sample handling is as described in the 2012 Sediment SAP for the Bullion Mine (CH2M HILL, 2012). Surface sediment samples were collected from the top 10 centimeters of sediments deposited in slow-moving areas of the stream. Samples were collected from downstream to upstream in order to avoid cross-contaminating downstream samples. All applicable information was recorded (for example, date/time of collection) on the chain-of-custody form. Samples were secured in an ice-filled cooler and shipped via FedEx to Pace Analytical Services, Inc., in Billings. GPS coordinates were recorded to mark each sampling location. Field observations were made in a field notebook.

Figure 3-11 shows the 2012 sediment sample locations and also the GPS coordinates.

Target analytes included aluminum, antimony, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, thallium, and zinc. Upon receipt by the laboratory, sediment samples were first dried >40°C and then sieved through U. S. Standard Sieve Mesh sizes #10 (2.0 millimeters), 80 (0.18 millimeter), and 230 (0.0625 millimeter) to obtain three size fractions that consist of medium to coarse sand, very fine to fine sand, and silt/clay. The portions of the sediment that passes through the sieves were used to determine the total concentration of metals in each size fraction. Additionally, grain size distribution was evaluated to help with the characterization of sediments. The size fractions were identical to those obtained during the Basin Watershed OU2 RI (CDM, 2005b), except that CDM reported a #260 mesh for the silt-clay fraction.

The sediment samples were analyzed by Pace Analytical Services, Inc. Target detection limits for each analyte were established to achieve sediment quality benchmarks.

Following sample analysis, all data were assessed in terms of accuracy, precision, and completeness. Formal data validation (CH2M HILL, 2012) concluded that laboratory quality control data and field quality control procedures of the sample data collected, as specified in the SAP (CH2M HILL, 2010) were acceptable. The precision (reproducibility), accuracy (correctness), representativeness (degree to which data accurately and precisely depict the characteristics of a population), comparability (confidence with which one data set can be compared to another data set), and completeness (percentage of valid results in the data set) objectives were met.

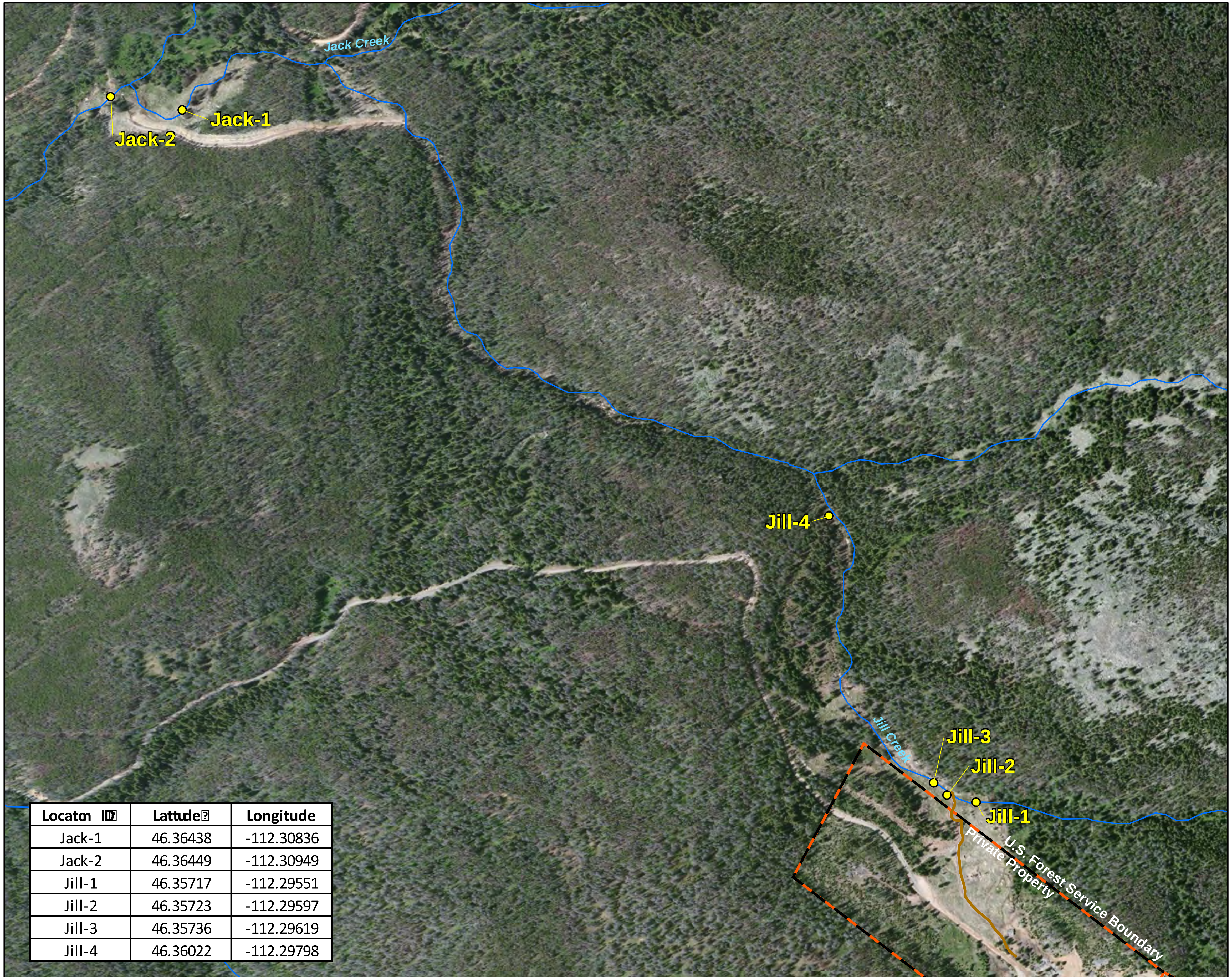
3.7.3 Sediment Sampling Results

Considering the limited human health exposures identified in the draft RI, risks to ecological receptors (for example, benthic macroinvertebrates) are expected to be the highest. Therefore, conservative Freshwater Sediments Screening Benchmarks are used. Refer to Section 1-6 for a discussion of Screening Benchmarks.

Results of the 2012 sampling are presented in Table 3-15. This table shows the concentration from an upstream to downstream direction. The adit channel intersects Jill Creek downstream from Jill-1 and just above Jill-2. However, springs discharge upslope from the Jill-1 sediment location and may discharge impacted groundwater at this location.

Sediment values of all three size fractions that exceeded the conservative ecological benchmark criteria are shown in bold. The highest concentrations were generally observed in the smaller size fractions (silt/clay), which is consistent in sediment results. However, for each sample, the smallest size fraction represents the smallest percentage by weight of the sample. The sediment concentrations were progressively higher in a downstream direction, but were highest at Station Jill-2, located immediately downstream of the confluence of Jill Creek and the Bullion Adit flow. Several springs and baseflow likely diluted the COI concentrations downstream. Concentrations of antimony, arsenic, cadmium, copper, iron lead, manganese, selenium, silver, and zinc all exceeded freshwater sediment screening benchmarks.

The results of the sediment sampling confirm the findings from the previous Basin Watershed OU2 RI (CDM, 2005), that enriched metalloid and trace metal concentrations occur in stream sediments from the Bullion Mine to its confluence with Jack Creek. The sediment sample results attest to the fate and transport of source material and will provide additional lines of evidence to evaluate the potential risk to human and ecological receptors in the pending final RI and FS. The final 2012 Sediment Sampling Technical Memorandum and sampling results are included in Appendix D.



Locaton ID	Lattude	Longitude
Jack-1	46.36438	-112.30836
Jack-2	46.36449	-112.30949
Jill-1	46.35717	-112.29551
Jill-2	46.35723	-112.29597
Jill-3	46.35736	-112.29619
Jill-4	46.36022	-112.29798

VICINITY MAP

LEGEND

- 2012 Sediment Sampling Location
- Adit Discharge Channel
- NHD Stream
- U.S. Forest Service Boundary
- Mine Claim Boundary

Note:
1. 2011 Imagery - ArcGIS Streaming Map Service.

N

0 250 500
Feet

FIGURE 3-11
Sediment Sampling Locations, July 2012
Bullion Mine OU6 Remedial Investigation

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TABLE 3-15
2012 Sediment Sampling Analytical Results (in mg/kg)

Sample Location	Sample Particle Size	Aluminum	Antimony	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Nickel	Selenium	Silver	Thallium	Zinc	Percent Clay % (w/w)	Percent Silt % (w/w)	Percent Sand % (w/w)
Jill-01-SD	#10 mesh (2.0 mm)	2,210	0.37J	**33J**	**1.3J**	21.6	7,200	9.6J	313J	1.9	**0.84**	0.045	0.12	**66.5**	3.75	3.75	92.5
	#80 mesh (0.18 mm)	2,220	0.22	**47.3**	**1.4**	18.2	6,070	9.3	264	1.8	0.3	0.047	0.13	**67.6**			
	#230 mesh (0.0625 mm)	10,700	**0.94**	**235**	**7.3**	**137**	**27,400**	**47.9**	**693**	7.7	**1.4**	0.053	0.14	**365**			
Jill-02-SD	#10 mesh (2.0 mm)	1,430	**8.4**	**1,800**	**25.4**	**64.3**	**118,000**	**112**	253	0.22	0.15	0.052	5.7	**67.2**	11.25	13.75	75
	#80 mesh (0.18 mm)	4,280	**6.4**	**1,320**	**18.6**	**68.2**	**70,800**	**203**	**556**	2.7	0.14	0.34	3.1	**145**			
	#230 mesh (0.0625 mm)	7,260	**7**	**1,840**	**25.7**	**110**	**124,000**	**397**	332	3.9	0.17	**1.5**	4.8	**230**			
Jill-03-SD	#10 mesh (2.0 mm)	3,250	0.083	**112J**	**2.9J**	**42.9**	9,160J	**18.2J**	382	3.9	0.59	0.041	0.11	**122**	5	2.5	92.5
	#80 mesh (0.18 mm)	2,520	0.12	**58.5**	**2.2**	**54.7**	7,630	**30.1J**	263	2.1	0.57	0.059	0.16	**105**			
	#230 mesh (0.0625 mm)	10,100	0.09	**288**	**12.7**	**474**	**48,100**	**96.8**	**1,590**	6.7	0.37	0.045	1.3	**538**			
Jill-04-SD	#10 mesh (2.0 mm)	3,460	**1.2**	**104J**	**2.5J**	**60.3J**	7,210J	**42.3J**	276	2.1	0.54	0.057	0.15	**131J**	5	6.25	88.75
	#80 mesh (0.18 mm)	4,390	**2.4**	**395**	**8.9**	**159**	14,300	**148**	548	3.4	**0.92**	0.21	0.14	**287**			
	#230 mesh (0.0625 mm)	11,200	**6.4**	**836**	**21.6**	**505**	**37,600**	**341**	**1,220**	7.9	**1.6**	**1.7**	0.28	**803**			
Jack-01-SD	#10 mesh (2.0 mm)	2,610	0.1UJ	**23**	**0.73J**	12.5J	6,440	**18.6J**	200J	2J	**0.61J**	0.051UJ	0.14UJ	**52.9**	3.75	1.25	95
	#80 mesh (0.18 mm)	3,260	0.09UJ	**47.1J**	**1.2J**	18.1J	8,430J	**33.3J**	287	2.9	0.48	0.23	0.12	**90.9J**			
	#230 mesh (0.0625 mm)	6,690	0.76	**129**	**3.2**	**45.8**	**26,500**	**92**	**583**	5.7	**1.8**	0.058	0.16	**231**			
Jack-02-SD	#10 mesh (2.0 mm)	2,230	0.1	**18.3**	**1.7**	**34.7**	**22,200**	**18.3**	385	2.9	**2.6**	0.05	1.7	**225**	5	0	95
	#80 mesh (0.18 mm)	3,610	**2.1**	**346**	**8.3**	**86.9**	12,100	**109**	**660**	3.4	**1.4**	0.14	0.15	**313**			
	#230 mesh (0.0625 mm)	7,690	**4.9**	**470**	**14.6**	**176**	**26,600**	**241**	**1,280**	7.2	**2.3**	**1.4**	0.25	**761**			
Screening Benchmarks (mg/kg)		**25,500**	**0.27**	**9.8**	**0.36**	**28**	**20,000**	**11**	**460**	**23**	**0.6**	**1**	**NA**	**46**			

Notes:
Freshwater Sediment Screening Benchmarks represent the lowest benchmarks for each respective medium reported. Refer to Tables 1-10, 1-11 and 1-12
These levels are intentionally conservative and exceedances of these levels should not be construed as actual risk.
% (w/w) = percent wet weight
Jack = Jack Creek
Jill = Jill Creek
J = Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.
mg/kg = milligram per kilogram
Bold values exceed Sediment Benchmark Screening Levels
Particle-size data (percent sand, silt and clay) are as reported by Pace Analytical Laboratory.

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3.8 Geology and Groundwater Investigations

3.8.1 Drilling and Subsurface Investigation

The purpose of the geologic and drilling exploration was to gather basic geologic and hydrogeologic data to assist in evaluating remedial alternatives for the reduction of AMD and ARD. The geologic subsurface investigation scope of this project included the following:

- Drilling a vertical boring to intercept the lower adit tunnel.
- Measuring depth to water and videolog the adit intercept boring.
- Drilling and logging vertical soil/rock borings to evaluate subsurface conditions; construct monitoring wells in vertical borings, and collect groundwater samples.
- Installing shallow piezometers to measure shallow groundwater levels and collect groundwater samples.
- Conducting a geophysical investigation to determine depth to bedrock and bedrock properties.
- Conducting general Site geologic reconnaissance and document observations.

The drilling and geologic exploration was performed in August 2010 and supervised by a CH2M HILL engineering geologist. Borings were drilled by Axis Drilling, Inc. of Belgrade, Montana, under subcontract to CH2M HILL. The soil borings were logged by a CH2M HILL geologist in accordance with American Standards for Testing and Materials (ASTM) 5434 *Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock*. Soil and rock samples were examined in the field and were visually classified in accordance with ASTM D2488, *Description and Identification of Soils (Visual-Manual Procedure)*. The soil boring logs are contained in the Geology Technical Memorandum in Appendix E.

3.8.2 Soil Borings and Monitoring Well Installation

The soil borings, and associated well construction, were positioned to develop a shallow hydrogeologic profile through the Site. The borings were drilled to depths between 25 and 60 feet using a 5-7/8-inch-diameter downhole hammer, deep enough to encounter the first water-bearing zones within weathered and fractured bedrock. Monitoring well MW-5 (BM-B-1) is an exception and was intentionally drilled to intercept the lower adit, total depth was 80.5 feet below ground surface (bgs). The purpose of placing this well was to assess potential mine flooding and evaluate groundwater inflow, collect water samples, and videolog the borehole and adit. The drilling was conducted using a Tubex downhole hammer with 4-inch casing of the first 13 feet, then 3-7/8-inch open hole until intercepting the adit. The borehole was drilled at a surveyed location upgradient of the lower adit portal location based on previous subsurface mapping.

The monitoring wells were constructed in compliance with ASTM D5092 *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers* and Montana Department of Water Resources Monitoring Well Construction rules.

Monitoring well casings and screens consisted of threaded, flush-jointed, 2-inch-diameter, Schedule 40 PVC. A 10-foot section of factory-slotted screen was installed at the bottom of each well. Colorado silica sand (10-20 gradation) was placed around the screen to act as a filter pack. The filter pack extended approximately 1 to 2 feet above the top of the well screen. Bentonite chips were placed in the boring annulus above the sand and hydrated to provide a seal from the top of the sand pack to within 2 feet of the ground surface. Because of the size of the boring, and the need to facilitate future videotaping of the adit, MW-5 was completed as an open hole with no additional PVC pipe. Above ground, the well was completed in the same manner as the other monitoring wells.

The wells were finished using an above-ground monument that consists of a 6-inch-diameter steel casing cemented into the ground with approximately 2.0 to 3.0 feet of stickup and a locking cover. In addition to the CH2M HILL monitoring wells, Maxim Inc. installed a groundwater monitoring well in 1998 during the Jill Creek tailings investigation. This well was located southwest of the Bullion Mine adit below the road switchback and is not represented in the figures or the well completion summary Table 3-13. This well is completed with the screen interval from 34.8 to 54.8 feet bgs and 0.020-inch slot, 1-inch-diameter PVC screen. The measured static water level in this well occurs within weathered and fractured granitic rock, similar to the CH2M HILL wells installed in 2010.

In areas of shallow groundwater and steep terrain or difficult access (northwest portion of the Bullion Extension Claim) standpipe drive-point piezometers were installed to measure groundwater levels and collect samples for analysis. These piezometers were installed downslope of the lower Bullion Adit and along Jill Creek. The piezometers consisted of 3/4-inch-diameter, Soloinst® Model 615N stainless-steel drive point piezometers with a 1-foot-long, stainless steel 50-mesh screen. The piezometers were installed using a slide hammer and were driven to depths between approximately 7 and 11 feet bgs. The monitoring wells and piezometers were surveyed by subcontractor Critigen, using Leica survey-grade GPS units.

The new monitoring wells were developed by a combination of surging and bailing to remove the sandy material and develop the filter pack within the annulus. Depth to water and measured during development were recorded for future reference.

Figure 3-12 shows the locations of monitoring wells and piezometers, with groundwater contours overlaid. The well construction diagrams are contained in the Geology Technical Memorandum in Appendix E. Table 3-13 shows the borehole, well construction, and piezometer details. Table 3-16 presents groundwater representative COI water quality results for the monitoring wells and piezometers.

3.8.3 Mine Workings and Mineral Deposits

3.8.3.1 Mine Workings Description

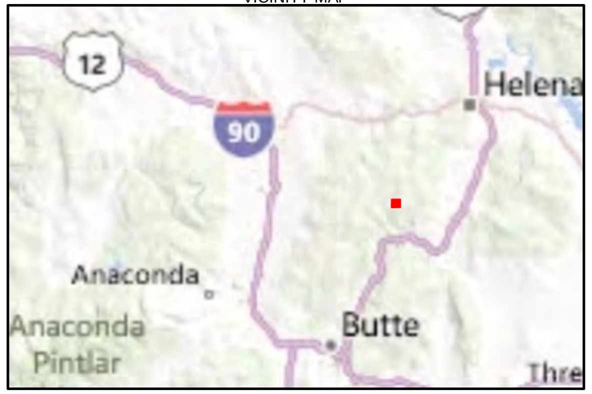
The Bullion Mine was worked periodically from 1897 to 1948, with some surface mining occurring until 1974. The mine consists of three adits on three different levels, connected by stopes raises, and inclines. Numerous vertical "discovery shafts" and exploratory trenches cut perpendicular to the direction of the vein were excavated at the surface. Based on historical information and mine maps, the main (lower) adit is the longest and extends at least 2,600 feet to the east-southeast. The middle and upper adits appear to extend approximately 800 and 200 feet to the east-southeast, respectively. The total mine workings are estimated to be approximately 4,500 feet. Ore has been mined by stoping between the lower, middle, and upper adit. The mined zone is up to 16 feet wide in the lower workings. The mine maps and long profiles show several cross-cuts and raises between the levels. A 100-foot-deep winze (a vertical shaft or passage between levels in a mine) was sunk from the lower tunnel and a short cross-cut runs northeast which cut the fault zone that contained the zinc ore.

Figure 3-13 shows a plan view of the underground workings, based on historic mining maps. The Conceptual Site Model in Figure 2-3 shows a generalized cross-section.

3.8.3.2 Mineralization

The Bullion vein is contiguous with the Crystal vein to the east. The Bullion vein trends N70W (110 degrees) and dips between 50 and 70 degrees to the northeast. The bullion vein is a fissure vein that varies from a few inches to about 40 feet wide. The vein consists of quartz, pyrite, tetrahedrite, galena, sphalerite, chalcopyrite, arsenopyrite, and siderite. The mine produced approximately 30,000 tons of ore containing 3,500 ounces of gold; 250,000 ounces of silver; 300 tons of copper; 1,000 tons of lead; and 1,000 tons of zinc.

VICINITY MAP



LEGEND

- Piezometer
- Monitoring Well
- Bullion Lower Adit
- Groundwater Contour (elevation in feet)
- Estimated Grounbdwater Contour
- Groundwater Flow Direction
- NHD Stream
- U.S. Forest Service Boundary
- Mine Claim Boundary

Notes:
1. 2011 Imagery - ArcGIS Streaming Map Service.

N

0 250 500
Feet

FIGURE 3-12
GROUNDWATER CONTOUR MAP
Bullion Mine OU6 Remedial Investigation

BOI \\OWL\PROJ\EPA\408158BULLIONMINE\GIS\MAPFILES\CONTOUR_GROUNDWATER.MXD JCARR3 2/22/2013 5:09:03 PM

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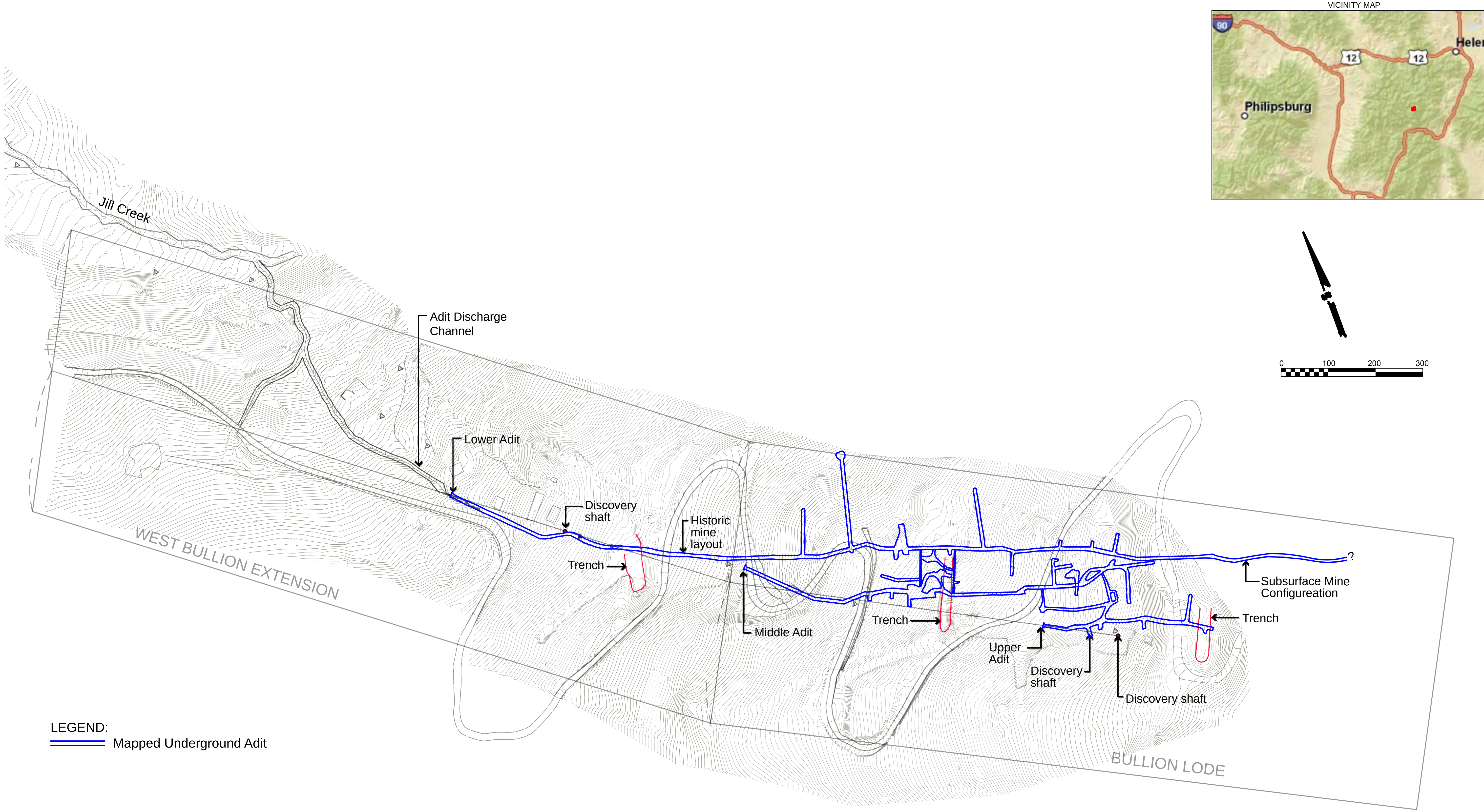

FIGURE 3-13
SUBSURFACE MINE CONFIGURATION
Bullion Mine OU6 Remedial Investigation

CH2MHILL

ES060711213019BOI Fig3-13_Subsurface_v4.ai

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TABLE 3-16
Borehole, Well Construction, and Piezometer Details

Well ID	Installation Date	Latitude (d-m-s.ss)	Longitude (d-m-s.ss)	Ground Elev. (feet amsl)	M.P. Elev. (feet amsl)	Borehole Depth (feet bgs)	Borehole Dia. (inches)	Casing Dia. (inches)	Screen Length (feet)	Screen Slot Size (inch)	Screen Depth (feet bgs)		Sand Filter Mesh	Sand Pack Interval (feet bgs)	
											Top	Bottom		Top	Bottom
MW-5	8/18/2010	46-21-18.61	112-17-38.61	7391.69	N/A	80.5	3.8 / 4	---	---	---	---	---	---	---	---
MW-1	8/28/2010	46-21-13.29	112-17-24.18	7701.55	7704.05	60	6	2	10	0.02	49.5	59.5	10-20	48	60
MW-2	8/27/2010	46-21-15.65	112-17-28.47	7581.98	7584.48	50	6	2	10	0.02	40	50	10-20	38	50
MW-3	8/26/2010	46-21-15.50	112-17-31.38	7558.84	7561.34	45	6	2	10	0.02	34	44	10-20	32.5	44
MW-4	8/25/2010	46-21-17.10	112-17-34.62	7469.17	7471.68	25	6	2	10	0.02	14	24	10-20	12.8	24
P-1	8/20/2010	46-21-22.25	112-17-43.16	7260.57	7262.59	9.0	1.0	¾	1	0.01	8.0	9.0	---	---	---
P-2	8/20/2010	46-21-23.08	112-17-42.20	7247.58	7249.43	7.2	1.0	¾	1	0.01	6.2	7.2	---	---	---
P-3	8/20/2010	46-21-21.37	112-17-42.13	7283.10	7284.83	7.3	1.0	¾	1	0.01	6.3	7.3	---	---	---
P-4	8/20/2010	46-21-25.80	112-17-45.63	7143.58	7145.40	7.2	1.0	¾	1	0.01	6.2	7.2	---	---	---
P-5	8/20/2010	46-21-26.56	112-17-48.29	7119.15	7120.95	7.2	1.0	¾	1	0.01	6.2	7.2	---	---	---
P-6	8/20/2010	46-21-29.57	112-17-51.27	7084.77	7087.75	6.0	1.0	¾	1	0.01	5.0	6.0	---	---	---

Notes:
amsl = above mean sea level
bgs = below ground surface
DTW = depth to water below measuring point
ft = feet
ID = identification
in = inches
MP = measuring point
No PVC monitoring well was installed in BM-B-1; only a locking steel flush mount set in concrete

3.9 Subsurface Geologic Conditions

3.9.1 Soil/Rock Borings

Four borings were advanced into the soil and weathered rock above the Bullion Mine. These borings were positioned and drilled directly above the Bullion vein, near old mine workings, and as expected, encountered moderate to highly weathered/altered granitic bedrock. These borings indicate subsurface conditions that consist primarily of a thin residual soil layer (typically less than 5 feet thick) overlying brownish to gray, iron-stained, slightly to moderately weathered and altered granitic rock. During drilling, the more highly weathered rock degenerated into silty to clayey sand.

When the rock was too hard to collect split spoon samples, only the cuttings were logged. The drilling action and rate of borehole advancement, indicated alternating harder and softer (more weathered) zones within the granitic bedrock.

3.9.2 Vertical Adit Intercept Boring

Boring MW-5 was drilled vertically open-hole to intercept the lower Bullion adit, as previously described. Because the rock was too hard to collect standard penetrometer tests, only the cuttings were logged. However, the subsequent downhole video camera enabled visual logging of the granitic rock in the boring. The boring profile from the surface down consists of moderate to highly weathered granite that was further weathered to sand, silt, and clay in the upper 13 feet. Below that point, the rock consisted primarily of grayish, medium- to coarse-grained granitic rock with occasional more highly weathered layers. The lower adit was intercepted at 74 feet bgs and the bottom of the adit was measured to be 80.5 feet bgs. Depth to water was measured at 48.5 feet bgs at the time of drilling in 2010, which indicated that the mine was flooded to a depth of more than 30 feet deep. The mine continues to remain flooded, based on depth-to-water measurements conducted during 2011 and 2012 (Table 3-16).

3.9.3 Downhole Videologging

A downhole video log was prepared to evaluate existing conditions within the lower adit (caving/stability etc.), and to observe groundwater inflow or mine flooding. The downhole video logging was performed by personnel from MBMG with assistance from CH2M HILL and Axis Drilling. The video log showed gray to orange-gray granitic rock in the upper 74 feet; consistent with the drill cuttings. The camera entered water at approximately 42 feet bgs, which limited the visibility because of the particulates in the water. The camera intersected the roof of the adit near the west side at 74 feet bgs, consistent with the drilling. Because of the poor (cloudy) water quality and limited light, the camera was not able to penetrate very far into the void of the adit. The drill rods appeared to hit the floor of the adit at approximately 80.5 feet bgs, which indicates the adit is approximately 6 to 6.5 feet high at this location. The width of the adit could not be determined by the downhole camera. However, given the level of water in the boring, the adit is clearly open and flooded in this area.

3.9.4 Geophysics Investigations

The geophysical exploration was conducted in order to determine P-Wave structure in the shallow subsurface, depth to rock, and seismic velocity of the sediments and rock in the shallow subsurface. The field geophysical exploration program consisted of P-Wave Seismic Refraction Surveys and was conducted by Sage Earth Science (Sage) of Idaho Falls, Idaho, under contract to CH2M HILL. Sage used seismic refraction techniques in accordance with ASTM 5777-00, *Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation.* Sage conducted a total of approximately 3,150 feet of continuous P-wave refraction profile, beginning below the Bullion mine along Jill Creek all the way to above the uppermost Bullion adit.

The results of the geophysical investigation demonstrated that the subsurface conditions in the vicinity of the Bullion Mine consist of two basic layers that include unconsolidated sediments overlying slightly to moderately weathered bedrock. Two general areas were investigated and the results of each are described in the following text. Figure 3-14 presents the seismic refraction transect lines use to delineate depth to bedrock throughout the Site. Appendix F contains the complete geophysics report.

VICINITY MAP

LEGEND

- Mine Claim Boundaries
- Adit Discharge
- Seismic Refraction Line and Station (Spreads) 17

N

0 250 500
Feet

FIGURE 3-14
SEISMIC REFRACTION LINES AND STATIONS
Bullion Mine OU6 Remedial Investigation

CH2MHILL

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3.9.4.1 Groundwater Cutoff Wall Area

Seismic refraction spreads A-A’ and B-B’ were located in the proposed groundwater cutoff wall area in the floodplain adjacent to Jill Creek in order to:

- Evaluate the thickness of sediments and depth to bedrock in an area proposed for a remedial subsurface cutoff wall.
- Evaluate the amount of weathering in the underlying bedrock to determine whether the rock is sufficiently low in permeability that a barrier keyed into the rock will function as intended.

The seismic survey indicated that the depth to bedrock ranged from approximately 10 feet bgs near the northwest end of the A-A’ spread to approximately 5 feet bgs at the southeast end.

The seismic P-wave velocities of the underlying granitic bedrock layer in this area range from approximately 8,000 to 13,000 feet per second (fps). Typical seismic P-wave velocities in granitic rock range from 15,000 to 19,000 fps. The variability is due to the degree of weathering, fracturing, and saturation of the rock mass. The P-wave velocities observed at this Site indicate that the granitic rock is likely to be moderately weathered and fractured.

3.9.4.2 Bullion Mine Long Profile

Seismic refraction spreads C-C’ and D-D’ were located along a profile parallel to the trend of the Bullion vein and mine workings. The seismic refraction spreads along this path were conducted in order to:

- Evaluate the thickness of sediments and depth to bedrock underlying the length of the Bullion Mine to select optimal locations for the monitoring well and piezometer installation (to evaluate the sediment/rock interface in the proposed piezometer locations).
- Evaluate the amount of weathering and fracturing in the underlying bedrock.

Because spread C-C’ was 2,400 feet long and crossed a variety of terrain, many variations in the seismic velocities and depth to rock existed. Therefore, the variations in “depth to rock” in part represent irregularities (highs and lows, cuts and fills, etc) in the present ground surface.

The results of this portion of the seismic survey could be divided into two general sections: from the beginning of the line (Spreads or Stations 5 through 9), and the remainder of the line (Spreads 10 through 20).
Spreads 5 through 9 traversed from the north side of Jill Creek, across the floodplain, and up the slope below the discharging lower Bullion Adit. The seismic spread in this area indicated that the depth to bedrock ranged from approximately 8 feet bgs under the Jill Creek floodplain, between 10 and 15 feet bgs up the slope below the Bullion adit, to as shallow as 5 feet near the lower Bullion adit portal. This is consistent with interpreted conditions that a lobe of fill materials and glacial till mantles the lower slope. P-wave velocities of the underlying granitic bedrock in this area ranged from approximately 6,000 to 9,000 fps which is low for granitic rock and indicates that the rock under this area is likely to be moderately to highly weathered and fractured.

Spreads 10 through 20 traversed from the discharging lower Bullion Adit along the trend of the Bullion vein to above the uppermost adit. This area is underlain by a veneer of sediment (primarily colluvium) and has also been reworked and regraded during previous mine excavations, reclamation activities, and road building. Thus the topography is irregular and contains several cuts and fills. The seismic spreads across this area indicated that the depth to bedrock ranged from approximately 5 feet bgs to as much as 20 feet bgs. These depths can be considered consistent with the slope configuration, where the rock is slightly deeper under the filled or disturbed portions of the slope. The seismic P-wave velocities of the underlying granitic bedrock layer along this spread are typically in the range of 5,000 fps, which indicates that the granitic rock under this area is likely to be moderately to highly weathered and fractured and is generally poor rock mass. This is consistent with the spread overlying the weathered and altered ore vein and also confirmed by the findings of the drilling investigation.

3.9.5 Local Groundwater Flow and Quality

In the immediate vicinity of the Bullion Mine, groundwater inflow into the underground workings originates primarily from infiltration of precipitation and snowmelt through a shallow soil profile, fractured/weathered bedrock, and collapsed historic mine features such as shafts and open trenches above the extensive underground mine workings. Shallow groundwater discharges at the Site through springs, seeps, diffuse seepage into Jill Creek, and discharge from the lower Bullion Mine adit. The Site Conceptual Model (Figure 2-3) shows a general geologic and hydrologic cross-section that demonstrates the groundwater levels, groundwater recharge pathways, and groundwater discharge as springs and adit flow.

Monitoring wells (MW-1 through 4) and piezometers (P-1 through 6) were positioned and constructed to evaluate an upgradient- to downgradient hydrogeologic section, measure depth to first water, determine water bearing zones, observe groundwater movement, and characterize the groundwater chemistry and COI concentrations. The soil borings and monitoring wells illustrated that the first groundwater occurred within shallow weathered and fractured bedrock, rather than the soil-bedrock interface. In contrast, Boring MW-5 was intended to directly intercept the lower adit, assess the depth of pooled water within the lower adit, and facilitate future monitoring/sampling of this water. As described above, recurring water level measurements indicate that the mine stays flooded with slight fluctuations of hydrostatic head.

Static water level measurements were collected from the monitoring wells and piezometers to evaluate the groundwater occurrence and movement in the vicinity, an important condition to understand when designing a remedial action alternative. Table 3-17 provides a summary of the groundwater measurements conducted between summer of 2010 and summer of 2012. As previously discussed, Figure 3-12 shows a water table contour map of the vicinity, based on the groundwater measurements in the monitoring wells and piezometers. Shallow groundwater flow direction follows Site topography in the direction of Jill Creek. It appears that groundwater is several feet higher during earlier summer (July) versus the fall (late September), as evidenced by the groundwater levels. This supports the assertion that the shallow groundwater system is recharged by local seasonal snowmelt and infiltration. In addition, the level of water in the mine (BM-B-1/MW-5) was 8 feet higher in July 2012 versus September 2010. This supports the theory that the flooding in the mine is due to shallow groundwater infiltrating downward through fractures and old mine workings and responds to seasonal changes in the groundwater levels.

Groundwater samples exceeded screening benchmarks for antimony, arsenic, cadmium, copper, lead, nickel, and zinc in most of the wells and piezometers. The groundwater sample collected from the adit intercept boring (MW-5) showed the highest concentrations of COIs in general. Field parameters recorded during the sampling of wells and piezometers are presented in Table 3-18. Table 3-19 presents water quality sample results from monitoring well and piezometer sampling.

TABLE 3-17
Groundwater Elevations – Bullion Mine Monitoring Wells and Piezometers

Well	Well Depth (feet)	Top of Casing Elevation (feet amsl)	Depth to Water (feet bgs)	Elevation (feet amsl)	Depth to Water (feet bgs)	Elevation (feet amsl)	Depth to Water (feet bgs)	Elevation (feet amsl)	Depth to Water (feet bgs)	Elevation (feet amsl)
Date			**Sept 24 & 30, 2010**		**18-Jul-11**		**7/23/12***		**8/26/12***	
MW-1	60.00	7704.05	54.38	7649.67	51.22	7652.83	52.56	7651.49	53.2	7650.85
MW-3	50.00	7561.34	47.35	7537.13	29.09	7532.25	31.71	7529.63	36.72	7524.62
MW-2	45.00	7584.48	35.93	7525.41	33.12	7551.36	41.54	7542.94	45.79	7538.69
MW-4	25.00	7471.68	16.68	7455.00	9.03	7462.65	12.44	7459.24	16.36	7455.32
BM-B-1 (MW-5)	80.50	7391.69	48.5	7343.19						
BM-B-1 (MW-5) (Repaired in 2011)	80.50	7386.94					40.25	7351.44	42.34	7349.35

TABLE 3-17
Groundwater Elevations – Bullion Mine Monitoring Wells and Piezometers

Well	Well Depth (feet)	Top of Casing Elevation (feet amsl)	Depth to Water (feet bgs)	Elevation (feet amsl)	Depth to Water (feet bgs)	Elevation (feet amsl)	Depth to Water (feet bgs)	Elevation (feet amsl)	Depth to Water (feet bgs)	Elevation (feet amsl)
Date			**Sept 24 & 30, 2010**		**18-Jul-11**		**7/23/12***		**8/26/12***	
Piezometer 1	9.00	7262.59	8.14	7254.45	8.31	7254.28	8.25	7254.34	8.39	7254.20
Piezometer 3	7.20	7284.83	7.31	7242.12	3.07	7281.76	2.93	7281.90	3.02	7281.81
Piezometer 2	7.30	7249.43	4.88	7279.95	6.78	7242.65	6.91	7242.52	7.49	7241.94
Piezometer 6	7.20	7087.75	2.59	7142.81	6.53	7081.22	3.25	7084.50	4.94	7082.81
Piezometer 5	7.20	7120.95	4.78	7116.17	4.18	7116.77	4.2	7116.75	4.4	7116.55
Piezometer 4	6.00	7145.40	4.61	7083.14	2.88	7142.52	2.81	7142.59	2.92	7142.48

Note:
* MW wells measurements taken at top of PVC pipe.

TABLE 3-18
Bullion Mine Groundwater Field Parameters

Site	Date	pH	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Temperature (°C)	ORP (mV)	Turbidity (NTU)
MW-1	9/23/2010	5.63	36.5	9.74	9.1	230	---
MW-2	9/23/2010	6.03	32.9	10.41	7.1	225	359
MW-3	9/23/2010	6.18	41.4	12.49	6.8	213	266
MW-4	9/23/2010	3.81	20.8	7.93	5.0	463	---
MW-5	9/23/2010	5.16	0.202	2.5	5.8	240	19
P-1	9/24/2010	4.64	0.138	7.91	8.3	222	7.9
P-2	10/10/2010	---	---	---	---	---	---
P-3	10/10/2010	6.31	0.137	8.49	8.2	-13	645
P-4	9/23/2010	5.37	0.122	8.41	8.8	175	862
P-5	10/10/2010	6.38	58.4	5.22	8.0	-57	113
P-6	10/10/2010	---	---	---	---	---	---

Notes:
Adequate sample volume was only available for lab analysis in P-2 and P-6, no field parameters recorded
µS/cm = microSiemens per centimeter
gpm = gallons per minute
mv = millivolts
NTU = nephelometric turbidity units
ORP = oxidation reduction potential

TABLE 3-19

Summary of 2010 Ground Water Analytical Results

Site	Date Sample Collected	Dissolved Metals (µg/L)													Anions (mg/L)		Alkalinity (mg/L)[f]	
		Al	Sb	As	Cd	Cu	Fe	Pb	Mn	Ni	Se	Ag	Tl	Zn	Cl [f]	SO_4^{2} [f]	Total	$CaCO_3$
MONITORING WELLS																		
MW-1	9/23/2010	33.6	**35.1**	**5.0**	**1.2**	**38.2**	200	**2.2**	1,460	**13.2**	0.50U	---	0.10U	**73.3**	2.9	31.9	33.0	33.0
MW-2	9/23/2010	25.1	0.50U	**0.51**	**0.13**	**19.4**	50.0U	**0.1**	115	**1.7**	0.50U	---	0.10U	**40.2**	1.0U	80.2	28.4	28.4
MW-3	9/23/2010	28.4	**3.1**	**64.4**	**0.39**	**15.7**	50.0U	**3.7**	70.6	**2.4**	0.50U	---	0.10U	**100**	1.0U	24.6	16.1	16.1
MW-4	9/23/2010	280	0.50U	**23.3**	**45.6**	**1,100**	168	**0.65**	1,240	**10.8**	0.50U	---	0.10U	**3,260**	1.0U	54.7	5.0U	5.0U
ADIT INTERCEPT BORING																		
MW-5	9/23/2010	280	0.50U	**1.5**	**62.4**	**148**	13,300	**43.2**	25,000	**255**	**0.78**	---	**0.11**	**51,200**	2.1	2,080	7.7	7.7
PIEZOMETERS																		
P-1	9/24/2010	7,980	0.50U	**33.4**	**165**	**2,180**	14,00	**2.1**	23,200	**108**	**2.2**	---	0.10U	**33,200**				
P-2	10/1/2010	26.2	**0.74**	**432**	**0.13**	**2.6**	51,500	0.10U	14,200	**4.7**	0.50U	0.50U	0.10U	**78.1**				
P-3	10/1/2010	23.9	**1.3**	**25.6**	**1.9**	**0.86**	7,890	**0.46**	34,800	**50.0**	0.50U	0.50U	**0.16**	**3,220**				
P-4	9/23/2010	327	0.50U	**4.6**	**226**	**832**	492	**0.9**	8,140	**103**	0.50U	---	0.10U	**37,500**	1.4	878	5.0U	5.0U
P-5	10/1/2010	11.4	**3.2**	**1.9**	0.08U	0.93	11,500	0.1U	2,780	**17.4**	0.50U	0.50U	0.10U	**47.5**				
P-6	10/1/2010	18.8	**1.0**	**1.3**	0.08U	0.5	9,890	0.10U	1,210	**7.4**	0.50U	0.50U	0.10U	**39.1**				
Screening Levels (mg/L)		***---***	***0.006***	***0.01***	***0.005***	***1.3***	***---***	***0.015***	***---***	***0.1***	***0.05***	***0.1***	***0.002***	***2.0***				

Notes:

Piezometers water yield was limited for sampling – no field parameters recorded.

All results are dissolved concentrations

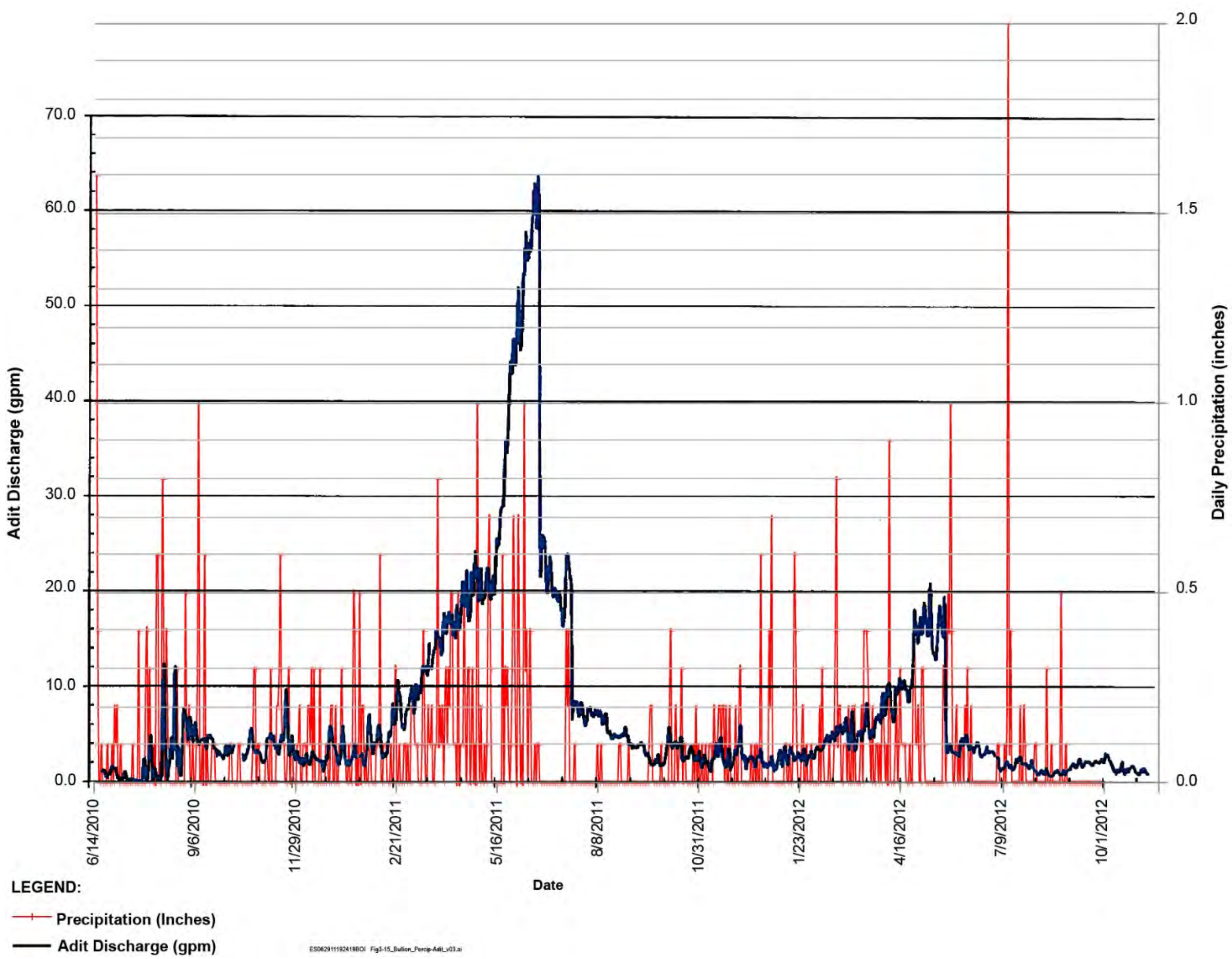
* See Tables 1-10 through 1-12 for Screen Level benchmarks (bold values indicate exceedance of screening benchmarks); **Bolding indicates value exceeds screening level.**

U = less than detection limits

The extent of the topographic area contributing to the recharge is unknown, but existing information (MBMG, 2012) suggests that the travel time from surface to underground workings is relatively short. By way of evidence for this statement, the following items were considered:

- On the basis of an empirical analysis of groundwater velocity and travel time using hydraulic conductivity estimates and travel distance, it is estimated that water could infiltrate from the surface and reach the mine workings in as a little as a few days to several months. However, the contributing area to the mine is not easily defined and it is not known whether the groundwater travels as seepage through a network of fractures, or along a few single large fracture systems.
- Figure 3-15 shows a graph of local daily precipitation from 2010-12 (Rocker Peak SNOTEL Station) superimposed on daily discharge from the Bullion Mine adit (MBMG, 2012). The purpose of this activity was to assess whether major recorded precipitation events or snowmelt could be matched with corresponding surges in adit discharge. These data appear to show pattern similarities, where precipitation and snowmelt runoff in April and May are followed by a corresponding spike in adit discharge in late April through June followed by a slow sustained drawdown in October through January. These events appear to be offset by a lag period of 2 to 3 weeks. The pattern presented by the data is not sufficiently clear to correlate, with confidence, significant individual precipitation or snowmelt events with discernible "spikes" in the adit discharge, however a seasonal response pattern is pretty clear.

FIGURE 3-15
2010-2012 Daily Precipitation Superimposed on Daily Adit Discharge



- Distinct seasonal fluctuations in discharge from the Bullion Mine's lower adit were documented by the USGS quarterly monitoring results (1999–2010). These data support a local recharge source with seasonal influence on adit discharge.
- In 2010–2011, MBMG collected water samples from the adit discharge, analyzed them for oxygen and hydrogen isotopes, and compared them to regional meteoric water quality data to assess the potential recharge source of the discharge. Findings indicated that the isotopic data from the adit discharge, when plotted with the regional meteoric water quality data (represented as the Meteoric Water Line), fell close to the meteoric water line. These data 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, 2012)

No groundwater discharge is currently emanating from the upper adit, which indicates that the groundwater level is below the elevation of the upper workings.

3.10 Surface Water and Groundwater Geochemistry

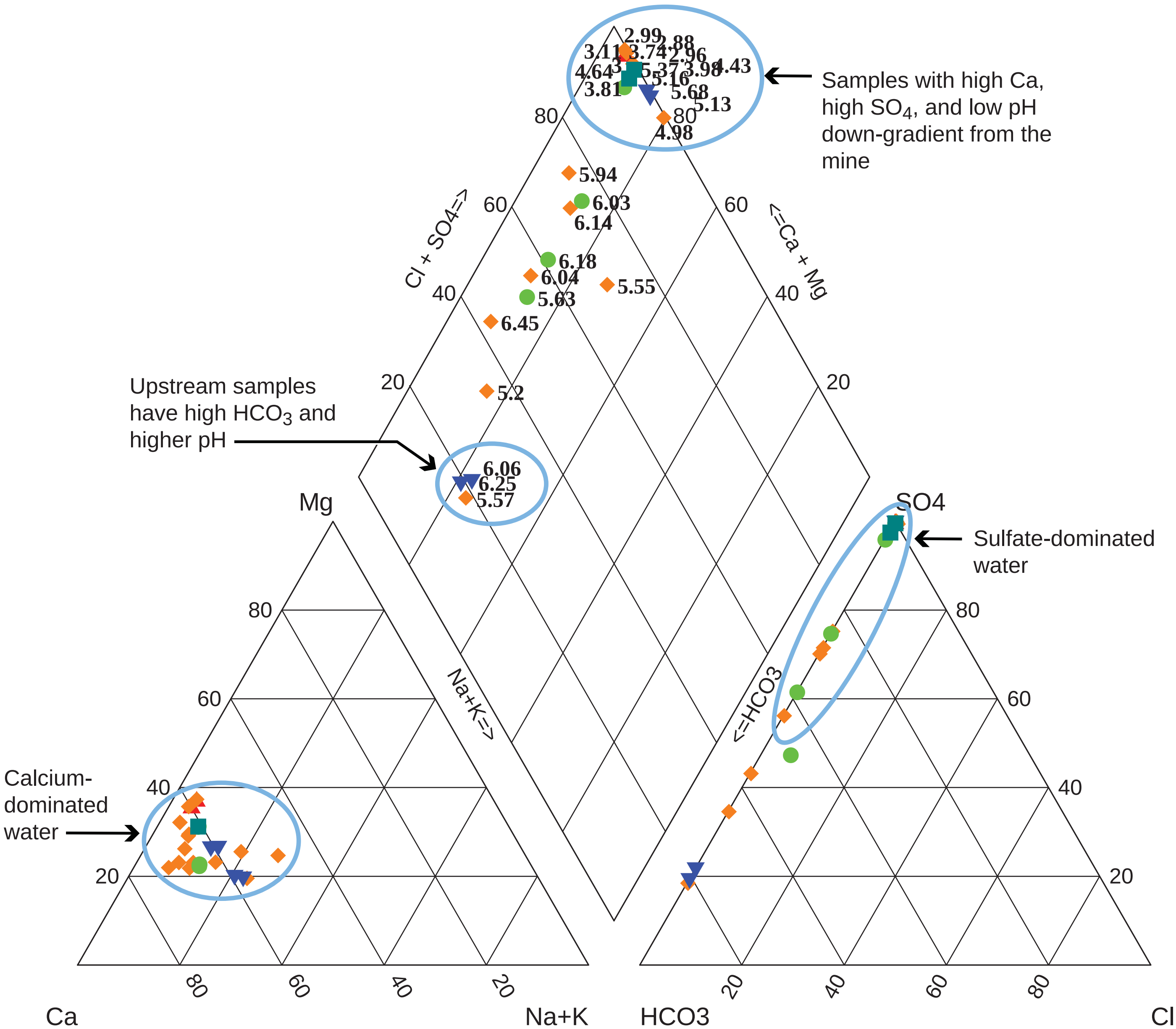
Surface and groundwater quality at the Site have been influenced by historic mining related activities and waste. The purpose of this section is to characterize the extent of that influence based on available data and data collected during the 2010 field season.

Surface water and groundwater samples were collected at the Site in July and September-October 2010. Samples were collected at four locations in Jill Creek (JC-1 through JC-4), at 14 springs (SPG-01 through SPG-14), at two adit locations (Adit and Adit Channel), at five monitoring wells (MW-1 through MW-5), and at six piezometers (P-1 through P-6). The creek, spring, and adit samples were analyzed for all general chemistry parameters along with total and dissolved concentrations of selected trace metals (aluminum, antimony, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, thallium, and zinc). The well and piezometer samples were not analyzed for total metals, including major cations (sodium, potassium, calcium, magnesium). Piezometers P-2, P-3, P-5, and P-6 were also not sampled for major anions (chloride, bicarbonate {alkalinity}, and sulfate) because of limited sample volume. Field parameters (pH, specific conductivity, dissolved oxygen, temperature, oxidation-reduction potential, and turbidity) along with dissolved iron and manganese were measured in all samples.

For the samples described previously in which major cation data were not available, concentrations of each were estimated by assuming the same relative percentages of each cation as were found in the average of samples with similar sulfate content. Sulfate content was sorted into three groups of low, medium, and high, based on the relative percentage of sulfate equivalents among all anions. Because cation percentages are very similar among all samples, this is not assumed to create a significant error. These estimations were made for the purposes of creating geochemical Piper and Stiff diagrams, which are described in the following text.

The water samples can be characterized by two broad categories with clear chemical distinctions: those affected by the mine and associated mineralization and those that are not. The mineralized zones that were mined are rich in sulfides and contain smaller amounts of COIs. When the sulfides are exposed to oxygen and water as a result of mining activity, the sulfides become oxidized to sulfate, producing acid and mobilizing COIs.

This chemical signature is illustrated most clearly on the trilinear (Piper) diagram in Figure 3-16. The purpose of this diagram is to permit cation and anion compositions of many samples to be shown on a single graph where trends or groupings can be discerned. The Piper diagram is convenient for showing the mixings of two waters from different sources, which will plot on a straight line joining the two points. The relative percentages of major cations are plotted on the lower left triangular diagram. Sodium and potassium are grouped together because of their geochemical similarity. Calcium and magnesium occupy the other two corners of the triangle. All water samples from the Site show calcium dominance. The anion triangle (lower right) similarly plots chloride, bicarbonate, and sulfate percentages. A large fraction of the samples plots on or near the sulfate corner, indicating sulfate accounting for nearly all of the anion concentration. The cation and anion plots from the two triangles are then projected onto the diamond-shaped field to provide a single point for each sample.



Legend	
▲	Adit
▼	Jill Creek
●	Monitoring Well
■	Piezometer
◆	Spring
6.06	pH

Notes:

1. pH are field measured.
2. All samples collected in September-October, 2010, except BS-2 collected July 2010.

FIGURE 3-16
PIPER DIAGRAM OF
BULLION WATER SAMPLES
Bullion Mine OU6 Remedial Investigation

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Samples from the September–October 2010 event are used in the diamond shaped plot, as the data from that event were more complete than the data from July 2010 episode. The one exception was for SPG-2, in which the July 2010 analysis was used because the spring was dry in September. Within this diagram, the field-measured pH is shown next to each sample point. Note that the samples occupying the top corner of the diamond (indicating sulfate dominance) are nearly all strongly acidic (pH under 5.6). These samples include both of the adit samples, the two piezometer samples with anionic data (P-1 and P-4), and half of the spring samples. The remaining samples are scattered away from the upper corner and show more variable content and higher pH. The samples that are furthest from the acid-sulfate mine signature are the two upstream Jill Creek samples (JC-1 and JC-2) and an upstream spring sample (SPG-08). These samples have bicarbonate dominance (around 80 percent of anion equivalence) rather than sulfate. The samples plotting between these and the samples at the upper point are most likely mixtures of these end members.

Concentrations of many COIs tend to correlate with pH and sulfate content because lower pH and higher sulfate concentrations are indicators of mining influence and mineralization (see Figures 3-16 and 3-17). The metals that are cations at low pH (all six of the analyzed trace metals except arsenic) are only stable in water at elevated concentrations under acidic conditions. When the pH rises above 5, the metals are mostly removed from solution by adsorption and precipitation reactions. The plot in Figure 3-17 shows this trend for copper, and similar relationships were observed for aluminum, cadmium, lead, and zinc. The USGS has been collecting samples at the adit since 1999 (USGS, 2011), and their data show a distinct seasonal fluctuation of sulfate and trace metals, with the highest concentrations appearing in mid-summer during the lowest precipitation period. Rainfall infiltration therefore acts to dilute the adit water during wetter months. The July 2010 sampling event occurred two days prior to the USGS adit sampling event, and the adit sample concentrations were mostly in agreement within analytical uncertainty (typically ±20 percent).

Arsenic exists as an anion in solution ($H_2AsO_4^-$ or $HAsO_4^{2-}$ in this pH range) and, therefore, shows a more scattered relationship with pH compared to the cationic trace metals. Arsenic is most commonly associated with the mineral pyrite (iron sulfide), and when pyrite dissolves, arsenic is released to solution. At higher pH, arsenic will tend to be associated with iron oxides that begin to form, either as a coprecipitate or adsorbed onto the surfaces of these minerals. Because iron oxides can commonly pass through sample filters, adsorbed arsenic may be counted along with dissolved arsenic. The abundance and availability of adsorbant minerals will determine how much dissolved arsenic is removed from solution as the pH rises, and because of its negative charge the tendency towards adsorption decreases with increasing pH. All of these factors produce a more scattered distribution of arsenic concentrations in measured samples.

Elevated sulfate is an indicator of the oxidized sulfide mineral source of these metals, so correlation with the trace metals is expected. Figure 3-18 shows the relationship of zinc versus sulfate as an example, but similar trends exist for the other metals.

A map view of the chemistry distribution is provided on Figures 3-19, 3-20, and 3-21. In this case, Stiff diagrams are used to show the variation of chemistry in different locations. A Stiff diagram shows the concentrations (in milliequivalents per liter [meq/L]) of cations on the left and anions on the right, with no vertical numeric scale. The more dominant ions are shown as the larger polygons in the plot. Larger diagrams indicate higher total dissolved solids (TDS). Each diagram serves as a fingerprint of the water chemistry, with different water types easily distinguished by changes in shape and size. Because the water samples showed a large range in TDS, the Stiff diagrams were made with two scales, color-coded on these figures. The blue diagrams represent low-TDS water (calculated TDS of around 400 mg/L or less) while the orange diagrams depict higher-TDS water, ranging up to about 2,900 mg/L. Note that the orange scale is about seven times that of the blue scale. In addition, the field-measured pH is provided with each diagram. The pH of pure water in equilibrium with atmospheric carbon dioxide is around 5.6, and this pH was used as a rough distinguisher between acidic and neutral waters, with pH values below 5.6 (acidic waters) plotted in red.

In Figures 3-19, 3-20, and 3-21 nearly all of the high-TDS (orange) Stiff diagrams have acidic pH values. These waters represent the most abundant mineralized zones that have been subjected to sulfide oxidation. On the contrary, however, not all low-TDS waters are neutral. A few have the same low-pH/high-sulfate signature as the high-TDS samples (for example, SPG-2, MW-4). These likely represent areas where sulfide oxidation is still producing acidity, but the soluble mineral content is lower in these areas. In other cases, low-TDS water still shows sulfate dominance but the pH is less acidic or even neutral (for example, SPG-07, SPG-12, SPG-14, and MW-2). These data may represent waters that have been partially neutralized by mixing with fresh water, which also reduces the TDS.

Other low-TDS samples appear to represent various mixtures of fresh water from local rainfall runoff and the mineralized more acidic groundwater.

The Jill Creek water chemistry changes significantly at the confluence with the Adit Channel. Upstream of this confluence, samples JC-1 and JC-2 are mixed-ion with pH greater than 6; downstream samples JC-3 and JC-4 are sulfate-dominated with pH in the 5.1-5.7 range (the July 2010 samples showed pH values below 5). Though the calculated TDS is still low in the downstream samples, it is roughly triple that of the upstream samples, so the creek has clearly picked up salts and acidity from the Adit Channel, groundwater, and runoff from barren areas where mineralized material is exposed.

According to Montana State University student studies (Montana State University, 2003), concentrations of redox indicators ferrous iron and As^{+3} both decrease sharply between adit and adit channel water near the discharge to Jill Creek, indicating more oxidizing conditions at the discharge point, as expected. However, the Montana State University data for fresh adit water indicate strongly reducing conditions, in contrast to the field parameter data reported for this study (Table 3-5), which show elevated dissolved oxygen and oxidation reduction potential values. Additional measurements of field parameters and redox-sensitive constituents are recommended below to verify these conditions prior to implementation of a remedy. Better understanding of redox evolution of the mine-affected waters will enable a more effective remedy design.

Based on the Stiff diagram map in Figures 3-19, 3-20, and 3-21 the most impacted groundwater and surface water may be traced by connecting the diagrams that are either shaded orange or have pH below 5.6 (red font). For the Site, this starts with MW-4 on the upstream end and follows a northwest-north curving line through MW-5, the Adit, SPG-04, SPG-05, and up through the Adit Channel. Other groundwater samples on either side of this line are less affected by various degrees, likely reflecting variations in hydraulic connection, degree of mineralization, and mixing with fresh water sources. Note that on Figure 3-19 the sample at MW-5 shows high TDS, low pH water chemistry. This sample was collected from the adit intercept boring and actually represents water that resides inside the adit itself, in contrast to the other monitoring wells that are completed in the uppermost water-bearing weathered granitic rock.

The pattern of chemical signatures suggests that the acidic, high-sulfate water containing elevated trace metals is concentrated in and around the main adit channel of the mine workings.

3.11 Water Volume in Bullion Mine Workings

On the basis of the information from the spring/seep inventory and sampling, old mine mapping, and the water level measurements from 2010 to 2012 in the lower adit intercept boring (MW-5), the concept of stored mine water (volume of water trapped behind the collapsed portion of the lower adit) was investigated. In the reducing environment of a sealed mine adit, this water is anticipated to be moderately acidic (pH 5.16, but becoming more depressed when exposed to the atmosphere) and high in metallic constituents; therefore, it will require treatment prior to removal and discharge.

Two general scenarios were initially evaluated to estimate the volume of water in the flooded mine workings intercepted by boring MW-5. Each scenario reflects a different assumption with respect to grade and size of the adit without regard for potential water storage within mine features resulting from ore removal beyond the adit (for example, stoped areas). Table 3-20 provides a rough estimate of the volume of water potentially stored within the mine workings.

FIGURE 3-17
Trace Metal Trends: Copper Concentrations vs. pH

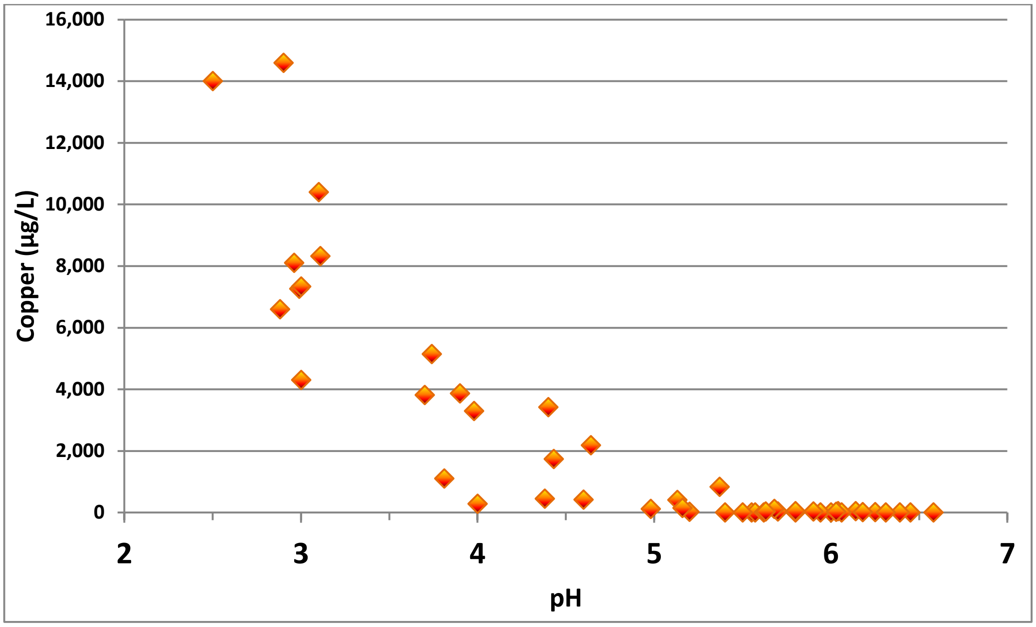
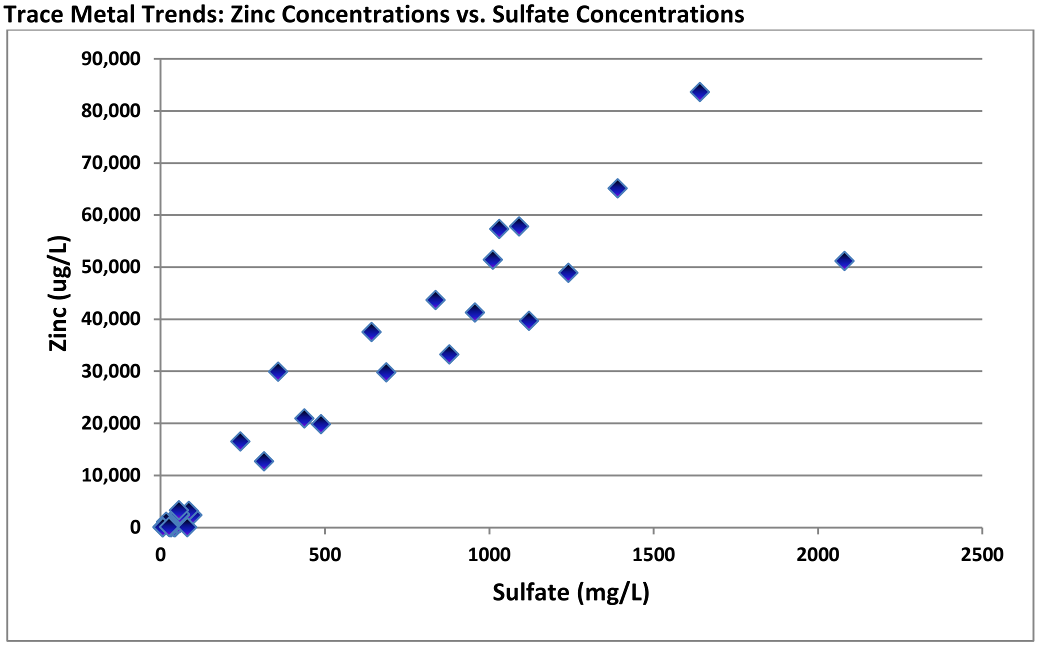


FIGURE 3-18
Trace Metal Trends: Zinc Concentrations vs. Sulfate Concentrations



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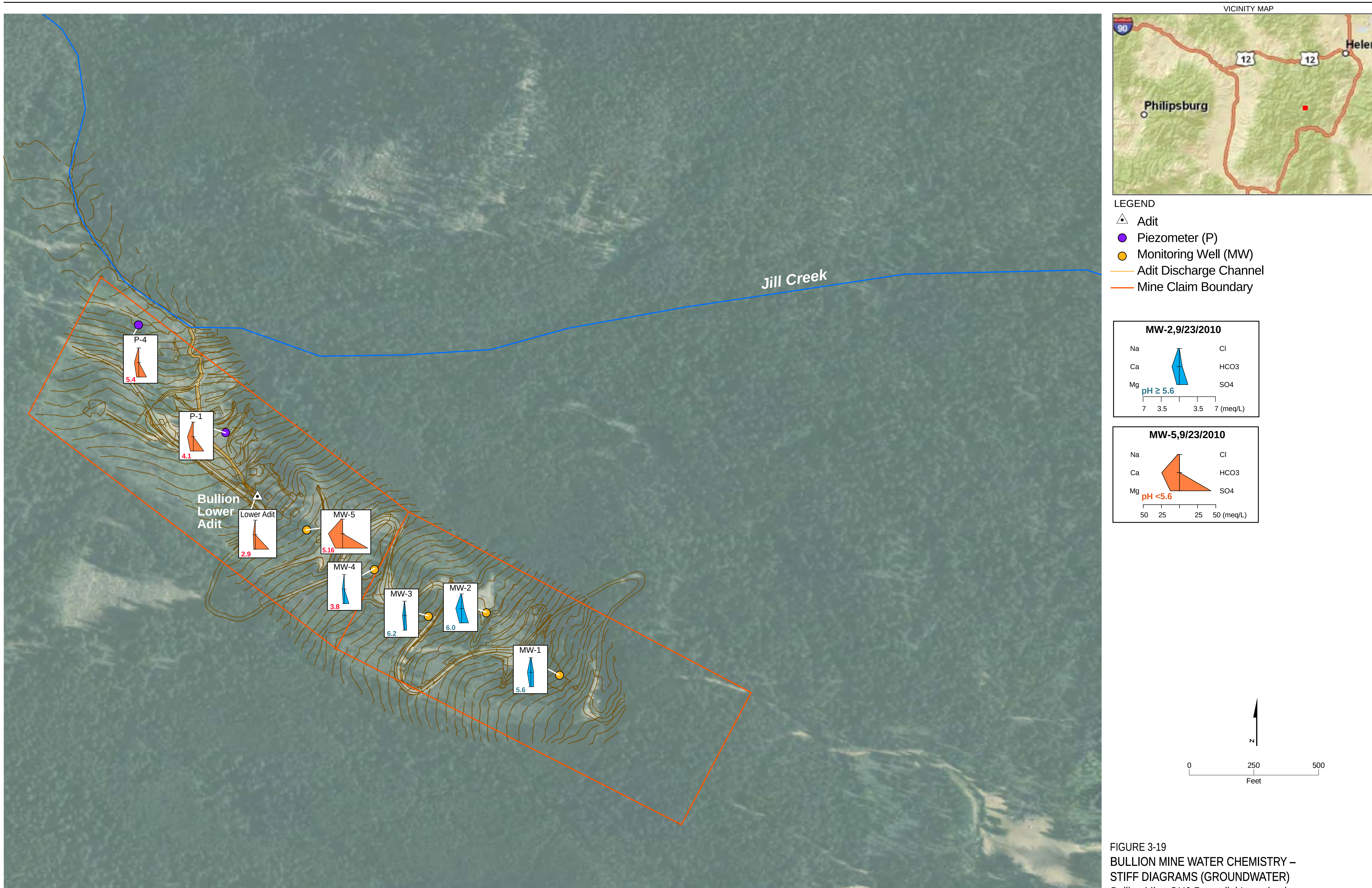

FIGURE 3-19
BULLION MINE WATER CHEMISTRY – STIFF DIAGRAMS (GROUNDWATER)
Bullion Mine OU6 Remedial Investigation

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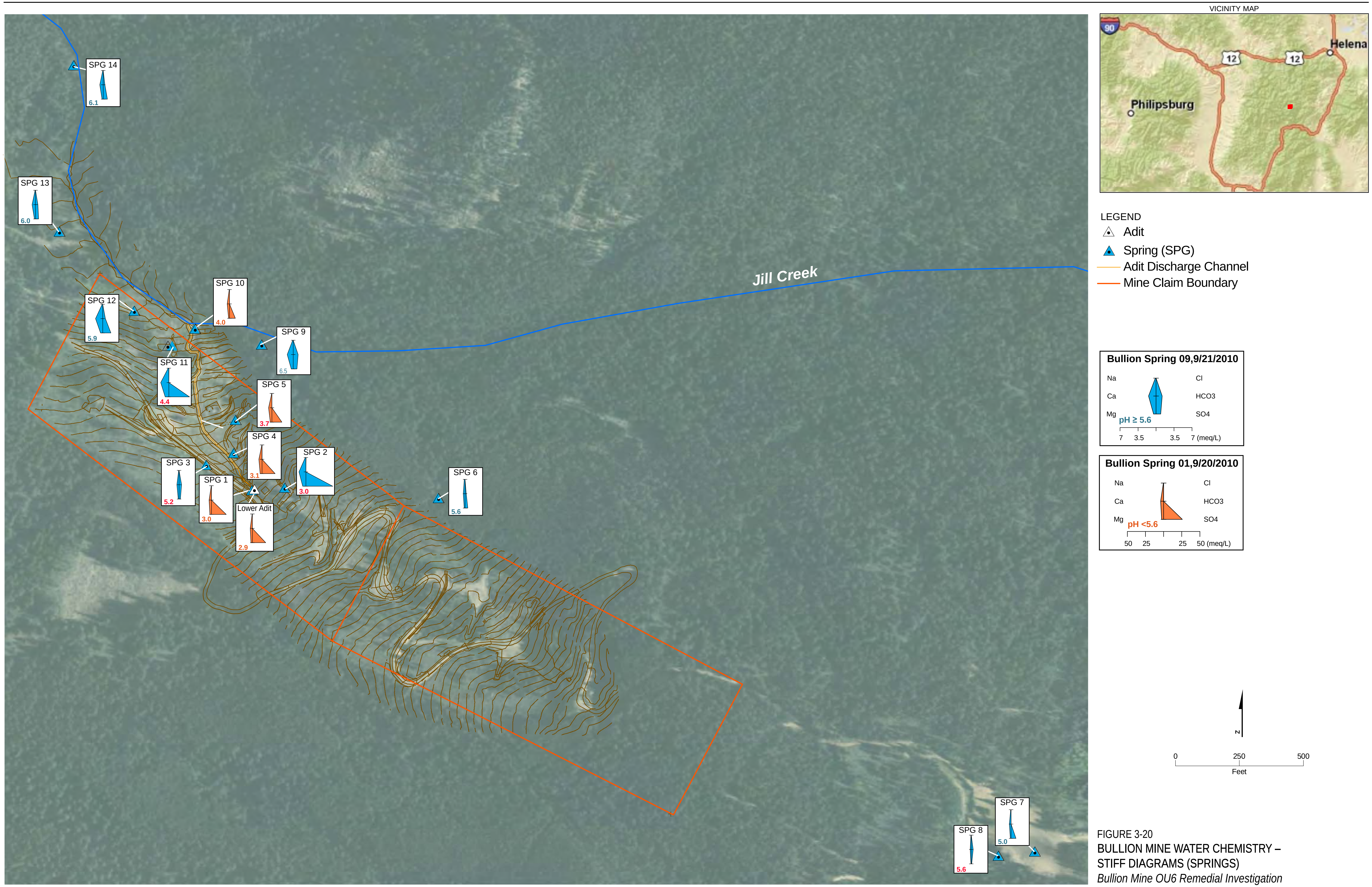

FIGURE 3-20
BULLION MINE WATER CHEMISTRY –
STIFF DIAGRAMS (SPRINGS)
Bullion Mine OU6 Remedial Investigation

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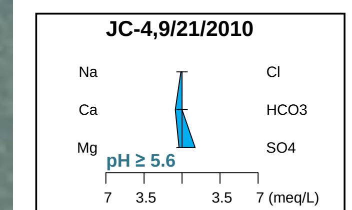
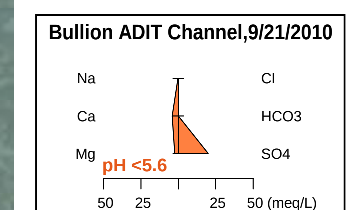
VICINITY MAP

LEGEND

- Adit
- Jill Creek (JC)
- Adit Discharge Channel
- Mine Claim Boundary





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Feet

FIGURE 3-21
BULLION MINE WATER CHEMISTRY –
STIFF DIAGRAMS (SURFACE WATER)
Bullion Mine OU6 Remedial Investigation

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TABLE 3-20
Potential Volume of Stored Water in Mine Workings Beyond Boring MW-5

	Scenario 1	Scenario 2	Worst Case Scenario*
Grade (incline) of mine workings	2 percent	3 percent	3 percent
Flooded distance (feet)	1,275	1,175	2,000
Assumed dimensions of adit (feet)	6 by 8 8 by 8	6 by 8 8 by 8	8 by 8 16 by 22
Adit volume in cubic feet			
8 by 8 feet	79,440	56,640	83,200
16 by 22 feet	102,720	73,387	246,400
Adit volume in gallons			
8 by 8 feet	594,211	423,667	624,000
16 by 22 feet	768,346	548,932	1,848,000
Estimated Total (gallons)	**1,400,000**	**972,600**	**2,500,000**

Notes:
**Worst Case Scenario*
Mine is 8 by 8 and full in first 700 feet (8 feet of head)
Mine is mined out (16 by 22 feet) according to maps from 700 to 1,300 feet, and water from 27 to 16 feet deep (22 average) and up to 16 feet wide
Mine reverts back to 8 by 8 from 1,300 to 2,000 feet. Based on static water level in boring 5 and grade of adit, water is estimated to extend into the mine 2,000 feet from lower adit portal.

In early 2012, EPA anticipated conducting a removal action to dewater the mine prior to a catastrophic failure of the soil/debris plug or initiation of formal remedial action. This activity stimulated development of a third, more detailed approach to estimating the volume of pooled mine water. This approach incorporated plan view mapping, a long profile of the mine workings, water level measurements, as well as mined zones (voids) and historic information that described the general extent and width of mining. No accounting was made for potential caved areas that might reduce volume. Based on the historic mine mapping, extensive mining occurred in an area between 600 and 1,300 feet from the mouth of the lower adit. In this location, 30,000 tons of ore were removed and the mining zone is up to 16 feet wide. The implications of this condition are that a large underground reservoir is potentially present in the mine.

On the basis of the measured water levels in boring MW-5, assuming a 3 percent slope, several cross-cuts, an adit size that expands from 8 by 8 feet to 16 by 22 feet (stoped area) and back to 8 by 8 feet, and a static water level projected back into the mine workings up to 2,000 feet from the adit portal, the estimated stored volume of water in the mine may be as high as 2.5 million gallons (worst-case scenario).

A conceptual model is shown in Figure 2-3, which shows the general cross-sectional layout with mined areas and elevations of the water. This information has ramifications for potential remedial alternatives.

No groundwater was observed discharging from the middle and upper Bullion adits during the investigation. The pooled water stored within the mine workings may be contributing to the numerous springs observed in the western portion of the Bullion Extension Claim in the vicinity and downgradient of the discharging lower adit (see Section 3.4.2.3). The water quality of some of the springs suggests an influence from AMD. These springs were inventoried and discharge measurements collected in the early summer and fall. The flow in most springs decreased by the fall, which indicates that these are likely fed by recharge from snowmelt and precipitation.

3.12 Aquatic Resource Investigations

A benthic macroinvertebrate inventory was conducted on Jill Creek in late August to early September 2010 to assess the relative health of aquatic biota along the Bullion Mine reach. This section describes the methods implemented and the findings of this activity. The entire benthic macroinvertebrate inventory report is presented in Appendix G.

3.12.1 Benthic Macroinvertebrate Inventory

To assess the benthic community in Jill Creek, existing USGS information was reviewed, and a new benthic survey was planned and implemented by Dan McGuire of McGuire Consulting (McGuire, 2011). Mr. McGuire is an experienced freshwater benthic macroinvertebrate insect scientist who annually performs benthic macroinvertebrate surveys for EPA on the nearby Clark Fork River OU. Results of this survey will be compared to existing pertinent USGS data.

As previously described, the Bullion Mine is located on the west slope of Jack Mountain near the head of the Jill Creek Watershed. From the top of the Site, the stream flows through approximately two kilometers of constructed stream channel to its confluence with Jack Creek. Monitoring stations were established at four sites on Jill Creek and at two sites on Jack Creek that bracket the Jill Creek confluence (see Figure 3-22).

3.12.2 Field Sampling Locations

Above the Site (Jill-1), the stream channel is entrenched, typically less than 0.5 meter wide, and lined with alders. The stream flows over predominately coarse sand and gravel and, at base flow, is generally less than five centimeters deep. Small quantities of aquatic moss grows on alder roots and on a few highly embedded boulders.

Within and downstream from the Site, the channel has been stabilized and lined with limestone boulders. Water depth during the inventory was typically a few centimeters in the high gradient channel. Monitoring sites were located immediately above (Jill-2) and below (Jill-3) the mine adit confluence. Jill-4 was located approximately 600 meters downstream from the adit.

Monitoring sites were established on Jack Creek above (Jack-6) and below (Jack-5) the Jill Creek confluence. In this reach, Jack Creek has a gradient of less than 1 percent. Riffles and pools were generally associated with woody debris, and the substrate was predominately gravel, sand, and fines. Tailings and metallic precipitants were evident throughout the stream channel and floodplain.

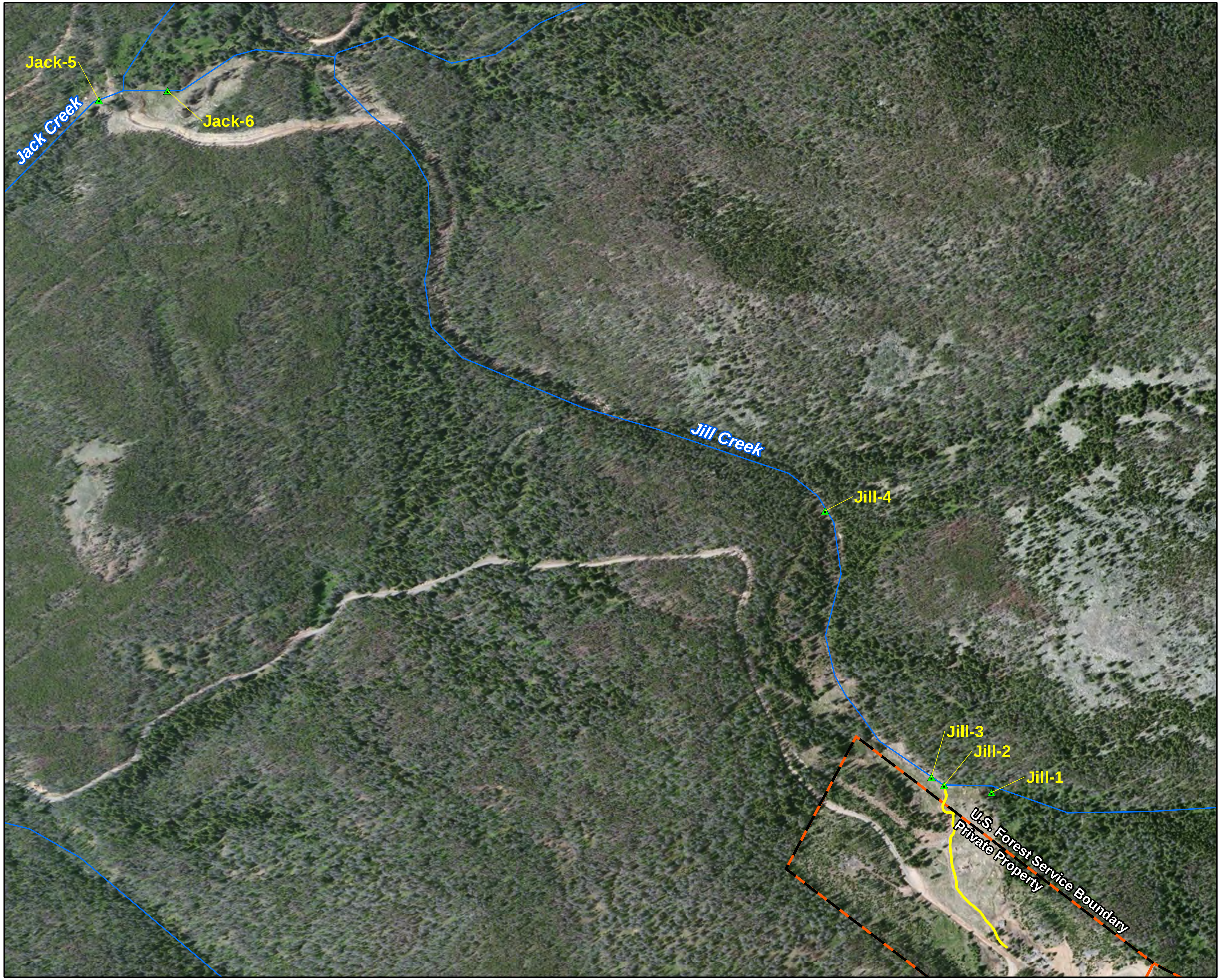
3.12.3 Field Methods

Benthic macroinvertebrates were collected at six sites during late August and September 2010. Four quantitative samples were collected at each site. Standard quantitative samplers (Hess or Surber) were precluded by minimal water depths and large, highly embedded substrates. Rather, a standard sampling area was delineated and boulders, cobbles and large gravels were hand-picked and brushed to dislodge organisms. The remaining substrate was raked with a garden claw to a depth of 2 to 4 centimeters. Macroinvertebrates were collected in a rectangular net (18 inches wide; 1,000 micron mesh) held immediately downstream from the sample area. Because of low catch rates, sampling effort (area sampled) was 0.2 square meter. Samples were preserved in 95 percent ethanol and delivered to the lab in Espanola, New Mexico.

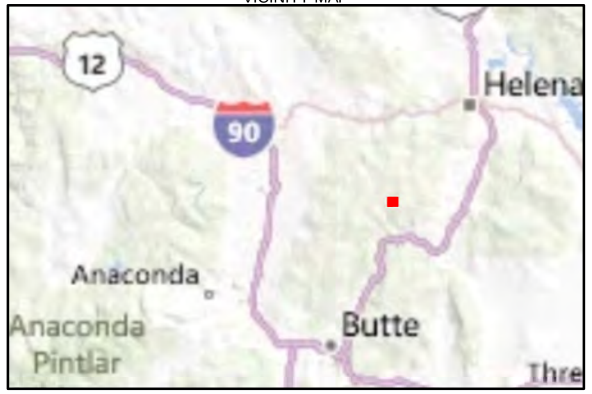
In the laboratory, samples were rinsed in a U.S. Standard 30 sieve to remove the preservative. All macroinvertebrates were removed from the sample, identified to the lowest level practical, usually genus or species, and enumerated. Data were entered into spreadsheets, which calculated a variety of metrics and summary statistics

3.12.4 Community Density

Relatively few macroinvertebrates were present in these streams. Catch rates varied from zero to 167 organisms per 0.2-square-meter sample. Density estimates ranged from 4 to 585 organisms per square meter (see Figure 3-23). Density estimates were similar for Jill Creek sites above the mine adit (Jill-1 and Jill-2) and Jack Creek upstream from the Jill Creek confluence (Jack-6). Several hundred macroinvertebrates per square meter were present at these sites. Community density was significantly lower in Jill Creek below the adit (Jill-3 and Jill-4) and in Jack Creek below the Jill Creek confluence (Jack-5).



VICINITY MAP



LEGEND

- Macro-Invertebrate Sampling Location
- Adit Discharge Channel
- NHD Stream
- U.S. Forest Service Boundary
- Mine Claim Boundary

Notes:
1. Area of interest subject to change.
2. 2011 Imagery - ArcGIS Streaming Map Service.

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0 250 500
Feet

FIGURE 3-22
BENTHIC MACRO-INVERTEBRATE MONITORING LOCATIONS
Bullion Mine OU6 Remedial Investigation

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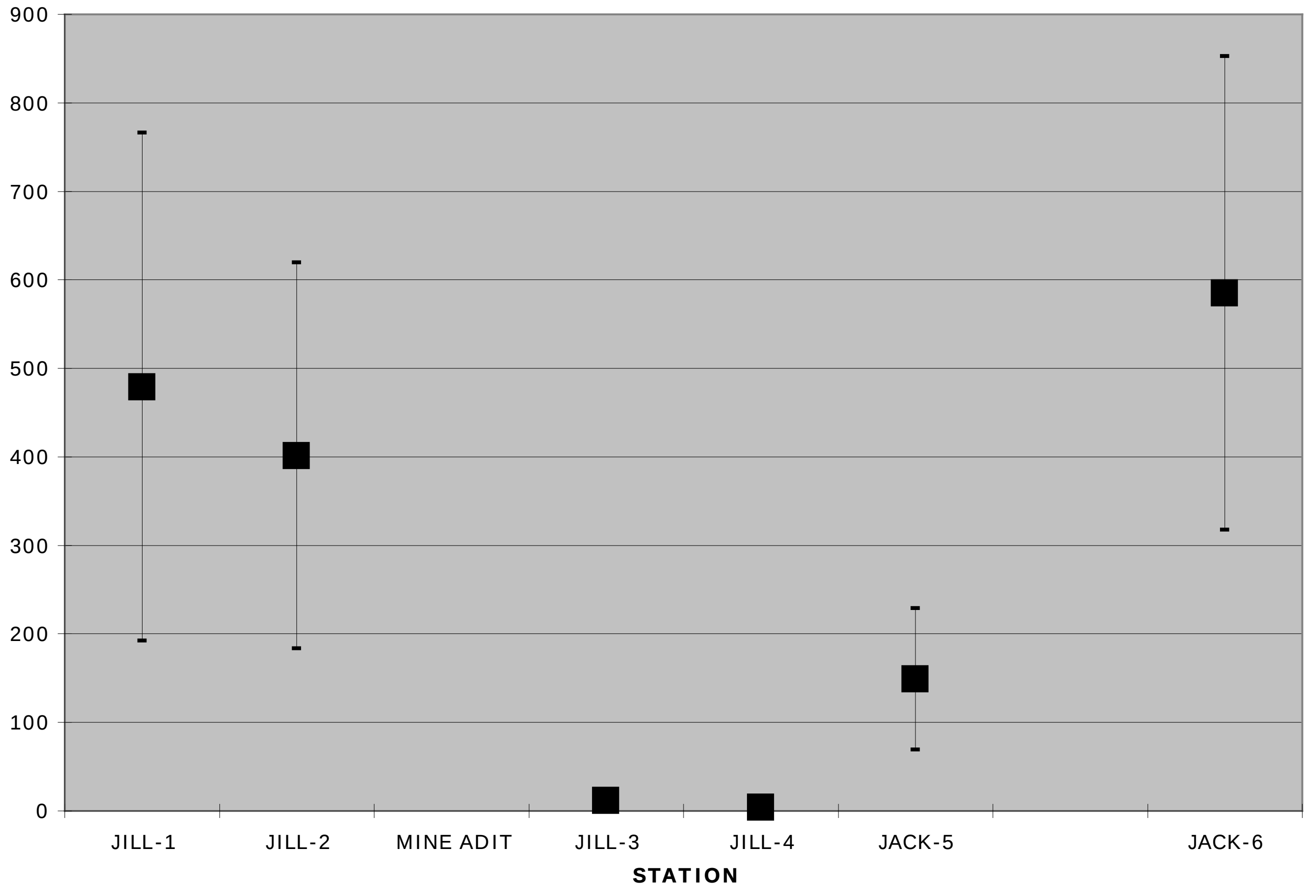
FIGURE 3-23
Mean Macroinvertebrate Community Density (±1SD) at Six Locations near the Bullion Mine



3.12.5 Macroinvertebrate Taxa Richness

Fifty-eight macroinvertebrate taxa were identified from the study sites (see Table 3-21). Mayflies, stoneflies, and caddisflies (collectively EPT) accounting for 61 percent of the taxa collected. For all samples combined, individual sites yielded from 3 to 40 taxa (see Figure 3-24). Mean taxa richness ranged from 21.75 at Jill-1 to 0.75 at Jill-4 (see Figure 3-25) and was significantly higher at sites above the mine discharge than below. In Jack Creek, mean taxa richness and EPT richness (see Figure 3-26) were noticeably higher above the Jill Creek confluence than below.

3.12.6 Macro Community Composition

The late summer macroinvertebrate fauna in upper Jill Creek and Jack Creek was dominated by stoneflies (see Figure 3-27). Mayflies were abundant at three sites but were relatively scarce at the downstream Jack Creek site (Jack-5). Dipterans replaced mayflies as the second most abundant taxonomic group at this site. Community composition analyses were not warranted for Jill Creek sites downstream from the mine adit discharge (Jill-3 and 4). Only 12 macroinvertebrates were collected from these sites.

Differences in the relative abundances of major groups reflected shifts in taxonomic composition among stations. *Heptageniid* mayflies were common in Jill Creek above the mine adit (Jill-1 and 2) and in Jack Creek above Jill Creek (Jack-6). *Diamesa*, a metals-tolerant chironomid, was present in each sample from lower Jack Creek (Jack-5), but was not collected at any other site. *Zapada columbiana* was the most abundant taxon at each site.

TABLE 3-21
Checklist of Macroinvertebrate Taxa Identified at Six Locations near the Bullion Mine, August/September 2010

Taxon	JILL-1	JILL-2	JILL-3	JILL-4	JACK-5	JACK-6
COLEOPTERA						
Heterlimnius corpulentus					X	X
Optioservus sp.					X	X
DIPTERA						
Thienemannimyia gp.	X					
Diamesa sp.					X	
Pagastia sp.	X	X			X	X
Brillia sp.	X				X	X
Cricotopus nostocladius	X					X
Eukiefferiella sp.					X	
Orthocladius sp.					X	
Parametriocnemus sp.		X				
Paraphaenocladius sp.	X					
Rheocricotopus sp.	X	X				
Tvetenia sp.	X	X				
Stempellinella sp.	X					
Micropsectra sp.	X	X				X
Dicranota sp.		X				X
Hexatoma sp.					X	
Limnophila sp.	X					
Tipulidae nr Ormosia	X					
Chelifera sp.	X					
Prosimulium sp.	X	X				
EPHEMEROPTERA	X					
Baetis bicaudatus	X	X		X		
Baetis tricaudatus					X	X
Drunella coloradensis	X	X				
Drunella doddsi					X	X
Drunella spinifera					X	X
Cinygma sp.	X				X	
Cinygmula spp.	X	X	X			X
Epeorus deceptivus	X					
Epeoris grandis		X			X	X
Rhithrogena sp.	X	X				X
Paraleptophlebia sp.	X					X
Ameletus sp.	X	X			X	X
PLECOPTERA						
Leuctridae	X					X
Visoka cataractae	X	X	X		X	X
Zapada oregenensis gp.	X	X				
Zapada columbiana	X	X	X	X	X	X
Yoraperla sp.	X	X	X			X
Sweltsa sp.	X	X				X
Megarcys sp.	X	X			X	X
Isoperla sp.	X					
Setvena bradleyi						X
Doroneuria sp.	X	X			X	X

TABLE 3-21
Checklist of Macroinvertebrate Taxa Identified at Six Locations near the Bullion Mine, August/September 2010

Taxon	JILL-1	JILL-2	JILL-3	JILL-4	JACK-5	JACK-6
TRICHOPTERA						
Arctopsyche sp.					X	
Parapsyche sp.	X	X	X		X	X
Dicosmoecus sp.					X	
Psychoglypha sp.	X	X				
Chryptochia sp.	X			X		
Lepidostoma sp.	X					X
Glossosoma sp.						X
Rhyacophila betteni gp.	X					X
Rhyacophila brunnea gp.	X	X			X	X
Rhyacophila hyalinata gp.		X	X		X	X
Rhyacophila iranda gp.	X	X	X		X	X
Rhyacophila sibirica gp.	X	X			X	X
Rhyacophila verrula	X					
ANNELIDA						
Enchytraeidae						X
TURBELLARIA						
Polycelis sp.	X	X				X
TOTAL TAXA (58)	**40**	**28**	**7**	**3**	**25**	**32**
EPT TAXA (35)	**26**	**20**	**7**	**3**	**17**	**23**

FIGURE 3-24
Total Number of Macroinvertebrate Taxa Collected at Six Locations near the Bullion Mine

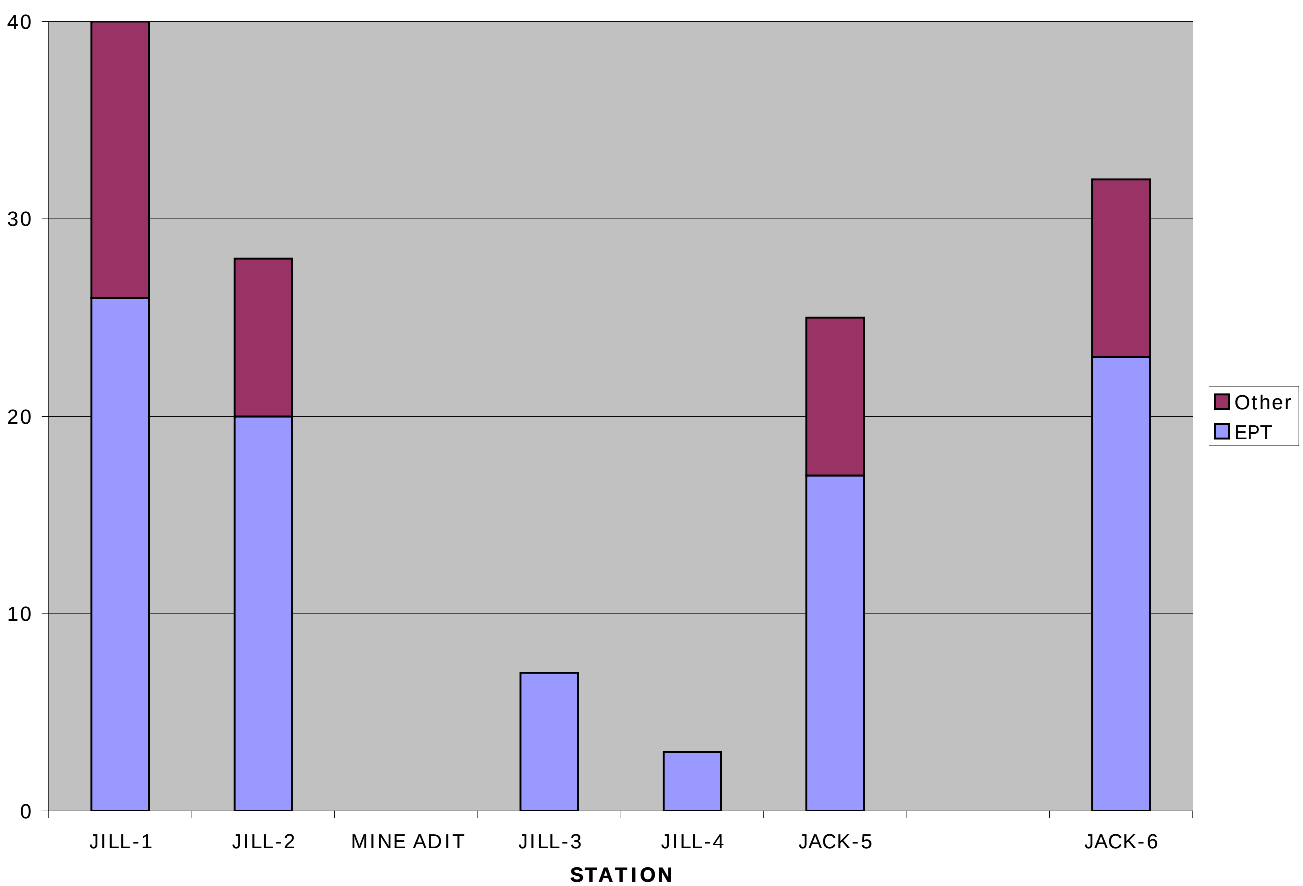


FIGURE 3-25
Mean Macroinvertebrate Taxa Richness (±1SD) at Six Locations near the Bullion Mine

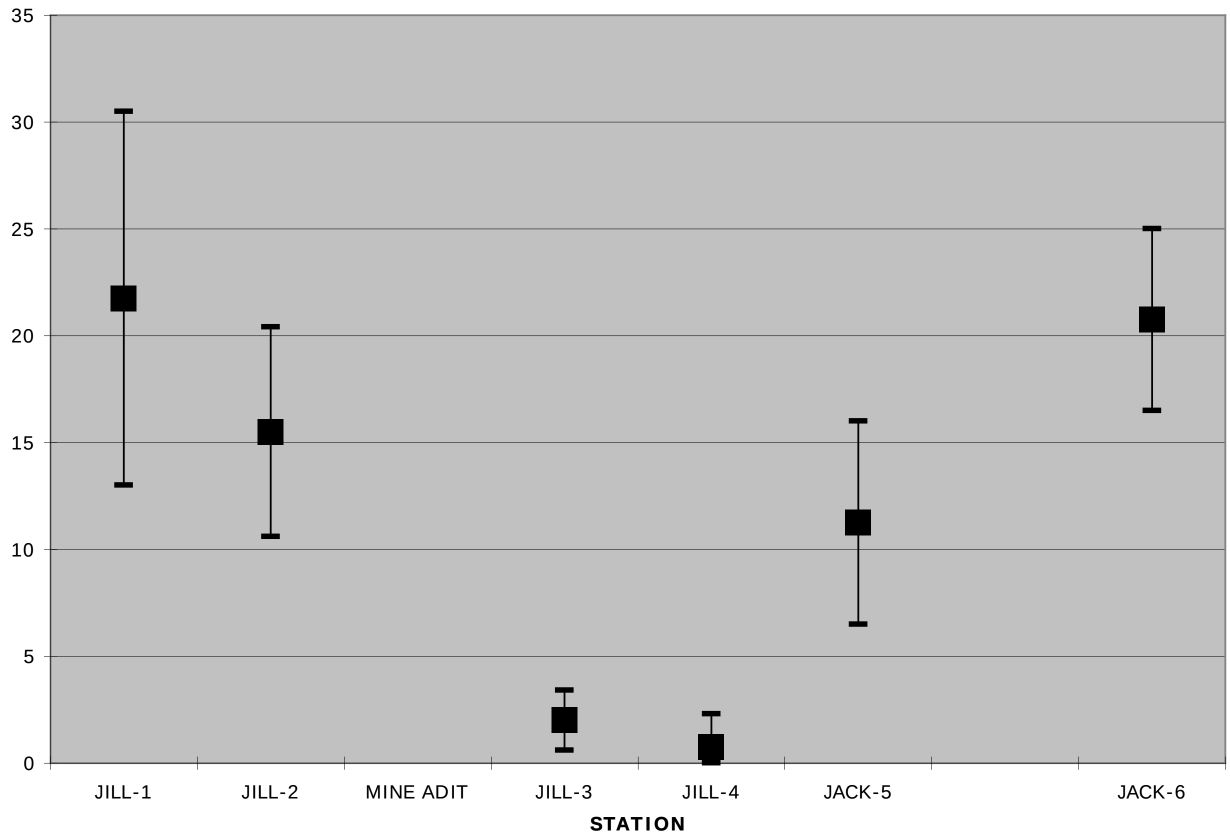


FIGURE 3-26
Mean EPT Richness (±1SD) at Six Locations near the Bullion Mine

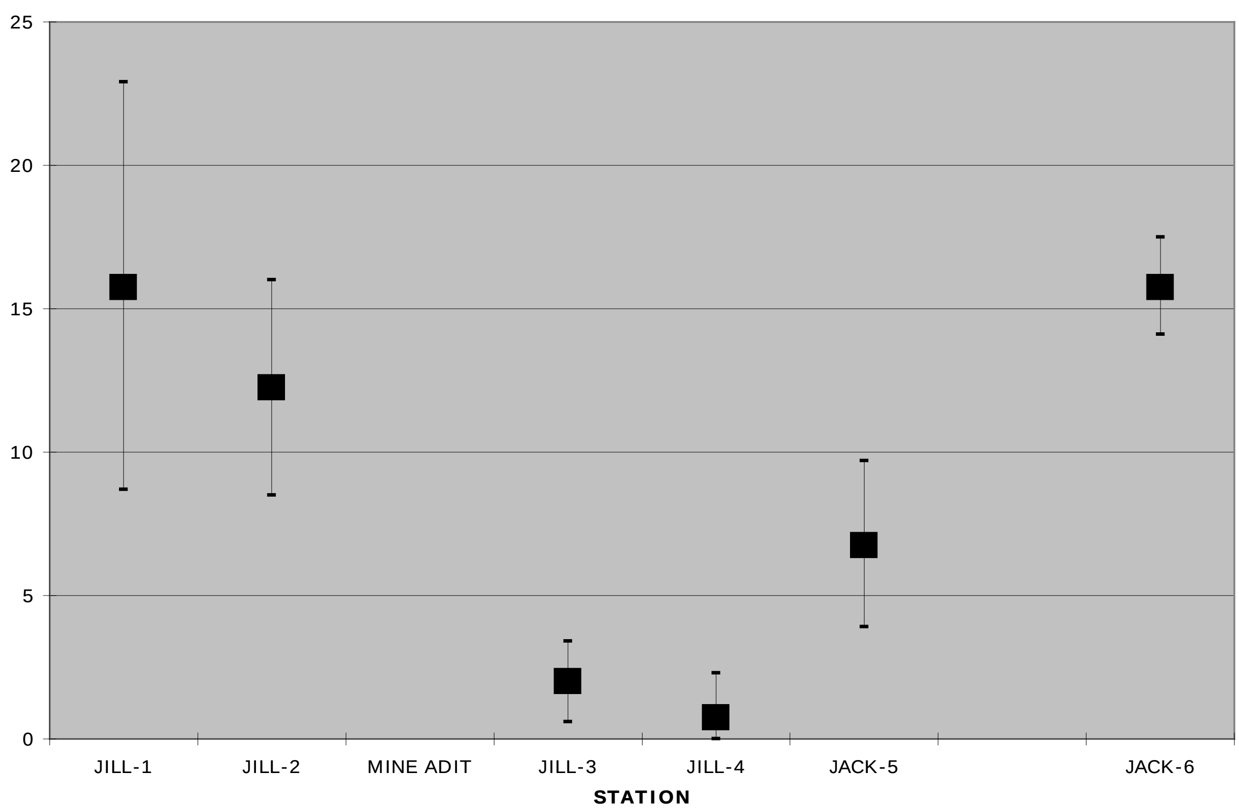
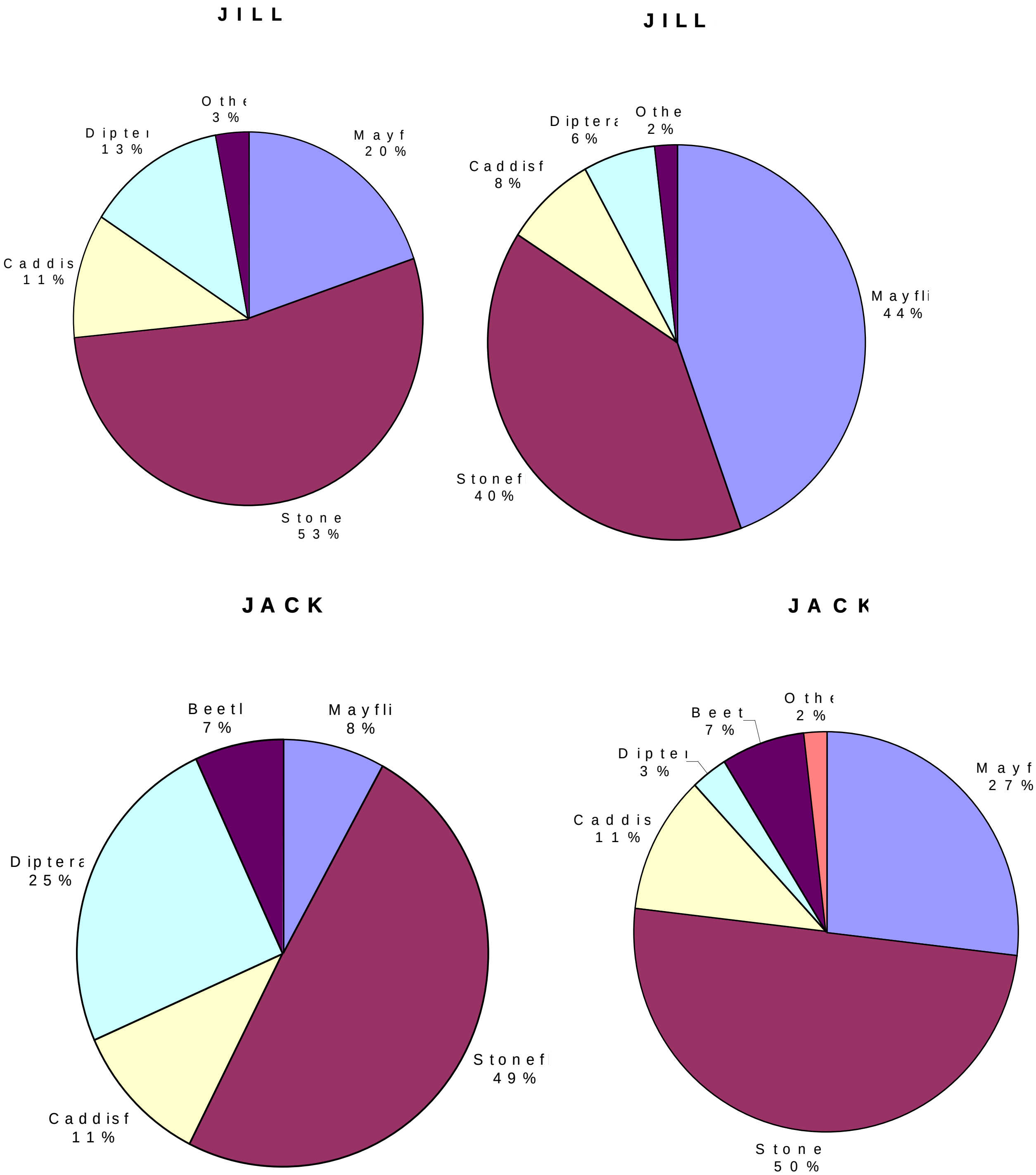


FIGURE 3-27
Relative Abundance (%) of Major Macroinvertebrate Taxonomic Groups at Four Locations near the Bullion Mine



3.12.7 Discussion

These data clearly show deleterious impacts to the aquatic resources from AMD and elevated metal levels in stream waters originating from the Bullion Mine. A sparse, but relatively diverse macroinvertebrate assemblage was present above the mine. Downstream from the mine discharge, Jill Creek was essentially devoid of life (approximately 1 mile). The few macroinvertebrates collected downstream from the adit had probably recently drifted into the reach from upstream. Measurable impacts extended 2 miles downstream into Jack Creek.

Both Jack and Jill Creeks are sterile streams with poor to fair benthic habitat. Macroinvertebrates were scarce throughout the study area. Only 1,301 organisms were collected during this survey. Nevertheless, several hundred macroinvertebrates were collected at each site in upper Jill Creek and in Jack Creek above the Jill Creek confluence. These sites supported diverse assemblages dominated by stoneflies and mayflies. Taxa considered sensitive to AMD were present at each site. In contrast, only 12 macroinvertebrates were collected from Jill Creek downstream from the Bullion Mine discharge. Impacts from AMD were also evident in Jack Creek below the confluence of Jill Creek. Macroinvertebrate density and taxa richness were reduced, and community composition shifted to more tolerant species in Jack Creek below Jill Creek compared to the Site approximately 80 meters upstream.

Data from Jill-1, Jill-2, and Jack-6 can be used as references for evaluating biological recovery at downstream sites. While these sites are not pristine, they support relatively robust macroinvertebrate faunas that are characteristic of least impaired streams in the region (see Table 3-22).

TABLE 3-22
Metrics Characterizing Macroinvertebrate Assemblages in Least-Impaired Stream Reaches in the Upper Boulder River and Tenmile Creek Drainages

	Jack Creek Drainage			Cataract Creek Drainage[a]		Tenmile Creek Drainage[b]	
Metric	**Jill-1**	**Jill-2**	**Jack-6**	**USG-1**	**CC-5**	**Banner Creek**	**Monitor Creek**
Density	479	401	585	600	340	213 to 620	147 to 577
Total taxa	40	28	32	26	35	37 to 39	33 to 44
Percent mayfly	20	45	27	45	29	36 to 63	20 to 42
Percent stonefly	54	40	50	26	33	20 to 32	16 to 30

Notes:
[a] McGuire (2011). Stations Ji-1: Uncle Sam Gulch above Crystal Mine; CC-5: Cataract Creek above USG.
[b] Skaar and McGuire (2008). Annual mean values from a 3-year study.

3.13 Bullion Mine Wetland Inventory

3.13.1 Wetland Survey

This section summarizes an inventory of wetlands associated with the Site. The entire technical memorandum is provided in Appendix H.

3.13.1.1 Wetland Survey Objectives

A significant portion of the soils at the Site have been excavated, removed, moved and replaced during the course of mining, both from direct action, as well as from gravitational and alluvial movement of mine tailings. In addition, during efforts at Site cleanup and restoration, Site soils were significantly disturbed through removal and construction. Given these factors, wetlands at the Bullion Mine are disturbed and some may have been incidentally created by human activities. As the atypical situation that these man-induced changes have created are now the "normal circumstances" for the area, the Bullion Mine was examined as it currently is for jurisdictional wetland status, not as it might have been predisturbance. The objective of the mapping was to establish a baseline from which to help gauge the overall effect of remedial activities at the Bullion Mine on the wetlands of the Site, and assure no wetland acreage is lost during remedial action.

3.13.1.2 Wetland Survey Methods

The U.S. Army Corps of Engineers *Wetlands Delineation Manual* (USACE, 1987) and *Regional Supplement for Western Mountains, Valleys, and Coast Region* (2010) provide methods to be used when natural or human-induced alterations have significantly changed the area soils, hydrology and/or vegetation (atypical situations). This is pertinent in that all three of the wetland criteria have been altered at the Bullion Mine. The wetlands at the Bullion Mine were jurisdictionally delineated through the routine methods defined in the Manual and Regional Supplement.

From the top to the bottom of its major watercourses, the Site is approximately 0.5 mile long (approximately 2,400 feet) and averages 0.1 mile wide (approximately 600 feet) (see Figure 3-28). The wetland areas appear in the western portion of the Site, the focus of this study. The red line represents the area where the surveys were conducted. Jill Creek runs along the northern boundary of the survey area. On areas more than 5 acres in size, but less than 0.5 mile long, USACE (1987) specifies the establishment of three transects perpendicular to a baseline that lies parallel the major watercourse. A separate vegetation survey mandated additional transects be placed perpendicular to the vertical face of the mine. The area covered by the vegetative survey overlays part of the area covered by the wetlands survey. Five collocated wetland and vegetation survey transects were established as shown in Figure 3-28. In addition, a sixth and seventh wetlands transect were established in an area not covered by the vegetative survey. The yellow lines represent the five transects across the face of the reclaimed area, while the blue lines represent the additional wetlands assessed in the lower portion of the survey area.

Because the Site has only recently been revegetated and that mature plant communities have yet to take hold, manual-mandated methods for evaluating herbaceous overstory, herbaceous understory, and herbaceous vine were modified by using a 1-meter-wide band along each transect, making breaks between investigative quadrats based upon observable changes in hydrologic patterns (the presence of inundated conditions versus dry conditions) and in vegetation (the presence of upland species versus wetland species). Hydrologic characterization followed USACE (1987). Vegetative information was collected using plant cover per Daubenmire (1959) for the herbaceous layer, and plant counts for the herbaceous understory and overstory layers (USACE, 1987). No vines were found within the study area. Dominance by canopy position was determined through the standard 50/20 rule (USACE, 1987).

3.13.1.3 Wetland Survey Results

On the basis of data collected from the transects, approximately 2.6 acres of the 40-acre Site were delineated as jurisdictional wetlands (see Table 3-23). Given the degree of historic disturbance of the Site and the recent efforts at revegetation, however, the Bullion Mine is best characterized as a mixed matrix of wetlands and uplands, with wetland and upland status varying mostly because of subtle differences in elevation relative to groundwater.

Within the remediated portion of the Bullion Site (see Figure 3-29) are 2.1 jurisdictional wetland acres scattered across the reclaimed hillside.

Figure 3-30 shows Jill Creek and the lower seep area. The purple line surrounds the jurisdictional wetland boundaries.

TABLE 3-23
Jurisdictional Wetland Acres Observed on the Bullion Mine Survey Area

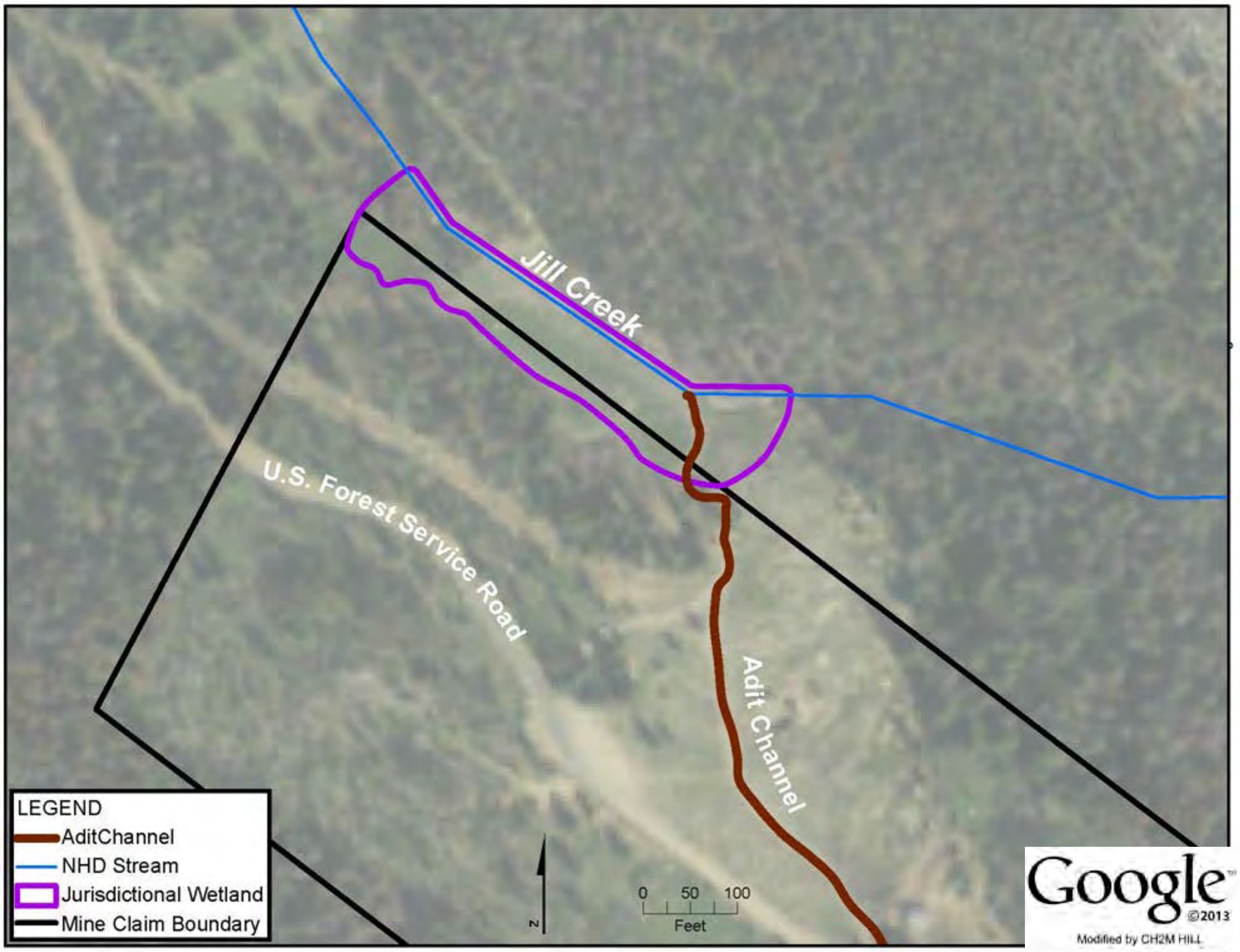
	Jurisdictional Wetland Acres
Wetland along the Reclaimed Area	2.1
Jill Creek and Lower Seep Area	0.5
Total	**2.6**

FIGURE 3-28

Bullion Mine Project Area with Five Collocated Wetland/Vegetation Survey Transects (yellow) and Two Additional Wetland Transects (blue)

FIGURE 3-29
Remediated Area at Bullion Mine

FIGURE 3-30
Wetlands along Jill Creek and Lower Seep Area



The jurisdictional wetland acres are those regulated by USACE, that meet the three criteria for a wetland (hydric soils, hydrophytic vegetation and wetland hydrology), and are connected or adjacent to a water of the United States. These wetlands are also subject to the "no net loss" requirement of Executive Order 11990, and remedial actions performed at the Site must avoid impacting functional wetlands.

Thirty-one different plant species were found in the wetland transects of the Bullion Mine (see Table 5 in the original text from ESG, Appendix H). Nineteen species were rated as being facultative wetland plants, nine species were rated as being upland plants, and two species were not rated. Seventeen species were woody (both overstory and understory), and fourteen species were herbaceous. Among the dominant woody plants species present, *Pinus contorta* (lodgepole pine) contributed the greatest average cover, followed by *Picea glauca* (white spruce). Nonetheless, more white spruce plants were found than lodgepole pine trees. Among the dominant herbaceous species, *Deschampsia cespitosa* (tufted hairgrass) had the greatest overall presence at the Bullion Mine, particularly in wetland areas. *Festuca idahoensis* (Idaho fescue) and *Lotus corniculatus* (birds-foot trefoil) were dominant in upland areas.

Wetlands at the Site were scored as "non-functioning" or unhealthy with an overall score of 33 percent. Unimpacted wetlands in the upper reaches of Jill Creek scored much higher at 93 percent. A vegetation survey and wetland health assessment was conducted and detailed findings are provided in Appendix H of this report.

3.14 Threatened and Endangered Species Survey

This section describes a survey of the Site and its immediate vicinity for threatened and endangered species.

3.14.1.1 Methods for the Survey of Threatened and Endangered Species

The review of threatened and endangered species potentially present at the Site was conducted in September 2010 and revisited in February 2013. This work included a review of current lists of endangered, threatened, proposed, and candidate species from the United States Fish and Wildlife Service (USFWS), Montana Fish, Wildlife & Parks (Montana FWP), and the MNHP. The review also included direct interviews with technical experts at Montana FWP, and the MNHP.

3.14.1.2 Results—Threatened and Endangered Species Survey

While an enumeration of threatened and endangered plant and animal species potentially present near the Bullion Mine would seem to be a simple exercise, it is complicated by three issues.

First, while the Bullion Mine lies in Jefferson County, Montana, the location is near the boundaries with two other Montana counties, Lewis and Clark, and Powell. For this reason, the threatened and endangered species of all three counties were considered as being potentially present near the project site (see Table 3-29).

Second, the USFWS maintains a list of threatened and endangered species that are probably present, arranged by county. This list is different than the list attributed to the USFWS that is maintained by the MNHP (2012). The other source of differences is that the USFWS relies on historic probable range data to determine the counties "where one would reasonably expect the species to occur" (USFWS, 2012). The MNHP, however, relies upon recent formally reported sightings of species to designate in which counties a species occurs. For this reason, the USFWS lists the black-footed ferret (*Mustela nigripes*) as occurring in Jefferson County and Lewis and Clark County, which are part of the species' historic range, while the MNHP does not because of a lack of recent sightings in these counties. Conversely, the MNHP lists the whooping crane as occurring in Jefferson County because of a 1985 sighting of a single migrating bird 20 miles south of Boulder, Montana, while the USFWS does not list it as occurring in this county as the bird is not reasonably expected to be present.

TABLE 3-29
Threatened and Endangered Species Present at the Montana Counties Surrounding the Bullion Mine

Species Name	Jefferson County	Lewis and Clark County	Powell County
Mammal			
Black-footed ferret	LE[a]	LE[a]	—
Canada lynx	LT[a, b]	LT[a, b]	LT[a, b]
Grizzly bear	—	LT, XN[a, b]	LT, XN[a, b]
Wolverine	P	P	
Bird			
Bald eagle	—	DM[b]	DM[b]
Peregrine falcon	DM[b]	DM[b]	DM[b]
Whooping crane	LE[b]	—	—
Fish			
Bull trout	—	LT[a, b]	LT[a, b]
Plants			
Ute ladies tresses	LT[a, b]	—	—

Notes:
[a]Data source: USFWS (2013)
[b]Data source: MNHP (2012)
— = not present
DM = Recovered, Delisted, and Being Monitored
LE = Listed Endangered
LT = Listed Threatened
XN = Experimental Nonessential Population

The third factor complicating an enumeration of threatened and endangered species at the Bullion Mine is that while a species may be present in Jefferson, Lewis and Clark, and/or Powell Counties, its range may not encompass the approximately 7000-foot elevation of the Bullion Mine. For instance, the black-footed ferret preys exclusively on prairie dogs, whose towns are found only in grasslands, steppe, and shrub-steppe. Therefore, the black-footed ferret will not be found near the Bullion Mine. While bull trout do spawn in rocky tributary streams, the small size of the streams near the project area and the harsh winters at 7000 feet, which may freeze the eggs and or fry, make it unlikely that bull trout would have been found historically near the Bullion Mine (Schmetterling, personal communication, 2010). Ute ladies tresses are restricted in area to alkaline wetlands in the valley bottoms, and so they will not be found at the Bullion Mine (Ute ladies tresses [*Spiranthes diluvialis*] 2010). For these reasons, only the following two, currently listed threatened and endangered species have a realistic potential of being at or near the Bullion Mine: Canada lynx (2010) and grizzly bear (2010). Descriptions of these species from the Montana Field Guides are included in Appendix H.

3.15 Methods of Analysis

3.15.1 Laboratory and Field Methods of Analysis

This section describes the methods used for the collection of field data during 2010. Protocol for assessing wetlands and performing a riparian health assessment of Jill Creek are also described. The laboratory analytical methods for analyzing media samples are also presented.

3.15.2 Soil

Soil samples, under the direction of a sampling and analysis plan (CH2M HILL, 2010), were collected from soil pits excavation at selected locations at the Site in the Basin Creek Watershed during summer and early fall 2010. Field and laboratory quantification of total concentrations of selected metals (aluminum, antimony, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, thallium, and zinc,) and arsenic in soils were conducted. A calibrated field portable XRF instrument was the primary piece of equipment for determining concentrations of the elements. EPA Method 6200 was used in these determinations. Confirmation soil samples (1/20) were submitted to an analytical laboratory for determination of elemental levels using EPA methods 3050 (acid digestion) and 6020 (ICP spectroscopy). Levels of pH in the soil samples were determined in a saturated soil paste extract solution (ASA Method 10-2.1 and 10-3.2). Statistical comparisons of data generated by the two different analytical techniques were conducted. A summary of the results is presented in Section 2.8.2. A technical memorandum providing detail of these statistical evaluations and results is found in Appendix L.

3.15.3 Water

Water samples were collected from springs, creeks, adits, and monitoring wells at the Site in the Basin Creek Watershed during summer and early fall 2010. Collections and determination of concentrations selected total and dissolved metals and arsenic, alkalinity, chloride, and sulfate were conducted under the procedures in a sampling and analysis plan (CH2M HILL, 2010). Field determinations of pH, specific conductivity, dissolved oxygen, and temperature were made at the time of collection using calibrated Horiba U-22 meter. Samples were preserved in pre-acidified sample bottles and under chain of custody, shipped to the analytical laboratory. Concentrations of total metals, dissolved metals, and arsenic were determined using EPA method 200.8—ICP/MS (mass spectroscopy). Alkalinity measurements were conducted using SM 2320-B, and chloride and sulfate levels were determined using EPA 300.0.

3.15.4 Soil Pore Water

Pore water samples were not collected at the Site.

3.15.5 Aquatic Resources

Section 3.12.3 presents the methods used for analyzing aquatic resources.

3.15.6 Wetlands Delineation Methods—Jurisdictional Wetland Survey

Appendix H presents the methods used for wetland delineation.

3.15.7 Lotic Wetland (Riparian) Health Assessment

Appendix H presents the methods used to analyze lotic wetland health.

3.16 Quality Assurance/Quality Control—Data Validation

3.16.1 Data Validation

3.16.1.1 Field XRF Data

Soil samples were collected from soil pits developed at selected locations at the Bullion Mine Site during the summer and early fall of 2010. The concentrations of antimony, arsenic, cadmium, copper, iron, manganese, lead, nickel, selenium, silver, and zinc were determined using a field XRF instrument. Collections and determinations were conducted under the direction of a sampling and analysis plan (CH2M HILL, 2010). The analytical data were subjected to a modified validation process similar to those described in the following documents:

- EPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review, OSWER 9240.1-51, EPA 540-R-10-011 (January 1, 2010).
- Clark Fork River Superfund Site Investigations, data management/Data Validation Plan (PTI, 1992 with revision (1993), and addendum (2000).

The XRF instrument quality control (QC) protocol included initial and continuing calibrations and blanks, and duplicate analysis. The control limits for each QC type were specified as follows:

- Blank value less than LOD (limit of detection)
- Duplicate sample less than + 35 percent RPD (relative percent difference)
- Standard (NIST 2702-marine sediment) within two standard deviations of the mean value as calculated by 20 determinations of the analytes using the XRF instrument.

Eight separate analytical events took place and eight data packages were received from CH2M HILL. These data packages were identified as follows:

- XRF result-100807
- XRF result-100810
- XRF result-100811
- XRF result-100812
- XRF result-100813
- XRF result-100814
- XRF result-100815
- XRF result-100816

A summary of the validation of data contained in each data package and results of the validation are described in Appendix I.

3.16.1.2 Soil—Laboratory Data

Soil samples were collected from soil pits developed at selected locations at the Bullion Mine Site in the Basin Creek Watershed during the summer and early fall of 2010. Collections and determination of concentrations selected total metals and arsenic, and pH levels were conducted under the direction of a Sampling and Analysis Plan (CH2M HILL, 2010). Samples were and shipped under chain of custody, to the analytical laboratory. Concentrations of total metals and arsenic were determined using EPA Methods 3050 (acid digestion) and 6020—ICP. Levels of pH in the soil samples were determined using ASA 10-3.2. The analytical data were subjected to a validation process as described in the following documents:

- EPA CLP National Functional Guidelines for Inorganic Data Review, OSWER 9240.1-51, EPA 540-R-10-011 (January 1, 2010).
- Clark Fork River Superfund Site Investigations, data management/Data Validation Plan (PTI, 1992 with revision (1993), and addendum (2000).

Three separate sampling events took place and three data packages were received from the analytical laboratory. These data packages were identified as follows:

- Pace Analytical 10135486
- Pace Analytical 10135942
- Pace Analytical 10135946

A summary of the validation of soil laboratory data contained in each data package and results of the validation are described in Appendix J.

3.16.1.3 Water Data (Surface and Groundwater)

Water samples were collected from springs, creeks, adits, monitoring wells, and piezometers at the Bullion Mine Site in the Basin Creek Watershed during the summer and early fall of 2010. Collections and determination of concentrations selected total and dissolved metals and arsenic, alkalinity, chloride, and sulfate were conducted under the direction of a Sampling and Analysis Plan (CH2M HILL, 2010). Field determinations of pH, specific conductivity, and temperature were made at the time of collection using calibrated meters. Samples were preserved in pre-acidified sample bottles and under chain of custody, shipped to the analytical laboratory. Concentrations of total and dissolved metals and arsenic was determined using EPA method 200.8—ICP/MS. Alkalinity measurements were conducted using SM 2320-B, and chloride and sulfate levels were determined using EPA 300.0. The analytical data were subjected to a validation process as described in the following documents:

- EPA CLP National Functional Guidelines for Inorganic Data Review, OSWER 9240.1-51, EPA 540-R-10-011 (January 1, 2010)
- Clark Fork River Superfund Site Investigations, data management/Data Validation Plan (PTI, 1992 with revision (1993), and addendum (2000).
- Four separate sampling events took place and four data packages were received from the analytical laboratory. These data packages were identified as follows:
- Pace Analytical 10133880
- Pace Analytical 10138195
- Pace Analytical 10138755
- Pace Analytical 10139035

A summary of the validation of water data contained in each data package and results of the validation are described in Appendix K.

3.16.2 Sediment Data (2012)

A chemical data quality evaluation assessed the quality of analytical data for sediment samples for the purpose of determining the current contaminant levels in sediment in streams adjacent to or down gradient of the former Bullion Mine. This subsection summarizes the results of the quality assurance/quality control activities. A total of 24 native environmental sediment samples and 8 sediment field duplicates (FD) were collected. The samples were analyzed for particle size by method D422 and total metals by method SW6010. Analyses were performed by Pace Analytical Services, Billings, Montana.

CH2M HILL chemists performed hard copy and electronic deliverable data quality evaluation as described in the SAP (CH2M HILL, 2012). Analytical performance was assessed by sample delivery group or analytical batch.

Laboratory quality control data and field quality control procedures were reviewed to assess the precision (reproducibility), accuracy (correctness), representativeness (degree to which data accurately and precisely depict the characteristics of a population), comparability (confidence with which one data set can be compared to another data set), and completeness (percentage of valid results in the data set) of the sample data collected, as specified in the SAP (CH2M HILL, 2010); the assessment concluded that these parameters are acceptable.

Data precision was verified through a review of the field and laboratory data quality indicators, including duplicate MS and FD sample results. MS imprecision affected 5 results and FD variability affected 18 results. Precision was found to be generally acceptable.

Data accuracy was verified through a review of laboratory control samples and MS. MS recovery exceedances affected 17 results. Accuracy was acceptable.

Data representativeness was verified through a review of the sample collection, storage, and preservation procedures and hold-time compliance, and an evaluation of laboratory blank data. The procedures were followed correctly. Blank contamination did not affect sample results.

Data comparability was accomplished through the use of standard EPA analytical procedures and standard units for reporting. The results obtained are comparable to industry standards in that collection and analytical techniques followed documented procedures.

Completeness is a measure of the number of valid measurements obtained in relation to the total number of measurements planned. Completeness is expressed as the percentage of valid, or usable, measurements compared to planned measurements. Valid data are defined as data that were not rejected during data evaluation. The data set is 100 percent complete.

3.16.3 Statistical Comparison of XRF and Lab Soil Data

Of the 73 soil samples, in which concentrations of the COIs were determined in the field using a calibrated XRF instrument, 14 were split and sent to a analytical laboratory for determination of COI levels using conventional methods (acid digestion and ICP quantification). These Bullion soil samples accompanied soil samples collected at the Crystal Mine. Comparisons of the concentrations of the elements in the soils determined by the different methods were performed as follows:

- Display descriptive statistics for each data set.
- Display histograms of each data set.
- Calculate the RPD between each pair of elemental concentrations.
- Perform paired t-tests.
- Use linear regression analysis to evaluate systematic error.
- Calculate relative XRF error as a function of ICP concentration.

A summary of the results of these statistics is exhibited in see Table 3-30. With the exception of antimony, iron, manganese, and zinc, P values of paired t tests indicated significant difference between XRF and lab values for antimony, iron, manganese, and zinc. The slope and intercept values, and their respective 95 percent confidence limit values indicate acceptable correspondence between XRF and lab values for most elements except antimony and iron. Mean relative percent difference values between XRF and lab values are acceptable except for antimony and iron determinations. A 35% XRF at the specified ICP concentration for each analyte is also provided in Table 3-30.

A technical memorandum providing detail of these statistical evaluations and results is found in Appendix L.

TABLE 3-30
Summary of Statistical Comparisons between Field XRF Elemental Data and Laboratory ICP Data in Soils

Element	P value of Paired t Test	Linear Regression Analysis		Mean RPD	mg/kg Associated with 35% XRF Error
		Slope + 95CL	Intercept + 95CL		
Arsenic	0.521	0.91 ± 0.06	49.2 ± 128	-8.0	400
Antimony	<0.001	1.92 ± 0.72	56.7 ± 82.6	-59.7	195
Copper	0.193	1.01 ± 0.11	5.82 ± 29.6	-9.9	90
Iron	<0.001	1.38 ± 0.22	3,838 ± 5,958	-42.9	40,000
Lead	0.152	0.92 ± 0.10	25.0 ± 149	-5.1	215
Manganese	<0.001	0.94 ± 0.43	213 ± 366	-29.8	32
Zinc	<0.001	1.06 ± 0.11	32.0 ± 56.9	16.7	110
Selenium	NC*				
Silver	NC*				
Cadmium	NC*				

Note:
* NC = not calculated. XRF data values were less than LOD.

3.16.4 Data Usability Assessment

Table 3-31 presents an assessment of the quality of the generated data and information in terms of its intended uses as defined by the DQOs presented in the *Final Bullion Mine Sampling and Analysis Plan* (CH2M HILL, 2010), and presented in this document in Section 3.3.

TABLE 3-31
Assessment of the Quality of the Generated Data and Information in Terms of its Intended Uses

Intended Use of the Data	Data and Information Collected	Assessment of Data Quality
Mine Adit		
Define the water quality, flows, and contaminant loads from the adit, and determine if the adit flow impacts water quality.	Observations and water flows, loads, and quality were determined	These data are of sufficient quality to meet the intended use
Soil		
Define concentrations of COIs in surface and subsurface soils. Determine if soils and waste rock may produce acidic drainage.	Soil were collected from multiple location and depths and characterized for COI levels using both field and laboratory methods.	The field XRF data, with the exception of some arsenic, zinc, lead, and copper levels, are considered to be of Enforcement Quality (highest) as specified in CFR SSI Data management/Data Validation Plan. Total metal and arsenic in the soils concentrations generated by the laboratory were judged to be of highest quality (Enforcement Quality) with some data for iron and manganese being screening quality.
Water (Surface and Groundwater)		
Determine concentrations of total and dissolved concentrations of COI and other characteristics of adit and stream waters, springs and groundwater.	Waters were collected from multiple locations (adit, springs, wells, piezometers, and streams) determinations of total and dissolved metals and arsenic concentrations were made.	Except for the dissolved manganese, and lead in some samples, all other total and dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan.

TABLE 3-31

Assessment of the Quality of the Generated Data and Information in Terms of its Intended Uses

Intended Use of the Data	Data and Information Collected	Assessment of Data Quality
Sediment		
Determine concentrations of COIs in stream sediments and their downstream extent in Jill Creek to its confluence with Jack Creek. (collected in 2012)	Stream sediment samples were collected from four stations in Jill Creek to its confluence with Jack Creek. Samples were collected in Jack Creek above and below the confluence. Samples were separated into 3 size categories and analyzed for COIs.	These data are of sufficient quality to meet the intended use.
Aquatics		
Determine species richness, abundance, and other attributes within the benthic communities.	Benthic macroinvertebrate survey was performed in 2010 on Jill Creek downstream to its confluence with Jack Creek.	These data are of sufficient quality to meet the intended use.
Vegetation		
Delineate wetlands and characterize vegetation attribute within the Site.	A wetlands survey of the Bullion site was performed in 2010	These data are of sufficient quality to meet the intended use.
Risk Assessments		
Determine potential risks to human health from both on- or near-Site mine wastes. Determine potential risks to human health through offsite migration of contaminants. Determine potential risks to ecological receptors from both on- or near-Site mine wastes.	A screening level human health and ecological risk assessment were completed in 2012. A soil arsenic and lead bioavailability study was also performed and results were incorporated into the risk assessments.	These data are of sufficient quality to meet the intended use.

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4. Nature and Extent of Contamination

Section 4 describes the nature and extent of the Bullion Mine OU5 COIs. Previous sections described the findings of historic investigations and the 2010–2012 media sampling activities. Fate and transport of contaminants by media are also described in this section.

4.1 Mine Waste

Mine waste at the Site was excavated and transported to the Luttrell Repository in 2001. In general, residual waste material onsite now lies beneath a revegetated, 10- to 18-inch cover soil cap. The former upper and middle waste rock dump areas still exhibit some barren areas where vegetation has not yet been established. However, waste rock exposure at the Site was largely mitigated by the 2001 removal action.

4.2 Soils and Vadose Zone

Soils contaminated by mine wastes, although generally buried under cover soil, contain elevated concentrations of contaminants. The interpretation of metal and arsenic concentrations in the Site soils is somewhat complicated because of the cover soil that was imported after excavation activities were completed in 2001. Mean levels of arsenic and metals increase with sample depth and represents residual soil contamination after the excavation of wastes and contaminated soils. Recontamination of the imported cover soil may be occurring via elemental mobility: (1) redeposition of contaminants from dusts and contaminated surface water (and snowmelt); (2) erosion of the cover soil that exposes contaminated layers; and (3) upward movement of waters containing a metal signature from the underlying wastes into the cover soil. Upward movements of metal ions can impede vegetation establishment and persistence if excessive. Vegetation can assimilate contaminants from soil into roots and into above ground biomass. Metals can participate in several types of reactions within soils including adsorption, precipitation, complexion with organic matter, as well as desorption, and solubilization. Residual soil contamination exposed by excessive erosion can represent risks to terrestrial and aquatic animals.

4.3 Surface Water and Sediments

Movement of contaminants from source materials (contaminated soils) into surface waters occurs during snowmelt, rainfall, and erosion of materials. Additionally, flow from an open mine adit and groundwater is directed to surface waters. The water column within the receiving stream contains metal hydroxides, metal ions and suspended sediments. Precipitation of contaminants on stream sediments and channel strata is visible, and desorption of the metals from the sediment into surface waters may also ensue.

Sediments in the Jill Creek tributary to Jack Creek were sampled and characterized in the Basin Watershed RI (CDM, 2005b). The highest concentrations of COIs in Basin Creek in 2001 occurred in sediments from Jack Creek (up to 51 times greater than the previous tributary and up to 230 times greater than ecological benchmarks). 2001 sample results exceeded ecological benchmarks for arsenic, cadmium, copper, lead and zinc. Lead exceeded the human health benchmark of 1,000 mg/kg.

Sediments were also sampled in 2012. As with the 2001 sampling, the highest concentration of COIs was found in the smallest size fraction (230 mesh). Concentrations of COIs in sediment exceeded freshwater sediment benchmarks (EPA Region III) for seven COIs (arsenic, cadmium, copper, iron, lead, manganese, and zinc) in Jill Creek (Jill-1) upstream of the confluence with the Bullion adit discharge and for nine COIs (antimony, arsenic, cadmium, copper, iron, lead, manganese, silver, and zinc) below the mine at the mouth of Jill Creek (Jill-4). COI concentrations for arsenic, cadmium, copper, lead, and zinc increased between the confluence of Jill Creek and the adit discharge (Station Jill-3) downstream to the last surface water station on Jill Creek (Jill-4). This suggests that Jill Creek continues to be impacted by the influx and migration of residual contaminated sediment in bank deposits below the Site. The Concentrations of COIs in sediment declined downstream of the confluence of Jack and Jill Creeks; however, seven COI concentrations (arsenic, cadmium, copper, iron, lead, manganese, and zinc) still exceeded the freshwater sediment benchmarks. 2012 sampling stations were collocated with the macroinvertebrate sampling stations. Evidence of fish and macroinvertebrates in Jill Creek from its confluence with AMD down to Jack Creek is nonexistent, and only limited aquatic life exists immediately below the Jack Creek confluence with Basin Creek. Vegetation along the banks of Jill Creek adjacent to the mine property is less diverse and robust when compared to undisturbed upstream reaches.

4.4 Groundwater

Groundwater quality can be impacted by infiltration and vadose zone transport of contaminants, and pore water/groundwater interactions. Groundwater quality may also be impacted as it migrates down through fractured bedrock and into the former mine workings where it is exposed to pyritic material and bacteria, as appears to be occurring within the Bullion Mine. Metal contaminated water within the underground mine workings can then migrate into local aquifers. Residual wastes and contaminated soils can also release contaminants to groundwater.

The lower adit has a small variable discharge ranging from about 1.8 to 14 gpm with pH ranging from 2.5 to 3.7 with a median value of 2.95. The constituent concentrations in adit discharge far exceed ecological and human health benchmarks for all COIs. As previously explained the portal of the lower adit is mostly obstructed by collapsed soil, rock and debris. Mine water has pooled behind the debris plug and appears to be moving through the plug and fractured bedrock to the slope downgradient of the adit resulting in discharge of elevated concentrations of COIs.

4.5 Air

In spite of the removal and reclamation action that occurred in early 2000, wind entrainment and dispersal of airborne particulates remains a slight possibility for the following reasons:

- Some areas are barren of vegetation resulting in exposed soil.
- Weathering of residual waste rock/soils and use of the area by recreational vehicles may potentially generate dust containing COIs.
- Wind could entrain exposed material dispersing it beyond the current operable unit boundaries, resulting in potential risk-based exposure.

However, on the basis of observations by field personnel during recent field seasons, much of the Site supports vegetation which protects the surface soils from wind generated erosion. Little or no airborne dust was observed. In exposed areas, surface soil fines have generally been removed by wind and water erosion. It should be noted, because of the remote location, elevation, and climate, access to the Site and potential exposure to airborne dust is limited to a 4- to 5-month window. No air sampling was performed as part of the focused RI.

5. Contaminant Fate and Transport

Section 5 describes the fate and transport mechanisms at the Site.

5.1 Pathways of Migration

Contaminants emanating from mine adit discharge and contaminated soils are released to receptors via multiple pathways including erosion, wind dispersion, and runoff into surface waters, infiltration into subsurface soils, vadose zone waters, and groundwater. Metals in surface waters can be precipitated onto stream sediments, move towards groundwater, and be assimilated by aquatic receptors and vegetation. Through desorption processes the sediment bound metals can be released back into the water column. Metals in soils can be taken up by vegetation and organisms residing in soils. Animals foraging on vegetation (where palatable forage is present) may ingest the contaminants. Some animals can ingest contaminated soils while foraging on vegetation. Ponds, resulting from summer thunderstorm events, can develop atop contaminated soils thereby posing a threat to animals that may ingest the tainted water. Metals in the vadose zone waters may move upward in response to dry climatic conditions and form evaporative salts which can be flushed into surface waters during rainfall/runoff events. Metals can also move downward into the groundwater. Dissolved metals in the groundwater can recharge surface waters or discharge into deeper depths. Metals in the waste rock and contaminated soils can be entrained by wind and be transported offsite and be deposited in the surrounding environment.

5.2 Release Mechanisms

Host rock underlying the Site contains many sulfide minerals associated with metal ore deposits, including pyrite (FeS_2), the most common sulfide. Acid rock drainage (ARD) occurs when sulfide ores are exposed to the atmosphere, which can be enhanced through mining and milling processes where oxidation reactions are initiated. Mining increases the exposed surface area of sulfur-bearing rocks allowing for excess acid generation beyond natural buffering capabilities found in host rock and water resources. Collectively the generation of acidity from sulfide weathering is termed acid mine drainage (AMD). Mine tailings and waste rock, having much greater surface area than in-place geologic material because of their smaller grain size, are more prone to generating AMD. Because large masses of sulfide minerals are exposed quickly during the mining processes, the surrounding environment is often not able to attenuate the resulting low pH conditions. Metals that were once part of the host rock are solubilized and exacerbate the deleterious effect of low pH on terrestrial and aquatic receptors. Concentrations of common elements such as copper, zinc, aluminum, iron, and manganese all dramatically increase in waters with low pH. Significant increases in metal levels in waters from sulfide-rich mining environments are common where surface or groundwater pH is depressed by acid generation from sulfide minerals.

The reaction of pyrite with oxygen and water produces a solution of ferrous sulfate and sulfuric acid. Ferrous iron can further be oxidized producing additional acidity. Iron and sulfur oxidizing bacteria are known to catalyze these reactions at low pH thereby increasing the rate of reaction by several orders of magnitude (Nordstrom and Southam, 1997). In undisturbed natural systems, this oxidation process occurs at slow rates over geologic time periods. When pyrite is exposed to oxygen and water it is oxidized, resulting in hydrogen ion release—acidity, sulfate ions, and soluble metal ions as shown in equation 1. The acidity of water is typically expressed as pH or the logarithmic concentration of hydrogen ion concentration in water such that a pH of 6 has ten times the hydrogen ion content of neutral pH 7 water.

$$2FeS_{2\,(s)} + 7O_2 + 2H_2O \rightarrow 2Fe^{+2} + 4SO_4^{-2} + 4H^{+} \quad (1)$$

Further oxidation of Fe^{+2} (ferrous iron) to Fe^{+3} (ferric iron) occurs when sufficient oxygen is dissolved in the water or when the water is exposed to sufficient atmospheric oxygen (equation 2).

$$2Fe^{+2} + ½\ O_2 + 2H^+ \rightarrow 2Fe^{+3} + H_2O \qquad (2)$$

Ferric iron can either precipitate as $Fe(OH)_3$, a red-orange precipitate seen in waters affected by ARD, or it can react directly with pyrite to produce more ferrous iron and acidity as shown in equations 3 and 4.

$$2Fe^{+3} + 6H_2O \leftrightarrow 2Fe(OH)_{3\,(s)} + 6H^+ \qquad (3)$$

$$14Fe^{+3} + FeS_{2\,(s)} + 8H_2O \rightarrow 2SO_4^{-2} + 15Fe^{+2} + 16H^+ \qquad (4)$$

When ferrous iron is produced (Equation 4) and sufficient dissolved oxygen is present the cycle of reactions 2 and 3 is perpetuated (Younger, et al., 2002). Without dissolved oxygen Equation 4 will continue to completion and water will show elevated levels of ferrous iron (Younger, et al., 2002). The rates of chemical reactions (equations 2, 3, and 4) can be significantly accelerated by bacteria, specifically *Thiobacillus ferrooxidans*. Another microbe, *Ferroplasma Acidarmanus*, has been identified in the production of acidity in mine waters (McGuire et al., 2001).

Hydrolysis reactions of many common metals also form precipitates and in doing so generate H^+. These reactions commonly occur where mixing of acidic waters with substantial dissolved metals blend with cleaner waters resulting in precipitation of metal hydroxides on stream channel substrates (Equations 5 through 8).

$$Al^{+3} + 3H_2O \leftrightarrow Al(OH)_{3(s)} + 3H^+ \qquad (5)$$

$$Fe^{+3} + 3H_2O \leftrightarrow Fe(OH)_{3(s)} + 3H^+ \qquad (6)$$

$$Fe^{+2} + 0.25\ O_2 + 2.5\ H_2O \leftrightarrow Fe(OH)_{3(s)} + 2H^+ \qquad (7)$$

$$Mn^{+2} + 0.25\ O_2 + 2.5\ H_2O \leftrightarrow Mn(OH)_{3(s)} + 2H^+ \qquad (8)$$

Metal sulfide minerals in addition to pyrite may be associated with economic mineral deposits and some of these minerals may also produce acidity and SO_4^{-2}. Oxidation and hydrolysis of metal sulfide minerals pyrrhotite ($Fe_{1-x}S$), chalcopyrite, sphalerite, and others release metals such as zinc, lead, nickel, and copper into solution in addition to acidity and SO_4^{-2} (Jennings et al., 2000; Younger et al., 2002).

5.3 Contaminant Mobilization and Transport

The mobilization of COIs is dependent upon several factors, including: (1) the rate at which acid is produced from the oxidation of the waste rock and tailings, and the exposure of oxygen within the inner working of the Bullion Mine; (2) The flow of surface water and groundwater that carry the low pH and elevated metal signature; (3) erosion (streambank loss and runoff) and transport of metals from contaminated soils and sediment into surface waters; and (4) assimilation of contaminants by terrestrial and wetland vegetation and aquatic receptors (see Photograph 5-1).

Once the contaminants reach the receiving streams as dissolved or in particulate forms they may precipitate on sediments. Under some circumstances the metals in sediment can also become a source to surface water when they become remobilized because of desorption, dissolution or resuspension in the water column. Exposure and subsequent uptake by primary producers and lower trophic level organisms (benthic organisms) may represent sources of exposure to higher trophic level consumers. Impacted surface water can through infiltration and percolation contaminate deeper soils or vadose zone water, and groundwater. Metals in groundwater are transported downgradient into deeper aquifers or resurface into surface waters, stream channels, and their associated soils and sediments.

PHOTOGRAPH 5-1. **Acid Mine Drainage Entering Jill Creek**

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6. Risk Assessment

The risk assessment described in this section was conducted to determine the nature, magnitude, and probability of actual or potential harm to public health, safety, or welfare, or to the environment, posed by the threatened or actual releases of hazardous substances originating from the Bullion Mine. This risk assessment consists of a human health risk assessment (HHRA) segment and an ecological risk assessment (ERA) segment. These risk assessment segments identify and characterize the following:

- Contaminants of potential concern (COPCs) for human health and contaminants of potential ecological concern (COPECs)
- Potential exposure pathways
- Potential human and environmental receptors
- Likelihood and extent of impact or threat under current and reasonably anticipated future land use conditions associated with the Bullion Mine

The overall objective of the risk assessment is to determine the appropriate risk management steps for the Bullion Mine. The resulting actions may include, with consideration of the magnitude of the risks posed by the Site and other factors, the following:

- A determination of the presence of unacceptable risk, and the need to evaluate remedial options at some or all of the Site.
- A determination of the absence of unacceptable risk, and the determination that no further action is necessary.
- A determination that additional site characterization is necessary to refine the conceptual site model.

6.1 Organization of this Section

This risk assessment includes the following components:

- **Section 6.2, Data Used for the Risk Assessment.** Identifies the data used and constituents considered to be most important to the human health and ecological risk quantification processes.
- **Section 6.3, Conceptual Exposure Model.** Identifies the pathways by which human and ecological exposures could occur.
- **Section 6.4, Human Health Risk Assessment.** Provides the methodologies used and results of the human exposure assessment, toxicity assessment, and risk characterization.
- **Section 6.5, Ecological Risk Assessment.** Provides the screening-level ecological problem formulation and screening results, and methodologies used and results of the ecological exposure assessment, effects assessment, and risk characterization.
- **Section 6.6, Uncertainties Associated with the Risk Assessments.** Provides a summary of the limitations and uncertainties with the assumptions used to estimate risk.

6.2 Data Used for the Risk Assessment

This section presents the site-specific data to be used in the Bullion Mine risk assessment. Both current (collected between 2010 and 2012 specifically for this RI) and historical data were evaluated for potential use in the risk assessment. All available data are described in Section 3. Historical investigations within the Basin Watershed, which included data collected around the Bullion Mine, allowed for a focused analyte list for this RI (see Section 1.6). These analytes are aluminum, antimony, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, thallium, and zinc. A determination of the adequacy of data for use in the risk assessment was based on the following two lines of evaluation:

- Identification of the adequacy of detection limits for detecting potential risks
- Evaluation of the spatial, chemical, and temporal representativeness of the available analytical data, and an assessment of whether these data are relevant to plausible exposure pathways

For the first step, detection limits were compared to risk-based screening criteria in medium-specific tables presented in Section 3. Thallium was the only targeted soil analyte not detected at the Site with detection limits as low as 0.7 mg/kg. Data validation reports for data collected during this RI are provided in Appendices I through K. As a whole, the data were deemed to exhibit sufficient sensitivity to detect whether risk to human and ecological receptors is present.

The soil samples collected for this RI (in 2010) include samples analyzed using an XRF and a subset of samples sent to Pace Analytical Laboratory. A data quality evaluation comparing the results from these methods is provided in Appendix J and the results indicated that the XRF data correlate well (for example, correlation coefficient of 0.91 for arsenic) for arsenic, copper, lead, manganese, and zinc (see Section 3.16.2). XRF data were not available for aluminum and thallium, and adequate correlations were not found between the XRF and laboratory data sets for antimony, cadmium, iron, nickel, selenium, and silver. Therefore, a decision was made to combine XRF data and laboratory data sets for use in the risk assessment for arsenic, copper, lead, manganese, and zinc. For the remaining metals, results from only laboratory samples are used.

For the second step, the representativeness of the data was evaluated using the following criteria:

- **Chemical representativeness.** Identifies whether analyses were conducted for constituents expected to be present on the basis of an understanding of historical processes or practices and potential releases at the Bullion Mine.
- **Exposure representativeness.** Identifies whether environmental media were evaluated where receptor exposure is most feasible.
- **Spatial representativeness.** Identifies whether samples were collected with a sufficient density and areal coverage. Site maps from this RI were reviewed to determine whether sampling locations were spatially representative of exposures possible at the Bullion Mine.
- **Temporal representativeness.** Identifies whether samples were collected within a timeframe such that detected constituent concentrations indicate current Site conditions.

6.2.1 Data Representativeness Conclusions

On the basis of a review of the existing data and with consideration of the general representativeness criteria described in the previous text, the following conclusions were drawn from this evaluation:

- **Soil.** Soil samples collected in 2010 (see Figures 3-5 and 3-5a for XRF and laboratory sample location, respectively) for the RI were collected at the most likely source areas and along areas of potential exposure, and were analyzed for COPCs previously identified during the Basin Watershed OU2 RI. These samples provide a conservative evaluation of the current and future conditions at the Bullion Mine, assuming no remediation occurs. These meet all four criteria listed above (Section 6.2) and considered adequate for use in the risk assessment. Historical soil data from previous Site investigations (described Section 3) were only available for samples collected prior to 2003 and, for many locations, prior to interim remedial actions (soil removal). Considering this, these data are not used for risk characterization.
- **Surface Water at Jill and Jack Creeks.** Bullion Mine is located in the upper part of the Jill Creek subbasin within the Jack Creek drainage, approximately 6 miles north of the town of Basin. Jill Creek is located adjacent to the lower workings and downgradient of the mine. Surface water samples collected in these creeks before the interim remedial actions were completed in 2002 are not considered temporally representative of current conditions at the Site. Surface water data collected in 2010 (see Figure 3-1 to 3-4) are considered temporally representative of current conditions at the Site, and adequate for use in the risk assessment. Older surface

water data collected between 2005 and 2009 at USGS Station 462153112181701 at the mouth of Jill Creek prior to its confluence with Jack Creek are used in the RI to provide information on the temporal variances, however were not used in the assessment of risk since newer data are available. No actions have occurred since the 2010 sampling events that would significantly influence the conditions in the creeks.

- **Surface Water at the Adit Discharge and Spring/Seeps.** Adit discharge water data collected for this RI in July and September of 2010 (see Figure 3-1), are conservatively representative of current concentrations entering the adit discharge channel and eventually discharging to Jill Creek. These data, collected for the RI after previous remedial actions, are considered most representative of current concentrations discharging from the adit. As a result, adit discharge water data from 2010 are used in the risk assessment. Spring/seep water data collected from 14 locations during the 2010 field investigation for this RI (see Figure 3-1 to 3-4) are considered representative of current Site conditions, and are adequate for use in screening for potential surface water exposures.
- **Sediment.** Jill and Jack Creek sediment samples were collected in July 2012 for this RI. Sample locations are shown on Figure 3-11. The USG Creek sediment data collected in 2012 are considered to be most representative of current and future site conditions, and are adequate for use in the risk assessment. Historical data collected by the USGS in 2001 were considered as temporally unrepresentative and were not used in the risk assessment. These historical data were not considered representative because remedial actions in 2001–2002 included removal of mine tailings adjacent to Jill Creek as well as soil removal, capping, and revegetation at the mine.
- **Groundwater.** As described in Section 2.3.5, groundwater at the mine is limited outside of the water that flows through the mine workings and that is eventually discharged at the adit or nearby seeps described above. Groundwater data collected during the RI are described in Section 3.8 and 3.10. Five groundwater monitoring wells and six piezometers were installed during the RI; however, these were installed for the purpose of understanding the groundwater influx to the mine area and its inner workings. For the reasons described in Section 2.3.5 exposure to groundwater at the Site is not likely and the data collected are not meaningful for exposure estimation in the risk assessment.

The data described above include background data for surface water, sediment, and soil collected from areas of the watershed that have not been influenced by historical mining activities.

6.2.2 Summary of Data Used in the Risk Assessment

The analytical data used in this risk assessment include data from soil, sediment, surface water, spring/seep water, and adit discharge samples collected during field investigations between 2010 and 2012. These investigations were described in Section 3. Summaries of samples used in this risk assessment are provided by medium, sample identification number, date of collection, sampling depth interval, and target receptor types in Table 6-1 (for reader convenience, all tables for Section 6 are located at the end of the Section).

For duplicate samples, the following procedure was applied:

- If there were two detections, the average of the two concentrations was used.
- If there was one detection and one nondetection, the detected value was used.
- If there were two nondetections, the lowest detection limit was used.

For the purpose of this risk assessment, analytical data were partitioned into six primary media exposure groupings (see Table 6-1 for target receptors), which include the following:

- Surface soil (defined as 0 to 10[1] inches bgs for the HHRA and 0 to 2 feet bgs for the ERA)
- Subsurface soil (defined as 0 to 10 feet bgs)

[1] A surface soil interval of 0 to 2 inches bgs is typical for most human health exposures, however (as described in Section 4.1) previous remedial actions at the Site included a soil cap described as 18 to 24 inches bgs. Soil sampling results and figures presented in Section 3.6 indicate that COI concentrations are relatively uniform to a depth of 10 inches bgs. Therefore, data collected in soils from 0 to 10 inches were aggregated to provide a more robust data set for the risk assessment.

- Sediment
- Surface water
- Adit discharge water
- Seep/spring water

Additional information about the samples used for the risk assessment is provided by medium in the following sections.

6.2.2.1 Soil Data

Soil data generated during the 2010 RI field season were used in the risk evaluation. The locations of soil samples used for the risk assessment are shown in Figures 3-5 and 3-5a. The soil data sets include combined XRF and laboratory data. For sample locations where both are available, only the laboratory data are used. The numbers of sample locations for each soil depth classification used in the risk assessment are as follows:

- **Surface soil (HHRA).** 26 samples collected between 0 and 10 inches bgs.
- **Surface soil (ERA).** 51 samples collected between 0 and 2 feet bgs.
- **Subsurface soil.** 53 samples collected between 0 and 10 feet bgs.

6.2.2.2 Sediment Data

Sediment data generated during the 2012 RI field season were used in the risk assessment. The locations of sediment samples used for the risk assessment are shown in Figure 3-11. Data collected from four sampling locations in Jill Creek and two locations in Jack Creek were included in the risk assessment.

6.2.2.3 Surface Water, Adit Discharge Water, and Spring/Seep Water Data

Surface water, adit discharge, and spring/seep data included in the risk assessment were from rounds of RI sampling collected during July and September of 2010. A description of water beneficial uses is provided in Section 4. The numbers of specific sample types used in the risk assessment are as follows:

- **Surface water.** Eight samples collected at 4 Jill Creek locations in July and September 2010, and annual mean data for Jill Creek (near the mouth) collected between 2005 and 2009.
- **Spring/Seep.** 30 samples (including two duplicates) collected at 14 spring/seep locations in July and September 2010.
- **Adit discharge channel.** 2 samples collected from the adit discharge channel just above its confluence with Jill Creek in July and September 2010.
- **Adit discharge.** 2 samples collected at the mine adit in July 2010 and September 2010.

6.3 Conceptual Exposure Model

This section describes the potential exposure pathways within the locality of the Bullion Mine for contaminants believed to be associated with historical mining activities. The conceptual exposure model (CEM) is formulated according to applicable guidance, with the use of professional judgment and site-specific information on land use (Section 6.3.1), water use (Section 6.3.2), ecological habitat (Section 6.3.4), contaminant sources (Section 6.3.5.1), release mechanisms (Section 6.3.5.2), routes of migration (Section 6.3.5.2), potential exposure points (Sections 6.3.5.3 and 6.3.5.4), potential routes of exposure (Sections 6.3.5.3 and 6.3.5.4), and potential receptor groups associated with the Site (Sections 6.3.5.3 and 6.3.5.4).

6.3.1 Current and Reasonably Likely Future 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, with the Town of Basin residing at the mouth of the watershed. Land uses within the vicinity of the Bullion Mine include historical mining, and seasonal recreational use (for example, hiking, ATV riding, camping, and big game hunting). Given the present understanding of baseline conditions at the Bullion Mine 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.

6.3.2 Current and Reasonably Likely Future Water Use

Jill Creek is adjacent to and immediately downgradient of the Bullion Mine. As described in Section 1.3.4.2, MDEQ does not provide specific water use classifications for this stream. However, Jill Creek is expected to provide an aesthetic quality, support of aquatic life typical of high altitude first order streams, and recharge downgradient streams. The creek is a tributary to Jack Creek and the confluence is approximately 1 mile downstream from the mine adit discharge. MDEQ classifies Jack Creek (and Jill Creek as its tributary) as a B-1. B-1 indicates that water quality of the stream must be sufficient to support recreational activities such as bathing and swimming; growth and propagation of salmonid fish and associated aquatic life and other wildlife; agricultural and industrial water supply; and after conventional treatment, drinking and culinary purposes. Water from Jack Creek eventually recharges Basin Creek and shallow alluvial aquifers which are a source of drinking water for Basin residents and was a primary human exposure pathway considered during the Basin Watershed OU2 RI.

Surface and groundwater use and flows are described in detail in Section 1 of this RI.

6.3.3 Meteorology

The Bullion Mine, located in the upper Basin Watershed, has an average annual precipitation of approximately 29 inches. The highest precipitation for the area generally occurs in the months of May, June, and July. Temperature extremes for the Site range from the highs near 85°F in late summer to lows near -40°F in December and January. Snowfall accumulation typically occurs between October and March (Weather Underground, 2009) and snow cover is typically present for about 6 months per year.

6.3.4 Ecological Habitat and Wildlife

Habitat in the watershed is primarily forest land dominated by lodgepole pine (*Pinus contorta*), and to a lesser extent, by subalpine fir (*Abies bifolia*), Douglas fir (*Pseudotsuga menziesii*), Engleman spruce (*Picea engelmannii*), quaking aspen (*Populus tremuloides*), and common juniper (*Juniperus communis*). At the Bullion Mine project area the dominant woody plants species present, *Pinus contorta* (lodgepole pine) contributed the greatest average cover, followed by *Picea glauca* (white spruce). Nonetheless, more white spruce plants were found than lodgepole pine trees. Among the dominant herbaceous species, *Deschampsia cespitosa* (tufted hairgrass) had the greatest overall presence at the Bullion Mine, particularly in wetland areas. *Festuca idahoensis* (Idaho fescue) and *Lotus corniculatus* (birds-foot trefoil) were dominant in upland areas. Wetland inventories for the Bullion Mine are summarized in Appendix H. Approximately 2.6 acres of the 40-acre Site may be delineated as a jurisdictional wetland, and 36.2 acres of the Site as upland (see Table 3-23). Given the degree of historic disturbance of the Site and the recent efforts at revegetation; however, the Bullion Mine is best characterized as a mixed matrix of wetlands and uplands.

6.3.4.1 Wildlife

Salmonid fish (within the Basin Creek drainage), aquatic invertebrates, piscivorus birds, omnivorous birds, benthic macroinvertebrates, small burrowing mammals, soil microbes, and large game species are reportedly found within OU2 (CDM 1999). Raptors found in the area include eagles and goshawks. Among the mammals potentially using the watershed are snowshoe hair, lynx, deer, elk, moose, black bear, and small mammals (for example, mice).

A review of threatened and endangered species potentially present at the Site was conducted in September 2010. This work included a review of current lists of endangered, threatened, proposed, and candidate species from USFWS, the State of Montana Department of Fish, Wildlife and Parks, and the MNHP. The review also included direct interviews with technical experts at the State of Montana's Department of Fish, Wildlife and Parks, and the Montana Natural Heritage Program. The findings are detailed Section 3.4.14 and Appendix H. Only the Canada lynx, gray wolf, and grizzly bear were determined to have the potential of using habitats consistent with those found at Bullion Mine. Each is a large carnivore with foraging areas significantly greater than the area occupied by the Bullion Mine. Since the September 2010 review of threatened and endangered species (Appendix H), the U.S. Congress has delisted the gray wolf.

6.3.5 Human and Ecological Conceptual Exposure Model

The CEM provides a framework for understanding conditions and physical processes which influence the potential for risk. The CEM describes the following:

- **Sources** of contaminants of potential concern.
- **Pathways** describing the physical mechanism through which a contaminant could come into contact with receptors (that is, potentially exposed humans or wildlife).
- **Receptors,** consisting of human or ecological populations potentially exposed to the contaminant of potential concern.

A complete exposure pathway must exist from the hazardous substances in the environment (in soil, groundwater, sediment, and surface water) to human or ecological receptors for chemical intake to occur. An exposure pathway is considered incomplete in the absence of any one of these components (source, pathway or receptor), and in the absence of a complete pathway, there is no risk or hazard. Figure 6-1 shows the CEM for the Bullion Mine which illustrates the potentially complete human and ecological exposure pathways. These exposure pathways are discussed in more detail below (in Sections 6.3.5.3 and 6.3.5.4).

6.3.5.1 Sources

Past investigations characterizing the possible releases of contaminants from the Bullion Mine are detailed in Section 3. Historical mining activities have left waste rock dump piles and soil contaminated with degenerated waste rock. The waste rock piles contain materials of varying size fractions from sand and silts to larger rocks rich in metals. Metals are the only COPCs known or expected at the Bullion Mine. Specifically, arsenic, cadmium, copper, lead, and zinc were the metals identified during the Basin Watershed OU2 RI, and that are considered COPCs at Bullion Mine. These five metals along with aluminum, antimony, iron, manganese, nickel, selenium, silver, and thallium are considered as potential Site-related contaminants at Bullion Mine (see Section 1.6).

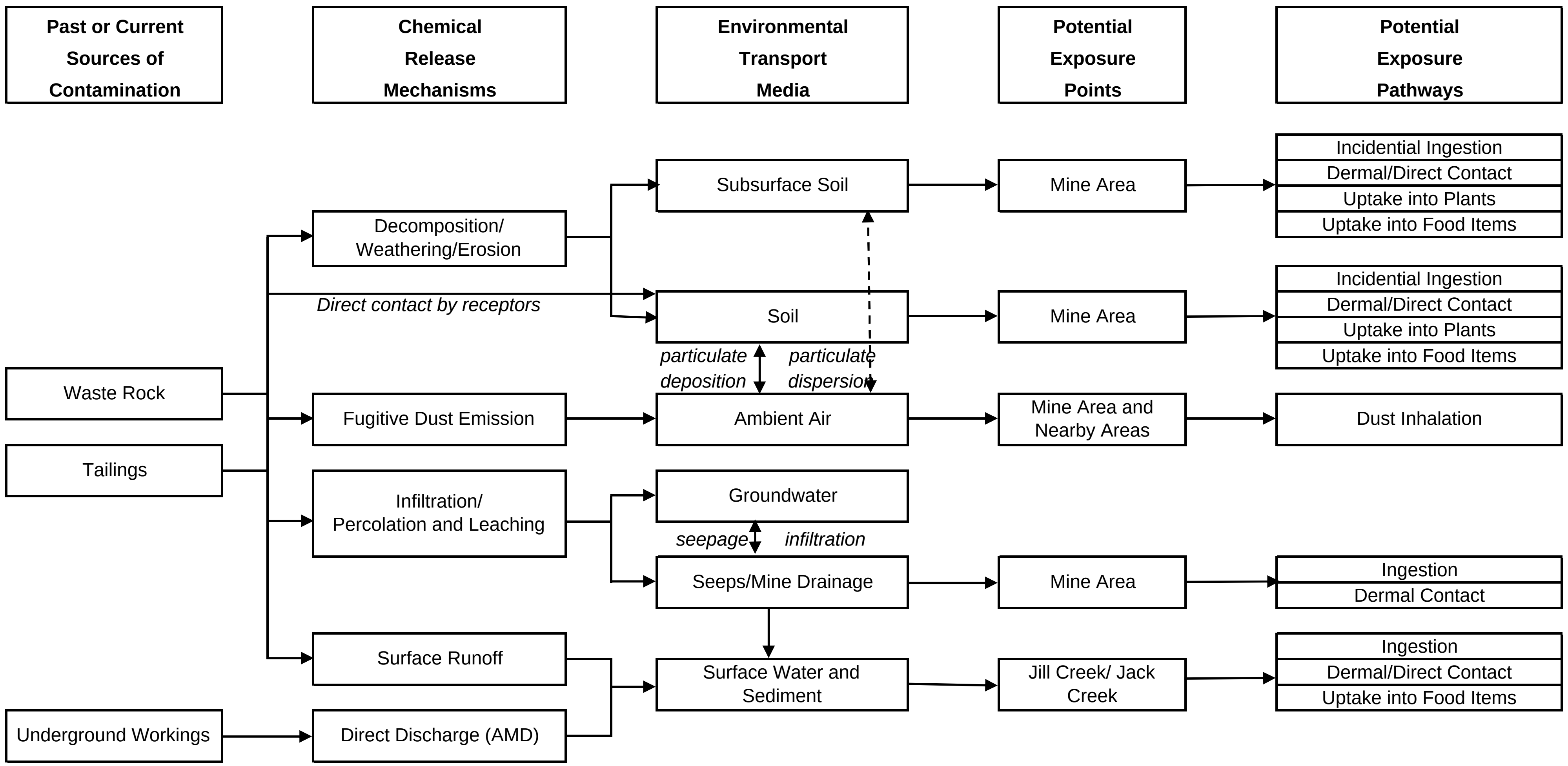
6.3.5.2 Release Mechanisms and Potential Transport Media

Receptor exposure may occur when chemicals migrate from their source to an exposure point (in other words, a location where individuals or organisms can come into contact with the contaminants) or when a receptor moves into direct contact with chemicals or contaminated media connected to the source. An exposure pathway is complete (in other words, exposure) if a means exists for the receptor to take in chemicals through ingestion, inhalation, or dermal absorption at a location where site-related chemicals are present. No exposure (and therefore no risk) exists unless the exposure pathway is complete. Determining the exposure/risk linkage is an important element in the risk assessment process.

Potential release mechanisms and transport media at the Bullion Mine are shown in the CEM depicted on Figure 6-1 and summarized below.

- Historic surface erosion and runoff from snow melt, flooding, rainfall, and stream bank erosion to surface water and sediment in surrounding surface water bodies
- Leaching, percolation, and infiltration of COPCs from the waste rock to shallow groundwater
- Discharge of leached COPCs AMD and shallow groundwater to adjacent surface water bodies
- Direct contact with soil containing COPCs (in this instance, receptor contact with site-related metals in Site soil replaces the release and transport of the COPCs)
- Fugitive dust emissions from wind, excavation, or recreational activities (for example, recreational ATV riding)

FIGURE 6-1
Conceptual Exposure Model (CEM) for Potential Human Health and Ecological Receptors at the Bullion Mine



Environmental Transport Media	Potential Exposure Points	Potential Exposure Pathways	Current and Future Recreational Users (Adolescent and Adult)	Future Intermittent Worker	Future Excavation Worker	Hypothetical Industrial Worker	Hypothetical Residents	Terrestrial Wildlife (birds and mammals)	Vegetation (upland plants)	Aquatic Biota (fish and invertebrates)
Subsurface Soil	Mine Area	Incidential Ingestion	--	--	C	--	--	--	--	--
		Dermal/Direct Contact	--	--	C	--	--	--	--	--
		Uptake into Plants	--	--	--	--	--	--	C	--
		Uptake into Food Items	I	--	--	--	--	--	--	--
Soil	Mine Area	Incidential Ingestion	C	C	--	C	C	C	--	--
		Dermal/Direct Contact	C	C	--	C	C	I	--	--
		Uptake into Plants	--	--	--	--	--	--	C	--
		Uptake into Food Items	I	--	--	--	--	C	--	--
Ambient Air	Mine Area and Nearby Areas	Dust Inhalation	C	C	C	C	C	I	--	--
Seeps/Mine Drainage	Mine Area	Ingestion	--	--	--	--	--	I	--	--
		Dermal Contact	--	--	--	--	--	I	--	--
Surface Water and Sediment	Jill Creek/ Jack Creek	Ingestion	C	--	--	--	--	C	--	--
		Dermal/Direct Contact	I	--	--	--	--	I	--	C
		Uptake into Food Items	I	--	--	--	--	C	--	C

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

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6.3.5.3 Potentially Complete Human Exposure Pathways and Receptors

The Basin Watershed and surrounding areas are frequently used for recreational purposes. Based on available information, the most plausible current or future human receptor populations that may contact COPCs originating from the Bullion Mine include the following:

- Future intermittent workers (for example, road maintenance, environmental sampling, USFS 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 Jill Creek) by recreational users

Given the present understanding of current and reasonably anticipated land uses and Site conditions including its remote location, steep land slopes, high elevation, unreliable domestic water source, underground mine workings, and unconsolidated material on which to build structure, the Site conditions preclude residential use. 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 are considered in the HHRA. Although the Basin Watershed may also be used for fishing, Jill 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 are considered incomplete within the mine area.

6.3.5.4 Potentially Complete Ecological Exposure Pathways and Receptors

Based on the habitat present at and surrounding the Bullion Mine, ecological exposure pathways considered possible at the Site include the following:

- Potential exposure of avian and terrestrial wildlife (primarily birds and mammals) to contaminants in soil
- Potential exposure of wildlife to contaminants in surface water and sediment
- Potential ingestion of site-related contaminants via the food chain by higher trophic level terrestrial and avian wildlife
- Potential exposure of aquatic resources to contaminants present in shallow groundwater (measured by spring/seep and adit water concentrations) potentially discharging to nearby surface water
- Potential exposure of vegetated and forested areas to contaminants present in soil

6.4 Human Health Risk Assessment

This HHRA presents an analysis of the potential for adverse human health effects associated with metals detected in the vicinity of the Bullion Mine.

6.4.1 Human Health Risk Assessment Guidance

The procedures in this risk assessment are consistent with those described in the following guidance documents:

- *Risk Assessment Guidance for Superfund (RAGS)–Volume I: Human Health Evaluation Manual, Part A* (Interim Final). (EPA, 1989c)

- *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.* OSWER Directive 9285.6-03. (EPA, 1991a)
- *Exposure Factors Handbook Volume I General Factors.* EPA/600/P-95/002Fa. August 1997. (EPA, 1997a)
- *Risk Assessment Guidance for Superfund–Volume I: Human Health Evaluation Manual* (Part E, Supplemental Guidance for Dermal Risk Assessment Final) (EPA, 2004)
- *Risk Assessment Guidance for Superfund–Volume I: Human Health Evaluation Manual* (Part F, Supplemental Guidance for Inhalation Risk Assessment) (EPA, 2009c)
- *Guidelines for Carcinogenic Risk Assessment* (EPA, 2005a)
- *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (EPA, 2005b)

6.4.2 Human Exposure Assessment

The exposure assessment step of the HHRA for the Bullion Mine combines the information in Section 6.3.5 with the following:

- Identification of COPCs for the HHRA.
- Calculation of exposure point concentrations (EPCs).
- Development of human exposure assumptions for potentially complete exposure pathways.
- Calculation of chemical intake for COPCs.

These activities are discussed in the following subsections.

6.4.2.1 Identification of Contaminants of Potential Concern for Human Health

COPCs are those constituents that are carried through the human health risk quantification process. During the course of the HHRA, the COPCs will be evaluated to identify and prioritize which constituents, if any, are estimated to pose unacceptable risks and therefore may need to be addressed during an FS. For this HHRA, all detected analytes are included as COPCs for the HHRA.

Historical investigations at the Bullion Mine have focused on metals and metalloids that have been released to site media of concern. The general area was historically mined because the soil is rich in minerals and metals, and inorganic COPCs identified for site media of concern include constituents that also occur naturally. In areas of past mining activity the availability of and potential for these constituents to adversely affect human health and the environment may have been increased for several reasons, including changes in the topography and hydrology of the mine area that can result in increased erosion, surface water runoff, and sediment transport to downstream areas as well as geochemical changes in the metals or other parameters (for example, pH). It is possible that some metals occur at levels above risk-based screening criteria in site and/or background areas. Consistent with EPA guidance (EPA, 2002b), no COPCs were eliminated on the basis of comparison to background concentrations. Instead, potential risks attributable to background levels are discussed in the risk characterization.

6.4.2.2 Estimating Exposure Point Concentrations (EPCs)

EPCs are estimated constituent concentrations that a receptor may come into contact with, and are specific to each exposure medium. The EPCs for exposure pathways associated with the Bullion Mine were estimated, where appropriate, by aggregating concentration data from media samples collected over a relevant exposure area. The EPCs for aggregate risk estimation were calculated by using the best statistical estimate of an upper bound on the average exposure concentrations, in accordance with EPA guidance for statistical analysis of monitoring data (EPA, 1989c, 1992, 2002a). EPA considers the 95 percent upper confidence limit (UCL) on the mean concentration as a conservative upper-bound estimate that is not likely to underestimate the mean concentration. EPCs were calculated for each analyte using EPA's statistical program ProUCL, Version 4.1.01 (EPA, 2011b). This procedure identifies the statistical distribution type (normal, lognormal, or non-parametric) for each constituent within the defined exposure area (the area of interest) and computes the corresponding 95 percent UCL for the identified distribution type. The maximum detected concentration was used in place of the

95 percent UCL when the calculated 95 percent UCL is greater than the maximum detected value. However, using maximum detected values for EPCs may contribute to overestimation of risk (this and other uncertainties are discussed in Section 6.6).

For each of the identified COPCs, the soil EPCs generated through ProUCL are provided in Table 6-2 and the ProUCL output summaries are provided in Appendix M. For estimation of current and future risks from exposure to COPCs in surface and subsurface soil, EPCs generated by ProUCL were used.

For evaluation of surface water and seep water, EPCs were identified on a sample-specific basis (maximum detected concentrations from each location were used) rather than aggregating data spatially. This is because there is no way of knowing which location a recreational user would choose for obtaining drinking water.

6.4.2.3 Human Exposure Assumptions

The estimation of exposure requires numerous assumptions to describe potential exposure situations. The exposure assumptions used are specific to the identified exposure scenarios at the Bullion Mine. The scenarios evaluated were selected based on the CEM (see Figure 6-1) and are consistent with the reasonably anticipated future land and water uses.

Upper-bound exposure assumptions are used to estimate reasonable maximum exposure (RME) conditions to provide a bounding estimate on exposure. The risk assessment also uses central tendency estimates (CTE) of exposure and risk. The exposure parameters used for generating reasonable maximum and central tendency exposure risk estimates are listed in Tables 6-4 and 6-5, respectively. Most of the exposure assumptions for ingestion, dermal contact, and inhalation are provided by EPA guidance documents (listed in Section 6.4.1). The dermal absorption pathway is considered to be insignificant for this RI because only metals are considered as COPCs and the dermal absorption factors for metals are very low. Some of the exposure assumptions (for example, exposure frequency for recreational users) are based on site-specific information (for example, seasonal snow cover) and best professional judgment.

6.4.2.4 Calculation of Intake for COPCs

This section describes the equations used to calculate exposures to COPCs in soil and ambient air. Exposure that is normalized over time and body weight is termed intake (expressed as milligrams of chemical per kilogram body weight per day [mg/kg-day]).

Incidental Ingestion of Soil. The following equation was used to calculate the intake associated with the incidental ingestion of contaminants in soil for the intermittent worker, recreational user (both adult and adolescent), hypothetical industrial worker, and excavation worker exposure scenarios:

$$Intake = \frac{C_s \times BF \times IR_s \times 10^{-6}\,kg/mg \times EF \times ED}{BW \times AT}$$

where:

C_S	=	Constituent concentration in soil (mg/kg)
BF	=	Bioavailability adjustment factor
IR_S	=	Soil ingestion rate (milligrams per day [mg/day])
EF	=	Exposure frequency (days per year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

The exposure assumptions for estimating chemical intake from the ingestion of contaminants in soil are provided in Tables 6-4 and 6-5.

Oral Bioavailability Adjustment Factor for Arsenic and Lead. Oral bioavailability is a measure of the amount of a constituent that is absorbed into the body after ingestion exposure. Some constituents are absorbed almost completely (100 percent bioavailability) when ingested in their pure, soluble form. Others may pass through the body largely unabsorbed. EPA recently published the *Recommendations for Default Value for Relative*

Bioavailability of Arsenic in Soil (EPA, 2012a) which recommends a default bioavailability for arsenic of 60 percent. The default bioavailability for risk estimation from exposure to lead is 12 percent (EPA, 2003b). The oral bioavailability of soil-bound metals largely depends on the rate at which it dissociates from the soil matrix in the gastrointestinal (GI) tract. Soil-bound arsenic and lead are usually absorbed by the GI tract to a lesser degree than when in the pure, soluble forms. This reduced absorption results from the affinity between arsenic and lead and the soil matrix, the low solubility of the chemical form of arsenic and lead associated with the soil, or both. Thus, the bioavailability of arsenic and lead from the Site soil is expected to be low for constituents that are tightly bound within the soil matrix and/or are in a form that is insoluble in the GI tract under physiological conditions. When animals are exposed to arsenic and lead, the degree of absorption from the GI tract is reflected in the degree of toxicity. Toxicity values used for risk assessment are usually derived from studies where exposures are to highly soluble forms of these metals. Therefore, overestimates of risk can result if site soil contains a form that is less bioavailable than the form in these studies. Given this, this risk assessment adjusts oral exposure to account for this reduced bioavailability.

This risk assessment assesses risk from incidental ingestion of soil using site-specific bioavailability factors for arsenic and lead. The bioavailability of the other COPCs is considered to be 100 percent. The analytical procedures and results of the site-specific bioavailability studies are presented in Section 3.6.2 and Appendix C and summarized below.

Site-Specific Arsenic Bioaccessibility. The ability of inorganic arsenic in site soil to be extracted under laboratory conditions that simulate physiological conditions should approximate their relative bioavailability from the Site soil. This measured extracted fraction is referred to as bioaccessible arsenic. The test results indicated that, of the 7 site soil samples (not including duplicates) that the bioaccessibile range was from 3.6 to 48 percent with a mean of 22 percent. These results indicate that the forms of arsenic in soil at Bullion Mine are of low bioavailability relative to the default of 60 percent. A 95% UCL (see Table 6-3) on the mean was calculated to be 33.5 using the methodology described in Section 6.4.2.2. This value is used as the site-specific arsenic bioaccessibility adjustment factor for the HHRA. Therefore, for the site-specific case, a BF of 0.335 is used for incidentally ingested arsenic in soil.

Site-Specific Lead Bioaccessibility. The test results for lead indicated that, of the 7 site soil samples (not including duplicates) that the bioaccessibile range was from 9.1 to 54 percent with a mean of 21 percent. A 95% UCL (see Table 6-3) on the mean was calculated to be 35.3 using the methodology described in Section 6.4.2.2. This value is included as the site-specific lead bioaccessibility for incorporation into the ALM for the HHRA.

Inhalation of Ambient Dust Originating from Soil. In accordance with EPA (2009c), the following equation was used to calculate the exposure concentration of carcinogenic and noncarcinogenic contaminants associated incidental inhalation of ambient dust originating from soil for the intermittent worker, recreational user (both adult and adolescent), hypothetical industrial worker, and excavation worker exposure scenarios

$$EC_a = \frac{C_s \times \left(\frac{1}{PEF}\right) \times EF \times ED}{AT}$$

where:

ECa = Constituent concentration in ambient air (mg/m^3)
Cs = Constituent concentration in soil (mg/kg)
PEF = Particulate emissions factor (m^3/kg)
EF = Exposure frequency (days per year)
ED = Exposure duration (years)
AT = Averaging time (days)

The particulate emission factor (PEF) used for all exposure estimates was the default value recommended by EPA (2012b) with the exception of the recreational user scenario, which is described in the following subsection. The exposure assumptions used to estimate exposure from inhalation of dust from soil are provided in Tables 6-4 and 6-5.

Particulate Emission Factor for Recreationalist (assumed to be ATV user). The PEF used for all scenarios was EPA's default value of 1.36×10^9 cubic meters per kilogram (m^3/kg), with the exception of the PEF used for recreational users. For recreational users, represented by ATV users at Bullion Mine, the PEF would be expected to be much higher as a result of the activities assumed. A PEF of 8.47×10^5 mg^3/kg derived for EPA Region 8 (SRC, 2009) was applied for the RME and CTE recreational user scenarios. The PEF value for riding ATVs was derived from empirical data where EPA collected measurements of total dust in air during use of ATVs at the Quincy Smelter site in California.

Ingestion of Surface Water. Ingestion of water at the Site is likely minimal, however recreational users (for example, hunters) could drink water from Jill Creek or seeps. Adit discharge water was not considered because the pH levels from data collected in 2010 is very low pH (less than 4) and would be an unlikely source of drinking water. As with soil, dermal absorption of COPCs in surface water is expected to be insignificant. For the purpose of providing information for risk management decisions on future water use, maximum detected concentrations in surface water and seeps from the Bullion Mine area were used to calculate possible risk to recreations users.

The following was used to calculate the intake of contaminants associated with the ingestion of water:

$$Intake = \frac{C_w \times IFW \times ED \times EF}{AT \times BW}$$

where:

C_W = chemical concentration in water (mg/L)
IFW = water ingestion rate (liters per day)
ED = exposure duration (years)
EF = exposure frequency (days per year)
BW = body weight (kg)
AT = averaging time (days)

The exposure assumptions for estimating chemical intake from the ingestion water are provided in Table 6-4 and 6-5.

6.4.3 Human Health Toxicity Assessment

The toxicity assessment evaluates 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 provides, where possible, a numerical estimate of the increased likelihood of adverse effects associated with chemical exposure (EPA, 1989c). The toxicity assessment contains two steps: hazard characterization, and dose-response evaluation. These two components are discussed in the following two subsections.

6.4.3.1 Hazard Characterization

Hazard characterization identifies the types of toxic effects a chemical can exert. For the toxicity assessment, chemicals can be divided into two broad groups on the basis of their effects on human health: noncarcinogens, and carcinogens. This classification has been selected because health risks are calculated quite differently for carcinogenic and noncarcinogenic effects, and separate toxicity values have been developed for them.

Carcinogens are those chemicals suspected of causing cancer following exposure. Noncarcinogenic compounds are associated with a wide variety of systemic effects, such as liver toxicity or developmental effects. Some chemicals (such as arsenic) are capable of eliciting both carcinogenic and noncarcinogenic responses; therefore, these carcinogens are also evaluated for systemic (noncarcinogenic) effects.

EPA developed a carcinogen classification system (EPA, 1986) that used a weight-of-evidence approach to classify the likelihood that a chemical is a human carcinogen. This classification scheme has been superseded in the more recent *Guidelines for Carcinogen Risk Assessment* (EPA, 2005a), where a narrative approach, rather than the alphanumeric categories, is used to characterize carcinogenicity. Five standard weight-of-evidence descriptors are used: *Carcinogenic to Humans, Likely to Be Carcinogenic to Humans, Suggestive Evidence of Carcinogenic Potential, Inadequate Information to Assess Carcinogenic Potential, and Not Likely to Be Carcinogenic to Humans.* For noncancer effects, toxicity values are derived on the basis of the critical toxic endpoint (that is, the most sensitive adverse effect following exposure).

6.4.3.2 Dose-Response Evaluation

The magnitude of toxicity of a chemical depends on the dose to a receptor. Dose refers to exposure to a chemical concentration over a specified period of time. Human exposures are generally classified as acute (typically less than 2 weeks), subchronic (about 2 weeks to 7 years), or chronic (7 years to a lifetime). This HHRA specifically addresses subchronic and chronic exposure. A dose-response curve describes the relationship between the degree of exposure (the dose) and the incidence of the adverse effects (the response) in the exposed population. EPA uses this dose-response information to establish toxicity values for particular chemicals, as described in the following subsections.

6.4.3.3 Toxicity Values

Toxicity values (cancer slope factors and reference doses) used in the HHRA were obtained from EPA regional screening level (RSL) tables (EPA, 2012b), which are selected in accordance with EPA guidance (EPA, 2003a), from the following sources (listed in order of preference):

- The Integrated Risk Information System (IRIS) database available through the EPA Environmental Criteria and Assessments Office in Cincinnati, Ohio. IRIS, prepared and maintained by EPA, is an electronic database containing health risk and EPA regulatory information on specific chemicals (EPA 2012b).
- EPA Provisional Peer Reviewed Toxicity Values (PPRTVs), provided by the Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center, which develops these values on a chemical-specific basis when requested under the EPA Superfund program. PPRTVs were obtained from EPA RSL tables (EPA 2012b).
- Other sources of information, with a preference for sources that (1) provide toxicity information based on similar methods and procedures as those used for IRIS and PPRTV values, and (2) contain values that are peer-reviewed, available to the public, and transparent with respect to the methods and processes used to develop the values. Examples of recommended sources include, but are not limited to, the California Environmental Protection Agency, available at http://www.oehha.ca.gov/tcdb/, and the Agency for Toxic Substances and Disease Registry Minimal Risk Levels, which represent estimates of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure.

The toxicity values used for the Bullion Mine HHRA are provided in Table 6-6, following the hierarchy above.

6.4.3.4 Reference Doses and Reference Concentrations for Noncancer Effects

The toxicity value describing the dose-response relationship for noncancer effects is the reference dose value (RfD), or in the case of inhalation, the reference concentration (RfC). For noncarcinogenic effects, the body's protective mechanisms must be overcome before an adverse effect is manifested. If exposure is high enough and these protective mechanisms (or thresholds) are exceeded, adverse health effects can occur. EPA attempts to identify the upper bound of this tolerance range in the development of noncancer toxicity values. EPA uses the apparent toxic threshold value, in conjunction with uncertainty factors based on the strength of the toxicological evidence, to derive an RfD. EPA defines an RfD (also applies to RfC) as follows:

> In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is generally expressed in units of mg/kg-day (EPA, 1989c).

The HHRA used available chronic RfDs for the oral exposure route.

6.4.3.5 Slope Factors and Inhalation Unit Risk for Cancer Effects

Dose-response relationships for cancer effects for oral and dermal routes of exposure are expressed as a cancer slope factor that converts estimated intake directly to excess lifetime cancer risk (ELCR). Slope factors are expressed in units of risk per level of exposure (or intake). The data used for estimating the dose-response relationship were taken from lifetime animal studies or human occupational or epidemiological studies where excess cancer risk has been associated with exposure to the chemical. However, because risk at low intake levels cannot be directly measured in animal or human epidemiological studies, a number of mathematical models and procedures have been developed to extrapolate from the high doses used in the studies to the low doses typically associated with environmental exposures. The model choice leads to uncertainty. EPA assumes linearity at low doses and uses the linearized multistage procedure when uncertainty exists about the mechanism of action of a carcinogen and when information suggesting nonlinearity is absent.

It is assumed, therefore, that if a cancer response occurs at the dose levels used in the study, some probability exists that a response will occur at all lower exposure levels. That is, a dose-response relationship with no threshold is assumed. Moreover, the dose-response slope chosen is usually the UCL on the dose-response curve observed in the laboratory studies. As a result, uncertainty and conservatism are built into the EPA risk extrapolation approach. EPA has stated that cancer risks estimated by this method produce estimates that "provide a rough but plausible upper limit of risk." In other words, it is not likely that the true risk would be much more than the estimated risk, but "the true value of the risk is unknown and may be as low as zero" (EPA, 1986).

For the inhalation route, this HHRA uses the IUR to estimate risk in accordance with *Risk Assessment Guidance for Superfund–Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)* (EPA, 2009c). EPA defines an IUR as "the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air" (EPA, 2009c).

6.4.4 Human Health Risk Characterization

This section summarizes the approach used to develop the human health risk estimates for the Bullion Mine and presents a quantitative risk characterization for surface soil, subsurface soil, and surface water based on the results obtained from the samples used in this risk assessment.

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, as described in the following subsections.

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.

For the purposes of this evaluation, the potential for unacceptable human health risk is identified using the following risk thresholds:

- In interpreting estimates of excess lifetime cancer risks, 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 1×10^{-4}. Action generally is not required for risks falling within 1×10^{-6} and 1×10^{-4}; however, this is judged on a case-by-case basis. Under state guidance, MDEQ considers a cancer risk exceeding 1×10^{-5} as unacceptable risk.

- Under 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, 1991a).

- If lead concentrations in exposure media result in a predicted blood-lead level of 10 micrograms per deciliter (μg/dL) in greater than 5 percent of the potentially exposed population, lead will be identified as a COC.

6.4.4.1 Cancer Risk Estimation Method

The potential for cancer effects is evaluated by estimating 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 2×10^{-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). As previously mentioned, cancer slope factors developed by EPA represent upper bound estimates, so any cancer risks generated in this assessment should be regarded as an upper bound on the potential cancer risks rather than accurate representations of true cancer risk. The true cancer risk is likely to be less than that predicted (EPA, 1989c). For the Bullion Mine, ELCRs were estimated by using the following formula:

$$Risk = Intake \times SF$$

where:

Risk	=	Excess lifetime cancer risk (unitless probability)
Intake	=	Chronic daily intake averaged over a lifetime (mg/kg-day)
SF	=	Cancer slope factor $(mg/kg\text{-}day)^{-1}$

Inhalation risk is calculated by multiplying intake by the IUR. The IUR is expressed in different units than the cancer slope factor (above), and a conversion factor is necessary to normalize units between the IUR and intake values. Inhalation risk is estimated by using the following formula:

$$Risk_{inh} = Intake_{inh} \times IUR \times CF$$

where:

$Risk_{inh}$	=	Excess lifetime cancer risk from inhalation (unitless probability)
$Intake_{inh}$	=	Chronic inhalation intake averaged over a lifetime (mg/m^3)
IUR	=	Inhalation unit risk $(\mu g/m^3)^{-1}$
CF	=	Conversion factor (μg/mg)

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). For estimating the cancer risks from exposure to multiple carcinogens from a single exposure route, the following equation is used:

$$Risk_T = \sum_1^N Risk_i$$

where:

$Risk_T$	=	Total cancer risk from route of exposure
$Risk_i$	=	Cancer risk for the i^{th} constituent
N	=	Number of constituents

6.4.4.2 Noncancer Risk Estimation

For noncancer effects by oral and dermal 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 (that is, its RfD). The ratio of the chronic daily intake divided by RfD is termed the hazard quotient (HQ):

$$HQ = \frac{Intake}{RfD}$$

where:

HQ = Noncancer HQ from route of exposure
Intake = Chronic daily intake averaged over the exposure duration (mg/kg-day)
RfD = Noncancer reference dose (mg/kg-day)

For noncancer effects by inhalation exposure, the following equation is used:

$$HQ_{inh} = \frac{Intake}{RfC}$$

where:

HQ_{inh} = Noncancer HQ from inhalation
$Intake_{inh}$ = Chronic inhalation intake averaged over the exposure duration (mg/m^3)
RfC = Noncancer reference concentration (mg/m^3)

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 EPA guidance (EPA, 1989c). 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 hazard index (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. The HI is calculated as the sum of all HQs as follows:

$$HI = HQ_1 + HQ_2 + \ldots + HQ_i$$

where:

HI = Hazard index (unitless)
HQ_i = HQ for the i^{th} constituent (unitless)

6.4.4.3 Risk Estimation Method for Lead

Potential risks from lead concentrations were evaluated using different methods than conventionally used for other chemicals. This is because for lead most human health effects data are based on blood lead concentrations rather than on the external dose. The adverse health outcomes, which include neurotoxic and developmental effects, may occur at exposures so low that they may be considered to have no threshold. EPA views it as inappropriate to develop noncarcinogenic “safe” exposure levels (RfDs) for lead. The Adult Lead Model (ALM) version date June 21, 2009 (EPA, 2003b) was used to evaluate the risk from exposure to lead in soil. The ALM develops a risk-based soil concentration that is protective of fetuses carried by women who may be exposed to lead.

Potential risk from lead in surface water is conservatively evaluated by comparing the EPC in water to the drinking water action level of 0.015 mg/L.

6.4.4.4 Summary of Risk Estimates by Exposure Scenario

This subsection summarizes the RME and CTE risk estimates for the four most plausible human health exposure scenarios and two hypothetical exposure scenarios at the Bullion Mine and includes the following:

- Future Intermittent Worker Scenario
  - Incidental ingestion of surface soil
  - Dust inhalation

- Future Adult Recreational User Scenario
  - Incidental ingestion of surface soil
  - Dust inhalation
  - Ingestion of surface water and seeps
- Future Adolescent Recreational User Scenario
  - Incidental ingestion of surface soil
  - Dust inhalation
  - Ingestion of surface water and seeps
- Future Excavation Worker Scenario
  - Incidental ingestion of subsurface soil
  - Dust inhalation
- Hypothetical Industrial Worker Scenario
  - Incidental Ingestion of surface soil
  - Dust inhalation

The cancer and noncancer risk estimates are summarized in the following subsections. The risk calculation data sheets used to develop the risk summary tables for each exposure scenario described below are provided by area in Appendix N. Note, this HHRA uses intentionally conservative high-end exposure assumptions to ensure potential risks to human health are not understated. Any interpretation of these results should consider the nature and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding them.

Current and Future Intermittent Worker Scenario. Potential exposure to surface soil (0 to 10 inches bgs) was evaluated under this scenario. Potential routes of exposure to surface soil include incidental ingestion, dermal contact, and inhalation of dust. The following assumptions were used to estimate potential exposure for workers:

- A 70-kg adult was assumed to be exposed to surface soil for 60 days per year over 5 years under the RME scenario, and for 20 days per year over 2 years under the CTE scenario.

The noncancer and excess lifetime cancer risk estimates for the worker scenario are summarized in Table 6-7. The Site intermittent worker risk calculation data tables are provided in Appendix N, Tables N-1 through N-2.

The HI for noncancer effects is 0.1 under the RME scenario and 0.02 under the CTE scenario. Both scenarios are below the EPA and MDEQ regulatory threshold value of 1. The cumulative ELCR from all carcinogenic COPCs is 4×10^{-6} under the RME scenario and 2×10^{-7} under the CTE scenario. Both scenarios are within but do not exceed EPA's risk management range of 1×10^{-6} to 1×10^{-4} and are below the MDEQ regulatory target risk of 1×10^{-5} for cumulative risk. These results indicate that there are no unacceptable risks for current and future intermittent workers, under the exposure assumptions used.

Current and Future Adult Recreational User Scenario. Potential exposure to surface soil (0 to 10 inches bgs) and ingestion of surface water were evaluated under this scenario.

Exposure to Surface Soil. Potential exposure to surface soil was evaluated under this scenario. Potential routes of exposure to surface soil include incidental ingestion, dermal contact, and inhalation of dust. The following assumptions were used to estimate potential exposure for adult recreational users:

- A 70-kg adult was assumed to be exposed to surface soil for 52 days per year over 24 years under the RME scenario, and for 14 days per year over 12 years under the CTE scenario.

For surface soil, the noncancer and ELCR estimates for the adult recreational user scenario are summarized in Table 6-8. The adult recreational user risk calculation data tables are provided in Appendix N, Tables N-3 through N-4.

The HI for noncancer effects is 2 under the RME scenario and 0.2 under the CTE scenario. The RME scenario exceeds the EPA and MDEQ regulatory threshold value of 1 with arsenic as the primary contributor (RME HQ=1)). The cumulative ELCR from all carcinogenic COPCs is 4×10^{-5} under the RME scenario and 2×10^{-6} under the CTE scenario. The RME is within EPA's risk management range of 1×10^{-6} to 1×10^{-4} and exceeds the MDEQ regulatory target risk of 1×10^{-5} for cumulative risk. The individual ELCR for arsenic under the RME scenario is 4×10^{-5}. The CTE scenario is within but does not exceed EPA's risk management range of 1×10^{-6} to 1×10^{-4} and is below the MDEQ regulatory target risk of 1×10^{-5} for cumulative risk. These results indicate that unacceptable risks could exist for current and future adult recreational users under the RME scenario, although no unacceptable risk is anticipated under the CTE exposure scenario.

Exposure to Surface Water. Potential ingestion of surface water in Jill Creek and springs/seeps were evaluated under this scenario.

For surface water in Jill Creek, the noncancer and ELCR estimates for the adult recreational user scenario are summarized in Table 6-8. The adult recreational user risk calculation data tables are provided in Appendix N, Tables N-11 through N-12.

The HI for noncancer effects is 0.5 under the RME scenario and 0.2 under the CTE scenario. Both scenarios are below the EPA and MDEQ regulatory threshold value of 1. The cumulative ELCR from all carcinogenic COPCs is 6×10^{-5} under the RME scenario and 2×10^{-5} under the CTE scenario. Both scenarios are within but do not exceed EPA's risk management range of 1×10^{-6} to 1×10^{-4} and exceed MDEQ regulatory target risk of 1×10^{-5} for cumulative risk. The individual ELCR for arsenic is 6×10^{-5} for the RME scenario. Risks are approximately an order of magnitude higher if spring/seeps (Tables N-13 through N-14) are assumed to be the source of drinking water. These results indicate that there are unacceptable risks for current and future adult recreational users, under the exposure assumptions used.

Current and Future Adolescent Recreational User Scenario. Potential exposure to surface soil (0 to 10 inches bgs) and ingestion of surface water were evaluated under this scenario.

Exposure to Surface Soil. Potential exposure to surface soil was evaluated under this scenario. Potential routes of exposure to surface soil include incidental ingestion, dermal contact, and inhalation of dust. The following assumptions were used to estimate potential exposure for adolescent recreational users:

- A 36-kg adolescent was assumed to be exposed to surface soil for 52 days per year over 6 years under the RME scenario, and for 14 days per year over 3 years under the CTE scenario.

For surface soil, the noncancer and ELCR estimates for the adolescent recreational user scenario are summarized in Table 6-8. The adolescent recreational user risk calculation data tables are provided in Appendix N, Tables N-5 through N-6.

The HI for noncancer effects is 2 under the RME scenario and 0.2 under the CTE scenario. The RME scenario exceeds the EPA and MDEQ regulatory threshold value of 1 with arsenic as the primary contributor (RME HQ=1). The cumulative ELCR from all carcinogenic COPCs is 2×10^{-5} under the RME scenario and 1×10^{-6} under the CTE scenario. The RME is within EPA's risk management range of 1×10^{-6} to 1×10^{-4} and exceeds the MDEQ regulatory target risk of 1×10^{-5} for cumulative risk. The individual ELCR for arsenic under the RME scenario is 2×10^{-5}. The CTE scenario is below EPA's risk management range of 1×10^{-6} to 1×10^{-4} and the MDEQ regulatory target risk of 1×10^{-5} for cumulative risk. These results indicate that unacceptable risks could exist for current and future adolescent recreational users under the RME scenario, although no unacceptable risk is anticipated under the CTE exposure scenario.

Exposure to Surface Water. Potential ingestion of surface water in Jill Creek and springs/seeps were evaluated under this scenario.

For surface water in Jill Creek, the noncancer and ELCR estimates for the adolescent recreational user scenario are summarized in Table 6-8. The adolescent recreational user risk calculation data tables are provided in Appendix N, Tables N-15 through N-16.

The HI for noncancer effects is 0.1 under the RME scenario and 0.4 under the CTE scenario. Both scenarios are below the EPA and MDEQ regulatory threshold value of 1. The cumulative ELCR from all carcinogenic COPCs is 2×10^{-5} under the RME scenario and 5×10^{-6} under the CTE scenario. Both scenarios are within but do not exceed

EPA's risk management range of 1×10^{-6} to 1×10^{-4} and the RME scenario exceeds MDEQ regulatory target risk of 1×10^{-5} for cumulative risk. The individual ELCR for arsenic is 2×10^{-5} for the RME scenario. Risks are approximately an order of magnitude higher if spring/seeps (Tables N-17 through N-18) are assumed to be the source of drinking water. These results indicate that there are unacceptable risks for current and future adolescent recreational users, under the exposure assumptions used.

Excavation Worker Scenario. Potential exposure to subsurface soil (0 to 10 feet bgs) was evaluated under this scenario. Potential routes of exposure to surface soil include incidental ingestion, dermal contact, and inhalation of dust. The following assumptions were used to estimate potential exposure for excavation workers:

- A 70-kg adult was assumed to be exposed to subsurface soil for 20 days per year over 6.6 years under the RME scenario, and for 10 days per year over 1 year under the CTE scenario.

The noncancer and excess lifetime cancer risk estimates for the excavation worker scenario are summarized in Table 6-9. The Site excavation worker risk calculation data tables are provided in Appendix N, Tables N-7 through N-8.

The HI for noncancer effects is 0.4 under the RME scenario and 0.2 under the CTE scenario. Both scenarios are below the EPA and MDEQ regulatory threshold value of 1. The cumulative ELCR from all carcinogenic COPCs is 1×10^{-5} under the RME scenario and 1×10^{-6} under the CTE scenario. The RME and CTE are within EPA's risk management range of 1×10^{-6} to 1×10^{-4} and do not exceed the MDEQ regulatory target risk of 1×10^{-5} for cumulative risk. These results indicate that there are no unacceptable risks for hypothetical excavation workers, under the exposure assumptions used

Hypothetical Industrial Worker Scenario. Potential exposure to surface soil (0 to 10 inches bgs) was evaluated under this scenario. Potential routes of exposure to surface soil include incidental ingestion, dermal contact, and inhalation of dust. The following assumptions were used to estimate potential exposure for industrial workers:

- A 70-kg adult was assumed to be exposed to surface soil for 125 days per year over 25 years under the RME scenario, and for 125 days per year over 6.6 years under the CTE scenario.

The noncancer and excess lifetime cancer risk estimates for the worker scenario are summarized in Table 6-10. The Site industrial worker risk calculation data tables are provided in Appendix N, Tables N-9 through N-10.

The HI for noncancer effects is 0.4 under the RME scenario and 0.2 under the CTE scenario. Both scenarios are below the EPA and MDEQ regulatory threshold value of 1. The cumulative ELCR from all carcinogenic COPCs is 6×10^{-5} under the RME scenario and 7×10^{-6} under the CTE scenario. The RME and CTE are within EPA's risk management range of 1×10^{-6} to 1×10^{-4} and the RME scenario exceeds the MDEQ regulatory target risk of 1×10^{-5} for cumulative risk. These results indicate that there are unacceptable risks for hypothetical industrial workers, under the exposure assumptions used

Lead Evaluation. For the purposes of evaluation of potential risks from exposure to lead in soil, the ALM was used with default assumptions, with the exception that the absorption fraction was adjusted to incorporate the relative bioavailability of lead from soil of 0.35 based on the site-specific bioaccessibility studies (see Appendix C). Using these assumptions with the ALM (Table 6-11), a risk-based concentration of 4,340 mg/kg soil lead results in a blood lead level of 10 µg/dL in no more than 5 percent of exposed individuals. Therefore 4,340 mg/kg was used as a threshold for unacceptable risk. As indicated in Table 6-2, surface soil and subsurface soil EPCs for Bullion Mine are 123 and 399 mg/kg, respectively—both well below the risk-based concentration. These results indicate that there are no unacceptable risks from exposure to soil lead levels, under the exposure assumptions used.

6.5 Ecological Risk Assessment

This section describes the methodology and results for the ERA for the Bullion Mine. 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 Bullion Mine.

The overall objective of the ERA is 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, if necessary.

The ERA characterizes the ecological communities at and in the vicinity of the Bullion Mine, identifies complete ecological exposure routes, identifies contaminants of ecological concern, and determines whether ecological exposures are estimated to pose unacceptable risks and therefore may need to be addressed during a FS. The ERA uses multiple lines of evidence, to determine whether any releases at the Site could pose unacceptable risk to these ecological receptors.

6.5.1 ERA Guidance

The procedures used for the ERA are consistent with those described in the following EPA guidance documents:

- *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final* (EPA, 1997c)
- *Final Guidelines for Ecological Risk Assessment* (EPA, 1998)
- *Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (EPA, 1999)
- *The Role of Screening-Level Risk Assessments and Refining Contaminants of Concern in Baseline Ecological Risk Assessments* (EPA, 2001)
- *Wildlife Exposure Factors Handbook* (EPA, 1993)
- *Eco Updates, Volume 1, Numbers 1 through 5* (EPA, 1991b, 1991c, 1992a, 1992b, 1992c)
- *Eco Updates, Volume 2, Numbers 1 through 4* (EPA, 1994a, 1994b, 1994c, 1994d)
- *Eco Updates, Volume 3, Numbers 1 and 2* (EPA, 1996a, 1996b)

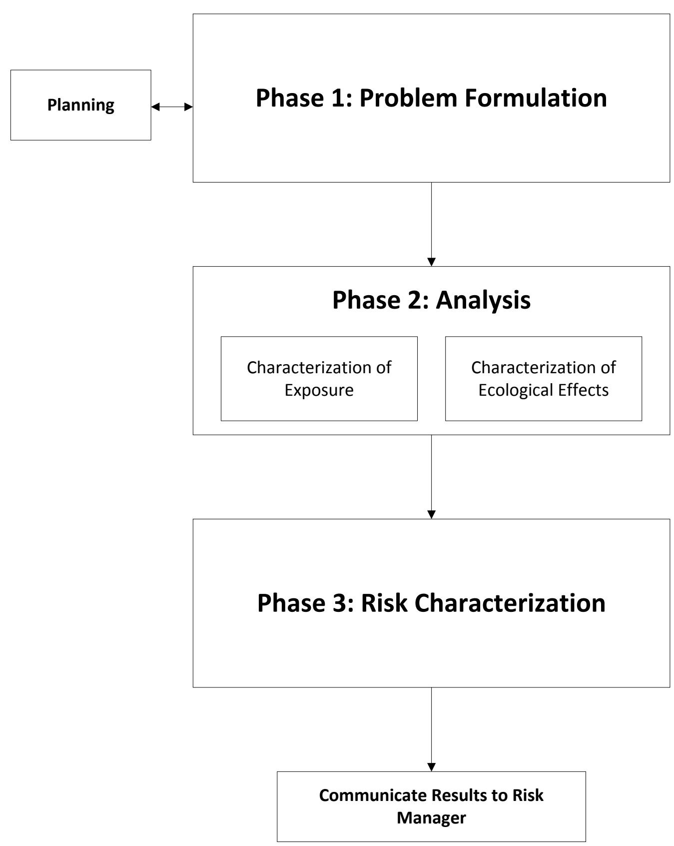
6.5.2 ERA Methodology

The ERA follows the eight-step approach recommended by EPA (1997a). This process is shown in Figure 6-2 and is listed as follows:

- **Step 1.** Screening-level problem formulation and ecological effects evaluation
- **Step 2.** Screening-level exposure estimate and risk calculation
- **Step 3.** Baseline risk assessment problem formulation
- **Step 4.** Study design and DQO process
- **Step 5.** Verification of field sampling plan
- **Step 6.** Site investigation and data analysis
- **Step 7.** Risk characterization
- **Step 8.** Risk management

The process begins with the screening level ecological risk assessment (SLERA) which uses intentionally conservative assumptions to screen the initial list of detected constituents to identify those constituents requiring further evaluation. The principal components of the SLERA are the screening level problem formulation (Step 1), exposure estimation, effects evaluation, and screening level risk calculation (Step 2). If any COPECs are present at concentrations that indicate the need for further evaluation, the process is

FIGURE 6-2
EPA's Ecological Risk Assessment Framework (EPA, 1998)



repeated using more site-specific and, generally, less conservative exposure assumptions and a second risk calculation that includes a less conservative toxicity reference value (Step 3, baseline problem formulation). These refined calculations can lead to a decision to conduct additional studies to further refine exposure estimates and effects relationships (Steps 4 through 6) or, through completion of Step 7, serve as the baseline ERA for the Site. The final step, Step 8, concludes with risk management decisions.

EPA recognizes that the eight-step approach is not a linear or sequential process and some steps may not be necessary to reach a decision point. Throughout the ERA process, the risk assessment review team, risk managers, and stakeholders evaluate available information through stages termed as Scientific Management Decision Point (SMDP). Possible decision points are (1) no further action is warranted, (2) further evaluation is warranted, (3) additional data are required, or (4) remedial action is warranted.

6.5.3 Step 1—Screening-Level Problem Formulation

Step 1 of the EPA's ERA process (EPA, 1997c), screening-level problem formulation, integrates available information (environmental setting; contaminant sources, transport and fate, and ecotoxicity; and receptors) and serves to provide focus to the ERA. The screening-level problem formulation includes a description of the Site setting, identification of COPECs, identification of the important aspects of the Site to be protected (referred to as "assessment endpoints"), the means by which the assessment endpoints were evaluated (measures of exposure and effects), and previous site investigations. The end product of the preliminary problem formulation is an ecological CEM that describes the contaminant sources and transport mechanisms, evaluates potential exposure pathways, and identifies the representative species that were used to assess potential ecological risk to those and other similar species.

6.5.3.1 Ecological Setting and Attributes

A detailed description of the physical and biological setting of the Bullion Mine is provided in Sections 1 and 2, and was summarized in Section 6.3. The summary included information on the following:

- Land and water use
- Aquatic and terrestrial habitat descriptions
- Potential presence of special-status species
- Contaminant sources and release mechanisms
- Contaminant release mechanisms
- Exposure points
- Receptors potentially exposed

6.5.3.2 Ecological Conceptual Site Model

A CEM schematic depicting the potential ecological exposures was developed for the Site and is presented in Figure 6-1.

Potentially Complete Ecological Exposure Pathways and Receptors. As identified in the CEM (Section 6.3.5.4), the most plausible ecological exposure pathways based on the available habitat and food sources at the Bullion Mine are as follows:

- Potential exposure of avian and terrestrial wildlife (primarily birds and mammals) to contaminants in surface soil (0 to 2 feet bgs).
- Potential exposure of wildlife to contaminants in surface water and sediment.
- Potential ingestion of site-related chemicals via uptake in the food chain by higher trophic level terrestrial and avian wildlife.
- Potential exposure of aquatic resources to contaminants present in surface water.
- Potential exposure of vegetated and forested areas to contaminants present in surface and subsurface soil.

These exposure pathways and receptor types are the focus of this ERA.

Assessment and Measurement Endpoints. One outcome of the screening level problem formulation is the identification of assessment and measurement endpoints. Generally, there are three components to the selection of endpoints: an *entity* (for example, herbivorous mammals), an *attribute* of that entity (for example, individual survival), and a *measure* (for example, a measurable value, such as an effect level). Superfund guidance states that assessment endpoints are any adverse effects on ecological receptors, where receptors are populations and communities, habitats, and sensitive environments (EPA, 1997a). The assessment endpoints for Bullion Mine are any adverse effects on receptor populations and communities for non-threatened and endangered species. Adverse effects on these assessment endpoints are predicted from measurement endpoints. The measurement endpoints for this site are the effects of contaminant exposure on reproduction, survival, or growth, which can be used to predict effects at all levels of organization (individual, population, and community). These factors are considered in the identification and evaluation of appropriate toxicity information.

Assessment endpoints frequently cannot be directly measured because they tend to correspond to complex ecosystem attributes. Because of this, the ERA identifies other related measures that serve as representations or surrogates of each assessment endpoint. These measures are called “measures of effect” and “measures of exposure” (EPA, 1998b). The strength of the relationships between these measures and their corresponding assessment endpoints is critical to the identification of ecological adversity. For this ERA, these measures will be defined as follows:

- Measures of exposure are quantitative or qualitative indicators of a contaminant’s occurrence and movement in the environment in a way that results in contact with the assessment endpoint. For example, chemical concentrations detected in surface soil serve as a measure of exposure to terrestrial wildlife that could use habitats at the Bullion Mine area.
- Measures of effect are measurable adverse changes in an attribute of an assessment endpoint (or its surrogate) in response to a chemical to which it is exposed. For example, literature-derived critical toxicity values from available laboratory studies on birds are used to indicate when raptors may be adversely affected.

On the basis of the information gathered during previous investigations and for this RI, the assessment endpoints identified for the Bullion Mine and the corresponding measures of exposure and effect are summarized in Table 6-12.

Selection of Representative Ecological Receptors. To facilitate quantitative evaluation of potential exposures and effects associated with chemical stressors on assessment endpoints, ecological receptors are identified that are considered representative of indigenous wildlife functional groups at the Site. For example, the mule deer is considered to be representative of all large herbivorous species visiting the Bullion Mine, and risk estimates for this species are used to support a management decision for all ungulates. Like the assessment endpoint, the endpoint species should preferably be one that has ecological relevance, is of social value, is susceptible to chemical stressors at the Bullion Mine, and allows risk managers to meet policy goals. These four factors collectively describe the ecological value of the species selected, as well as the functional groups they represent. Another consideration in selection of endpoint species is the availability of literature-based exposure parameters such as body weight and dietary composition. Table 6-12 lists the selected endpoints, as well as their corresponding assessment endpoints and measures. The primary avian functional groups that use the various habitat types occurring at the Bullion Mine include herbivorous birds, insectivorous birds, and carnivorous birds. Key mammalian functional groups include herbivorous mammals, omnivorous mammals, and carnivorous mammals. The ecological receptors chosen as representatives of each functional group are presented in Table 6-12. A short description of each representative wildlife receptor is presented below.

Dusky Flycatcher (insectivorous bird). The dusky flycatcher (*Empidonax oberholseri*) is a small insectivorous bird that frequently inhabits open coniferous forests, mountain chaparral, aspen groves, and streamside willow thickets in Montana (MNHP and Montana FWP, 2011). Flycatchers are aerial foragers consuming insects. The territory size in Western Montana Douglas-fir forests is reported to be 4.0 to 4.3 acres (MNHP and Montana FWP, 2011). The dusky flycatcher is a migratory bird that spends the summer in Montana, typically arriving in late May and leaving in early September. This species was chosen as an endpoint species because it is representative of insectivorous song birds using the Bullion Mine.

Spruce Grouse (herbivorous bird). Spruce grouse (*Falcipennis canadensis*) inhabit dense forest types such as alpine fir, Engelmann spruce, Douglas fir, or lodgepole pine (MNHP and Montana FWP, 2011). These grouse are smaller than blue grouse and are mostly herbivorous, foraging on conifer needles, herbaceous vegetation, and some insects (during the summer). Grouse are year-round residents of Montana and have reported home ranges of 10 to 15 acres (MNHP and Montana FWP, 2011). This species was selected as a representative herbivorous bird because of its common occurrence in Montana, its representativeness of other important species in the watershed (for example ptarmigan), and its potential exposure to vegetation and incidental ingestion of soil at the Bullion Mine.

Northern Goshawk (carnivorous bird/raptor). The northern goshawk (*Accipiter gentilis*) is the largest accipiter common to North America. The northern goshawk is a raptor that is found in woodlands and is known to use ponderosa pine, lodgepole pine, Douglas fir, and grand fir forests in Montana (MNHP and Montana FWP, 2011). The northern goshawk is an opportunistic feeder, preying on such animals as mice, shrews, voles, rabbits, squirrels, birds, and grouse. The reported home ranges in Montana are highly variable, from 235 to 14,000 acres (MNHP and Montana FWP, 2011). Northern goshawks are migratory; however, many are year-round residents in Montana and only migrate when prey availability is low. Because the northern goshawk is a raptor in the area and could feed on prey using the Bullion Mine area, it was chosen as the carnivorous avian receptor species for the Bullion Mine ERA.

Raccoon (omnivorous riparian mammal). The raccoon (*Procyon lotor*) is a widespread, permanent resident throughout much of Montana. Raccoons are omnivorous and highly opportunistic feeders. They are found in variety freshwater riparian habitats, foraging in shallow water, in vegetation, and on the ground. In spring, raccoons eat primarily animal matter that consists of fish, insects, and small mammals and birds. In the summer and fall, the diet shifts to large amounts of vegetative matter. Home ranges have been reported from 267 acres to 6,326 acres (EPA, 1993). This species was selected as a representative omnivorous mammal endpoint species because of its common occurrence in Montana, its representativeness of other omnivorous mammals common to the area, and the potential for exposure through ingestion of prey and ingestion of soil and sediment at the Bullion Mine.

Deer Mouse (small omnivorous mammal). The deer mouse (*Peromyscus maniculatus*) is a small mammal that is common in most dry-land habitats throughout the United States. It is an omnivorous and highly opportunistic feeder, eating primarily seeds, arthropods, green vegetation, roots, fruit, and fungi. The deer mouse is primarily nocturnal and is preyed upon by hawks, owls, snakes, and carnivorous mammals (EPA, 1993). Deer mice are year-round residents of Montana and have reported home ranges as low as 0.1 acres (EPA, 1993). The deer mouse was selected because it is representative of small mammals that occur at the Bullion and is expected to have high potential exposure because of its small foraging area, dietary composition, and incidental ingestion of soil.

Red Fox (carnivorous mammal). The red fox (*Vulpes vulpes)* is primarily a carnivorous mammal of approximately 3 to 7 kg that primarily prey on small mammals (for example, mice, voles, squirrels, and rabbits), as well as insects, berries, birds, and reptiles (EPA, 1993). The red fox is the most widely distributed carnivore in the world (EPA, 1993) and is found across many types of habitats, including cropland, brush, pastures, hardwood stands, and coniferous forests. Red foxes are highly mobile, often covering distances of more than 10 kilometers in a single day. Territories are maintained throughout the year, primarily by the male, but are largest during the winter and smallest during the rearing period. The home range size of red foxes is highly variable with a reported range from 237 acres to approximately 3,980 acres (EPA, 1993). Red fox may hunt and forage in the vicinity of the Bullion Mine; therefore, this species was selected as a representative carnivorous mammalian receptor for the risk assessment.

Mule Deer (large herbivorous mammal). Mule deer (*Odocoileus hemionus*) are larger herbivores that frequent open forest, brush, and shrub lands in mountain foothill habitats. Mule deer are common to central Montana and occur in the vicinity of the Bullion Mine. The mule deer was selected for evaluation as a large herbivorous mammal species because exposure parameters are available for this species and it is representative of other ungulates using the watershed (for example, elk). The diet of deer varies spatially and temporally and is difficult to generalize. Deer are primarily opportunistic browsers and their food sources may include twigs, bark, and leaves from trees, shrubs, and forbs. The mule deer home range is reported to be 704 acres (Sample et al., 1997). This species was chosen as a representative large herbivorous mammal endpoint species because of its common occurrence and potential for exposure via ingestion of vegetation and incidental ingestion of soil at the Bullion Mine.

Terrestrial Vegetation Endpoint Species. For the Bullion Mine, plants as a group represent the vegetation endpoint species. Toxicity data are unavailable for most native plant species. Therefore, any plants with available chemical toxicity data are selected as endpoint species.

Aquatic and Benthic Endpoint Species. Freshwater aquatic species as a group represent the endpoint species. These include the majority of freshwater fish and invertebrate species that are anticipated to be protected in the development of regulatory surface water criteria for aquatic life protection. Ambient water quality criteria are generally designed to protect 95 percent of a group of diverse genera (Stephan, 1985). Representative aquatic organisms potentially occurring in the Jill Creek near the Bullion Mine include macroinvertebrates (for example, riffle beetles [*Heterlimnius corplentus*], stoneflies [*Zapada columbiana*] and mayflies [*Baetis bicaudatus*]). The size of the stream and harsh winter temperatures preclude fish populations from occurring in surface water near the Bullion Mine. Historically, fish would be expected in downgradient streams (Jack Creek and Basin Creek). Fish residing in these streams could include salmonids (trout).

6.5.4 Step 2—Screening Level Exposure Estimate and Risk Calculation

The screening level risk calculation is the final step in the SLERA. In this step, the maximum exposure concentrations for each medium are compared with corresponding, and intentionally conservative ecological screening values (ESVs) to derive screening risk estimates. For example, site-wide maximum media-specific concentrations for all detected constituents are compared to risk-based screening values without consideration of fraction of time a receptor forages at the Bullion Mine. If ESVs are unavailable, then the constituents will be carried forward for further evaluation. The ecological screening levels used are described in the following text.

6.5.4.1 Soil Screening Values

The primary source of soil ESVs are EPA's ecological soil screening levels (Eco SSLs) (EPA, various dates). Soil ESVs for wildlife represent the lowest of the bird and mammal Eco SSL for each detected analyte. The preferential soil ESVs for terrestrial plants is also EPA's Eco SSLs. If no Eco SSLs are available, toxicological benchmarks for terrestrial plants from other literature sources are used. Soil ESVs are presented in Tables 6-13 and 6-14 for plants and wildlife, respectively.

6.5.4.2 Surface Water Screening Values

The freshwater chronic ESVs used are generally protective for most aquatic receptors that reside in the water column including aquatic plants, water-column invertebrates, amphibians, and fish. For the SLERA, an assumption is made that mine-related contaminants in seep and adit discharge water may discharge to surface water where aquatic organisms are present (Jill Creek), and detected contaminant concentrations in these media are also screened against ESVs. Surface water ESVs are presented in Table 6-15.

Chronic freshwater aquatic ESVs were selected using the most conservative values from the following sources:

- EPA National Recommended Water Quality Criteria available at: http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm
- Montana DEQ – Circular DEQ-7 Aquatic Life Criteria (MDEQ, 2012a).
- EPA Region 3 Freshwater Screening Benchmarks available at: http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fw/screenbench.htm

6.5.4.3 Sediment Screening Values

The sediment ESVs used are considered generally protective for most benthic receptors that reside in sediment including benthic microorganisms, benthic invertebrates, and benthic fish. The primary source used for sediment ESVs are the EPA Region 3's Freshwater Sediment Screening Benchmarks available at: http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm

Sediment ESVs are presented in Table 6-16.

6.5.4.4 Screening Risk Calculation

In this step, the maximum exposure concentrations detected at Bullion Mine (in each medium) were compared with the corresponding ESV to derive screening level risk estimates. Detected contaminants were evaluated using the HQ method. HQs were calculated by dividing the appropriate EPC (for the SLERA; that is, maximum detected concentrations) by corresponding medium-specific ESVs. Contaminants with HQs greater than or equal to 1 were identified as COPECs and carried forward for additional evaluation. Detected constituents for which ESVs are not available are also carried forward. The following were identified in the SLERA as COPECs for their respective exposures:

- **Soil** (plants; see Table 6-13)—aluminum, antimony, arsenic, cadmium, copper, iron, lead, manganese, selenium, zinc
- **Soil** (wildlife; see Table 6-14)—aluminum, antimony, arsenic, cadmium, copper, iron, lead, selenium, silver, zinc
- **Surface Water** (aquatic organisms; see Table 6-15)—aluminum, arsenic, cadmium, copper, iron, lead, manganese, nickel, zinc
- **Sediment** (benthic infauna; see Table 6-16)—antimony, arsenic, cadmium, copper, iron, lead, manganese, silver, thallium, zinc

6.5.4.5 Recommendation for SMDP 1

This SLERA was conducted using conservative assumptions to determine whether there are any contaminants, receptors, and/or exposure pathways that should be carried forward for additional evaluation as part of a baseline ecological risk assessment (BERA). Screening-level risk estimates were completed for plants, aquatic organisms, sediment infauna, birds, and mammals. The resulting characterization indicates that a BERA is warranted because contaminant levels may be high enough to pose an unacceptable risk to ecological receptors. Therefore, the COPECs and exposures identified in Section 6.5.4.4 were evaluated further in Step 3.

6.5.5 Step 3—Baseline Ecological Risk Assessment Problem Formulation

Upon completion of the SLERA, several metals/metalloids were identified as COPECs and are carried forward for additional evaluation in the 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. At the conclusion of Step 3, SMDP 2 is completed.

6.5.6 Refinements to Risk Estimates

Potential effects to plant and wildlife communities were assessed using an approach that considers multiple lines of evidence collectively, in accordance with EPA guidance in *Guidelines for Ecological Risk Assessment* (EPA, 1998). The various lines of evidence include the following:

6.5.6.1 Lines of Evidence for Plants

1. Soil EPCs are calculated using EPA's statistical program ProUCL (EPA, 2011b) following the procedures described in Section 6.4.2.2. These EPCs are compared with ESVs for plants.
2. Relative contribution of background levels is considered.

6.5.6.2 Lines of Evidence for Aquatic Organisms

1. Data collected nearest to exposure points (for example, surface water collected within Jill Creek) are the focus of the BERA.
2. Relative contribution of background levels is considered.
3. Historical in situ fish toxicity testing results are discussed.

6.5.6.3 Lines of Evidence for Sediment Infauna

1. Sediment concentrations are compared with freshwater sediment benchmarks above which adverse effects were likely to occur.
2. The results of a site-specific benthic macroinvertebrate investigation conducted in 2010 are considered.
3. The relative contribution of background is considered.

6.5.6.4 Lines of Evidence for Wildlife

1. Soil EPCs are calculated using EPA's statistical program ProUCL. Sediment and surface water EPCs from samples collected in Jill Creek are used along with the soil EPCs to refine exposure estimates.
2. Site-specific food chain models are used to evaluate the exposures and risk to endpoint species representative of those using the habitats at Bullion Mine.
3. Chronic-lowest-observed-adverse-effect levels (LOAELs) are included to evaluate the range of risk associated with a COPEC in each feeding guild.
4. The relative contribution of background is considered.

6.5.7 Analysis Phase

Building on the CSM and ecological endpoints and measures identified during preliminary problem formulation, the analysis phase provides quantification of potential exposures to the selected endpoint species (or representatives of the functional groups) and characterization of the toxic properties of the COPECs detected in site media at the Bullion Mine.

The following sections (1) describe the methods and equations that were used to compute potential exposure to aquatic resources, wildlife, and vegetation, and (2) identify the toxicity associated with the COPECs at the Bullion Mine.

6.5.7.1 Estimation of Exposure and Effects to Terrestrial Plants

Terrestrial plants experience exposure primarily through the soil in which they live. This exposure occurs as a consequence of living in a contaminated medium (that is, receptors are directly exposed to COPECs). Although other exposure pathways (for example, foliar uptake) may contribute to total exposure for these receptors, exposure through the soil predominates. Consequently, estimates of exposure for terrestrial plants may be represented by the concentration of COPECs in the soil (mg/kg). For the BERA, soil EPCs were calculated by using the same approaches described for the HHRA methodology (Section 6.4.2.2) and are used for comparisons with soil ESVs for terrestrial plants.

6.5.7.2 Estimation of Exposure and Effects to Aquatic Resources

Aquatic organisms (such as invertebrates and fish in the water column) in Jill Creek and further downstream in Jack Creek and Basin Creek may be exposed to current or historic releases of metals and acidic water from the Bullion Mine (Note: Basin Creek is influenced by several mines in the watershed that are not evaluated as part of this RI). For the BERA, aquatic organisms potentially exposed to COPECs in surface water were evaluated using COPEC concentrations measured directly from Jill Creek. For each COPEC in surface water, federal (EPA, 2013) and state chronic water quality criteria (MDEQ, 2012) were selected as the toxicological endpoint. Hardness dependent metals were conservatively adjusted based on the lowest hardness measured (38 mg/L) in Jill Creek during 2010 July and August sampling events.

6.5.7.3 Estimation of Exposure and Effects to Benthic and Epibenthic Organisms

Benthic and epibenthic (such as freshwater beetles, mayflies, and stoneflies) in Jill Creek and further downstream in Jack Creek may be exposed to site-related COPECs in sediment adjacent to and immediately downgradient of the Bullion Mine. A screening of shallow sediment with conservative freshwater sediment benchmarks was conducted during the SLERA. For the BERA, invertebrates potentially exposed to contaminated sediments are evaluated by comparing COPEC concentrations with available freshwater sediment probable effects-based benchmarks. Additionally, benthic macroinvertebrate surveys have been conducted at several locations in Jill Creek and Jack Creek. The statistics for several metrics are used to determine whether adverse impacts are seen in the creeks downgradient of potential source areas at the Bullion Mine.

6.5.7.4 Estimation of Exposure to Wildlife

Wildlife experience contaminant exposure through multiple pathways, including ingestion of abiotic media (surface water and sediment/soil) and biotic media (food), as well as inhalation and dermal contact. To assess this multiple pathway exposure, modeling can be/or is often employed. The exposure estimate for wildlife is expressed as a dosage rather than a medium concentration, as is the case for the other receptors (for example, aquatic resources, benthic organisms, plants). This is a function of both the multiple pathway approach and the typical methods used in toxicity testing. The general form of the model used to estimate exposure of wildlife to chemicals in environmental media is as follows (Suter II et al., 2000):

$$E_t = E_o + E_d + E_i$$

where:

E_t = Total chemical exposure experienced by wildlife
E_o = Oral exposure
E_d = Dermal exposure
E_i = Inhalation exposure

Oral exposure occurs through the consumption of contaminated food, water, or sediment/soil. Dermal exposure occurs when contaminants are absorbed directly through the skin, and inhalation exposure occurs when volatile compounds or fine particulates are inhaled into the lungs. Although methods are available for assessing dermal exposure to humans, data necessary to estimate dermal exposure generally are not available for wildlife. Similarly, methods and data necessary to estimate wildlife inhalation exposures are poorly developed. Additionally, a wildlife receptor's exposure to contaminants by inhalation and dermal contact usually contributes little to its overall exposure. Dermal exposure also is likely to be low, even in burrow-dwelling animals, because of the presence of protective dermal layers (for example, feathers and fur). Therefore, this ERA assumes that both dermal and inhalation exposure is negligible.

According to the CEM, the most feasible means of ecological exposure of upland and wildlife (birds and mammals) to COPECs is by food chain transfer. Quantitative exposure estimates for birds and mammals were developed using food web modeling procedures consistent with EPA guidance (1993). These models use best available information for predicting the ability and extent of the movement of a chemical through the food chain with ultimate uptake into an endpoint species. In addition, the food web models consider concomitant chemical intake from soil or sediment incidentally ingested with food items and during preening or digging activities. As a result of the historical physical disturbance of the land, likely effects of elevated COPECs, and lack of top soil possibly limiting nutrient levels suitable for growth, much of the Bullion Mine contains barren land (devoid of vegetated) that provides little cover or food source for wildlife. Therefore, in the land's current state, wildlife are not expected to receive a large portion of their forage from the Site, and exposure estimates likely to overstate the actual risk to wildlife. This and other uncertainties are described in Section 6.6.

Ingestion of surface water containing mine-related COPECs is another potential source of exposure for wildlife and could occur through (1) ingestion of adit discharge water, and (2) ingestion of the seep and in-stream surface water concentrations. Data collected in 2010 from the latter are used for the summation of cumulative risk to a receptor as use of adit discharge water for drinking is unlikely because of the very low pH (less than 4).

For evaluating exposure to avian and mammalian endpoint species through the food chain at areas containing usable upland/riparian habitat, the following generic equation was used to estimate chemical-specific intake:

$$E_o = \left[(I_f) \times \left((P_m \times Tiss_m) + (P_{ti} \times Tiss_{ti}) + (P_p \times Tiss_p) + (C_s \times P_s \times BF)\right)\right] + (C_w \times I_w) + (C_{sd} \times I_f \times P_{ai} \times Tiss_{ai}) \times (AUF)$$

where:

E_c = Chemical exposure (mg/kg-day)
C_s = Soil concentration (mg/kg)
I_f = Daily food intake (kg food [dry weight]/kg body weight/day)
P_m = Proportion of small mammals/birds in diet (unitless)
$Tiss_m$ = Estimated small mammal tissue concentration (unitless)
P_{ti} = Proportion of terrestrial invertebrates in diet (unitless)
$Tiss_{ti}$ = Estimated terrestrial invertebrate tissue concentration (unitless)
P_p = Proportion of plant tissue in diet (unitless)
$Tiss_p$ = Estimated plant tissue concentration (unitless)
P_s = Proportion of soil or sediment in diet (unitless)
BF = Bioavailability adjustment factor (unitless) [2]
C_w = Surface water concentration (mg/kg)
I_w = Daily water intake (mg/L)
C_{sd} = Sediment concentration (mg/kg)
P_{ai} = Proportion of aquatic invertebrates in diet (unitless)
$Tiss_{ai}$ = Estimated aquatic invertebrate tissue concentration (unitless)
AUF = Area use factor (unitless)

Exposure calculations for wildlife are provided in Table 6-18.

Wildlife Exposure Parameters. As can be seen from the intake equations presented above, to estimate mammalian or avian exposure, media concentration data are needed as well as exposure parameters that are specific to the endpoint species. EPCs that serve as input to the intake equations were developed by using the same approaches described for the HHRA methodology (Section 6.4.2.2).

Species-specific exposure parameters (for example, food intake rate or dietary composition) are provided in Table 6-17. All weight-based exposure parameters are provided on a dry-weight basis.

When biological information (for example, food ingestion rates) was unavailable, allometric equations were used to approximate exposure parameters (EPA, 1993). Food ingestion rates for the mule deer and deer mouse are measured rates reported by Nagy (2001). The daily food ingestion rates, in grams of forage consumed per day were estimated using trophic group-specific or taxa-specific allometric equations provided by Nagy (2001) as follows:

Carnivorous birds (grams[g]/day) = 0.849 * $BW^{0.663}$ (used for northern goshawk)
Carnivorous mammals (g/day) = 0.153 * $BW^{0.834}$ (used for red fox)
Omnivorous mammals (g/day) = 0.432 * $BW^{0.678}$ (used for raccoon)
Insectivorous birds (g/day) = 0.540 * $BW^{0.705}$ (used for dusky flycatcher)
Galliformes (g/day) = 0.088 * $BW^{0.891}$ (used for spruce grouse)

where:

BW = Body weight (g)

The food intake rates are then normalized by converting to kg of food per kg of body weight per day for the exposure estimates.

[2] Note: The bioavailability factor for all COPECs is conservatively assumed to be 1. However, it should be recognized that the arsenic bioavailability adjustment factor of 0.15 used in HHRA is based on methods derived using mammal studies.

Estimation of Bioaccumulation into Food Items. Bioaccumulation can be defined as the uptake and accumulation of chemicals by organisms from the nonliving (abiotic) environment or through the diet. The concentration of a site-related chemical in a food chain item is not always available, but must be estimated. For the purposes of exposure estimation, the partitioning of chemicals from soil or sediment to vegetation or prey food items were estimated regression equation and literature values.

This ERA evaluates the risk to endpoint species that consume four primary classes of food items (small mammals, aquatic and terrestrial invertebrates, and plants). The primary source for estimation of bioaccumulation into biota tissue from soil and sediment is Table 4a – Uptake Equations for Inorganics provided in Attachment 4-1 of EPA's *Guidance for Developing Ecological Soil Screening Levels.* (EPA, 2005c)

Table 6-18 provides the estimated tissue concentrations used for exposure calculations. Table 6-19 presents the methods used to derive tissue concentrations using site-specific COPEC concentrations along with the resulting estimated tissue concentrations for each food item.

Consideration of Endpoint Species Home Range. Each of the endpoint species selected for the ERA has a typical geographic home range where foraging occurs. The size of the home range can influence the likelihood that a species will forage at a particular area of concern at the Bullion Mine (40 acres). The larger the home range, the less likely that a significant portion of the total diet comes from a particular area of concern. Where appropriate, the risk calculations account for available species-specific home ranges from literature. The species-specific AUF is an estimate of the fraction of the geographic area occupied by each site relative to the overall area that the endpoint species will actually use for foraging in this region of Montana. For receptors with exposure areas larger than reported foraging areas, an AUF of 1 is assumed.

6.5.7.5 Estimate of Toxicity to Mammals and Birds

For mammalian and avian receptors, a literature review of the toxicological properties for site chemicals was conducted to identify the highest exposure level considered to be without adverse ecological impact. This level is referred to as a no observed adverse effect levels (NOAEL). A toxicity reference value (TRV) is then derived by interpreting existing toxicology studies and adjusting those data, if necessary, to obtain values that are expected to protect the selected endpoint species. Literature references citing use of laboratory animals that have similar sensitivity, life history, or habitat requirements were used as surrogates for the wildlife ecological receptor species. Toxicity data were adjusted for the uncertainty associated with differences between the laboratory tests and the receptor in the environment.

Derivation of wildlife TRVs for the endpoint species involved the following three-step process:

1. Conducting a literature search to compile data on toxicity of the COPECs to surrogate (laboratory test) species.
2. Reviewing these toxicity data to select the most appropriate values for each COPEC.
3. Applying uncertainty factors from the toxicology literature to derive a chronic, NOAEL or LOAEL (lowest observed adverse effect level) from other endpoints (for example, subchronic studies), if necessary.

For mammalian and avian receptors, the primary toxicological endpoint used for development of the TRV is the chronic NOAEL for assessing effects to threatened and endangered (T&E) species. A LOAEL is considered more relevant than the NOAEL for identifying acceptable risk to animal populations. Because ecological populations will be the primary focus of this ERA, population-level endpoints such as reproduction or survival are of greatest concern. The primary sources of TRVs for this ERA are the EPA's *Ecological Soil Screening Level (Eco SSLs) Reports* (2005 through 2007), if available. Avian and mammalian toxicity studies used to derive NOAEL-based and LOAEL-based TRVs are summarized in Tables 6-20 and 6-21, respectively.

6.5.8 Risk Characterization Methodology

Risk characterization is a way of quantitatively or qualitatively characterizing the potential risks for each COPEC and receptor identified in the COPEC screening process. The primary means of characterizing ecological risk for wildlife is to determine the ratio of the estimated chemical exposure level or dose for the wildlife receptor with the COPEC-specific TRV. Hazard quotients can be calculated to quantitatively characterize these risks. The following equation was used:

$$HQ = \frac{E}{TRV}$$

where:

HQ = Ecological hazard quotient (unitless)
E = Estimated COPEC exposure (mg/kg-day)
TRV = Toxicity reference value (mg/kg-day)

The primary means for quantifying ecological risk for plants, aquatic organisms, and sediment infauna is to determine the ratio of the estimated COPEC exposure levels for the endpoint species of concern with the COPEC-specific ecological benchmark criterion.

$$HQ = \frac{EPC}{ESV}$$

where:

HQ = Ecological hazard quotient (unitless)
EPC = Exposure point concentration (mg/kg or mg/L)
ESV = Ecological screening value criterion (mg/kg or mg/L)

The HQ estimates were expressed in one significant figure, in accordance with EPA guidance. A HQ that exceeds 1 indicates that there is a potential for adverse ecological effects associated with exposure to that COPEC and further evaluation of remedial actions may be warranted. A HQ value less than or equal to 1 is considered protective of each receptor's feeding guild that it represents because it is developed using conservative exposure assumptions. HQs were provided using both NOAEL-based and LOAEL-based TRVs and relative differences between the LOAEL and NOAEL is also considered.

The risk quantification results are discussed separately for plants, aquatic resources, benthic infauna, and wildlife (mammals and birds).

Risk Estimation for Plants. The potential for adverse effects on terrestrial vegetation was evaluated by comparing chemical concentrations detected in surface (0 to 2 feet bgs) and subsurface soil (0 to 10 feet bgs) with plant screening benchmarks. This ERA uses the following benchmarks for the screening:

- Plant screening levels reported in *Ecological Soil Screening Level (EcoSSLs) Reports* (EPA, 2005 through 2007).
- *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision* (Efroymson et al., 1997).

These terrestrial plant screening benchmarks for COPECs are summarized in Table 6-22. In additional, surface and subsurface soil background levels collected at the Site during 2010 are provided for comparison.

The comparisons of COPEC EPCs detected in surface soil collected in 2010 with plant benchmarks are provided in Table 6-22. The results indicate that concentrations for the following 7 COPECs exceeded benchmarks (maximum factor of exceedance in parenthesis for surface and subsurface soil, respectively) and levels measured at background locations:

- Antimony (28, 28)
- Arsenic (64, 62)
- Copper (3, 2)
- Lead (3, 3)
- Manganese (3, 3)
- Selenium (2, 2)
- Zinc (2, 2)

Exceedances occur in both surface and subsurface soils, with the greatest factors of exceedances being from antimony and arsenic. Antimony and arsenic EPCs were also greater than 10 times abovebackground levels. These results indicate that soil concentrations at the Bullion Mine exceed levels known to pose a risk to vegetation and the levels of the COPECs at the Site are above measured background levels. Considering higher concentrations occur below the soil cap, deeper rooted vegetation forms are expected to have the greatest potential of being affected.

Conclusions of Risk Estimation for Plants. The risk evaluation for plants indicates that measured levels of several COPECs exceed levels that may pose a risk to vegetation. Previous remedial actions at the Bullion Mine included soil removal and capping with clean cover soil to approximately 18 inches. Therefore, exposure of plants to elevated levels of contaminants in soil is likely limited to forms that root below the soil cap.

Ecological Risk Quantification for Aquatic Resources. Freshwater aquatic resources represent endpoint species of concern because they serve as a food source for upper-trophic-level species that frequent habitat adjacent to and within the influence of the Bullion Mine. To provide confidence in any decision making regarding aquatic resources in the Jill Creek and downgradient streams, potential effects on aquatic communities are assessed using an approach that considers multiple lines of evidence collectively (EPA, 1997c). The lines of evidence evaluated to identify the potential for risks to aquatic resources are as follows:

- Identification of constituent concentrations in surface water that exceed effects-based screening benchmarks (for example, freshwater WQC).
- Comparison of constituent concentrations detected in surface water adjacent to and downstream of the Bullion Mine with those detected from upstream in Jill Creek.
- Historical fish in situ fish survivability studies.

Benchmark Comparisons for Surface Water in USG Creek. The comparisons of COPEC concentrations detected in surface water collected in 2010 with surface water benchmarks are provided in Table 6-23. The results indicate that acute WQC were exceeded for the following COPECs (maximum factor of exceedance in parenthesis):

- Dissolved aluminum at JC-3 (1.3) and JC-4 (1.2)
- Dissolved cadmium at JC-3 (28) and JC-4 (28)
- Dissolved copper at JC-2 (2.1), JC-3 (88), and JC-4 (83)
- Dissolved zinc at JC-2 (2.0), JC-3 (51), and JC-4 (48)

The results indicate that chronic WQC were exceeded for the following COPECs (maximum factor of exceedance in parenthesis):

- Dissolved aluminum at JC-3 (12) and JC-4 (10.5)
- Dissolved cadmium at JC-2 (6.1), JC-3 (173), and JC-4 (172)
- Dissolved copper at JC-2 (2.8), JC-3 (123), and JC-4 (115)
- Dissolved iron at JC-3 (6.2) and JC-4 (5.6)
- Dissolved lead at JC-3 (8.7) and JC-4 (8.3)
- Dissolved zinc at JC-2 (2.0), JC-3 (51), and JC-4 (48)

The pH of surface water ranged from 4.9 (JC-3) to 5.9 (JC-2) which is below the chronic WQC range of 6.5 to 9.0. In addition, as shown in Table 6-23, aluminum, arsenic, cadmium, copper, iron, lead, manganese, nickel, and zinc are significantly elevated in JC-3 located below the influence of the adit discharge when compared with the upstream reference location (JC-1).

Historical In Situ Fish Toxicity Testing. A study published by the USGS (2000) reported that the survivability of juvenile cutthroat trout (hatchery-raised) following a 96-hour exposure was zero at several sites within the Upper Jack Creek. USGS reported (2000), that during the 1999 in situ testing, fish died within 5 and 8 hours at the Bullion Mine tributaries.

Conclusions of Risk Characterization for Aquatic Resources. The results of the benchmark comparisons for surface water indicate that cadmium, copper, and zinc significantly exceeded freshwater acute and chronic WQC. To a lesser extent, aluminum, iron, and lead concentrations in Jill Creek were also measured at levels exceeding freshwater chronic WQC. As indicated in the SLERA (Table 6-15), the analytical results indicate that a substantial portion of the concentrations observed downstream are a result of high metals concentrations discharging from the mine adit, which is located upgradient of JC-3 where surface water concentrations are the highest. These exceedances indicate that water quality within Jill Creek is not suitable to support aquatic life. Furthermore, historical fish toxicity testing conducted within Jack Creek provides empirical evidence in support of this conclusion. Considered collectively, these lines of evidence provide a strong indication that these COPECs in surface water in Jill Creek are at levels that pose significant risk to aquatic resources.

Ecological Risk Quantification for Benthic Infauna. Benthic invertebrates represent receptors of concern because they serve as a food source for upper-trophic-level species that frequent the riparian areas along the Bullion Mine. 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. The lines of evidence evaluated to identify the potential for risks to sediment infauna are as follows:

- Identification of constituent concentrations in sediment that exceed probable effects-based screening benchmarks (for example, upper effects thresholds and cleanup screening levels [CSLs])
- Comparison of constituent concentrations detected in sediment from adjacent to and downstream of the Bullion Mine with those detected from upstream in Jill Creek.
- Comparison of the macroinvertebrate field survey results from adjacent to and downstream of the Bullion Mine with those detected from upstream in Jill Creek.
- Comparison of COPC concentrations in sediment with macroinvertebrate population metrics.

Effects-Based Benchmark Screening for Sediment. The comparisons of COPEC concentrations detected in sediment collected in 2012 with probable (upper) effects benchmarks are provided in Table 6-24. These represent levels above which significant benthic macroinvertebrate impairment would be likely. The following conclusions can be drawn from the benchmark comparisons:

- Probable effects benchmarks are exceeded for antimony, arsenic, cadmium, iron, and silver at sample locations adjacent to or downgradient of the Bullion Mine area. Arsenic had the highest levels of exceedance with levels 15 times above the CSL 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. Although the results in Table 6-24 indicate arsenic slightly exceed the CSL at the location upstream of the Bullion Mine (JC-1), the levels downstream are significantly elevated (at JC-2, JC-3, and JC-4).

2010 Benthic Macroinvertebrate Survey. An additional line of evidence supporting the ecological risk characterization for sediment consists of a site-specific benthic macroinvertebrate investigation conducted in 2010. The methodology and results are summarized in Section 3.12 and the report is provided in Appendix G. Six sampling locations were evaluated during this investigation: (1) Jill-1—upstream of the mine, (2) Jill-2—adjacent to the mine and immediately upstream of the adit discharge channel, (3) Jill-3—immediately below the adit discharge channel, (4) Jill-4—1,000 feet below the adit discharge channel, (5) Jack-5—Jack Creek below its confluence with Jill Creek, and (6) Jack-6—Jack Creek above its confluence with Jill Creek. The first four (in Jill Creek) correspond with sampling locations for surface water collected during 2010.

The study found that a sparse but diverse macroinvertebrate community occurs in Jill Creek above the Bullion Mine and that few organisms are living downstream of the mine. The study clearly showed significant impairment of benthic macroinvertebrate populations downstream of the Bullion Mine. Measurable impacts extended beyond the confluence of Jill Creek and Jack Creek, which is approximately one mile downstream of the mine. A sparse, but relatively diverse macroinvertebrate assemblage was present above the mine (Jill-1 and Jill-2).

Macroinvertebrate density and number of species declined significantly downstream of the mine Site (Jill-3 and Jill-4), which was essentially devoid of life. Macroinvertebrate density and taxa richness were also reduced in Jack Creek below Jill Creek (Jack-5) compared to the Site immediately upstream from the confluence with Jill Creek (Jack-6). In addition, macroinvertebrate community composition shifted to more tolerant species in Jack Creek (Jack-5) below Jill Creek compared to the Site approximately 80 m upstream (Jack-6).

Concentration-Response Evaluation. A supporting line of evidence is noting geographic trends between COPEC concentrations in sediment and corresponding benthic macroinvertebrate survey results. The relationship between COPEC concentrations in sediment and benthic macroinvertebrate health metrics (abundance and taxa richness) was explored. Limited data exist 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.

Conclusions of Risk Estimation for Sediment Infauna. The results of the benchmark comparisons for sediment indicate that antimony, arsenic, cadmium, iron, and silver exceed upper effects benchmarks above which adverse effects are expected. These exceedances indicate that sediment quality within Jill Creek is not suitable to support sediment infauna. The benthic macroinvertebrate study conducted in 2010 within Jill Creek and Jack Creek provided empirical evidence in support of this conclusion. Furthermore, although a statistical correlation could not be made, there appears to be an association between benthic macroinvertebrate impairment and COPEC concentrations in sediment. Considered collectively, these lines of evidence provided a strong indication that these COPECs in sediment in Jill Creek and Jack Creek near its confluence with Jill Creek are at levels that pose significant risk to sediment infauna.

Ecological Risk Quantification for Wildlife. The primary means of quantifying risks posed to mammalian and avian species that may use the Site is to determine the ratio of the estimated constituent exposure level for the endpoint species of concern (described in Section 6.5.7.4) with the constituent-specific TRV (described in Section 6.5.7.5). The following equation is used to determine the ratio:

$$Ecological\ HQ = I/TRV$$

where:

HQ	=	Hazard quotient (unitless)
I	=	Constituent intake level (mg/kg-day)
TRV	=	Toxicity reference value (mg/kg-day)

This ratio is called the ecological HQ. When the HQ exceeds 1, there is a potential for ecological risk. Wildlife risks from exposure to COPECs in surface soil, sediment, and water are addressed in this section.

Risk Estimation for Mammals and Birds. For wildlife, ecological HQs were derived by comparing the calculated (and combined) chemical intake of COPECs detected in surface soil, sediment, and surface water (based on food web models) with NOAEL-based and LOAEL-based TRVs identified to be protective of the birds and mammal. Exposure was assumed to occur to COPECs in soil and surface water collectively. The HQ results are provided in Table 6-25, and the intake estimates are presented in Table 6-18. COPECs resulting in ecological HQs exceeding 1 are presented below by endpoint species (HQs based on NOAEL and LOAEL are provided in parenthesis):

- Deer mouse—aluminum (231, 23), antimony (198, 20), arsenic (13, 8), cadmium (17, 10), copper (2, 1), lead (2, 2)
- Mule deer—aluminum (7, <1), antimony (5, <1), arsenic (3, 2)
- Red fox—aluminum (9, <1), antimony (3, <1)
- Raccoon—aluminum (46, 5), antimony (26, 3), arsenic (4, 2), cadmium (2, 1)
- Northern goshawk—none

- Dusky flycatcher—aluminum (10, not available), arsenic (7, 4); cadmium (23, 14), copper (11, 9), lead (16, 14), silver (4, <1), zinc (3, 2)
- Spruce grouse —none

A comparison of surface soil EPCs with the range of COPEC concentrations measured at background locations is provided in Table 6-22. For those COPECs identified with ecological HQs exceeding 1, surface soil EPCs for all are above background levels with the exception of aluminum. Additionally, as previously mentioned, early remedial actions at the Bullion Mine included the removal of contaminated soils and placement of a soil cover (capping) to an approximate depth of 18 inches bgs. Direct soil exposure for the majority of wildlife species generally occurs in the upper few inches of the soil profile. This uncertainty is discussed further in Section 6.6.

6.5.9 Conclusions of Risk Estimation for Mammals and Birds

The risk evaluation of mammalian and avian wildlife indicates that the combined exposures to measured levels of 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) and for species that burrow and consume burrowing organisms or deeper-rooted plant forms.

6.6 Uncertainty Associated with the Risk Assessments

Full characterization of human health and 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 sources of uncertainty can affect the overall estimates of human and ecological health presented in this assessment. The sources are generally associated with the following:

- Sampling, analysis, and data evaluation
- Chemical fate and transport estimation
- Exposure assessment
- Toxicity assessment
- Risk estimation

These sources of uncertainty are discussed in the following subsections.

6.6.1 Uncertainties Associated With Sampling, Analysis, and Data Evaluation

Uncertainties associated with sampling and analyses include the inherent variability (standard error) in the analysis, the representativeness of the samples, sampling errors, and heterogeneity of the sample matrix. The QA/QC program used during the various investigations serves to maintain acceptable precision and accuracy in measuring chemical concentrations, but it cannot eliminate all errors associated with sampling and analysis.

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.

6.6.2 Uncertainties Associated With Chemical Fate and Transport Estimation

This risk assessment made simplifying assumptions about the environmental fate and transport of COPCs/COPECs; specifically, that no attenuation has occurred since the sampling data were collected, or will occur in the future. In cases for which natural attenuation is high, the analytical data chosen to represent exposure concentrations could overstate actual long-term exposure levels.

6.6.3 Uncertainties Associated with Exposure Assessment

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.

As noted by SRC (2009), dust levels during ATV use is highly variable and greatly depends on the meteorological conditions, location of the riders relative to others, and ATV speed. The PEF used for the recreational user scenarios were derived from empirical data and are expected to provide a reasonable measure of exposure; however, depending on the actual particulate emissions at the Site, use of this PEF could over- or under-state actual risks to site users.

There is a relatively high level of uncertainty associated with the evaluation of exposure and risks for exposure to springs/seeps, since the results are based a limited data set and the degree of attenuation of seep water is expected to be considerable upon discharging and mixing into the Jill Creek. The risk assessment conservatively assumes these could be used as intermittently as drinking water sources.

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 COPCs/COPECs toxicity in a laboratory study (as reported in literature) used to derive a TRV. For this assessment, with the exception of arsenic and lead in the HHRA, 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 forage at the Bullion Mine 100 percent of the time when higher quality habitat is available in nearby locations. As previously stated, early remedial actions at the Bullion Mine included the removal of contaminated soils and placement of a soil cover (capping) to an approximate depth of 18 inches bgs. Direct soil exposure for the majority of wildlife species occurs in the upper few inches of the soil profile. Therefore, the assumption made that wildlife exposure occurs in the soil profile from 0 to 2 feet bgs likely overestimates the exposure to most species.

Maximum sediment concentrations were used for the food chain calculations, which likely results in an overestimation 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.

6.6.4 Uncertainties Associated With Toxicity Assessment

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.

The levels of uncertainty associated with the RfDs and RfCs for the COPCs (as judged by EPA) are expressed as uncertainty factors and modifying factors and are provided in IRIS or other sources listed in Section 6.4.3.3.

6.6.5 Uncertainties Associated with Risk Characterization

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to site contaminants is the sum of the risk attributed to each individual contaminant. Likewise, the potential for the development of noncancer adverse effects is the sum of the HQs estimated for exposure to each individual contaminant. This approach, in accordance with EPA guidance, did not account for the possibility that chemicals act synergistically or antagonistically. Because the COPCs/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.

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TABLE 6-1
Samples Used for Risk Assessment

Medium	Site	Location Description	Starting Depth (feet)	Ending Depth (feet)	Date Sample Collected	Intermittent Worker	Industrial Worker	Recreational User	Excavation Worker	Wildlife	Terrestrial Vegetation	Aquatic Resources	Benthic Infauna
Soil- XRF data	Bullion Test Pit 1: 0-2"	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 10: 0-2"	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 11: 0-2"	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 2: 0-2"	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 4: 0-2"	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 5: 0-2" Dup	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 5: 0-2"	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 6: 0-2"	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 7: 0-2"	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 7: 0-2" Dup	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 8: 0-2"	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 9: 0-2"	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 3: 0-2"	See Figure 3-5	0	0.2	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 8: 4-6"	See Figure 3-5	0.3	0.5	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 9: 4-6"	See Figure 3-5	0.3	0.5	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 3: 4-6"	See Figure 3-5	0.3	0.5	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 6: 7-9"	See Figure 3-5	0.6	0.8	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 9: 7-9"	See Figure 3-5	0.6	0.8	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 3: 7-9"	See Figure 3-5	0.6	0.8	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 11: 8-10"	See Figure 3-5	0.7	0.8	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 2: 8-10"	See Figure 3-5	0.7	0.8	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 4: 8-10"	See Figure 3-5	0.7	0.8	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 7: 8-10"	See Figure 3-5	0.7	0.8	8/7/2010	x	x	x	x	x	x		
Soil- XRF data	Bullion Test Pit 5: 9-11"	See Figure 3-5	0.8	0.9	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 10: 10-12"	See Figure 3-5	0.8	1.0	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 3: 11-13"	See Figure 3-5	0.9	1.1	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 1: 12-13"	See Figure 3-5	1.0	1.1	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 5: 12-14"	See Figure 3-5	1.0	1.2	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 7: 12-14"	See Figure 3-5	1.0	1.2	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 1: 14-15"	See Figure 3-5	1.2	1.3	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 10: 14-16"	See Figure 3-5	1.2	1.3	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 11: 14-16"	See Figure 3-5	1.2	1.3	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 8: 17-19"	See Figure 3-5	1.4	1.6	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 2: 18-19"	See Figure 3-5	1.5	1.6	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 4: 18-20"	See Figure 3-5	1.5	1.7	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 10: 20-23"	See Figure 3-5	1.7	1.9	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 11: 20-23"	See Figure 3-5	1.7	1.9	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 9: 20-23"	See Figure 3-5	1.7	1.9	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 1: 22-24"	See Figure 3-5	1.8	2.0	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 2: 22-24"	See Figure 3-5	1.8	2.0	8/7/2010				x	x	x		

TABLE 6-1
Samples Used for Risk Assessment

Medium	Site	Location Description	Starting Depth (feet)	Ending Depth (feet)	Date Sample Collected	Intermittent Worker	Industrial Worker	Recreational User	Excavation Worker	Wildlife	Terrestrial Vegetation	Aquatic Resources	Benthic Infauna
Soil- XRF data	Bullion Test Pit 3: 22-24"	See Figure 3-5	1.8	2.0	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 7: 22-24"	See Figure 3-5	1.8	2.0	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 6: 23-25"	See Figure 3-5	1.9	2.1	8/7/2010				x	x	x		
Soil- XRF data	Bullion Test Pit 4: 25-27"	See Figure 3-5	2.1	2.3	8/7/2010				x	x	x		
Soil- Lab data	Bullion Test Pit 10: 4-6"	See Figure 3-6	0.3	0.5	8/5/2010	x	x	x	x	x	x		
Soil- Lab data	Bullion Test Pit 5: 4-6"	See Figure 3-7	0.3	0.5	8/5/2010	x	x	x	x	x	x		
Soil- Lab data	Bullion Test Pit 1: 6-8"	See Figure 3-8	0.5	0.7	8/4/2010	x	x	x	x	x	x		
Soil- Lab data	Bullion Test Pit 3: 7-9"	See Figure 3-9	0.6	0.8	8/4/2010	x	x	x	x	x	x		
Soil- Lab data	Bullion Test Pit 8: 7-9"	See Figure 3-10	0.6	0.8	8/5/2010	x	x	x	x	x	x		
Soil- Lab data	Bullion Test Pit 9: 11-13"	See Figure 3-11	0.9	1.1	8/5/2010				x	x	x		
Soil- Lab data	Bullion Test Pit 4: 13-15"	See Figure 3-12	1.1	1.3	8/4/2010				x	x	x		
Soil- Lab data	Bullion Test Pit 6: 14-16"	See Figure 3-13	1.2	1.3	8/5/2010				x	x	x		
Soil- Lab data	Bullion Test Pit 2: 15-17"	See Figure 3-14	1.3	1.4	8/4/2010				x	x	x		
Soil- Lab data	Bullion Test Pit 11: 18-21"	See Figure 3-15	1.5	1.8	8/6/2010				x	x	x		
Soil- Lab data	Bullion Test Pit 7: 22-23"	See Figure 3-16	1.8	1.9	8/5/2010				x	x	x		
Surface water	USGS Station 462120112173701	Mouth of Jill Creek			2005 to 2009			x		x		x	
Surface water	Bullion ADIT Channel	Below Bullion Mine within the Adit Channel			7/15/2010			x		x		x	
Surface water	Bullion ADIT Channel	Below Bullion Mine within the Adit Channel			9/21/2010			x		x		x	
Surface water	Bullion Mine ADIT	Adit Discharge			7/17/2010			x		x		x	
Surface water	Bullion Mine ADIT	Adit Discharge			9/20/2010			x		x		x	
Surface water	Bullion Spring 1	See Figure 3-1			7/17/2010			x		x		x	
Surface water	Bullion Spring 1	See Figure 3-1			9/20/2010			x		x		x	
Surface water	Bullion Spring 2	See Figure 3-1			7/17/2010			x		x		x	
Surface water	Bullion Spring 2	See Figure 3-1			9/20/2010			x		x		x	
Surface water	Bullion Spring 3	See Figure 3-1			7/17/2010			x		x		x	
Surface water	Bullion Spring 3	See Figure 3-1			9/20/2010			x		x		x	
Surface water	Bullion Spring 5	See Figure 3-1			7/17/2010			x		x		x	
Surface water	Bullion Spring 5	See Figure 3-1			9/20/2010			x		x		x	
Surface water	Bullion Spring 6	See Figure 3-1			7/17/2010			x		x		x	
Surface water	Bullion Spring 6	See Figure 3-1			9/20/2010			x		x		x	
Surface water	Bullion Spring 7	See Figure 3-1			7/17/2010			x		x		x	
Surface water	Bullion Spring 7	See Figure 3-1			9/20/2010			x		x		x	
Surface water	Bullion Spring 8	See Figure 3-1			7/18/2010			x		x		x	
Surface water	Bullion Spring 8	See Figure 3-1			9/20/2010			x		x		x	
Surface water	Bullion Spring 9	See Figure 3-1			7/18/2010			x		x		x	
Surface water	Bullion Spring 9	See Figure 3-1			9/21/2010			x		x		x	
Surface water	Bullion Spring 10	See Figure 3-1			7/18/2010			x		x		x	
Surface water	Bullion Spring 10	See Figure 3-1			9/21/2010			x		x		x	
Surface water	Bullion Spring 11	See Figure 3-1			7/18/2010			x		x		x	
Surface water	Bullion Spring 11	See Figure 3-1			9/21/2010			x		x		x	

TABLE 6-1
Samples Used for Risk Assessment

Medium	Site	Location Description	Starting Depth (feet)	Ending Depth (feet)	Date Sample Collected	Intermittent Worker	Industrial Worker	Recreational User	Excavation Worker	Wildlife	Terrestrial Vegetation	Aquatic Resources	Benthic Infauna
Surface water	Bullion Spring 12	See Figure 3-1			7/18/2010			x		x		x	
Surface water	Bullion Spring 12D	See Figure 3-1			7/18/2010			x		x		x	
Surface water	Bullion Spring 12	See Figure 3-1			9/21/2010			x		x		x	
Surface water	Bullion Spring 13	See Figure 3-1			7/18/2010			x		x		x	
Surface water	Bullion Spring 13	See Figure 3-1			9/21/2010			x		x		x	
Surface water	Bullion Spring 13D	See Figure 3-1			9/21/2010			x		x		x	
Surface water	Bullion Spring 14	See Figure 3-1			7/18/2010			x		x		x	
Surface water	Bullion Spring 14	See Figure 3-1			9/21/2010			x		x		x	
Surface water	Jill Creek 1	Above Bullion Mine			7/15/2010			x		x		x	
Surface water	Jill Creek 1	Above Bullion Mine			9/21/2010			x		x		x	
Surface water	Jill Creek 2	Jill Creek Immediately Above Bullion Mine Adit Discharge Channel			7/15/2010			x		x		x	
Surface water	Jill Creek 2	Jill Creek Immediately Above Bullion Mine Adit Discharge Channel			9/21/2010			x		x		x	
Surface water	Jill Creek 3	Jill Creek Immediately Below Bullion Mine Adit Discharge Channel			7/15/2010			x		x		x	
Surface water	Jill Creek 3D	Jill Creek Immediately Below Bullion Mine Adit Discharge Channel			7/15/2010			x		x		x	
Surface water	Jill Creek 3	Jill Creek Immediately Below Bullion Mine Adit Discharge Channel			9/21/2010			x		x		x	
Surface water	Jill Creek 4	Jill Creek - Approximately 1000 feet below Adit Discharge Channel			7/15/2010			x		x		x	
Surface water	Jill Creek 4	Jill Creek - Approximately 1000 feet below Adit Discharge Channel			9/21/2010			x		x		x	
Sediment	JILL-01-SD		Solid		7/23/2012								x
Sediment	JILL-01-SD		10 MESH Solid		7/23/2012								x
Sediment	JILL-01-SD		80 MESH Solid		7/23/2012								x
Sediment	JILL-01-SD		230 MESH Solid		7/23/2012								x
Sediment	JILL-02-SD		Solid		7/23/2012								x
Sediment	JILL-02-SD		10 MESH Solid		7/23/2012								x
Sediment	JILL-02-SD		80 MESH Solid		7/23/2012								x
Sediment	JILL-02-SD		230 MESH Solid		7/23/2012								x
Sediment	JILL-03-SD		Solid		7/23/2012								x
Sediment	JILL-03-SD		10 MESH Solid		7/23/2012								x
Sediment	JILL-03-SD		80 MESH Solid		7/23/2012								x
Sediment	JILL-03-SD		230 MESH Solid		7/23/2012								x
Sediment	JILL-03-FD		Solid		7/23/2012								x
Sediment	JILL-03-FD		10 MESH Solid		7/23/2012								x
Sediment	JILL-03-FD		80 MESH Solid		7/23/2012								x
Sediment	JILL-03-FD		230 MESH Solid		7/23/2012								x
Sediment	JILL-04-SD		Solid		7/23/2012								x
Sediment	JILL-04-SD		10 MESH Solid		7/23/2012								x
Sediment	JILL-04-SD		80 MESH Solid		7/23/2012								x
Sediment	JILL-04-SD		230 MESH Solid		7/23/2012								x
Sediment	JILL-04-FD-MS/MSD		Solid		7/23/2012								x
Sediment	JILL-04-FD-MS/MSD		10 MESH Solid		7/23/2012								x
Sediment	JILL-04-FD-MS/MSD		80 MESH Solid		7/23/2012								x

TABLE 6-1
Samples Used for Risk Assessment

Medium	Site	Location Description	Starting Depth (feet)	Ending Depth (feet)	Date Sample Collected	Intermittent Worker	Industrial Worker	Recreational User	Excavation Worker	Wildlife	Terrestrial Vegetation	Aquatic Resources	Benthic Infauna
Sediment	JILL-04-FD-MS/MSD		230 MESH Solid		7/23/2012								x
Sediment	JACK-01-SD		Solid		7/23/2012								x
Sediment	JACK-01-SD		10 MESH Solid		7/23/2012								x
Sediment	JACK-01-SD		80 MESH Solid		7/23/2012								x
Sediment	JACK-01-SD		230 MESH Solid		7/23/2012								x
Sediment	JACK-02-SD		Solid		7/23/2012								x
Sediment	JACK-02-SD		10 MESH Solid		7/23/2012								x
Sediment	JACK-02-SD		80 MESH Solid		7/23/2012								x
Sediment	JACK-02-SD		230 MESH Solid		7/23/2012								x

TABLE 6-2

Soil Summary Statistics and Exposure Point Concentrations for Combined XRF and Laboratory Results

Depth Interval	Variable	Units	Number of Samples	Number of Detects	% Detects	Minimum	Maximum	Mean	Median	95% UCL	95% UCL Basis	EPC	EPC Basis
0-10 in bgs	Aluminum	mg/kg	5	5	100	13,800	16,500	15,060	15,000	16,088	95% Student's-t UCL	16,088	95% Student's-t UCL
0-10 in bgs	Arsenic [a]	mg/kg	26	24	92	2.5	1,496	195.5	59.75	442.8	95% KM (Chebyshev) UCL	442.8	95% KM (Chebyshev) UCL
0-10 in bgs	Cadmium	mg/kg	5	5	100	0.062	2.4	0.92	0.36	1.872	95% Student's-t UCL	1.872	95% Student's-t UCL
0-10 in bgs	Copper [a]	mg/kg	26	24	92	20.3	259	65.41	42.25	112.5	95% KM (Chebyshev) UCL	112.5	95% KM (Chebyshev) UCL
0-10 in bgs	Iron	mg/kg	5	5	100	16,100	18,000	16,880	16,500	17,635	95% Student's-t UCL	17,635	95% Student's-t UCL
0-10 in bgs	Lead [a]	mg/kg	26	26	100	18.5	192	74	46.5	122.6	95% Chebyshev (Mean, Sd) UCL	122.6	95% Chebyshev (Mean, Sd) UCL
0-10 in bgs	Manganese [a]	mg/kg	26	26	100	254	1,213	559.9	510	640.3	95% Student's-t UCL	640.3	95% Student's-t UCL
0-10 in bgs	Nickel	mg/kg	5	5	100	6.5	9.1	7.8	7.7	8.694	95% Student's-t UCL	8.694	95% Student's-t UCL
0-10 in bgs	Selenium	mg/kg	5	2	40	0.99	1.5	1.245	1.245	1.367	95% KM (t) UCL	1.367	95% KM (t) UCL
0-10 in bgs	Zinc [a]	mg/kg	26	26	100	39.2	1,442	218.3	117	487.7	95% Chebyshev (Mean, Sd) UCL	487.7	95% Chebyshev (Mean, Sd) UCL
0-2 ft bgs	Aluminum	mg/kg	11	11	100	6,560	16,500	12,771	14,300	14,793	95% Modified-t UCL	14,793	95% Modified-t UCL
0-2 ft bgs	Antimony	mg/kg	11	1	9	141	141	141	141		NA	141	Max Detect
0-2 ft bgs	Arsenic [a]	mg/kg	51	48	94	2.5	3,090	525.4	204.5	1,159	97.5% KM (Chebyshev) UCL	1,159	97.5% KM (Chebyshev) UCL
0-2 ft bgs	Cadmium	mg/kg	11	11	100	0.032	45.1	10.2	1.5	43.53	95% Adjusted Gamma UCL	43.53	95% Adjusted Gamma UCL
0-2 ft bgs	Copper [a]	mg/kg	51	48	94	20.3	887	101.2	57	178.3	95% KM (Chebyshev) UCL	178.3	95% KM (Chebyshev) UCL
0-2 ft bgs	Iron	mg/kg	11	11	100	16,100	35,400	20,155	17,500	23,639	95% Student's-t UCL	23,639	95% Student's-t UCL
0-2 ft bgs	Lead [a]	mg/kg	51	51	100	18.5	2,870	168	86	411.8	95% Chebyshev (Mean, Sd) UCL	411.8	95% Chebyshev (Mean, Sd) UCL
0-2 ft bgs	Manganese [a]	mg/kg	51	51	100	199	1,809	597.1	512	671.9	95% Student's-t UCL	671.9	95% Student's-t UCL
0-2 ft bgs	Nickel	mg/kg	11	11	100	6	11.4	7.936	7.7	8.741	95% Student's-t UCL	8.741	95% Student's-t UCL
0-2 ft bgs	Selenium	mg/kg	11	2	18	0.99	1.5	1.245	1.245	1.15	95% KM (t) UCL	1.15	95% KM (t) UCL
0-2 ft bgs	Silver	mg/kg	11	2	18	0.79	29.2	15	15	38.02	99% KM (Chebyshev) UCL	29.2	Max Detect
0-2 ft bgs	Zinc [a]	mg/kg	51	51	100	36.9	1,442	255.3	154	336.5	95% H-UCL	336.5	95% H-UCL
0-10 ft bgs	Aluminum	mg/kg	11	11	100	6,560	16,500	12,771	14,300	14,793	95% Modified-t UCL	14,793	95% Modified-t UCL
0-10 ft bgs	Antimony	mg/kg	11	1	9	141	141	141	141		NA	141	Max Detect
0-10 ft bgs	Arsenic [a]	mg/kg	53	50	94	2.5	3,090	510.8	204.5	1,124	97.5% KM (Chebyshev) UCL	1,124	97.5% KM (Chebyshev) UCL
0-10 ft bgs	Cadmium	mg/kg	11	11	100	0.032	45.1	10.2	1.5	43.53	95% Adjusted Gamma UCL	43.53	95% Adjusted Gamma UCL
0-10 ft bgs	Copper [a]	mg/kg	53	50	94	20.3	887	98.73	52.5	173.3	95% KM (Chebyshev) UCL	173.3	95% KM (Chebyshev) UCL
0-10 ft bgs	Iron	mg/kg	11	11	100	16,100	35,400	20,155	17,500	23,639	95% Student's-t UCL	23,639	95% Student's-t UCL
0-10 ft bgs	Lead [a]	mg/kg	53	53	100	18.5	2,870	163.8	67	398.7	95% Chebyshev (Mean, Sd) UCL	398.7	95% Chebyshev (Mean, Sd) UCL
0-10 ft bgs	Manganese [a]	mg/kg	53	53	100	199	1,809	596	512	668.1	95% Student's-t UCL	668.1	95% Student's-t UCL
0-10 ft bgs	Nickel	mg/kg	11	11	100	6	11.4	7.936	7.7	8.741	95% Student's-t UCL	8.741	95% Student's-t UCL
0-10 ft bgs	Selenium	mg/kg	11	2	18	0.99	1.5	1.245	1.245	1.15	95% KM (t) UCL	1.15	95% KM (t) UCL
0-10 ft bgs	Silver	mg/kg	11	2	18	0.79	29.2	15	15	38.02	99% KM (Chebyshev) UCL	29.2	Max Detect
0-10 ft bgs	Zinc [a]	mg/kg	53	53	100	36.9	1,442	250	152	323.4	95% H-UCL	323.4	95% H-UCL

Notes:

Unless noted; Lab data only

[a] Lab and XRF Data Combined- Lab data used for XRF locations (when available)

bgs = below ground surface

EPC = exposure point concentration

ft = feet

NA = UCL not available due to insufficient number of detected values

UCL = upper confidence limit on the mean

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TABLE 6-3
Bioavailability Summary Statistics and Exposure Point Concentrations

Variable	Number of Samples	Minimum	Maximum	Mean	Median	EPC	EPC Basis
% Arsenic IVBA	7	3.564	48.11	22.18	21.73	33.49	95% Student's-t UCL
% Lead IVBA	7	9.1	53.94	21.01	14.69	35.27	95% Approximate Gamma UCL

Notes:
EPC = exposure point concentration
IVBA = in vitro bioaccessibility assay
UCL = upper confidence limit on the mean

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TABLE 6-4
Summary of Human Health Reasonable Maximum Exposure (RME) Assumptions Used for Risk Estimates

Parameter	Symbol	Units	Future Intermittent Worker	Source	Adult Recreational User	Source	Adolescent Recreational User	Source	Hypothetical Industrial Worker	Source	Hypothetical Excavation Worker	Source
Body weight	BW_a	kg	70	a	70	a	36.3	h	70	a	70	a
Contaminant concentration in soil	C_s	mg/kg	95% UCL of mean	calc.	95% UCL of mean	calc.	95% UCL of mean	calc.	95% UCL of mean	calc.	95% UCL of mean	calc.
Incidental soil ingestion rate	IRS_a	mg/day	100	a	100	a	200	a	100	a	330	d
Ingestion of water	IRW_a	L/day	0	j	1.48	k	0.91	k	0	j	0	j
Particulate emission factor	PEF	m^3/kg	1.36E+09	b	8.47E+05	e	8.47E+05	e	1.36E+09	b	1.36E+09	b
Exposure frequency	EF	day/yr	60	c	52	g	52	g	125	b,f	20	i
Exposure duration	ED_a	yrs	5	c	24	b	6	b	25	b	6.6	b,i
Exposure time	ET	hrs	8	b	5	g	5	g	8	b	8	b
Bioavailability factor for arsenic	BF	%	33.49	e	33.49	e	33.49	e	33.49	e	33.49	e
Bioavailability factor for other metals	BF	%	100	e	100	e	100	e	100	e	100	e
Noncarcinogenic averaging time	ATN	yrs	5	a	24	a	6	a	25	a	6.6	a
Carcinogenic averaging time	ATC	yrs	70	a	70	a	70	a	70	a	70	a

Notes:
Examples of intermittent workers include workers periodically monitoring and sampling, USFS workers, or maintaining roads.
calc. = calculated value; EPC = exposure point concentration; UCL = upper confidence limit
[a] Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual. Supplemental Guidance: Standard Default Exposure Factors. OSWER 9285.6-03. (EPA, 1991)
[b] Standard values reported in EPA's Regional Screening Levels User's Guide (EPA, 2012b)
[c] Professional Judgment: assumes workers are onsite 5 days per week for 12 weeks per year over a 5 year duration
[d] EPA's 2002 Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites for construction workers (http://www.epa.gov/superfund/health/conmedia/soil/pdfs/ssg_main.pdf)
[e] As described in Section 6.4.2.4.
[f] Exposure frequency was modified to account for snow cover at the Mine, which is locate >8,000 feet above sea level; assumes snow cover is present 6 months per year.
[g] Professional Judgment: recreational users ATV riders that reside within the Basin Watershed; recreators are assumed onsite 5 hours per day, 2 days per week, for 26 weeks per year over a typical residential exposure duration
[h] Assumes adolescent ATV rider is 10 years old. Exposure Factors Handbook Volume I General Factors - Table 7-3 average body weight for boys and girls. (EPA, 1997a)
[i] Professional Judgment: assumes work is onsite 5 day per week, 4 weeks per year, over 6.6 years.
[j] Assumes workers bring water to site
[k] Assumes half of the 95th percentile daily water intake is from the site per Table 3-1 of EPA's Exposure Factors Handbook (EPA, 2011d)

TABLE 6-5
Summary of Human Health Central Tendency Exposure (CTE) Assumptions Used for Risk Estimates

Parameter	Symbol	Units	Future Intermittent Worker	Source	Adult Recreational User	Source	Adolescent Recreational User	Source	Hypothetical Industrial Worker	Source	Hypothetical Excavation Worker	Source
Body weight	BW_a	kg	70	a	70	a	36.3	h	70	a	70	a
Contaminant concentration in soil	C_s	mg/kg	95% UCL of mean	calc.	95% UCL of mean	calc.	95% UCL of mean	calc.	95% UCL of mean	calc.	95% UCL of mean	calc.
Incidental soil ingestion rate	IRS_a	mg/day	50	a	50	a	100	a	50	a	330	d
Ingestion of water	IRW_a	L/day	0	j	0.52		0.26		0	j	0	j
Particulate emission factor	PEF	m^3/kg	1.36E+09	b	8.47E+05	e	8.47E+05	e	1.36E+09	b	1.36E+09	b
Exposure frequency	EF	day/yr	20	c	14	g	14	g	125	b,f	10	i
Exposure duration	ED_a	yrs	2	c	12	b	3	b	6.6	b	1	b,i
Exposure time	ET	hrs	8	b	2	g	2	g	8	b	8	b
Bioavailability factor for arsenic	BF	%	33.49	e	33.49	e	33.49	e	33.49	e	33.49	e
Bioavailability factor for other metals	BF	%	100	e	100	e	100	e	100	e	100	e
Noncarcinogenic averaging time	ATN	yrs	2	a	12	a	3	a	6.6	a	1	a
Carcinogenic averaging time	ATC	yrs	70	a	70	a	70	a	70	a	70	a

Notes:
Examples of intermittent workers include workers periodically monitoring and sampling, USFS workers, or maintaining roads.
calc. = calculated value; EPC = exposure point concentration; UCL = upper confidence limit
[a] Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual. Supplemental Guidance: Standard Default Exposure Factors. OSWER 9285.6-03. (EPA, 1991)
[b] Standard values reported in EPA's Regional Screening Levels User's Guide (EPA, 2012b)
[c] Professional Judgment: assumes workers are onsite 5 days per week for 4 weeks per year over a 2 year duration
[d] EPA's 2002 Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites for construction workers (http://www.epa.gov/superfund/health/conmedia/soil/pdfs/ssg_main.pdf)
[e] As described in Section 6.4.2.4.
[f] Exposure frequency was modified to account for snow cover at the Mine, which is locate >8,000 feet above sea level; assumes snow cover is present 6 months per year.
[g] Professional Judgment: recreational users ATV riders are hunters visiting the area; assumed onsite 2 hours per day, 7 days per week, for 2 weeks per year over half of a typical residential exposure duration
[h] Assumes adolescent ATV rider is 10 years old. Exposure Factors Handbook Volume I General Factors - Table 7-3 average body weight for boys and girls. (EPA, 1997a)
[i] Professional Judgment: assumes work is onsite 5 day per week, 2 weeks per year, over 1 years.
[j] Assumes workers bring water to site
[k] Assumes half of the mean daily water intake is from the site per Table 3-1 of EPA's Exposure Factors Handbook (EPA, 2011d)

TABLE 6-6
Toxicity Factors Used in Risk Estimations

Analyte	CAS#	GI Absorption Fraction	Oral Slope Factor (mg/Kg-day)-1	Ref	Inhalation Unit Risk (µg/m³)	Ref	Oral Reference Dose (mg/Kg-day)	Ref	Inhalation Reference Concentration (RfC) (mg/m³)	Ref
Aluminum	7429-90-5	1					1.0E+00	P	5.0E-03	P
Antimony	7440-36-0	0.15					4.0E-04	I		
Arsenic	7440-38-2	1	1.5E+00	I	4.3E-03	I	3.0E-04	I	1.5E-05	C
Cadmium	7440-43-9	0.025			1.8E-03	I	1.0E-03	I	2.0E-05	C
Copper	7440-50-8	1					4.0E-02	H		
Iron	7439-89-6	1					7.0E-01	P		
Lead	7439-92-1	*Note: lead is not evaluated with methods using these factors*								
Manganese	7439-96-5	1					1.4E-01	I	5.0E-05	I
Nickel	7440-02-0	0.04			2.6E-04	C	2.0E-02	I	9.0E-05	A
Selenium	7782-49-2	1					5.0E-03	I	2.0E-02	C
Silver	7440-22-4	0.04					5.0E-03	I		
Zinc	7440-66-6	1					3.0E-01	I		

Notes:
A = ATSDR
C = California EPA
GI = gastrointestinal
H = HEAST
I = IRIS
P = PPRTV
X = PPRTV

TABLE 6-7
Summary of Risk Estimates for Future Intermittent Worker Scenario—Surface Soil (0-10 in bgs)

Scenario	Exposure Route	RME ELCR	RME HI	Primary Contributors[a] to ELCR and HI	CTE ELCR	CTE HI	Primary Contributors[a] to ELCR and HI
Future Intermittent Worker	Ingestion	3.7E-06	0.13	Arsenic ELCR=4E-6, >99%	2.5E-07	0.021	None
	Inhalation	5.5E-09	0.0018		7.3E-10	0.00061	
	Total	**4E-06**	**0.1**		**2E-07**	**0.02**	

Notes:
[a] Primary constituents contributing to 90 percent or more of the ELCR, or constituents with HQ exceeding 1.
CTE = central tendency exposure
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient
RME = reasonable maximum exposure

TABLE 6-8

Summary of Risk Estimates for Current and Future Recreational User Scenario

Scenario	Exposure Route	RME ELCR	RME HI	Primary Contributors[a] to ELCR and HI	CTE ELCR	CTE HI	Primary Contributors[a] to ELCR and HI
Surface Soil (0-10 in bgs)							
Adult	Ingestion	1.6E-05	0.11	Arsenic ELCR=4E-5, >99%	1.0E-06	0.015	Arsenic ELCR=2E-6, >99%
	Inhalation	2.3E-05	1.6		1.2E-06	0.17	
	Total	**4E-05**	**2**		**2E-06**	**0.2**	
Adolescent	Ingestion	1.5E-05	0.43	Arsenic ELCR=2E-5, >99%	1.0E-06	0.058	None
	Inhalation	5.7E-06	1.6		3.1E-07	0.17	
	Total	**2E-05**	**2**		**1E-06**	**0.2**	
Surface Water							
Adult	Ingestion	6E-05	0.5	Arsenic ELCR=6E-5, 100%	2E-05	0.2	Arsenic ELCR=2E-5, 100%
Adolescent	Ingestion	2E-05	0.1	Arsenic ELCR=2E-5, 100%	5E-06	0.04	Arsenic ELCR=5E-6, 100%
Spring/Seeps							
Adult	Ingestion	4E-04	7	Arsenic ELCR=4E-4, 100% Arsenic HQ=2, 31% Cadmium HQ=2, 22%	1E-04	2	Arsenic ELCR=1E-4, 100%
Adolescent	Ingestion	1E-04	2.0	Arsenic ELCR=1E-4, 100%	3E-05	0.6	Arsenic ELCR=3E-5, 100%

Notes:

[a] Primary constituents contributing to 90 percent or more of the ELCR, or constituents with HQ exceeding 1.

CTE = central tendency exposure

ELCR = excess lifetime cancer risk

HI = hazard index

HQ = hazard quotient

RME = reasonable maximum exposure

TABLE 6-9
Summary of Risk Estimates for Excavation Worker Scenario—Subsurface Soil (0-10 ft bgs)

Scenario	Exposure Route	RME ELCR	RME HI	Primary Contributors[a] to ELCR and HI	CTE ELCR	CTE HI	Primary Contributors[a] to ELCR and HI
Excavation Worker	Ingestion	1.4E-05	0.44	Arsenic ELCR=1E-5, >99%	1.0E-06	0.22	None
	Inhalation	6.2E-09	0.0013		4.7E-10	0.00063	
	Total	**1E-05**	**0.4**		**1E-06**	**0.2**	

Notes:
[a] Primary constituents contributing to 90 percent or more of the ELCR, or constituents with HQ exceeding 1.
CTE = central tendency exposure
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient
RME = reasonable maximum exposure

TABLE 6-10
Summary of Risk Estimates for Hypothetical Industrial Worker Scenario—Surface Soil (0-10 in bgs)

Scenario	Exposure Route	RME ELCR	RME HI	Primary Contributors[a] to ELCR and HI	CTE ELCR	CTE HI	Primary Contributors[a] to ELCR and HI
Hypothetical Industrial Worker	Ingestion	5.6E-05	0.37	Arsenic ELCR=6E-5, >99%	7.4-06	0.19	Arsenic ELCR=7E-6, >99%
	Inhalation	5.7E-08	0.0038		1.5E-08	0.0038	
	Total	**6E-05**	**0.4**		**7E-06**	**0.2**	

Notes:
[a] Primary constituents contributing to 90 percent or more of the ELCR, or constituents with HQ exceeding 1.
CTE = central tendency exposure
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient
RME = reasonable maximum exposure

TABLE 6-11
Adult Lead Model Output and Screening for Soil Lead

Model Variable	Units	Parameter Value	Source
95th percentile PbB in fetus	µg/dL	10	ALM Default
Fetal/maternal PbB ratio	--	0.9	ALM Default
Biokinetic Slope Factor	µg/dL per µg/day	0.4	ALM Default
Geometric standard deviation PbB	--	1.8	ALM Default
Baseline PbB	µg /dL	1.0	ALM Default
Soil ingestion rate (including soil-derived indoor dust)	g/day	0.050	ALM Default
Absorption fraction (same for soil and dust)	--	0.062	Site-specific [a]
Exposure frequency (same for soil and dust)	days/yr	219	ALM Default
Averaging time (same for soil and dust)	days/yr	365	ALM Default
Risk-Based Concentration	mg/kg	4,342	
Surface Soil EPC	mg/kg	123	
Subsurface Soil EPC	mg/kg	399	

Notes:
[a] Absorption fraction computed by replacing the ALM default relative bioavailability of lead from soil of 60% with the site-specific 95% UCL of site-specific bioaccessibility of 31%.
ALM = EPA Adult lead Model
EPC = exposure point concentration
PbB = blood lead concentration

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TABLE 6-12
Ecological Endpoints and Measures of Exposure and Effect for the Bullion Mine Ecological Risk Assessment

Functional Group	Assessment Endpoint	Representative Ecological Receptors	Measure of Exposure	Measure of Effect
Aquatic organisms	Survival and health of aquatic organisms using Jill Creek and down-gradient waterways, and potentially exposed to constituents in surface water, sediment, and prey items	Freshwater fish and aquatic invertebrates	Measured constituent levels in surface water	Federal and state ambient water quality criteria;
Benthic and epibenthic organisms	Survival and health of benthic organisms using Jill Creek and down-gradient waterways, and potentially exposed to constituents in sediment	Benthic macroinvertebrates	Measured constituent levels in surface sediment	Sediment benchmarks from literature; site-specific benthic macroinvertebrate surveys
Insectivorous birds	Survival and health of insectivorous birds using areas with suitable habitat, and potentially exposed to constituents in sediment, surface water, and prey items	Dusky flycatcher	Measured constituent levels in soil and surface water; modeled constituent levels in food items	Literature-based chronic LOAEL for bird populations and NOAEL for T&E species
Upland raptors	Survival and health of raptors using onsite areas with suitable habitat, and potentially exposed to constituents in surface soil, surface water, and prey items	Northern goshawk	Measured constituent levels in surface water and soil; modeled constituent levels in food items	Literature-based chronic LOAEL for bird populations and NOAEL for T&E species
Herbivorous birds	Survival and health of herbivorous birds using areas with suitable habitat, and potentially exposed to constituents in surface water, soil, sediment, and forage items	Spruce grouse	Measured constituent levels in surface water and soil; modeled constituent levels in food items	Literature-based chronic LOAEL for bird populations and NOAEL for T&E species
Carnivorous mammals	Survival and health of carnivorous mammals using onsite areas with suitable habitat, and potentially exposed to constituents in surface soil and prey items	Red fox	Measured constituent levels in surface water and soil; modeled constituent levels in food items	Literature-based chronic LOAEL for mammal populations and NOAEL for T&E species
Herbivorous mammals	Survival and health of herbivorous mammals using onsite areas with suitable habitat, and potentially exposed to constituents in surface soil and forage items	Mule deer	Measured constituent levels in surface water and soil; modeled constituent levels in food items	Literature-based chronic LOAEL for mammal populations and NOEAL for T&E species
Omnivorous riparian mammals	Survival and health of omnivorous mammals using onsite areas with suitable habitat, and potentially exposed to constituents in surface water, sediment, and prey/forage items	Raccoon	Measured constituent levels in surface water and soil; modeled constituent levels in food items	Literature-based chronic LOAEL for mammal populations and NOAEL for T&E species
Small upland mammals	Survival and health of small omnivorous upland mammals using onsite areas with suitable habitat, and potentially exposed to constituents in surface water, soil, and prey/forage items	Deer mouse	Measured constituent levels in surface water and soil; modeled constituent levels in food items	Literature-based chronic LOAEL for mammal populations and NOAEL for T&E species
Terrestrial vegetation	Survival and health of plants at the Bullion Mine, and potentially exposed to constituents in soil	Various Plants	Measured constituent levels in soil	Available plant benchmarks from literature sources

Notes:
LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level

TABLE 6-13
Identification of Soil Contaminants of Potential Ecological Concern for Plants

Analyte	Surface Soil Maximum Detect (mg/kg)	Subsurface Soil Maximum Detect (mg/kg)	Eco SSL Plants (mg/kg)	ORNL Plant Screening Benchmark[a] (mg/kg)	Surface Soil Maximum Exceeds Screening Levels?	Subsurface Soil Maximum Exceeds Screening Levels?	Selected as COPEC?	Reason for Exclusion
Aluminum	16,500	16,500	c	50	Yes	Yes	Yes	
Antimony	141	141	--	5	Yes	Yes	Yes	
Arsenic	3,090	3,090	18	--	Yes	Yes	Yes	
Cadmium	45	45	32	--	Yes	Yes	Yes	
Copper	887	887	70	--	Yes	Yes	Yes	
Iron	35,400	35,400	b	--	--	--	Yes	
Lead	2,870	2,870	120	--	Yes	Yes	Yes	
Manganese	1,809	1,809	220	--	Yes	Yes	Yes	
Nickel	11	11	38	--	No	No	No	Site maximum < screening level
Selenium	2	2	0.52	--	Yes	Yes	Yes	
Silver	29	29	560	--	No	No	No	Site maximum < screening level
Thallium	ND (1.0)	ND (1.0)	--	1	No	No	No	Not detected and detection limit < screening level
Zinc	1,442	1,442	160	--	Yes	Yes	Yes	

Notes:
[a] Source: Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants (Efroymson et al., 1997)
[b] Iron is not considered a COPEC for plants at sites where soil pH is between 5 and 8; many waste rock samples have a pH less than 5; only waste rock/soil samples deeper than 1.5 feet bgs have a pH less than 5
[c] Aluminum is not considered a COPEC for plants at sites where soil pH is above 5.5; only waste rock/soil samples deeper than 1.5 feet bgs have a pH less than 5.5

Eco SSL = EPA Ecological Soil Screening Level
mg/kg = milligrams per kilogram
ND = Not detected (detection limit listed in parentheses)

TABLE 6-14
Identification of Surface Soil Contaminants of Potential Ecological Concern for Wildlife

Analyte	Surface Soil Maximum Detect (mg/kg)	Eco SSL Avian (mg/kg)	Eco SSL Mammalian (mg/kg)	Surface Soil Maximum Exceeds Screening Levels?	Selected as COPEC?	Reason for Exclusion
Aluminum	16,500	a	a	--	Yes	
Antimony	141	--	0.27	Yes	Yes	
Arsenic	3,090	43	46	Yes	Yes	
Cadmium	45	0.77	0.36	Yes	Yes	
Copper	887	28	49	Yes	Yes	
Iron	35,400	--	--	--	Yes	
Lead	2,870	11	56	Yes	Yes	
Manganese	1,809	4,300	4,000	No	No	Site maximum < screening level
Nickel	11	210	130	No	No	Site maximum < screening level
Selenium	2	1.2	0.63	Yes	Yes	
Silver	29	4.2	14	Yes	Yes	
Thallium	ND (1.0)	--	--	No	No	Not detected
Zinc	1,442	46	79	Yes	Yes	

Notes:
[a] Aluminum is considered a COPEC at sites where pH is less than 5.5; waste rock/soil samples were above this level at all locations to 1.5 feet bgs and less than 5.5 in some deeper samples
Eco SSL = EPA Ecological Soil Screening Level
mg/kg = milligram per kilogram
NA = Not available

TABLE 6-15
Identification of Surface Water Contaminants of Potential Ecological Concern

Analyte	Adit Discharge Water Maximum Detect (mg/L)	Spring/Seep Water Maximum Detect (mg/L)	Surface Water Maximum Detect in Jill Creek (mg/L)	Chronic Freshwater Screening Benchmark[ab] (mg/L)	Maximum Exceeds Screening Level?	Selected as COPEC?	Reason for Exclusion
Aluminum	20	36	1.0	0.087	Yes	Yes	
Antimony	0.0218	0.0077	0.5 U	0.03	No	No	Site maximum < screening level
Arsenic	5.16	0.264	0.0388	0.005	Yes	Yes	
Cadmium	0.52	0.624	0.0225	0.000097	Yes	Yes	
Copper	13	13	0.478	0.0029	Yes	Yes	
Iron	243	248	6	0.30	Yes	Yes	
Lead	0.682	0.0792	0.008	0.00055	Yes	Yes	
Manganese	30	35	1.3	0.12	Yes	Yes	
Nickel	0.114	0.155	0.006	0.016	Yes	Yes	
Selenium	0.0039	0.0084	0.5 U	0.001	No	No	Site maximum ≤ screening level
Silver	0.00097	0.0019	0.5 U	0.0032	No	No	Site maximum < screening level
Thallium	0.00042	0.00044	0.1 U	0.0008	No	No	Site maximum < screening level
Zinc	63	77	2.65	0.037	Yes	Yes	

Notes:
[a] Source: Lowest of State of Montana Chronic Standard (MDEQ 2012), EPA's Water Quality Criteria (EPA, 2011), and EPA Region 3's Freshwater Screening Benchmarks
[b] MDEQ (2012a) assumes a hardness of 25 mg/L, while EPA assumes hardness of 100 mg/kg.
mg/L = milligrams per liter
All water data are reported as dissolved metal concentrations except selenium which has screening level based on total concentrations
U = not detected; value listed represents the analyte’s detection limit

TABLE 6-16
Identification of Sediment Contaminants of Potential Ecological Concern

Analyte	Maximum Detected Levels (all mesh sizes) in Jill Creek (mg/kg)	EPA Region 3 Freshwater Sediment Screening Benchmark[a] (mg/kg)	Maximum Exceeds Sediment Screening Levels?	Selected as COPEC?	Reason for Exclusion
Aluminum	11,200	25,500[b]	No	No	Site maximum < screening level
Antimony	7	2	Yes	Yes	
Arsenic	1,840	9.8	Yes	Yes	
Cadmium	25.7	0.99	Yes	Yes	
Copper	505	31.6	Yes	Yes	
Iron	124,000	20,000	Yes	Yes	
Lead	397	35.8	Yes	Yes	
Manganese	1,590	460	Yes	Yes	
Nickel	7.9	22.7	No	No	Site maximum < screening level
Selenium	1.6	2	No	No	Site maximum < screening level
Silver	1.7	1	Yes	Yes	
Thallium	5	---	---	Yes	
Zinc	803	121	Yes	Yes	

Notes:
[a] Source: EPA Region 3 at: http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm
[b] Source: NOAA Screening Quick Reference Tables (SQuiRT)(Buchman, 2008)
Eco SSL = EPA Ecological Soil Screening Level
mg/kg = milligram per kilogram

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TABLE 6-17
Wildlife Exposure Factors for Receptors of Concern

Assessment Endpoint Functional Group	Endpoint Species	Body Weight (kg)	Source	Food Intake (kg/kg-bw/d)[a]	Water Intake (kg/kg-bw/d)[b]	Home Range[e] (acres)	Source	Area Use Factor[cd]	Food Ingestion from Site (kg/kg-bw/d)[e]	Water Ingestion from Site (kg/kg-bw/d)[e]	Diet Composition: % of Diet as Mammals/Birds	% Diet as Aquatic Invertebrates	% Diet as Terrestrial Invertebrates	% of Diet as Plants	% of Diet as Soil/Sediment	Source
Insectivorous birds	Dusky flycatcher *(Empidonax oberholseri)*	0.0098	Montana Field Guide, 2011	0.243	0.271	4 to 4.3	Montana Field Guide, 2011	1	2.43E-01	2.71E-01	0	50	50	0	2	f
Raptors	Northern goshawk *(Accipiter gentilis)*	0.98	Montana Field Guide, 2011	0.083	0.059	235 to 14,000	Montana Field Guide, 2011	0.17	1.42E-02	1.01E-02	100	0	0	0	2	f
Herbivorous birds	Spruce grouse *(Falcipennis canadensis)*	0.496	Montana Field Guide, 2011	0.045	0.074	10 to 15	Montana Field Guide, 2011	1	4.47E-02	7.44E-02	80	0	20	0	2	f
Small omnivorous mammals	Deer mouse *(Peromyscus maniculatus)*	0.018	Nagy, 2001	0.213	0.148	<1	EPA, 1993	1	2.13E-01	1.48E-01	0	0	35	65	2	EPA, 1993
Large carnivorous mammals	Red fox *(Vulpes vulpes)*	4.54	EPA, 1993	0.038	0.085	237 to 3,980	EPA, 1993	0.17	6.38E-03	1.44E-02	85	0	0	15	2.8	EPA, 1993
Large herbivorous mammals	Mule Deer *(Odocoileus hemionus)*	39.1	Nagy, 2001	0.040	0.069	704	Sample et al., 1997	0.06	2.27E-03	3.90E-03	0	0	0	100	2	Sample et al., 1997
Omnivorous riparian mammals	Raccoon *(Procyon lotor)*	5.75	EPA, 1993	0.027	0.083	267 to 6,326	EPA, 1993	0.15	3.99E-03	1.25E-02	20	10	30	40	9.4	EPA, 1993

Notes:
Parameters presented in terms of dry weight
[a] Source: Nagy (2001)
[b] Source: Allometric equations for all mammals and all birds were used to calculate drinking water ingestion (EPA, 1993); mammals: Intake (L/day)=0.099*BW0.90(kg); birds: Intake (L/day)=0.059*BW0.67(kg)
[c] Lower end of the home range used for area use factor estimates and a site acreage of 40 used for the Site.
[d] Migration is not considered for any endpoint species
[e] Daily Food Ingestion from Site = Daily Food Intake * Area Use Factor * Migration Factor; Daily Water Ingestion from Site = Daily Water Intake * Area Use Factor * Migration Factor
[f] Source: Default value of 2% assumed

TABLE 6-18
Intake Estimation for Upland Ecological Endpoint Species

COPEC	Endpoint Species	Body Weight (kg)	Daily Food Intake from Site (kg/kg-bw/day)	Daily Water Ingestion from Site (kg/kg-bw/day)	Fraction of Diet as Small Mammal/Bird	Small Mammal Tissue Concentration[b]	Fraction of Diet as Aquatic Invertebrates	Aquatic Invertebrate Tissue Concentration[b]	Fraction of Diet as Terrestrial Invertebrates	Terrestrial Invertebrate Tissue Concentration[b]	Fraction of Diet as Vegetation	Vegetation Tissue Concentration[a]	Fraction of Diet as Soil	Sediment Concentration[c] (mg/kg)	Surface Water Concentration[d] (mg/L)	Soil Concentration[e] (mg/kg)	Chemical Intake (mg/kg/d)
Aluminum	Deer mouse	0.018	0.213	0.1480	0.00	22.19	0.00	3,808.0	0.35	5,029.6	0.65	59.2	0.02	11,200	1.01	14,793	446
	Mule deer	39	0.040	0.0686	0.00	22.19	0.00	3,808.0	0.00	5,029.6	1.00	59.2	0.02	11,200	1.01	14,793	14.3
	Red fox	4.5	0.038	0.0851	0.85	22.19	0.00	3,808.0	0.00	5,029.6	0.15	59.2	0.03	11,200	1.01	14,793	16.8
	Raccoon	5.7	0.027	0.0831	0.20	22.19	0.10	3,808.0	0.30	5,029.6	0.40	59.2	0.09	11,200	1.01	14,793	88.1
	Northern goshawk	0.98	0.083	0.0594	1.00	22.19	0.00	3,808.0	0.00	5,029.6	0.00	59.2	0.02	11,200	1.01	14,793	26.6
	Dusky flycatcher	0.0098	0.243	0.2715	0.00	22.19	0.50	3,808.0	0.50	5,029.6	0.00	59.2	0.02	11,200	1.01	14,793	1,148
	Spruce grouse	0.496	0.045	0.0744	0.80	22.19	0.00	3,808.0	0.20	5,029.6	0.00	59.2	0.02	11,200	1.01	14,793	59.1
Antimony	Deer mouse	0.018	0.213	0.1480	0.00	0.14	0.00	7.0	0.35	141.0	0.65	4.1	0.02	7.0	---	141	11.7
	Mule deer	39	0.040	0.0686	0.00	0.14	0.00	7.0	0.00	141.0	1.00	4.1	0.02	7.0	---	141	0.28
	Red fox	4.5	0.038	0.0851	0.85	0.14	0.00	7.0	0.00	141.0	0.15	4.1	0.03	7.0	---	141	0.18
	Raccoon	5.7	0.027	0.0831	0.20	0.14	0.10	7.0	0.30	141.0	0.40	4.1	0.09	7.0	---	141	1.54
	Northern goshawk	0.98	0.083	0.0594	1.00	0.14	0.00	7.0	0.00	141.0	0.00	4.1	0.02	7.0	---	141	0.25
	Dusky flycatcher	0.0098	0.243	0.2715	0.00	0.14	0.50	7.0	0.50	141.0	0.00	4.1	0.02	7.0	---	141	18.70
	Spruce grouse	0.496	0.045	0.0744	0.80	0.14	0.00	7.0	0.20	141.0	0.00	4.1	0.02	7.0	---	141	1.39
Arsenic	Deer mouse	0.018	0.213	0.1480	0.00	2.53	0.00	48.7	0.35	35.2	0.65	43.5	0.02	1,840	0.039	1,159	13.6
	Mule deer	39	0.040	0.0686	0.00	2.53	0.00	48.7	0.00	35.2	1.00	43.5	0.02	1,840	0.039	1,159	2.67
	Red fox	4.5	0.038	0.0851	0.85	2.53	0.00	48.7	0.00	35.2	0.15	43.5	0.03	1,840	0.039	1,159	1.56
	Raccoon	5.7	0.027	0.0831	0.20	2.53	0.10	48.7	0.30	35.2	0.40	43.5	0.09	1,840	0.039	1,159	3.79
	Northern goshawk	0.98	0.083	0.0594	1.00	2.53	0.00	48.7	0.00	35.2	0.00	43.5	0.02	1,840	0.039	1,159	2.15
	Dusky flycatcher	0.0098	0.243	0.2715	0.00	2.53	0.50	48.7	0.50	35.2	0.00	43.5	0.02	1,840	0.039	1,159	15.9
	Spruce grouse	0.496	0.045	0.0744	0.80	2.53	0.00	48.7	0.20	35.2	0.00	43.5	0.02	1,840	0.039	1,159	1.45
Cadmium	Deer mouse	0.018	0.213	0.1480	0.00	1.69	0.00	109.4	0.35	166.3	0.65	5.2	0.02	26	0.023	43.5	13.3
	Mule deer	39	0.040	0.0686	0.00	1.69	0.00	109.4	0.00	166.3	1.00	5.2	0.02	26	0.023	43.5	0.24
	Red fox	4.5	0.038	0.0851	0.85	1.69	0.00	109.4	0.00	166.3	0.15	5.2	0.03	26	0.023	43.5	0.13
	Raccoon	5.7	0.027	0.0831	0.20	1.69	0.10	109.4	0.30	166.3	0.40	5.2	0.09	26	0.023	43.5	1.79
	Northern goshawk	0.98	0.083	0.0594	1.00	1.69	0.00	109.4	0.00	166.3	0.00	5.2	0.02	26	0.023	43.5	0.21
	Dusky flycatcher	0.0098	0.243	0.2715	0.00	1.69	0.50	109.4	0.50	166.3	0.00	5.2	0.02	26	0.023	43.5	33.78
	Spruce grouse	0.496	0.045	0.0744	0.80	1.69	0.00	109.4	0.20	166.3	0.00	5.2	0.02	26	0.023	43.5	1.59
Copper	Deer mouse	0.018	0.213	0.1480	0.00	16.29	0.00	260.1	0.35	91.8	0.65	15.0	0.02	505	0.48	178	9.75
	Mule deer	39	0.040	0.0686	0.00	16.29	0.00	260.1	0.00	91.8	1.00	15.0	0.02	505	0.48	178	0.78
	Red fox	4.5	0.038	0.0851	0.85	16.29	0.00	260.1	0.00	91.8	0.15	15.0	0.03	505	0.48	178	0.84
	Raccoon	5.7	0.027	0.0831	0.20	16.29	0.10	260.1	0.30	91.8	0.40	15.0	0.09	505	0.48	178	2.16
	Northern goshawk	0.98	0.083	0.0594	1.00	16.29	0.00	260.1	0.00	91.8	0.00	15.0	0.02	505	0.48	178	1.68
	Dusky flycatcher	0.0098	0.243	0.2715	0.00	16.29	0.50	260.1	0.50	91.8	0.00	15.0	0.02	505	0.48	178	43.84
	Spruce grouse	0.496	0.045	0.0744	0.80	16.29	0.00	260.1	0.20	91.8	0.00	15.0	0.02	505	0.48	178	1.60
Iron	Deer mouse	0.018	0.213	0.1480	0.00	472.78	0.00	124,000.0	0.35	23639.0	0.65	94.6	0.02	124,000	6.21	23,639	1,875
	Mule deer	39	0.040	0.0686	0.00	472.78	0.00	124,000.0	0.00	23639.0	1.00	94.6	0.02	124,000	6.21	23,639	23.1
	Red fox	4.5	0.038	0.0851	0.85	472.78	0.00	124,000.0	0.00	23639.0	0.15	94.6	0.03	124,000	6.21	23,639	41.3
	Raccoon	5.7	0.027	0.0831	0.20	472.78	0.10	124,000.0	0.30	23639.0	0.40	94.6	0.09	124,000	6.21	23,639	581.7
	Northern goshawk	0.98	0.083	0.0594	1.00	472.78	0.00	124,000.0	0.00	23,639.0	0.00	94.6	0.02	124,000	6.21	23,639	79.2
	Dusky flycatcher	0.0098	0.243	0.2715	0.00	472.78	0.50	124,000.0	0.50	23,639.0	0.00	94.6	0.02	124,000	6.21	23,639	18,090
	Spruce grouse	0.496	0.045	0.0744	0.80	472.78	0.00	124,000.0	0.20	23,639.0	0.00	94.6	0.02	124,000	6.21	23,639	250

TABLE 6-18
Intake Estimation for Upland Ecological Endpoint Species

COPEC	Endpoint Species	Body Weight (kg)	Daily Food Intake from Site (kg/kg-bw/day)	Daily Water Ingestion from Site (kg/kg-bw/day)	Fraction of Diet as Small Mammal/Bird	Small Mammal Tissue Concentration[b]	Fraction of Diet as Aquatic Invertebrates	Aquatic Invertebrate Tissue Concentration[b]	Fraction of Diet as Terrestrial Invertebrates	Terrestrial Invertebrate Tissue Concentration[b]	Fraction of Diet as Vegetation	Vegetation Tissue Concentration[a]	Fraction of Diet as Soil	Sediment Concentration[c] (mg/kg)	Surface Water Concentration[d] (mg/L)	Soil Concentration[e] (mg/kg)	Chemical Intake (mg/kg/d)
Lead	Deer mouse	0.018	0.213	0.1480	0.00	15.46	0.00	100.6	0.35	103.6	0.65	7.8	0.02	397	0.008	412	10.6
	Mule deer	39	0.040	0.0686	0.00	15.46	0.00	100.6	0.00	103.6	1.00	7.8	0.02	397	0.008	412	0.64
	Red fox	4.5	0.038	0.0851	0.85	15.46	0.00	100.6	0.00	103.6	0.15	7.8	0.03	397	0.008	412	0.98
	Raccoon	5.7	0.027	0.0831	0.20	15.46	0.10	100.6	0.30	103.6	0.40	7.8	0.09	397	0.008	412	2.29
	Northern goshawk	0.98	0.083	0.0594	1.00	15.46	0.00	100.6	0.00	103.6	0.00	7.8	0.02	397	0.008	412	1.98
	Dusky flycatcher	0.0098	0.243	0.2715	0.00	15.46	0.50	100.6	0.50	103.6	0.00	7.8	0.02	397	0.008	412	26.9
	Spruce grouse	0.496	0.045	0.0744	0.80	15.46	0.00	100.6	0.20	103.6	0.00	7.8	0.02	397	0.008	412	1.85
Selenium	Deer mouse	0.018	0.213	0.1480	0.00	0.70	0.00	1.3	0.35	1.0	0.65	0.6	0.02	1.6	---	1.2	0.16
	Mule deer	39	0.040	0.0686	0.00	0.70	0.00	1.3	0.00	1.0	1.00	0.6	0.02	1.6	---	1.2	0.02
	Red fox	4.5	0.038	0.0851	0.85	0.70	0.00	1.3	0.00	1.0	0.15	0.6	0.03	1.6	---	1.2	0.03
	Raccoon	5.7	0.027	0.0831	0.20	0.70	0.10	1.3	0.30	1.0	0.40	0.6	0.09	1.6	---	1.2	0.02
	Northern goshawk	0.98	0.083	0.0594	1.00	0.70	0.00	1.3	0.00	1.0	0.00	0.6	0.02	1.6	---	1.2	0.06
	Dusky flycatcher	0.0098	0.243	0.2715	0.00	0.70	0.50	1.3	0.50	1.0	0.00	0.6	0.02	1.6	---	1.2	0.29
	Spruce grouse	0.496	0.045	0.0744	0.80	0.70	0.00	1.3	0.20	1.0	0.00	0.6	0.02	1.6	---	1.2	0.04
Silver	Deer mouse	0.018	0.213	0.1480	0.00	0.12	0.00	3.5	0.35	59.7	0.65	0.4	0.02	1.7	---	29	4.63
	Mule deer	39	0.040	0.0686	0.00	0.12	0.00	3.5	0.00	59.7	1.00	0.4	0.02	1.7	---	29	0.04
	Red fox	4.5	0.038	0.0851	0.85	0.12	0.00	3.5	0.00	59.7	0.15	0.4	0.03	1.7	---	29	0.04
	Raccoon	5.7	0.027	0.0831	0.20	0.12	0.10	3.5	0.30	59.7	0.40	0.4	0.09	1.7	---	29	0.56
	Northern goshawk	0.98	0.083	0.0594	1.00	0.12	0.00	3.5	0.00	59.7	0.00	0.4	0.02	1.7	---	29	0.06
	Dusky flycatcher	0.0098	0.243	0.2715	0.00	0.12	0.50	3.5	0.50	59.7	0.00	0.4	0.02	1.7	---	29	7.83
	Spruce grouse	0.496	0.045	0.0744	0.80	0.12	0.00	3.5	0.20	59.7	0.00	0.4	0.02	1.7	---	29	0.56
Zinc	Deer mouse	0.018	0.213	0.1480	0.00	118.39	0.00	767.2	0.35	576.8	0.65	121.3	0.02	803	2.65	337	61.6
	Mule deer	39	0.040	0.0686	0.00	118.39	0.00	767.2	0.00	576.8	1.00	121.3	0.02	803	2.65	337	5.31
	Red fox	4.5	0.038	0.0851	0.85	118.39	0.00	767.2	0.00	576.8	0.15	121.3	0.03	803	2.65	337	5.08
	Raccoon	5.7	0.027	0.0831	0.20	118.39	0.10	767.2	0.30	576.8	0.40	121.3	0.09	803	2.65	337	9.63
	Northern goshawk	0.98	0.083	0.0594	1.00	118.39	0.00	767.2	0.00	576.8	0.00	121.3	0.02	803	2.65	337	10.6
	Dusky flycatcher	0.0098	0.243	0.2715	0.00	118.39	0.50	767.2	0.50	576.8	0.00	121.3	0.02	803	2.65	337	165
	Spruce grouse	0.496	0.045	0.0744	0.80	118.39	0.00	767.2	0.20	576.8	0.00	121.3	0.02	803	2.65	337	9.90

Notes:
Exposure factors and bioaccumulation factors are reported in dry weight
[a] Source: ORNL, 2013
[b] Sources provided on Table 6-19
[c] Concentration represents the maximum detected concentration collected in 2012 at adjacent and downstream sample locations in Jill Creek
[d] Concentration represents maximum detected concentration from collected in Jill Creek in 2010 adjacent to and downstream of the Bullion Mine
[e] Concentration represents 95% upper confidence on the mean for surface soil (0 to 2 feet bgs); as summarized in Table 6-2.

TABLE 6-19
Calculation of Site-Specific Bioaccumulation Rates and Tissue Levels for Wildlife Food Items

COPEC	Soil EPC (Cs)	Sediment EPC (Csd)	Small Mammal Equation	Source	Small Mammal Tissue Concentration (Cm)	Soil to Earthworm Tissue Equation	Source	Terrestrial Invertebrate Tissue Concentration (Cp)	Soil to Plant Tissue Equation	Source	Plant Tissue Concentration	Sediment to Aquatic Invertebrate Tissue Equation	Source	Aquatic Invertebrate Tissue Concentration (Ca)
Aluminum	14,793	11,200	Cm = Cs * 0.0015	Baes et al., 1984	22.2	Ce = Cs*0.34	Beyer and Stafford, 1993	5,030	Cp = Cs*0.004	Baes et al., 1984	59.2	Ca = Csd*0.34	Assume earthworm equation	3,808
Antimony	141	7	Cm = Cs * 0.001	Baes et al., 1984	0.14	Ce = Cs	EPA, 2007	141	Ln(Cp) = 0.938*ln(Cs)-3.233	EPA, 2007	4.1	Ca = Csd	Assume earthworm equation	7
Arsenic	1,159	1,840	Ln(Cm) = 0.8188*ln(Cs)-4.8471	EPA, 2007	2.5	Ln(Ce) = 0.706*ln(Cs)-1.421	EPA, 2007	35	Cp = Cs*0.03752	EPA, 2007	43.5	Ln(Ca) = 0.706*ln(Csd)-1.421	Assume earthworm equation	49
Cadmium	44	26	Ln(Cm) = 0.4723*ln(Cs)-1.2571	EPA, 2007	1.7	Ln(Ce) = 0.795*ln(Cs)+2.114	EPA, 2007	166	Ln(Cp) = 0.546*ln(Cs)-0.475	EPA, 2007	5.2	Ln(Ca) = 0.795*ln(Csd)+2.114	Assume earthworm equation	109
Copper	178	505	Ln(Cm) = 0.1444*ln(Cs)+2.042	EPA, 2007	16.3	Ce = 0.515*Cs	EPA, 2007	92	Ln(Cp) = 0.394*ln(Cs)+0.668	EPA, 2007	15.0	Ca = 0.515*Csd	Assume earthworm equation	260
Iron	23,639	124,000	Cm = Cs * 0.02	Baes et al., 1984	473	Ce = Cs	Assumed default	23,639	Cp = Cs*0.004	Baes et al., 1984	95	Ca = Csd	Assume earthworm equation	124,000
Lead	412	397	Ln(Cm) = 0.4422*ln(Cs)+0.0761	EPA, 2007	15.5	Ln(Ce) = 0.807*ln(Cs)-0.218	EPA, 2007	104	Ln(Cp) = 0.561*ln(Cs)-1.328	EPA, 2007	7.8	Ln(Ca) = 0.807*ln(Csd)-0.218	Assume earthworm equation	101
Selenium	1.2	1.6	Ln(Cm) = 0.3764*ln(Cs)-0.4158	EPA, 2007	0.7	Ln(Ce) = 0.733*ln(Cs)-0.075	EPA, 2007	1.0	Ln(Cp) = 1.104*ln(Cs)-0.677	EPA, 2007	0.6	Ln(Ca) = 0.733*ln(Csd)-0.075	Assume earthworm equation	1.3
Silver	29.2	1.7	Ln(Cm) = 0.004*Cs	EPA, 2007	0.1	Ce = 2.045*Cs	EPA, 2007	60	Cp = Cs*0.014	EPA, 2007	0.4	Ca = 2.045*Csd	Assume earthworm equation	3
Zinc	336.5	803	Ln(Cm) = 0.0706*ln(Cs)+4.3632	EPA, 2007	118.4	Ln(Ce) = 0.328*ln(Cs)+4.449	EPA, 2007	577	Ln(Cp) = 0.554*ln(Cs)+1.575	EPA, 2007	121.3	Ln(Ca) = 0.328*ln(Csd)+4.449	Assume earthworm equation	767

Notes:
All units reported in mg/kg
COPEC = contaminant of potential ecological concern
EPC = exposure point concentration

TABLE 6-20
NOAEL-based Toxicity Reference Values (TRV) for COPECs

COPEC	Source	Test Species	Exposure Route	Measured Effect	Toxicity Endpoint	NOAEL-based TRV (mg/kg-bw-day)
Avian TRVs						
Aluminum	Sample et al., 1996	Ringed dove	Oral in diet	reproduction	Chronic NOAEL	109.7
Antimony	NA	NA	NA	NA	NA	NA
Arsenic	Eco SSL 2005	Chicken	Oral in diet	reproduction, growth, mortality	Chronic NOAEL	2.24
Cadmium	Eco SSL 2005	Multiple species	Oral in diet	reproduction and growth	Chronic NOAEL	1.47
Copper	Eco SSL 2007	Chicken	Oral in diet	reproduction	Chronic NOAEL	4.05
Iron	NA	NA	NA	NA	NA	NA
Lead	Eco SSL 2005	Chicken	Oral in diet	reproduction	Chronic NOAEL	1.63
Selenium	Eco SSL 2007	Chicken	Oral in diet	reproduction	Chronic NOAEL	0.29
Silver	Eco SSL 2006	Turkey	Oral in diet	growth	Chronic LOAEL/10	2.02
Zinc	Eco SSL 2007	Multiple species	Oral in diet	reproduction and growth	Chronic NOAEL	66.1
Mammalian TRVs						
Aluminum	Sample et al., 1996	Mouse	Oral in diet	reproduction	Chronic LOAEL/10	1.93
Antimony	Eco SSL 2005	Rat	Oral in diet	reproduction	Chronic NOAEL	0.059
Arsenic	Eco SSL 2005	Dog	Oral in diet	growth	Chronic NOAEL	1.04
Cadmium	Eco SSL 2005	Rat	Oral in diet	growth	Chronic NOAEL	0.77
Copper	Eco SSL 2007	Pig	Oral in diet	growth	Chronic NOAEL	5.6
Iron	NA	NA	NA	NA	NA	NA
Lead	Eco SSL 2005	Rat	Oral in diet	growth	Chronic NOAEL	4.7
Selenium	Eco SSL 2007	Pig	Oral in diet	reproduction, growth, mortality	Chronic NOAEL	0.143
Silver	Eco SSL 2006	Pig	Oral in diet	reproduction, growth, mortality	Chronic LOAEL/10	6.02
Zinc	Eco SSL 2007	Multiple species	Oral in diet	reproduction and growth	Chronic NOAEL	75.4

Notes:
COPEC = contaminants of potential ecological concern
Eco SSL = EPA's Ecological Soil Screening Level
NOAEL = no observable adverse effect level
TRV = toxicity reference value

TABLE 6-21
LOAEL-based Toxicity Reference Values (TRV) for COPECs

COPEC	Source	Test Species	Exposure Route	Measured Effect	Toxicity Endpoint	LOAEL-based TRV (mg/kg-bw-day)
Avian TRVs						
Aluminum	NA	NA	NA	NA	NA	NA
Antimony	NA	NA	NA	NA	NA	NA
Arsenic	Eco SSL 2005	Chicken	Oral in diet	growth	Chronic LOAEL	3.55
Cadmium	Eco SSL 2005	Chicken	Oral in diet	reproduction	Chronic LOAEL	2.37
Copper	Eco SSL 2007	Turkey	Oral in diet	growth	Chronic LOAEL	4.68
Iron	NA	NA	NA	NA	NA	NA
Lead	Eco SSL 2005	Quail	Oral in diet	reproduction	Chronic LOAEL	1.94
Selenium	Eco SSL 2007	Chicken	Oral in diet	reproduction	Chronic LOAEL	0.368
Silver	Eco SSL 2006	Turkey	Oral in diet	growth	Chronic LOAEL	20.2
Zinc	Eco SSL 2007	Chicken	Oral in diet	reproduction	Chronic LOAEL	66.5
Mammalian TRVs						
Aluminum	Sample et al., 1996	Mouse	Oral in diet	reproduction	Chronic LOAEL	19.3
Antimony	Eco SSL 2005	Rat	Oral in diet	reproduction	Chronic LOAEL	0.59
Arsenic	Eco SSL 2005	Dog	Oral in diet	growth	Chronic LOAEL	1.66
Cadmium	Eco SSL 2005	Rat	Oral in diet	growth	Chronic LOAEL	1.30
Copper	Eco SSL 2007	Mink	Oral in diet	reproduction	Chronic LOAEL	6.79
Iron	NA	NA	NA	NA	NA	NA
Lead	Eco SSL 2005	Rat	Oral in diet	reproduction and growth	Chronic LOAEL	5.0
Selenium	Eco SSL 2007	Mouse	Oral in diet	reproduction	Chronic LOAEL	0.145
Silver	Eco SSL 2006	Pig	Oral in diet	reproduction, growth, mortality	Chronic LOAEL	60.2
Zinc	Eco SSL 2007	Cattle	Oral in diet	reproduction	Chronic LOAEL	75.9

Notes:
COPEC = contaminants of potential ecological concern
LOAEL = lowest observable adverse effect level
TRV = toxicity reference value

TABLE 6-22
Risk Estimation for Plant Exposures to COPECs

Soil COPEC	Eco SSL Plants (mg/kg)	ORNL Plant Screening Benchmark[a] (mg/kg)	Range of Surface Soil Background Levels (mg/kg)	Range of Soil Background Levels (mg/kg)	Surface Soil EPC (mg/kg)	Factor of Exceedance of Screening Benchmark	Surface Soil EPC Exceeds Background and Screening Levels?	Subsurface Soil EPC (mg/kg)	Factor of Exceedance of Screening Benchmark	Subsurface Soil EPC Exceeds Background and Screening Levels?
Aluminum	c	50	11,100 to 17,600	4,430 to 17,900	14,793	296	Yes	14,793	296	Yes
Antimony	--	5	0.35U to 125U	0.38U to 0.4	141	28	Yes	141	28	Yes
Arsenic	18	--	16 to 107	7.6 to 162	1,159	64	Yes	1,124	62	Yes
Cadmium	32	--	0.4 to 0.49	0.22 to 0.38	44	1	No	44	1	No
Copper	70	--	10.9 to 39	6.8 to 52	178	3	Yes	173	2	Yes
Iron	b	--	13,200 to 32,367	3,257 to 21,435	23,639	--	--	23,639	--	--
Lead	120	--	17 to 64	9.9 to 189	412	3	Yes	399	3	Yes
Manganese	220	--	NA	NA	672	3	Yes	668	3	Yes
Selenium	0.52	--	0.35U to 0.67U	0.58U to 0.98	1.2	2	Yes	1.2	2	Yes
Zinc	160	--	36 to 150	17.3 to 185	337	2	Yes	323	2	Yes

Notes:
[a] Source: Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants (Efroymson et al., 1997)
[b] Iron is not considered a COPEC for plants at sites where soil pH is between 5 and 8; many waste rock samples have a pH less than 5.
[c] Aluminum is not considered a COPEC for plants at sites where soil pH is above 5.5; only waste rock/soil samples deeper than 1.5 feet bgs have a pH less than 5.5COPEC = contaminant of potential ecological concern
Eco SSL = EPA Ecological Soil Screening Level
EPC = exposure point concentration; generally, the 95% UCL of the mean
mg/kg = milligram per kilogram
NA = not available
U = Not detected; value represents the detection limit

TABLE 6-23

Risk Estimation for Aquatic Organisms Exposure to COPECs in Jill Creek Surface Water

Sample Location	Date Sample Collected	Surface Water COPEC Concentrations (µg/L)												
		Al	Sb	As	Cd	Cu	Fe	Pb	Mn	Ni	Se[a]	Ag	Tl	Zn
JC-1	7/15/2010	41.1	0.5U	1.3	0.08U	1.4	50.0U	0.10U	1.3	0.50U	0.50U	0.50U	0.10U	5.0U
	9/21/2010	56.4	0.5U	1.1	0.08U	0.79	50.0U	0.10U	1.2	0.64	0.50U	---	0.10U	5.0U
JC-2	7/15/2010	51.3	0.5U	1.6	0.41	6.5	50.0U	0.10U	18.5	0.50U	0.50U	0.50U	0.10U	51.7
	9/21/2010	50.9	0.5U	1.6	0.79	11.1	50.0U	0.10U	40.0	0.63	0.50U	---	0.10U	102
JC-3	7/15/2010	966	0.5U	38.8	22.5	456	6,110	7.8	1,240	5.3	0.50U	0.50U	0.10U	2,460
	7/15/2010	1,010	0.5U	38.5	22.2	478	6,210	8	1,300	6	0.50U	0.50U	0.10U	2,650
	9/21/2010	390	0.5U	1.3	20.7	325	1,490	1	1,300	6.0	0.50U	---	0.10U	2,210
JC-4	7/15/2010	915	0.5U	36.8	22.4	449	5,580	7.5	1,130	5.6	0.50U	0.50U	0.10U	2,490
	9/21/2010	840	0.5U	19.5	20.6	338	5,130	6.9	1,230	6.0	0.50U	---	0.10U	2,300
Acute WQC		750	--	340	0.8	5.4	--	22	--	207	--	0.6	--	52
Chronic WQC		87	--	150	0.13	3.9	1,000	0.9	--	23	5	--	--	52

Notes:

[a] Total metal concentration

All concentrations are for dissolved levels except where noted

Hardness dependent WQC based on the minimum hardness reported in Jill Creek of 38.2 mg/l as $CaCO_3$.

Data source: USGS Station 462153112181701 (Bullion Mine Tributary/Jill Creek at mouth), 1998 - 2008

TABLE 6-24
Risk Estimation for Benthic Infaunal Communities Exposure to Sediment COPECs

Sediment COPEC	Units	Upper Effects Concentrations/ Cleanup Screening Levels	Source	JACK-01-SD			JACK-02-SD			JILL-01-SD			JILL-02-SD			JILL-03-SD			JILL-04-SD		
				JACK-01-SD 10 MESH	JACK-01-SD 80 MESH	JACK-01-SD 230 MESH	JACK-02-SD 10 MESH	JACK-02-SD 80 MESH	JACK-02-SD 230 MESH	JILL-01-SD 10 MESH	JILL-01-SD 80 MESH	JILL-01-SD 230 MESH	JILL-02-SD 10 MESH	JILL-02-SD 80 MESH	JILL-02-SD 230 MESH	JILL-03-SD 10 MESH	JILL-03-SD 80 MESH	JILL-03-SD 230 MESH	JILL-04-SD 10 MESH	JILL-04-SD 80 MESH	JILL-04-SD 230 MESH
				7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012	7/23/2012
Antimony	mg/kg	3	Buchman, 2008 UET	0.1 UJ	0.09 UJ	0.76	0.1	2.1	4.9	0.37 J	0.22	0.94	8.4	6.4	7	0.083	0.12	0.09	1.2	2.4	6.4
Arsenic	mg/kg	120	Michelsen, 2011 CSL	23	47.1 J	129	18.3	346	470	33 J	47	235	1,800	1,320	1,840	112 J	58.5	288	104 J	395	836
Cadmium	mg/kg	5.4	Michelsen, 2011 CSL	0.73 J	1.2 J	3.2	1.7	8.3	14.6	1.3 J	1.4	7.3	25.4	18.6	25.7	2.9 J	2.2	12.7	2.5 J	8.9	21.6
Copper	mg/kg	1,200	Michelsen, 2011 CSL	12.5 J	18.1 J	45.8	34.7	86.9	176	21.6	18.2	137	64.3	68.2	110	42.9	54.7	474	60.3 J	159	505
Iron	mg/kg	40,000	Buchman, 2008 UET	6,440	8,430 J	26,500	22,200	12,100	26,600	7,200	6,070	27,400	118,000	70,800	124,000	9,160 J	7,630	48,100	7,210 J	14,300	37,600
Lead	mg/kg	>1,300	Michelsen, 2011 CSL	18.6 J	33.3 J	92	18.3	109	241	9.6 J	9	48	112	203	397	18 J	30.1 J	96.8	42.3 J	148	341
Manganese	mg/kg	1,100	Buchman, 2008 UET	200 J	287	583	385	660	1,280	313 J	264	693	253	556	332	382	263	1,590	276	548	1,220
Silver	mg/kg	1.7	Michelsen, 2011 CSL	0.051 UJ	0.23	0.058	0.05	0.14	1.4	0.045	0.047	0.053	0.052	0.34	1.5	0.041	0.059	0.045	0.057	0.21	1.7
Thallium	mg/kg	NA	NA	0.14 UJ	0.12	0.16	1.7	0.15	0.25	0.12	0.13	0.14	5.7	3.1	4.8	0.11	0.16	1.3	0.15	0.14	0.28
Zinc	mg/kg	>4,200	Michelsen, 2011 CSL	52.9	90.9 J	231	225	313	761	66.5	67.6	365	67.2	145	230	122	105	538	131 J	287	803
Percent Clay	% (w/w)			3.75			5			3.75			11.25			5			5		
Percent Sand	% (w/w)			95			95			92.5			75			92.5			88.75		
Percent Silt	% (w/w)			1.25			0			3.75			13.75			2.5			6.25		

Notes:
% (w/w) = percent wet weight
J = Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.
mg/kg = milligram per kilogram
Bold values exceed probable effects levels
Particle-size data (percent sand, silt\clay) is as reported by Pace Analytical Laboratory.

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TABLE 6-25
Wildlife Hazard Quotient Summary

COPEC	Endpoint Species	Intake (mg/kgbw-d)	NOAEL-based TRV (mg/kgbw-d)	Hazard Quotient	LOAEL-based TRV (mg/kgbw-d)	Hazard Quotient
Aluminum	Deer mouse	446	1.93	**231**	19.3	**23**
	Mule deer	14.3	1.93	**7**	19.3	0.7
	Red fox	16.8	1.93	**9**	19.3	0.9
	Raccoon	88.1	1.93	**46**	19.3	**5**
	Northern goshawk	26.6	109.7	0.2	NA	NA
	Dusky flycatcher	1,148	109.7	**10**	NA	NA
	Spruce grouse	59.1	109.7	0.5	NA	NA
Antimony	Deer mouse	11.7	0.06	**198**	0.59	**20**
	Mule deer	0.3	0.06	**5**	0.59	0.5
	Red fox	0.2	0.06	**3**	0.59	0.3
	Raccoon	1.5	0.06	**26**	0.59	**3**
	Northern goshawk	0.2	NA	NA	NA	NA
	Dusky flycatcher	18.7	NA	NA	NA	NA
	Spruce grouse	1.4	NA	NA	NA	NA
Arsenic	Deer mouse	13.6	1.04	**13**	1.66	**8**
	Mule deer	2.7	1.04	**3**	1.66	**2**
	Red fox	1.6	1.04	1	1.66	1
	Raccoon	3.8	1.04	**4**	1.66	**2**
	Northern goshawk	2.1	2.2	1	3.55	1
	Dusky flycatcher	15.9	2.2	**7**	3.55	**4**
	Spruce grouse	1.4	2.2	1	3.55	0.4
Cadmium	Deer mouse	13.3	0.77	**17**	1.30	**10**
	Mule deer	0.2	0.77	0.3	1.30	0.2
	Red fox	0.1	0.77	0.2	1.30	0.1
	Raccoon	1.8	0.77	**2**	1.30	1
	Northern goshawk	0.2	1.5	0.1	2.37	0.1
	Dusky flycatcher	33.8	1.5	**23**	2.37	**14**
	Spruce grouse	1.6	1.5	1.1	2.37	0.7
Copper	Deer mouse	9.8	5.60	**2**	6.79	1
	Mule deer	0.8	5.60	0.1	6.79	0.1
	Red fox	0.8	5.60	0.1	6.79	0.1
	Raccoon	2.2	5.60	0.4	6.79	0.3
	Northern goshawk	1.7	4.1	0.4	4.68	0.4
	Dusky flycatcher	43.8	4.1	**11**	4.68	**9**
	Spruce grouse	1.6	4.1	0.4	4.68	0.3

TABLE 6-25
Wildlife Hazard Quotient Summary

COPEC	Endpoint Species	Intake (mg/kgbw-d)	NOAEL-based TRV (mg/kgbw-d)	Hazard Quotient	LOAEL-based TRV (mg/kgbw-d)	Hazard Quotient
Iron	Deer mouse	1,876	NA	NA	NA	NA
	Mule deer	23.1	NA	NA	NA	NA
	Red fox	41.3	NA	NA	NA	NA
	Raccoon	581.7	NA	NA	NA	NA
	Northern goshawk	79.2	NA	NA	NA	NA
	Dusky flycatcher	18,090	NA	NA	NA	NA
	Spruce grouse	250.0	NA	NA	NA	NA
Lead	Deer mouse	10.5	4.70	**2**	5.00	**2**
	Mule deer	0.6	4.70	0.1	5.00	0.1
	Red fox	1.0	4.70	0.2	5.00	0.2
	Raccoon	2.3	4.70	0	5.00	0
	Northern goshawk	2.0	1.6	1	1.94	1
	Dusky flycatcher	26.9	1.6	**16**	1.94	**14**
	Spruce grouse	1.8	1.6	1	1.94	1
Selenium	Deer mouse	0.2	0.14	1	0.15	1
	Mule deer	0.0	0.14	0.2	0.15	0.2
	Red fox	0.0	0.14	0.2	0.15	0.2
	Raccoon	0.0	0.14	0.2	0.15	0.2
	Northern goshawk	0.1	0.3	0.2	0.37	0.2
	Dusky flycatcher	0.3	0.3	1	0.37	1
	Spruce grouse	0.0	0.3	0.1	0.37	0.1
Silver	Deer mouse	4.6	6.02	0.8	60.2	0.08
	Mule deer	0.0	6.02	0.007	60.2	0.0007
	Red fox	0.0	6.02	0.006	60.2	0.0006
	Raccoon	0.6	6.02	0.1	60.2	0.01
	Northern goshawk	0.1	2.0	0.0	20.2	0.003
	Dusky flycatcher	7.8	2.0	**4**	20.2	0.4
	Spruce grouse	0.6	2.0	0.3	20.2	0.03
Zinc	Deer mouse	61.6	75.40	0.8	75.9	0.8
	Mule deer	5.3	75.40	0.1	75.9	0.1
	Red fox	5.1	75.40	0.1	75.9	0.1
	Raccoon	9.6	75.40	0.1	75.9	0.1
	Northern goshawk	10.6	66.1	0.2	66.5	0.2
	Dusky flycatcher	166.0	66.1	**3**	66.5	**2**
	Spruce grouse	9.9	66.1	0.1	66.5	0.1

7. Summary and Conclusions

A focused RI was performed on the Site, located in the Basin Mining District, near Basin, Montana. The purpose of the RI was to evaluate the nature and extent of Site contamination, identify contaminant fate and transport, assess the risks to human health and the environment, and facilitate development of appropriate remedial alternatives.

COCs identified by the previous Basin Watershed OU2 RI/FS and risk assessment were carried into this RI. The additional COIs are aluminum, antimony, iron, manganese, nickel, selenium, silver, and thallium. COCs are arsenic, cadmium, copper, lead, and zinc. Concentrations of these constituents in surface water, soils, sediments, and groundwater (mine adit discharge) were characterized. In addition, benthic macroinvertebrate community surveys in Jill Creek and identification of wetlands and T&E species potentially using the area provided important information to support management decisions at Bullion Mine. Historical data and previous investigations described the AMD/ARD from this mine as the most important contributor to water quality degradation in the Basin Creek Watershed, and it represents a constant threat to the environment. Results of the 2010–2012 RI of Site media describe a similar condition.

In general, the findings of the 2010–2012 RI revealed the following:

- The project Site consists of a high-altitude, steep, mine property of approximately 40 disturbed acres, much of it vegetated and reclaimed from previous removal activities. Some small areas barren of vegetation and topsoil exist in former waste rock dump locations. These are primarily upgradient and some distance from Jill Creek.
- The claims were mined on three levels with adits daylighting at three primary portals. All three are collapsed without much surface expression. Only one, the lowest in elevation, has a discernible discharge of mine water. Investigation of the discharging adit indicates a considerable pooling of mine water (estimated at 2.5 million gallons) within the mine behind the debris plug.
- Bedrock underlying the Site consists of a zone of weathered/fractured rock with a mantle of soil overburden varying in thickness from 5 to 20 feet.
- A perpetual point source of contaminated groundwater flows from a debris plugged lower adit portal into Jill Creek. The acidic discharge carries substantial concentrations of aluminum, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, and zinc exceeding state and federal drinking water standards and aquatic life standards. The discharge adversely influences water quality downstream to the mainstem of Jack Creek, a distance of approximately 1 mile.
- Water and sediment quality in Jill Creek is unsuitable for aquatic organisms. Residual mining impacts from the Site have degraded water and sediment quality to the point that it fails to support viable populations of benthic macroinvertebrates and other lower-trophic level organisms.
- Wetlands identified along Jill Creek within the project area are adversely impacted by the Bullion Mine. The riparian health of the same reach is negatively impacted based on vegetation species, composition, and density, and when compared to other local control streams or remediated streams.

In its current condition, the Bullion Mine is the most detrimental influence on water quality in the Basin Creek Watershed.

7.1.1 Nature and Extent of Contamination

Contaminants in the form of metals and arsenic move within and among aqueous and solid media, such as waste rock and soil, groundwater, surface water, and sediment. These contaminants reside in ore and residual waste rock extracted in the mining process, in contaminated groundwater discharging from the adit portal of the lower workings, and in ARD. Primary release mechanisms and pathways include the oxidation of pyritic material creating acid that releases metals in waste rock and soils, precipitation, dissolution, and adsorption/desorption mechanisms. Total and dissolved metals are transported by adit discharge, runoff, and erosion into streams where aquatic flora and fauna are exposed to acidic conditions and detrimental metal concentrations. Capillary action, in response to soil moisture movement and evaporative demands, can result in the migration of metal salts into cover soils and onto surface soil particles. Metal salts can also remain in dissoved form in the vadose zone interfering with the establishment of vegetation. Elevated concentrations of COIs in both dissolved and total forms (aluminum, arsenic, cadmium, copper, lead, manganese, and zinc) have been documented in Jill Creek along and below the Bullion Mine boundaries. Elevated concentrations of aluminum, arsenic, cadmium, copper, lead, manganese, and zinc were documented extensively across the Site in subsurface soils capped by the reclamation activities.

7.1.2 Fate and Transport

The fate of the arsenic and metals documented at this Site is dependent on physical processes (such as solubility, speciation, complexation, precipitation, dissolution, soil-water partitioning, and air-water and air-soil partitioning) and chemical processes such as oxidation/reduction and biological transformation. These processes are influenced by a variety of environmental conditions, climate, buffering capacity of host rock, surface area exposure, presence of organic matter, vegetation, and other factors.

The transport of contaminants at the Site occurs by infiltration/percolation, advection, dispersion, diffusion, physical transport by runoff, entrainment, and suspension by creek water. In the past, human activities transported source material across the Site through the act of mining and mechanical movement of Site materials. COIs are presently being transported offsite and downstream through their introduction into Jill Creek. The most important contribution to this continuous loading is the discharge from the lowest of three adits.

7.1.3 Risk Assessment

An HHRA and ERA were conducted at the Bullion Mine and in accordance with applicable MDEQ and EPA guidance. The resulting characterization of potential risk is expected to provide enough information for informed decisions at the Bullion Mine. The primary decision for which the results of the risk assessment provide input is whether to develop remedial alternatives for any areas and COPCs or COPECs at the Site because of the potential threat of human health or ecological risk. Based the exposure assumptions used in the risk assessment (Section 6), remedial alternatives will be needed to address unacceptable levels of human health and ecological risk.

7.1.4 Human Health

Risks were estimated for the most plausible pathways of human exposure, based on reasonably anticipated land and water uses at Bullion Mine. These exposure scenarios evaluated included current and intermittent workers, recreational users (assumes ATV users), and future excavation worker receptor groups. In addition, unrestricted use was evaluated using hypothetical future industrial worker exposure scenario.

7.1.4.1 Intermittent Workers

Current and future intermittent workers were evaluated for potential exposure to COPCs detected in surface soil (0 to 10 inches bgs). Cumulative ELCR estimates using the RME and CTE scenarios are within the EPA target risk range of 1×10^{-6} to 1×10^{-4}, and below the MDEQ statutory risk level of 1×10^{-5}. HI estimates were below the EPA and MDEQ threshold value of 1 for this exposure scenario. No COCs are identified for the intermittent worker RME exposure scenario based on the ELCR and HI estimates.

7.1.4.2 Recreational Users

Current and future adult and adolescent recreational users were evaluated for potential exposure to COPCs detected in surface soil (0 to 10 inches bgs). The recreational user scenarios assume predominant use is as ATV riders. Risk estimates are driven by the dust inhalation pathway and would overestimate the risk for other recreational users (for example, hikers). Considering this, risk estimates for the intermittent worker scenario are likely more representative of most recreationalists (for example, hikers). Cumulative ELCR estimates using the RME assumptions are within the EPA target risk range of 1×10^{-6} to 1×10^{-4}, and exceed the MDEQ statutory risk level of 1×10^{-5}. HI estimates above the EPA and MDEQ threshold value of 1 were also identified for these exposure scenarios. Arsenic was identified as the only COC for recreational users RME exposure scenario. No exceedances were identified using CTE assumptions.

Current and future adult and adolescent recreational users were also evaluated for potential exposure to COPCs detected in surface water. Cumulative ELCR estimates using the RME and CTE assumptions are within the EPA target risk range of 1×10^{-6} to 1×10^{-4}, and exceed the MDEQ statutory risk level of 1×10^{-5}. HI estimates were below the EPA and MDEQ threshold value of 1 for these exposure scenarios. Arsenic was identified as the only COC for recreational users.

7.1.4.3 Excavation Workers

Future excavation workers users were evaluated for potential exposure to COPCs detected in subsurface soil (0 to 10 feet bgs). Cumulative ELCR estimates using the RME and CTE scenarios are within the EPA target risk range of 1×10^{-6} to 1×10^{-4}, and do not exceed the MDEQ statutory risk level of 1×10^{-5}. HI estimates are below the EPA and MDEQ threshold value of 1 for this exposure scenario. No COCs are identified for the excavation worker exposure scenario based on the ELCR and HI estimates.

7.1.4.4 Hypothetical Industrial Workers

Hypothetical standard (default) industrial workers were evaluated for potential exposure to COPCs detected in surface soil (0 to 10 inches bgs). Cumulative ELCR estimates using the RME and CTE scenarios are within the EPA target risk range of 1×10^{-6} to 1×10^{-4}, and the RME scenario exceeds the MDEQ statutory risk level of 1×10^{-5}. HI estimates are below the EPA and MDEQ threshold value of 1 for this exposure scenario. Arsenic is the only COC identified for the hypothetical industrial worker exposure scenarios based on the ELCR and HI estimates.

7.1.5 Ecological

Risks were estimated for receptors representative of the types that use the habitats at the Site and the surrounding areas. Risks posed to wildlife and vegetation in upland and riparian areas on and around the Site are as follows:

- For five of seven wildlife endpoint species evaluated, estimates of exposure to COPECs in site media exceed the EPA and MDEQ regulatory threshold values (HQ greater than 1).
- The greatest risk to wildlife is from exposure to arsenic, antimony, and cadmium in surface soil, and arsenic, cadmium, copper, and zinc in sediment—although seven COPECs (antimony, arsenic, cadmium, copper, lead, silver, and zinc) exceed the EPA and MDEQ threshold value of 1 and background levels for at least one endpoint species using NOAELs for toxicity factors. Of those nine, all but silver also exceed the EPA and MDEQ threshold using LOAELs for toxicity factors.
- The receptors of with the greatest risk include wildlife that forage over a smaller area (for example, deer mice and flycatchers).
- Soil exposures to a depth of 2 feet bgs were assumed during the ERA to account for potential exposures during burrowing and through consumption of vegetation and prey that are exposed to contaminants at these depths. Considering historical remedial actions at the Site included a soil cap to approximately 18 inches, the risk estimates for most species are likely biased high.

- Measured soil concentrations exceed levels known to pose a risk to plants and background levels for seven COPECs (antimony, arsenic, copper, lead, manganese, selenium, and zinc). The greatest exceedance of benchmarks was found for arsenic.

On the basis of considering multiple lines of evidence: (1) media-specific benchmark screening, (2) comparisons with upstream sample locations, (3) historical in situ fish survivability studies, and (4) macroinvertebrate field surveys within Jill Creek and Jack Creek (near its confluence with USG Creek) the following findings can be made:

- Dissolved concentrations of many COPECs in adit discharge significantly exceed WQC.
- Dissolved concentrations of many COPECs in springs/seeps exceeded WQC.
- Dissolved concentrations of aluminum, cadmium, copper, iron, lead, and zinc in surface water collected from Jill Creek exceeded WQC with the greatest exceedances occurring for cadmium, copper, and zinc. The greatest exceedances occurred at JC-3 and JC-4, which are located downstream of the influence of the adit discharge.
- Historical in situ fish toxicity testing support the conclusion that water quality is unsuitable for survival.
- Sediment concentrations of arsenic, cadmium, iron, and silver exceed published probable effects benchmarks for benthic macroinvertebrates with the greatest exceedances occurring for arsenic.
- Macroinvertebrate field studies indicate that macroinvertebrate communities are significantly impaired downstream of the influence of the mine.
- The locations where macroinvertebrate population impairments are greatest concur with the highest COPEC concentrations in sediment.

On the basis of the results of the ERA, the contaminants with the highest potential for ecological exposure are (1) antimony, arsenic, cadmium, copper, lead, silver, and zinc in surface soil, and (2) aluminum, cadmium, copper, iron, lead, and zinc in surface water, and (3) arsenic, cadmium, iron, and silver in sediment. These contaminants are considered COECs because the potential ecological risks associated with exposures to them are significant. Recommendations on whether to develop remedial alternatives to address these risks and decisions regarding the need for early remedial actions are discussed in Section 7.2.

7.2 Conclusions

Based on a weight-of-evidence approach, multiple lines of evidence collectively support the RI findings that unacceptable risk exists to human and ecological receptors from mining-related wastes associated with the Site. Multiple investigators (USGS, MBMG, MDEQ) consider the AMD from this mine Site to be the most significant contribution to water quality degradation in Jack Creek and the entire Basin Creek Watershed. Its constant contribution of acidic metals laden discharge represents a perennial threat to the environment.

7.2.1 Data Limitations and Recommendations for Future Work

This RI was based on existing historic data and data collected in the 2010–1012 field seasons. The recent data collected during several field seasons are representative of current Site conditions. The data are adequate for the development of proposed alternatives in the feasibility study (Volume 2).

7.2.2 Recommended Preliminary Remedial Action Objectives

Proposed preliminary remedial action objectives (PRAOs) for the Bullion Mine Operable Unit are described in the following text.

7.2.2.1 Groundwater

Because of the steep topography and shallow occurrence of groundwater at this high-altitude mountain site, determination of the nature and areal extent of groundwater was limited. However, groundwater infiltrating through the bedrock fractures, into the underground workings, and discharging from the lower adit as AMD was evaluated. This discharge presently intercepts and degrades Jill Creek, which is a tributary to Jack Creek and eventually Basin Creek. Proposed PRAOs for groundwater are as follows:

- Prevent or minimize groundwater discharge (from adit) containing arsenic and metals that would degrade surface water.
- Establish a groundwater control area around the Site with groundwater use restrictions that include, but will not be limited to, drilling permit requirements and testing of the groundwater prior to use.

7.2.2.2 Surface Water

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

From a human health standpoint, Jack Creek does not currently meet the requirements for suitable drinking or culinary and food processing use, and appears on MDEQ's 303(d) list for the water quality parameters that exceeded standards set for arsenic, copper, lead, mercury, and zinc. In addition, the amount of sedimentation/siltation exceeded acceptable levels. Based on the Basin Watershed OU2 RI, Jill Creek is a major tributary to Jack Creek and is known to be a significant degrading factor to the quality of its water. This degradation adversely influences the potential human use of Jack and Basin Creek water and the ability of the creeks to sustain aquatic life now and in the future. Based on these characteristics, the surface water PRAOs proposed for Jill Creek are as follows:

- Reduce point (adit discharge) discharge of metals-laden runoff from the Site into Jill Creek.
- Achieve acceptable exposure risks for visitors and recreationists.
- Achieve acceptable exposure risks to terrestrial and aquatic species.

7.2.2.3 Mine Impacted Soils

The nature and extent of mine impacted soils at the Site are defined by the RI. Soils with elevated COIs typically appear at greater than 10 inches bgs. This is a result of the removal action and capping of excavated areas with lime gravel and cover soil (12 to 18 inches). The PRAO for this media is as follows:

- For human health – prevent or reduce exposure to arsenic-contaminated soils where incidental ingestion, dust inhalation, or direct contact would pose an unacceptable health risk.
- For the environment – prevent or reduce unacceptable risk to ecological systems (including aquatic and terrestrial) degraded by contaminated soils/tailings containing elevated levels of metals (antimony, arsenic, cadmium, copper, lead, silver, and zinc).

7.2.2.4 Stream Sediments

The nature and extent of contaminated sediments in Jill Creek is delineated in the RI and represent considerable exposure to ecological receptors. The PRAO for sediments is to prevent or reduce unacceptable risk to ecological systems (including aquatic and terrestrial) degraded by contaminated sediment containing elevated levels of metals (arsenic, cadmium, iron, and silver). This could be achieved through removal of mine Site contaminated source materials in close proximity to the creek, if warranted, and eliminating the discharge from the lower portal.

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8. References and Literature Cited

American Cancer Society. 2003. *Cancer Facts and Figures—2003.* Atlanta, Georgia.

Anderson, Paul, Jim Duran, and Dale Gray. 1995. *Cultural Site Record for the Bullion Mine, 24JF1311*. On file, Montana State Historic Preservation Office. Helena, Montana.

Baes III, C.F. R.D. Sharp, A.L. Sjoreen, R.W. Shor. 1984. *A Review and Analysis of Parameters of Assessing Transport of Environmentally Released Radionuclides Through Agriculture*. Oak Ridge National Laboratory, U.S. Department of Energy. ORNL-5786.

Beyer, W.N. and C. Stafford. 1993. *Survey and Evaluation of Contaminants in Earthworms and in Soils Derived from Dredged Material at Confined Disposal Facilities in the Great Lakes Region*. Environmental Monitoring and Assessment. 24: 151-165.

Bitterroot Restoration, Inc. 2002. *Riparian Assessments of Two Upper Clark Fork Basin Locations.* Bitterroot Restoration, Inc., Corvallis, Montana. 32 p.

CDM Federal Programs Corporation. 2002. *Draft Ecological Risk Evaluation, Basin Mining Area, Operable Unit 2, Jefferson County, Montana*. November.

CDM Federal Programs Corporation. 2005a. *Draft Feasibility Study Basin Mining Area Superfund Site, Operable Unit, Jefferson County, Montana*. May.

CDM Federal Programs Corporation. 2005b. *Remedial Investigation Report Addendum, Basin Mining Area Superfund Site, Operable Unit 2, Jefferson County, Montana*. April 18.

CH2M HILL. 2009. *Engineering Evaluation/Cost Analysis, Bullion and Crystal Mines, Basin Mining Area, Operable Unit 2, Jefferson County, Montana*. U.S. Environmental Protection Agency.

CH2M HILL. 2010. *Sampling and Analysis Plan Bullion Mine OU5 Basin Watershed NPL Site, Part 1: Quality Assurance Project Plan and Part 2: Field Sampling Plan*. Prepared by: CH2M HILL and Reclamation Research Group, for EPA Region 8, Montana. July.

CH2M HILL. 2012. *Sediment Sampling and Analysis Plan Bullion Mine OU6 Basin Watershed NPL Site, Jefferson County Montana*. July.

Daubenmire, R.D. 1959. "A Canopy-Coverage Method of Vegetation Analysis." *Northwest Science* 33: 43-66.

Drexler, J. W. and W.J. Brattin. 2007. "An In Vivo Procedure for Estimation of Lead Relative Bioavailability; with Validation." *Human and Ecological Risk Assessment*. 13: 383-401.

Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten. 1997. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 revision.* Environmental Restoration Division, ORNL Environmental Restoration Program. ES/ER/TM-85/R3.

EPA. See U.S. Environmental Protection Agency.

Godfrey, Anthony, 2003. *Historic Preservation Plan Placer and Hard Rock Mining Resources in Montana*, *U.S.* West Research, Inc., Salt Lake City, Utah. Submitted to Montana State Office, Bureau of Land Management, Billings, Montana.

Hansen, Paul L., William H. Thompson, Robert C. Ehrhart, Dan K. Hinckley, Bill Haglan, and Karen Rice. 2000. "Development of Methodologies to Evaluate the Health of Riparian and Wetland Areas." *In: Proceedings of the Fifth International Symposium of Fish Physiology, Toxicology and Water Quality, November 10-13, 1998, Hong Kong, China*. Vance Thurston, Editor. EPA/6000/R-00/015. United States Environmental Protection Agency, Office of Research and Development, Washington, DC, USA. 300 p.

Harrington, N. 1993. *Clark Fork Superfund Background Levels (Soils).* Montana Department of Health and Environmental Sciences, Helena, Montana.

Jennings, S.R., J.D. Dollhopf, and W.P. Inskeep. 2000. "Acid Production from Sulfide Minerals Using Hydrogen Peroxide Weathering." *Applied Geochemistry*. 15(235-243).

Maxim Technologies, Inc. 2001. *Bullion Mine and Mill Site Investigations, Beaverhead-Deerlodge National Forest*. Prepared for U.S. Department of Agriculture Forest Service, Region 1.

Maxim Technologies, Inc. 2003. *Final Construction Report. Bullion Mine and Millsite Removal Action. Jefferson County, Montana*. USFS Northern Region. Contract 53-0343-0-0014.

MBMG. See Montana Bureau of Mines and Geology.

McGuire, D.L. 2011 *An Assessment of Aquatic Macroinvertebrates near the Bullion Mine, Jefferson County, Montana*. McGuire Consulting. Prepared for CH2M HILL, Boise, Idaho.

McGuire, M.M., K.J. Edwards, J.F. Banfield, and R.J. Hamers. 2001. "Kinetics, Surface Chemistry, and Structural Evolution of Microbially Mediated Sulfide Dissolution." *Geochimica et Cosmochimica Acta*. 65(8): 1243-1258.

MDEQ. See Montana Department of Environmental Quality.

MDSL. See Montana Department of State Lands.

Mincemoyer, S. 2005. *Surveys of Significant Plant Resources and Related Vegetation Types for the Butte Office of the Bureau of Land Management*. Montana Natural Heritage Program, Natural Resource Information System, Montana State Library. November.

Montana Bureau of Mines and Geology. 1994. *Abandoned – Inactive Mines Program Deerlodge National Forest*. Volume I, Basin Creek Drainage. April.

Montana Bureau of Mines and Geology. 1995. *Abandoned – Inactive Mines Program Deerlodge National Forest*. Volume II, Cataract Creek Drainage. May.

Montana Bureau of Mines and Geology. 2012. Bullion and Crystal Mines Summary Report 2011. January.

Montana Department of Environmental Quality. 2005. *Action Level for Arsenic in Surface Soil*. April.

Montana Department of Environmental Quality. 2007. *Montana Numeric Water Quality Standards.* Circular DEQ-7. Planning, Prevention, and Assistance Division – Water Quality Standards Section.

Montana Department of Environmental Quality. 2012a. *Montana Numeric Water Quality Standards.* Circular DEQ-7. Planning, Prevention, and Assistance Division – Water Quality Standards Section. August.

Montana Department of Environmental Quality. 2012b. *Boulder-Elkhorn Metals TMDLs and Framework Water Quality Improvement Plan*. Section 5.0. December.

Montana Department of State Lands. 1994. *Abandoned Hardrock Mine Priority Sites, Summary Report*. Prepared by: Pioneer Technical Services, Inc, Butte, Montana and Thomas, Dean, and Hoskins, Inc., Great Falls, Montana. March.

Montana Natural Heritage Program. 2012. http://mtnhp.org/SpeciesOfConcern/. April 17.

Montana State University. 2003. "Reclaiming Hard Rock Mines: An In Depth Look at Vegetation, Soil, and Water on the Bullion Mine Site, Basin, Montana." Montana State University, LRES Capstone Course, Fall 2003. C. Zabinski, PhD, project instructor, LRES Department, Montana State University, Bozeman.

Nagy, K. 2001. "Food Requirements of Wild Animals: Predictive Equations for Free-Living Mammals, Reptiles, and Birds." *Nutr. Abs. Res.* Ser. B., 71: 1R-12R.

Nimick, D.A. and Cleasby, T.E. 2000. *Water-Quality Data for Streams in the Boulder River Watershed, Jefferson County, Montana.* U.S. Geological Survey Open-File Report 00–99, pp. 70.

Nimick et al. 2003. "Diel Cycles in Dissolved Metal Concentrations in Streams; Occurrence and Possible Causes." *Water Resources Research.* Vol. 39, No. 9, 1247.

Nordstrom, D.K. and Southam, G. 1997. *Geomicrobiology of Sulphide Mineral Oxidation*. Reviews in Mineralogy and Geochemistry. (January 1997) v. 35-1, p. 361-390.

NRCS. See USDA Natural Resources Conservation Service.

ORNL. 2013. *Chemical Specific Factors: Soil-to-Plant Dry Uptake*. Oak Ridge National Laboratory. http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=csf

Pioneer Technical Services, Inc. and Thomas, Dean and Hoskins, Inc. 1994. *Summary Report: Hazardous Materials Inventory Site Summary (Red Book)*. Prepared for Abandoned Mine Land Reclamation Bureau, Montana Department of State Lands, Helena, Montana.

Pioneer Technical Services. 2008.*Draft Final Reclaimed Mine Inspection Report for the Bullion Mine Sit*e. Prepared for US Department of Agriculture, Forest Service, Beaverhead-Deerlodge National forest, Butte Ranger District, Butte, MT. 59702.

PTI Environmental Services. 1992. *Clark Fork River Superfund Site Investigations, Data Management/Data Validation Plan*. Revised 1993, addendum added 2000.

Reclamation. See U.S. Bureau of Reclamation.

Rossillon, Mitzi. 2011. *Re-inventory and Re-evaluation of the Bullion Mine (24JF1311)*. Renewable Technologies, Inc., 8 W Park St, Suite 313, Butte, Montana 59701. Prepared for U.S. Environmental Protection Agency, 10 W. 15th St., Suite 3200, Helena, Montana 59626. November.

Rossillon, Mitzi, and Tom Haynes. 1999. *Basin Creek Mine Reclamation Heritage Resource Inventory 1998*. Renewable Technologies, Inc., Butte. Submitted to Beaverhead-Deerlodge National Forest, Dillon, Montana.

Reclamation Research Group (RRG)/MSU. 2006. *Abandoned Mine Lands Post-Remediation Assessment Protocols and Draft Handbook*. Reclamation Research Unit, Montana State University, Bozeman, Mt 59717.

Sample, B.E. et al. 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision*. Oak Ridge National Laboratory, Environmental Sciences Division. ES/ER/TM-86/R3.

Sample, B.E. et al. 1997. *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants.* Oak Ridge National Laboratory, Risk Assessment Program Health Sciences Research Division. ORNL/TM-13391.

Schafer and Associates. 1991. Final Report of the Clark Fork River Demonstration Project, Warm Springs, Montana. Report submitted to the Office of the Governor, Capitol Station, Helena, Montana.

Schmetterling. 2010. Personal communication, Fisheries Biologist. Montana Fish, Wildlife, and Parks. Missoula, Montana.

Skaar, D. and D. McGuire. 2008. "Aquatic Health Status of the Upper Tenmile Creek Drainage, Montana 1997-2001." *Impacts of Abandoned Mines and Municipal Water Diversions*. Montana Fish Wildlife & Parks, Helena, Montana.

SME. See Society for Mining, Metallurgy, and Exploration, Inc.

SRC. 2009. *Baseline Human Health Risk Assessment Standard Mine Site Gunnison County, Colorado Addendum*. Prepared for, and with oversight by the U.S. Environmental Protection Agency Region 8. November 24, 2009.

Stephan, C.E. 1985. *Are the Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Life and Its Uses Based on Sound Judgments?* Aquatic Toxicology and Hazard Assessment:

Seventh Symposium, ASTM STP 854, R.D. Cardwell et al., American Society for Testing and Materials. Philadelphia, PA. Pages 515-526.

Suter II, G.W., R.A. Efroymson, B.E. Sample, and D.S. Jones. 2000. *Ecological Risk Assessment for Contaminated Sites*. CRC Press LLC, Lewis Publishers.

The Weather Channel. 2011. Monthly Averages for Basin, Montana. http://www.weather.com/weather/wxclimatology/monthly/graph/USMT0017. Accessed January 4, 2011.

U.S. Army Corps of Engineers. 1987. *Corps of Engineers Wetlands Delineation Manual Technical Report Y-87-1 [On-line edition])*. U.S. Army Engineer Research and Development Center, Environmental Laboratory, Waterways Experiment Station, Vicksburg, Mississippi, USA. 143 p.

U.S. Army Corps of Engineers. 2010. *U.S. Army Corps of Engineers Manual and the Regional Supplement for Western Mountains, Valleys, and Coast Region*. (Version 2.0). U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, Mississippi. 153 p.

U.S. Environmental Protection Agency 1986. *Guidelines for Carcinogen Risk Assessment.* Federal Register 51:33992-34003. September 24.

U.S. Environmental Protection Agency. 1989a. *Final Guidance on Implementation of the "Consistency" Exemption to the Statutory Limits on Removal Actions*. Office of Solid Waste and Emergency Response. June 12.

U.S. Environmental Protection Agency. 1989b. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA.* EPA/540/G-89/004, OSWER Directive 9355.3-01, Office of Emergency and Remedial Response, Washington, DC. NTIS PB89-184626.

U.S. Environmental Protection Agency. 1989c. *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual. Interim Final.* March.

U.S. Environmental Protection Agency. 1991a. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.*

U.S. Environmental Protection Agency. 1991b. *The Role of the BTAGs in Ecological Assessment*. Office of Solid Waste and Emergency Response, Eco Update. Vol. 1, No. 1, Publication 9345.0-05I, September.

U.S. Environmental Protection Agency. 1991c. *Ecological Assessment of Superfund Sites: an Overview*. U.S. Environmental Protection Agency. Office of Solid Waste and Emergency Response, Eco Update. Vol. 1, No. 2, Publication 9345.0-05I. December.

U.S. Environmental Protection Agency. 1992a. *Supplemental Guidance to RAGS: Calculating the Concentration Term.* Office of Solid Waste and Emergency Response, publication 9285.7-081.

U.S. Environmental Protection Agency. 1992b. *Briefing the BTAG: Initial Description of Setting, History, and Ecology of a Site*. Office of Solid Waste and Emergency Response, Eco Update. Vol. 1, No. 5, Publication 9345.0-05I. August.

U.S. Environmental Protection Agency. 1992c. *Developing a Work Scope for Ecological Assessments*. Office of Solid Waste and Emergency Response, Eco Update. Vol. 1, No. 4, Publication 9345.0-05I, May.

U.S. Environmental Protection Agency. 1993. *Wildlife Exposure Factors Handbook*. Office of Research and Development. EPA/600/R-93/187b. December 1993.

U.S. Environmental Protection Agency. 1994a. *Catalog of Standard Toxicity Tests for Ecological Risk Assessment*. Office of Solid Waste and Emergency Response, Eco Update. Vol. 2, No. 2, Publication 9345.0-05I, EPA 540-F-94-013. September.

U.S. Environmental Protection Agency. 1994b. *Field Studies for Ecological Risk Assessment*. Office of Solid Waste and Emergency Response, Eco Update. Vol. 2, No. 3, Publication 9345.0-05I, EPA 540-F-94-014. September 1994.

U.S. Environmental Protection Agency. 1994c. *Selecting and Using Reference Information in Superfund Ecological Risk Assessments*. Office of Solid Waste and Emergency Response, Eco Update. Vol. 2, No. 4, Publication 9345.0-05I, EPA 540-F-94-050. September.

U.S. Environmental Protection Agency. 1994d. *Using Toxicity Tests in Ecological Risk Assessment*. Office of Solid Waste and Emergency Response, Eco-Update. Vol. 2, No. 1, Publication 9345.0-05I, EPA 540-F-94-012. September.

U.S. Environmental Protection Agency. 1996a. *Ecological Significance and Selection of Candidate Assessment Endpoints*. Office of Solid Waste and Emergency Response, Eco Update. Vol. 3, No. 1, Publication 9345.0-05I, EPA 540/F-95/037. January.

U.S. Environmental Protection Agency. 1996b. *Ecotox Thresholds*. Office of Solid Waste and Emergency Response, Eco Update. Vol. 3, No. 2, Publication 9345.0-05I, EPA 540/F-95/038. January.

U.S. Environmental Protection Agency. 1997a. *Exposure Factors Handbook*. EPA/600/P-95/002Fa. August.

U.S. Environmental Protection Agency. 1997b. *Health Effects Assessment Summary (HEAST), FY 1997 Update*.

U.S. Environmental Protection Agency. 1997c. *Interim Final Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final*. U.S. Environmental Protection Agency. EPA/540/R-97/006.

U.S. Environmental Protection Agency. 1998. *Guidelines for Ecological Risk Assessment. U.S. Environmental Protection Agency*. Washington, D.C. EPA/630/R-95/002F.

U.S. Environmental Protection Agency. 1999. *Ecological Risk Assessment and Risk Management Principles for Superfund Sites*. U.S. Environmental Protection Agency. OSWER Directive 92857.7-28P. October.

U.S. Environmental Protection Agency. 2002a. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites.*

U.S. Environmental Protection Agency. 2002b, *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*. U.S. Environmental Protection Agency. EPA 540-R-01-003 OSWER 9285.7-41 September.

U.S. Environmental Protection Agency. 2003a. *Memorandum—Human Health Toxicity Values in Superfund Risk Assessments*. OSWER Directive 9285.7-53. December 5, 2003.

U.S. Environmental Protection Agency. 2003b. *Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil*. EPA-540-R-03-001, OSWER Directive #9285.7-54 (January 2003) - The Adult Lead Methodology (ALM).

U.S. Environmental Protection Agency. 2004. *Risk Assessment Guidance for Superfund–Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), Final.* EPA/540/R/99/005. July 2004.

U.S. Environmental Protection Agency. 2005 and 2007. *Ecological Soil Screening Level (EcoSSL) Reports:* for Arsenic, Cadmium, Copper, Lead, and Zinc. U.S. Environmental Protection Agency, Office of Research and Development.

U.S. Environmental Protection Agency. 2005a. *Guidelines for Carcinogen Risk Assessment. EPA/630/P-03/001F.*

U.S. Environmental Protection Agency. 2005b. *Supplemental Guidance for Assessing Cancer Susceptibility from Early-Life Exposure to Carcinogens*. Risk Assessment Forum, Washington, DC. EPA/630/R-30/003F.

U.S. Environmental Protection Agency. 2005c. *Guidance for Developing Ecological Soil Screening Levels.* OSWER Directive 9285.7-55. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response.

U.S. Environmental Protection Agency. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process. EPA QA-G4. EPA/240/B-06/001. February.

U.S. Environmental Protection Agency. 2009a. *Basin Mining Area, Operable Unit 2, Engineering Evaluation/Cost Analysis, Bullion and Crystal Mines, Jefferson County, Montana*. Prepared by: CH2M HILL, Boise, Idaho. May.

U.S. Environmental Protection Agency. 2009b. *National Recommended Water Quality Criteria*. U.S. Environmental Protection Agency, Office of Water. EPA 822-R-02-047.

U.S. Environmental Protection Agency. 2009c. *Risk Assessment Guidance for Superfund–Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)*.

U.S. Environmental Protection Agency. 2011a. *Integrated Risk Information System (IRIS) Database*. U.S. Environmental Protection Agency, National Center for Environmental Assessment, Washington. DC. [Online] http://www.epa.gov/iris/index.html

U.S. Environmental Protection Agency. 2011b. *Software for Calculating Upper Confidence Limits (UCLs) ProUCL Version 4.01.01* U.S. Environmental Protection Agency. [Online]. July. http://www.epa.gov/nerlesd1/tsc/form.htm.

U.S. Environmental Protection Agency. 2012a. *Recommendations for Default Value for Relative Bioavailability of Arsenic in Soil.* December. OSWER 9200.1-113.

U.S. Environmental Protection Agency. 2012b. *Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites.* November. [Online] http://www.epa.gov/region09/superfund/prg/index.html

U.S. Fish and Wildlife Service. 2013. *Endangered, Threatened, Proposed and Candidate Species in Montana Counties, Endangered Species Act*. Department of the Interior, Fish and Wildlife Service, Ecological Services, Montana Field Office, Helena, Montana, USA. http://fwp.mt.gov/wildthings/tande/. February, 2013.

U.S. Geological Survey. 2000. *Characterizing Aquatic Health using Fish Mortality, Physiology, and Population Estimates in the Boulder River Watershed.* By A.M. Farag (USGS), D. Skaar (Montana FWP), and D. Nimick (USGS), and E. MacConnell (Montana FWP). December.

U.S. Geological Survey. 2004. *Integrated Investigations of Environmental Effects of Historical Mining in the Basin and Boulder Mining Districts, Boulder River Watershed, Jefferson County, Montana.* Edited by David A. Nimick, Stanley E. Church, and Susan E. Finger. Prepared in cooperation with the USDA Forest Service and U.S. Environmental Protection Agency.

U.S. Geological Survey. 2011. USGS Water Quality Data Web Site. http://waterdata.usgs.gov/nwis/qw).

USACE. See U.S. Army Corps of Engineers.

USDA Natural Resources Conservation Service. 2009. Web Soil Survey 2.1, http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm. Accessed March 27.

USDA Natural Resources Conservation Service 2011a. SNOTEL site: Frohner Meadow, Montana. http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=487&state=mt. January 4, 2011.

USDA Natural Resources Conservation Service. 2011b. SNOTEL site: Rocker Peak, Montana. http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=722&state=mt. Accessed January 4, 2011.

USFS. See USDA Forest Service.

USFWS. See U.S. Fish and Wildlife Service.

USGS WR. See USGS Water Resources of the United States.

USGS. See U.S. Geological Survey.

Vaughn, B., C. Hoschouer, R. Gleason, and C. Stilwell. 2000. *An Evaluation of Revegetation Success Within a Floodplain System Impaired by Sulfide Mine Waste*. 2000 Billings Land Reclamation Symposium. Billings, Montana, USA. 11 p.

Weather Underground. 2009. http://www.wunderground.com/US/MT/Basin/KBTM.html#History. Accessed March 27.

Windell, Jay, and Chuck Stilwell. 2000. *Bioengineered Streambank Stabilization on Silver Bow Creek, Butte, Montana*. 2000 Billings Land Reclamation Symposium. Billings, Montana. 15 p.

Younger, P. L., S.A. Banwart, and R.S. Hedin. 2002. *Mine Water: Hydrology, Pollution, Remediation*. New York, New York, Springer Pub.

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Appendix A
Summary of Previous Investigations and Removal Actions

APPENDIX A

Summary of Previous Investigations and Removal Actions

Interest in the Basin Mining area (including the Bullion Mine), its legacy of hard rock mining, and the impacts on local aquatic resources extends back to 1992 and water quality studies initiated by the USGS and the Montana Bureau of Mines and Geology (MBMG). Several studies documented water quality in the Boulder River, Basin Creek, and Cataract Creek. Previous sampling, risk assessments, and response actions have been undertaken in the Basin Watershed OU2. Mine sites designated as operable units within OU2, such as the Bullion Mine, were included in these activities, many of the results and conclusions from this previous work are pertinent to this investigation of the Bullion Mine OU6 Site.

Abandoned Hardrock Mine Priority Sites – Summary Report (Red Book) (MDSL, 1994)

This inventory was initiated in May-September 1993 as an effort to identify abandoned and inactive hard rock mine sites that resulted in severe environmental degradation to surface water and groundwater. Numerous state and federal land management stewards contributed lists of sites within their land holdings, and Montana Department of State Lands coordinated an effort to prioritize these sites with respect to exposure pathways, and the severity and extent of their contamination. This was accomplished by Site visits to confirm locations, assess remaining adit conditions and associated mining structures, quantify adit discharges, and sample waste piles, sediment, and surface water. These data were used to prioritize rankings of sites with respect to urgency and allocation of state resources. Of the 270 mine sites inventoried by the program for environmental threats and hazards, Bullion Mine ranked 32^{nd} (Pioneer Technical Services Inc., 1994).

Findings at the Bullion Mine included the following:

- Two discharging adits (one adit sampled—assume it was lower adit; continues to discharge in 2010-2012).
- Lower adit discharge pH of 2.92.
- Water quality exceeded federal Safe Drinking Water Act (SDWA) MCLs and MCL goals for arsenic, cadmium, copper, nickel, and antimony in sampled adit discharge.
- The fresh water chronic and acute aquatic life criteria presented in the Montana Numeric Water Quality Standards, Circular DEQ-7 (MDEQ, 2007) were exceeded for arsenic, cadmium, copper, lead, and zinc in sampled adit discharge.

Table A-1 shows the contaminants in soils that were elevated at least three times background concentrations.

TABLE A-1
Contaminants in Soils that were Elevated at Least Three Times Background Concentrations

Soil Contaminants	Minimum-Maximum Range (mg/kg)*	Local Soil Background Concentrations (mg/kg)
Arsenic	2,440 to 4,470	68
Cadmium	0.5 to 2.9	0.6
Copper	172 to 257	35
Lead	3,330 to 5,110	39
Mercury	0.383 to 0.575	0.08
Antimony	151 to 196	5
Zinc	34 to 695	188

Note:
*mg/kg = milligrams per kilogram

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)

In 1992, USFS and MBMG entered into an agreement to inventory and perform a preliminary characterization of abandoned and inactive mines on Deerlodge National Forest Lands. The objectives of this agreement were as follows:

- Identify sites with possible human health, environment, and/or safety related problems.
- Identify human health and environmental risks at each site based on specific site criteria.
- Identify those sites not affecting the National Forest System lands based on site criteria.
- Integrate the Northern Region program with other state and federal programs.
- Develop and maintain data files of site information in response to government and public interest group concerns.

Pre-field screening identified only sites with the potential to release hazardous substances or sites that did not have enough information to make a determination without a field visit. In order to receive a hazard classification, the Site had to have both a source of the hazardous waste and a method of transporting the hazardous waste from the Site. All sites meeting these criteria were visited. Sites were characterized by geology, samples collected for analysis (soils and surface water), and waste associated with the deposit, and the workings and processing facilities present on the Site assessed. Water samples for arsenic and selected metals were compared to both primary drinking water MCLs along with acute and chronic Aquatic Life Standards (CWA). Soil samples were compared to the limits set by the EPA and the Montana Department of Health and Environmental Sciences for (MDHES) sites within the Clark Fork River Basin in Montana (Harrington, 1993). 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.

Between 1992 and 1993, 39 abandoned or inactive mine sites were identified within the Basin Creek drainage, 14 of which were sampled—including the Bullion Mine. The Bullion Mine Site contained large amounts of tailings and waste rock, part of which had eroded and deposited on USFS-managed lands (most of these waste materials were removed in 2001 by USFS). Runoff from tailing and waste piles impacted Jill Creek. Two soil samples were collected where waste material and soils had been washed into Jill Creek (one at the upper soils wash area and one at the tailing wash area). The sample collected at the upper soils wash area exceeded one or more of the Clark Fork Superfund Background Levels for arsenic, cadmium, copper, lead, and zinc (Harrington, 1993). Only zinc from the sample collected at the tailings wash area did not exceed the Clark Fork Superfund Background Level.

Six surface water samples were collected during the field investigation including the main adit discharge, Jill Creek both above and below the confluence with the Bullion Mine discharge, and Jack Creek both above and below the confluence with Jill Creek. Mine discharge exceeded MCLs for aluminum, arsenic, cadmium, copper, iron, lead, manganese, mercury, zinc, sulfate, and pH. Even though the concentrations of metals were diluted downstream, cadmium, copper, manganese, and zinc all exceeded primary drinking water MCLs in Jack Creek below the confluence with Jill Creek approximately 1 mile from the Site. Along the drainage flow path, evidence of stressed vegetation or areas devoid of vegetation was noticed as far down as the confluence of Jack Creek and Basin Creek (approximately 2 miles below the Jill Creek Jack Creek confluence).

Sampling Activities Report: Basin Mining Area—Bullion Mine, Jefferson County, Montana (OUS, 2001)

URS Operating Services (UOS) conducted Site sampling and prepared a Sampling Activities Report in response to task elements specified in the Superfund Technical Assessment and Response Team 2 in Region 8 by the EPA. UOS conducted the Site work in August, 2001. The goal of this investigation was to characterize the soils and mine waste at and below the former mill area and in the adjacent adit discharge channel.

Soil samples were collected to determine the lateral extent, depth, and magnitude of metals concentrations and pH values. The sample zones were located based on factors that would influence removal or reclamation decisions, including slope steepness, presence of drainage channels, vegetative cover, and rock and debris cover. The focus of this site investigation was the three primary waste dumps and included digging shallow pits (less than 12 inches deep) and collecting soil samples. The samples were screened for pH and electroconductivity. Metals and arsenic were additionally screened using x-ray fluorescence (Spectratrace 9000 XRF).

The results of the sampling and analysis indicated that of the 183 samples, 159 had elevated arsenic concentrations above the reported State-wide background value of 40 mg/kg. No samples contained copper or zinc concentrations above the cleanup goals. The pH values were primarily between 2.5 and 4.5 in the samples. The areas with lowest pH values correlated with areas of highest arsenic concentrations.

Bullion Mine and Mill Site Investigation (Maxim, 2001)

Maxim Technologies Inc. (Maxim) conducted investigative activities at the Bullion Flotation Mill tailing site to aid in evaluation of a potential removal action that was being considered for the Site. The data from the tailings and subsurface characterization were used to develop a plan to excavate, transport, and place potentially hazardous material into a mine waste repository.

The main objectives of this study were to map the extent and thickness of tailing deposits in tailing impoundments along Jill Creek, determine onsite volumes, evaluate the chemical characteristics of the waste (total metals, acid potential, and pH), and evaluate the physical characteristics of the tailings including moisture content, plasticity, grain size, and hydraulic conductivity.

The investigation consisted of excavating test pits and describing materials, collecting tailing and subsurface material samples, analyzing physical and chemical properties of material samples, and surveying the extent and thickness of tailing deposits. The investigation was completed in fall 1999.

The investigation found that the impounded tailings ranged from 0.1 foot to 9 feet thick and consisted of silty sand, organic material, and native gravelly sand soil. The tailing materials were substantially enriched in arsenic, cadmium, copper, lead, silver, and zinc. The average arsenic and lead concentrations in the exposed tailings and soils underlying the tailings exceeded the recommended human health criteria for arsenic. In 2001–2002, a tailings and waste rock removal program was conducted in response to these findings as described in Section 3.3.

2003 and 2004 Montana State University Investigations

Montana State University performed several detailed investigations of the vegetation, soil, and water at the Bullion Mine Site in 2003 and 2004. The 2004 investigation also included stream flow data at Jill Creek both above and below the confluence with the Bullion Mine adit discharge, as well as groundwater infiltration into Jill Creek. Although not part of the formal RI, the results of the investigations, completed after the removal of mine wastes, confirmed the significant residual contamination of soils, shallow groundwater, and mine adit discharge.

Reclaiming Hard Rock Mines: An In Depth Look at Vegetation, Soil, and Water on the Bullion Mine Site, Basin, Montana (Montana State University, 2003)

Purpose. In fall 2003, 1 year after removal and reclamation, Montana State University students enrolled in Land Resources and Environmental Sciences Capstone class assessed the current condition of the Bullion Mine Site and developed a monitoring plan to guide future management decisions. Soil characteristics, including nutrient and metal/metalloid concentrations, were measured spatially across the Site and through soil profiles. Vegetation cover and density were recorded and compared to soil characteristics. Water quality parameters, including metal concentrations, were measured both onsite and up to 1 mile downstream. This data were then used to create a monitoring plan.

Study Conclusions for Soils. The following are conclusions for soils from the 2003 investigation:

- 1 year after active reclamation, the cover soil is acting as an effective barrier from the low pH metals contaminated wastes. Currently, there is no indication of upward migration of contaminants into the cover soils.
- Wet areas in general have greater concentrations of metals, especially zinc, compared to soils in dry areas.

- Residual waste rock, estimated at 2,300 tons and with a pH of 4.2, represents a potential risk to the downgradient reclaimed areas.

Study Conclusions for Vegetation. The following are conclusions for vegetation from the 2003 investigation:

- The cover soil is supporting 41 species of plants with an average cover of 13 percent and a density of 27 plants. This vegetation is stabilizing the slope, reducing the potential for erosion.
- Vegetation inventory revealed a good representation of seeded and volunteer species.
- The cover crop, cereal rye, provided good soil stability during the first growing season.
- Several volunteer species are invasive and their control may be necessary in the future.

Study Conclusion for Surface Waters. The following are conclusions for surface water from the 2003 investigation:

- At the adit source and until the AMD reaches Jill Creek, concentrations for all metals analyzed exceeded MDEQ's numeric water quality standards for metals.
- Diurnal fluctuations in concentrations were not found.
- Reduced form of iron and arsenic were present in waters at the adit, while oxidized forms were found in waters downgradient.
- AMD is evident at the Site.

This Montana State University report concluded with a section on suggested future monitoring of the reclaimed Bullion Mine Site.

Hard Rock Mine Reclamation: Water, Soil, and Vegetation Issues Bullion Mine, Montana (Montana State University, 2004)

Introduction and Purpose. To gain an understanding of the reclamation process the 2004 LRES Capstone course mapped the area and studied hydrology, soil characteristics and vegetation on and nearby the Bullion Mine Site. Students used GPS and geographic information system software to display and analyze spatial data related to the Site. The hydrology students characterized dissolved metal concentrations as well as overall metal loads in water affected by the Site. The soil students analyzed biological, physical, and chemical characteristics across the Site. The vegetation students documented the current status of vegetation on the reclaimed site and borrow area. Each group compared data to information from the 2003 Capstone course.

Study Conclusions for Hydrology. The water monitoring data indicated significant sources of metals in groundwater at the reclaimed site. This contaminated groundwater is entering the adit drainage and Jill Creek and is a concern; however, metals concentrations downstream (confluence with Jack Creek) are below human health standards. The study also suggested that the metal load data collected in 2004 could be used as baseline data in future monitoring, because metal load accounts for temporal changes in precipitation and discharge.

Study Conclusions for Soil. Soil analysis showed that the cover soil is suitable for vegetation growth, although upward migration of metals from contaminated subsoil is occurring and is a concern.

Study Conclusions for Soil Microbiology. Soil microbial activity shows no significant increase in activity between the unreclaimed and reclaimed areas.

Study Conclusions for Vegetation. Vegetation showed an increase in percent cover from 2003 along with an increase in species diversity.

Overall, the reclamation of the Bullion Mine has resulted in reduced contamination offsite.

Integrated Investigation of Environmental Effects of Historical Mining in the Basin and Boulder Mining Districts, Boulder River Watershed, Jefferson County, Montana (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. The study collected data on surface water quality and flow characteristics, impacts to soil and sediment, acid neutralizing potential of bedrock and mine waste, leaching potential of mine wastes, and geophysical surveys of mine sites in Basin Creek and Cataract Creek Watersheds. The USGS typically focused their investigations on priority mine sites such as: the Bullion Mine and Buckeye-Enterprise Mine complex in the Basin Watershed, the Crystal Mine in the Cataract Creek Watershed, and surface water quality throughout the entire Basin Watershed OU2.

Table A-2 summarizes the pertinent adit discharge data for the Bullion Mine from USGS monitoring are summarized for the period September 1999 through August 2010.

TABLE A-2
USGS Station 462120112173701 - Bullion Mine Adit Near Basin, Montana (September 1999 to August 2010)

Water Quality Constituent	Sample Size	Maximum	Minimum	Mean	(Median) 50 Percent
Discharge, instant, cubic feet per second	40	0.02	0.00	0.01	0.01
pH, field, std units	44	3.70	2.50	3.02	2.95
Arsenic, wf, µg/L	44	10,100	163	2,547	1,755
Arsenic, wu, µg/L	14	10,200	711	3,885	2,975
Cadmium, wf, µg/L	44	1,070	259	430	398
Cadmium, wu, µg/L	14	987	247	423	372
Copper, wf, µg/L	44	23,600	2,060	8,107	6,540
Copper, wu, recov, µg/L	14	24,100	2,610	8,739	5,420
Lead, wf, µg/L	44	801	234	414	358
Lead, wu, recov, µg/L	14	859	271	470	428
Zinc, wf, µg/L	44	131,000	23,400	46,586	39,600
Zinc, wu, recov, µg/L	14	120,000	26,100	49,029	41,800

Notes:
wf = filtered sample (dissolved)
wu = without filtering (total recoverable)

Basin Watershed OU2 Remedial Investigation/Feasibility Study (CDM, 2005a and 2005b)

To facilitate the evaluation of inorganic constituents and loading of metals/metalloids to the environmental media, the Basin Watershed OU2 was divided into three areas of concern based on major perennial surface water streams draining from the watershed—the Boulder River, Basin Creek, and Cataract Creek AOCs. During the RI, data were collected from each of the AOCs and used to formulate a watershed conceptual model upon which the draft FS was based. Historic and 2001 remedial field investigation sampling data were used to define and explain the nature and the extent of the contamination in the Basin Creek drainage.

During a 1993 supplemental investigation, seepage from the lowest Bullion Mine adit was sampled and analyzed for flow, metals concentrations, pH, and sulfate. The results showed that the discharge exceeded the human health risk based standards identified in the 2005 RI/FS for arsenic, cadmium, and lead. Analysis also showed that the discharge had a low pH and high sulfate concentration (see Table A-3). The 2005 RI/FS concluded that, of the 14 mines within the Basin Creek drainage with groundwater discharges, 10 had contaminants (chemicals) of concern (COCs) that exceeded either the ecological or human health benchmarks. Of the 10 mines with COCs that exceeded benchmarks, the Bullion Mine had the highest concentrations of COCs. The 2005 RI/FS concluded that

AMD/ARD from adit drainage and waste rock (see Table A-4) into Jack Creek was one of the leading sources of contaminated sediments for COCs within the Basin Creek drainage.

TABLE A-3
Bullion Mine Adit Discharge Water Quality Summary (2001)

Water Quality Constituent	Maximum	Minimum
Total discharge (gpm)	11	11
pH	3.0	3.0
Arsenic, total (μg/L)	**12,700**	**2,380**
Arsenic, dissolved (μg/L)	**1,510**	**316**
Cadmium, total (μg/L)	**736**	**523**
Cadmium, dissolved (μg/L)	**453**	**448**
Copper. total (μg/L)	**19,400**	**12,300**
Copper, dissolved (μg/L)	**11,600**	**7,770**
Lead, total (μg/L)	**743**	**444**
Lead, dissolved (μg/L)	**392**	**166**
Mercury, total (μg/L)	---	0.04U
Mercury, dissolved (μg/L)	0.20U	0.14U
Zinc, total (μg/L)	**80,600**	**49,800**
Zinc, dissolved (μg/L)	**48,900**	**48,000**
SO_4 (mg/L)	934	896

Notes:
mg/L = milligrams per liter
(μg/L = micrograms per liter
U The material was not detected above the level of the associated value (quantification of detection limit).
--- No data.
Bolded values indicate exceedance of human health and ecological risk based benchmarks.
Source: Remedial Investigation Report Addendum, Basin Mining Area Superfund Site, Operable Unit 2, Jefferson County, Montana. April 2005, Table 6.5-2. Prepared by CDM

TABLE A-4
Mine Waste COC Concentrations (Soil/Waste Rock)

	Concentration of COCs (mg/kg)												Field Parameters	
	Arsenic		Cadmium		Copper		Mercury		Lead		Zinc		pH	
Mine Site	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Bullion Mine*	0 U	13,000	0.51	1,300	10 U	9,000	0.21	2.4	0 U	16,000	1.59 U	18,000	2.9	3.9

Notes:
*Basin Mining Area, Operable Unit 2, Jefferson County, Montana. Remedial Investigation Report, CDM April 2005. Table 6.5-1
Notes: U = Not detected with reported detection limit

The former Buckeye, Enterprise, Dew Drop, and Bullion Mines had the greatest total COC concentrations among the 41 tested mine sites. The Bullion Mine had two discharging adits during a 1993 investigation (see Table 6.5-2 in CDM, 2005b). One adit had a reported discharge of 7 gpm with a pH of 2.92 (lower adit), and the second adit had a discharge of 4 gpm with a pH of 6.5. The mine discharge exceeded human health and ecological benchmarks for arsenic, cadmium, copper, lead, and zinc. The Bullion Mine adits contributed approximately 8.31 dissolved and 15.1 total pounds per day. The combined flow of 11 gpm contributed 34 times more total loading than the next major contributor (Enterprise) and 277 times more dissolved loading than the next contributor (Lady Keith).

Engineering Evaluation/Cost Analysis, Bullion and Crystal Mines, Basin Mining Area, Operable Unit 2, Jefferson County, Montana (CH2M HILL, 2009)

A draft EE/CA was prepared for the Bullion and Crystal Mines located in the Basin Mining District, near Basin, Montana. The purpose of the EE/CA was to evaluate various non-time-critical removal action alternatives at the Bullion and Crystal Mine Sites in accordance with the National Contingency Plan in Part 40 Code of Federal Regulations (CFR) Section 300.415. Both are the source of ARD and AMD that flows from dilapidated adits and waste rock into subbasin streams.

The removal action alternatives for the Bullion Mine developed and evaluated in this EE/CA are as follows:

- **Alternative 1**—No Action
- **Alternative 2**—Mine Plugging and groundwater control
- **Alternative 3**—Active Treatment of AMD
- **Alternative 4**—Semi-Active Treatment of AMD (quicklime injection system with Settling Ponds)
- **Alternative 5**—Semi-Passive Treatment of AMD (sulfate reducing bioreactor)

While this study was conducted, no final removal action was initiated at the Site. EPA later decided to pursue a focused RI/FS and Interim ROD for both the Bullion and Crystal mine sites before completing the scoring of remedial alternatives in the EE/CA.

Draft Final Reclaimed Mine Inspection Report for the Bullion Mine Site (Pioneer Technical Services, 2008)

In 2008, Pioneer Technical Services completed a comprehensive post-reclamation inspection to evaluate the performance of reclamation activities at the Bullion Mine Site implemented in 2001–2002. The evaluation, performed at the request of the USFS, was to be used to determine if the reclamation efforts were successful and if the regulatory and risk-based cleanup goals were being met. The inspections were done using the *Abandoned Mine Lands Post-Remediation Assessment Protocols and Draft Handbook* (RRU/MSU 2006). The handbook protocols describe a systematic and precise approach to assessing the status of the remediation using a series of field forms that ask multiple questions regarding pertinent attributes that are found at specific locations within a reclaimed mine site (for example, repository, wetland, adit/shafts, waste rock and tailings removal areas, seeps, streams). The attributes may include vegetation cover, status of a cap or liner, roads, evidence of AMD, erosion, slope failure, public safety issues etc. The responses are qualitative in nature. Field information is entered onto specific forms or entered into handheld GPS instruments for database storage and information retrieval.

Bullion Mine Site Features Assessed

At the Bullion Mine Site the following mine features were assessed:

- General Safety and Maintenance Issues (fences, gates, and signs; roads, culverts, and bridges; soil erosion; geotechnical stability; adits and shafts; recent fire activity; waste repositories; exposed waste materials; monitoring wells; historic features; surface waters; land use issues; weeds; stormwater controls; and site boundaries)
- Waste rock dumps
- Waste removal areas
- Adits and shafts

- General remediated areas
- Streambank/riparian areas

Remediation Evaluation Conclusions and Recommendations

Overall, reclamation efforts at the Bullion Mine and Smelter Site were judged to be effective, erosion controls and diversion structure appeared to be functioning as designed. Vegetation was becoming established on the waste rock dump and tailings removal areas and on the reconstructed streambanks.

Public safety concerns were the easy and unlimited access to the Site; unstable historic structures; no clearly defined Site boundaries; and no signs, fences or gates. Water discharging for the adit into the constructed channel is acidic and metal laden and located adjacent to public USFS Road 8524.

The evaluators provided the following recommendations based on observations in 2008.

- Install fencing around historic structures to limit public access.
- Repair soft spot on USFS Road 8524 near the historic buildings.
- Control noxious weeds on the Site.
- Conduct forensic sampling and analysis of soils in barren areas to ascertain factors limiting vegetation establishment. Possible additional actions could include in-place treatment with lime, additional soil cover, or excavation/removal.

Design and install a treatment system for adit discharge. In conjunction with treatment system, sample sediments currently in the channel for pH and metals to determine if removal of these materials is warranted.

Previous Bullion Mine Site Removal Actions

In 2001–2002, a time critical removal action at the Bullion Mine was completed through a joint USFS and EPA initiative. The goal of the agencies was to reduce metal contamination associated with soil erosion and sedimentation and to reduce risks to human and environmental health (Maxim, 2003). Maxim and UOS conducted site investigations in 2001 to characterize the tailings and waste rock piles. The results of these investigations led to the following actions:

- Upgrading and reconditioning roads, constructing percolation basins, removing and burning debris, and protecting historical features including a mill foundation. Approximately 4 miles of forest roads were reconditioned, including installation of culverts, placement of pit run and base course material, and installation of geotextile fabric.
- Removing approximately 27,238 cubic yards of waste rock from the upper, middle, and lower waste rock piles (below the three adits), and removing tailings from impoundments adjacent to Jill Creek. In addition, 700 cubic yards of Bullion smelter wastes were removed. Waste was removed from approximately 8 acres. These materials were transported and placed in the Luttrell Repository on the northern boundary of the watershed near the headwaters of Basin Creek. Confirmation soil sampling was performed to verify that excavation had achieved removal action objectives.
- Recontouring and reseeding impacted slopes. Lime gravel (3 tons per acre) and triple super phosphate (250 pounds per acre) were incorporated in the subsoil with an 18-inch-thick layer of cover soil, compost (20 tons per acre), and Biosol Mix© fertilizer. The areas were seeded and trees were planted.
- Removing the old drainage channel from the lower adit, and constructing a new engineered polyvinyl chloride (PVC)-lined channel armored with limestone to direct the acid discharge from the lower adit to a confluence with Jill Creek.
- Reconstructing approximately 500 feet of stream channel for Jill Creek to accommodate additional flow from two adit discharges and runoff from the reclaimed areas to Jill Creek. The second discharging adit referenced by this report is located on the north side of the main access road, northwest and downgradient of the adit

with the perennial discharge. This adit does not appear to be part of the main workings of the mine and has not been observed to discharge since initiation of the RI investigation in 2010. However it does appear that it has some discharge historically.

The removal action (removal of 27,000 cubic yards of waste rock and tailings, soil capping/revegetation of disturbed areas, consolidation of adit discharge into a channel to Jill Creek, and reconstruction of the Jill Creek channel) provides a new baseline condition for the Site with respect to wind and runoff generated erosion and direct exposure from contaminated waste rock and soils.

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Appendix B
Soil Test Pit Logs; Soil Field (XRF) and Analytical Sample Results

TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit 1	Northing (ft)[1]:	779677.81
Location:	Uppermost removal area	Easting (ft)[1]:	1264305.28
Logger:	J Franklin	Photo(s):	Pit 1-1, Pit 1-2
Date Excavated:	8/4/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Fill, light brown with gravel and cobbles	Sample time: 1010
2			
3			
4			
5			
6	6-8"		Sample time: 1005 sent to lab for analysis
7			
8			
9			
10			
11			
12	12-13"		Sample time: 1000
13		Red sandy loam with gravel	
14	14-15"		Sample time: 0955
15			
16			
17			
18			
19			
20	20-24"	Red sandy loam with cobbles (<4" dia)	Sample time: 0950
21			
22			
23			
24			
25	End of Test Pit 1 - Total Depth: 25"		
26			
27			
28			
29			
30			

Notes:
[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.
[2]All information is transcribed from field notebooks.

TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit 2	GPS Northing[1]:	779977.28
Location:	Below the middle Adit	GPS Easting[1]:	1263709.38
Logger:	J Franklin	Photo(s):	Pit 2-1, Pit 2-2
Date Excavated:	8/4/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Red sandy loam with gravel	Sample time: 1140
2			
3			
4			
5			
6			
7			
8	8-10"		Sample time: 1135
9			
10			
11			
12			
13			
14			
15	15-17"		Sample time: 1130 sent to lab for analysis
16			
17			
18	18-19"		Sample time: 1125
19			
20		Brown sandy loam with some organic matter	
21			
22	22-24"		Sample time: 1120
23			
24	End of Test Pit 2 - Total Depth: 24"		
25			
26	Notes:		
27	[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.		
28	[2]All information is transcribed from field notebooks.		
29			
30			

TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit 3	GPS Northing[1]:	780331.01
Location:	50' below Adit (road side)	GPS Easting[1]:	1263196.64
Logger:	J Franklin	Photo(s):	Pit 3-1, Pit 3-2
Date Excavated:	8/4/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Brown sandy loam (Fill)	Sample time: 1345
2			
3			
4	4-6"		Sample time: 1340
5			
6			
7	7-9"		Sample time: 1335 sent to lab for analysis
8			
9			
10		Red coarse sandy loam (water in bottom of pit)	
11	11-13"		Sample time 1330
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22	22-24"		Sample time: 1325
23			
24			
25	End of Test Pit 3 - Total Depth: 25"		
26			
27	Notes:		
28	[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.		
29	[2]All information is transcribed from field notebooks.		
30			

TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number: Location: Logger: Date Excavated:	Pit 4 30' above old mill site J Franklin 8/4/2010	GPS Northing[1]: GPS Easting[1]: Photo(s): Excavation Equipment:	780456.32 1263164.62 Pit 4-1, Pit 4-2 Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Brown sandy loam (Fill)	Sample time: 1520
2			
3			
4			
5			
6			
7			
8	8-10"		Sample time: 1515
9			
10			
11			
12			
13	13-15"		Sample time: 1510 sent to lab for analysis
14			
15			
16			
17			
18	18-20"		Sample time: 1505
19			
20			
21			
22			
23			
24			
25	25-27"	Red coarse sandy loam and limestone	Sample time: 1500
26			
27	End of Test Pit 4 - Total Depth: 27"		
28			
29			
30			
31			
32			

Notes:
[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.
[2]All information is transcribed from field notebooks.

TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit 5	GPS Northing[1]:	780580.18
Location:	Just below old mill site	GPS Easting[1]:	1263137.59
Logger:	J Franklin	Photo(s):	Pit 5-1, Pit 5-2
Date Excavated:	8/5/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Rocky sandy loam (Fill)	Sample time: 0855
2			
3			
4	4-6"		Sample time: 0850 sent to lab for analysis
5			
6			
7			
8			
9	9-11"		Sample time: 0845
10			
11			
12	12-14"	Mottled clay (native)	Sample time: 0840
13			
14			
15			
16			
17			
18		Sandy loam (native) (water at bottom of pit)	
19			
20			
21			Sample time: 0835
22	22-24"		
23			
24	End of Test Pit 5 - Total Depth: 24"		
25			
26	Notes:		
27	[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.		
28	[2]All information is transcribed from field notebooks.		
29			
30			

TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit 6	GPS Northing[1]:	780738.07
Location:	At top of steep section	GPS Easting[1]:	1263137.46
Logger:	J Franklin	Photo(s):	Pit 6-1, Pit 6-2
Date Excavated:	8/5/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Sandy loam (Fill)	Sample time: 1010
2			
3			
4			
5			
6			
7	7-9"		Sample time: 1005
8			
9			
10			
11			
12			
13			
14	14-16"		Sample time: 1000 sent to lab for analysis
15			
16			
17	17-19"	Organic matter, roots (native) (water at bottom of pit)	Sample time: 0955
18			
19			
20			
21			
22			
23	23-25"		Sample time: 0950
24			
25			
26	End of Test Pit 6 - Total Depth: 26"		
27			
28	Notes:		
29	[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.		
30	[2]All information is transcribed from field notebooks.		
31			
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TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit 7	GPS Northing[1]:	780795.62
Location:	Mid-way down steep section	GPS Easting[1]:	1263091.70
Logger:	J Franklin	Photo(s):	Pit 7-1, Pit 7-2
Date Excavated:	8/5/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Brown sandy loam (Fill)	Sample time: 1115
2			
3			
4			
5			
6			
7			
8	8-10"		Sample time: 1110
9			
10			
11			
12	12-14"		Sample time: 1105
13			
14			
15		Sandy loam with organic matter (native) (very wet at bottom of pit)	
16	16-18"		Sample time: 1100
17			
18			
19			
20			
21			
22	22-25"		Sample time: 0950 sent to lab for analysis
23			
24			
25			
26	End of Test Pit 7 - Total Depth: 26"		
27			
28	Notes:		
29	[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.		
30	[2]All information is transcribed from field notebooks.		
31			
32			

TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit 8	GPS Northing[1]:	780900.51
Location:	100' downstream of confluence	GPS Easting[1]:	1262920.95
Logger:	J Franklin	Photo(s):	Pit 8-1, Pit 8-2
Date Excavated:	8/5/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Sandy loam (Fill)	Sample time: 1310
2			
3			
4	4-6"		Sample time: 1305
5			
6		Mixed zone (fill and native mixed together)	
7	7-9"		Sample time: 1300 sent to lab for analysis
8			
9			
10	10-12"	Native soil (water at bottom of pit)	Sample time: 1255
11			
12			
13			
14			
15			
16			
17	17-19"		Sample time: 1250
18			
19	End of Test Pit 8 - Total Depth: 19"		
20			
21	Notes:		
22	[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.		
23	[2]All information is transcribed from field notebooks.		
24			

TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit 9	GPS Northing[1]:	780963.78
Location:	Downstream limit of upper removal	GPS Easting[1]:	1262797.60
Logger:	J Franklin	Photo(s):	Pit 9-1, Pit 9-2
Date Excavated:	8/5/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Light brown sandy loam with rocks (Fill)	Sample time: 1405
2			
3			
4	4-6"		Sample time: 1400
5			
6			
7	7-9"		Sample time: 1355
8			
9			
10		Sandy loam with less rocks (native)	
11	11-13"		Sample time: 1345 sent to lab for analysis
12			
13			
14			
15			
16			
17			
18			
19			
20	20-23"		Sample time: 1340
21			
22			
23			
24	End of Test Pit 9 - Total Depth: 24"		
25			
26	Notes:		
27	[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.		
28	[2]All information is transcribed from field notebooks.		
29			
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TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit 10	GPS Northing[1]:	781167.60
Location:	In the tailings impoundment area	GPS Easting[1]:	1262572.04
Logger:	J Franklin	Photo(s):	Pit 10-1, Pit 10-2
Date Excavated:	8/5/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Fill	Sample time: 1540
2			
3			
4	4-6"		Sample time: 1535 sent to lab for analysis
5			
6			
7			
8			
9			
10	10-12"		Sample time: 1525
11			
12		Compacted native soil	
13			
14	14-16"		Sample time: 1520
15			
16			
17			
18			
19			
20	20-23"		Sample time: 1515
21			
22			
23			
24	End of Test Pit 10 - Total Depth: 24"		
25			
26	Notes:		
27	[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.		
28	[2]All information is transcribed from field notebooks.		
29			
30			

TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit 11	GPS Northing[1]:	781231.10
Location:		GPS Easting[1]:	1262626.17
Logger:	J Franklin	Photo(s):	Pit 11-1, Pit 11-2
Date Excavated:	8/6/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Brown sandy loam (Fill)	Sample time: 0905
2			
3			
4			
5			
6			
7			
8	8-10"		Sample time: 0900
9			
10			
11			
12			
13		Native soil	
14	14-16"		Sample time 0855
15			
16			
17			
18	18-21"	Tailings	Sample time 0845 sent to Lab for analysis
19			
20			
21	21-25"	Native organic matter	Sample time: 0840
22			
23			
24			
25	End of Test Pit 11 - Total Depth: 25"		
26			
27	Notes:		
28	[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.		
29	[2]All information is transcribed from field notebooks.		
30			

TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit BG-1	GPS Northing[1]:	780163.15
Location:	Outside upper removal area	GPS Easting[1]:	1263950.09
Logger:	J Franklin	Photo(s):	BBG 1-1, BBG 1-2
Date Excavated:	8/16/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Native soil	Sample time: 1000
2			
3			
4	4-6"		Sample time: 0955
5			
6			
7			
8			
9			
10	10-12"		Sample time: 0950 sent to Lab for analysis
11			
12			
13			
14			
15			
16	16-18"		Sample time 0945
17			
18			
19			
20			
21			
22			
23			
24	24-26"		Sample time: 0940
25			
26	End of Test Pit BG-1 - Total Depth: 26"		
27			
28			
29			
30			
31			
32			

Notes:
[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.
[2]All information is transcribed from field notebooks.

TABLE B-1
Bullion Test Pits

Project:	Bullion Mine		
Test Pit Number:	Pit BG-2	GPS Northing[1]:	780546.22
Location:	Just south of lower waste area	GPS Easting[1]:	1262850.05
Logger:	J Franklin	Photo(s):	BBG 2-1, BBG 2-2
Date Excavated:	8/16/2010	Excavation Equipment:	Hand Dug with Rock Bar
Depth Below Surface (in)	Sample Interval[2]	General Soil Description[2]	Comments[2]
1	0-2"	Native soil	Sample time: 1130
2			
3			
4	4-6"		Sample time: 1120
5			Dup time: 1125
6			sent to Lab for analysis
7			
8	8-10"		Sample time: 1115
9			
10			
11			
12			
13			
14	14-16"		Sample time 1110
15			
16			
17			
18			
19			
20	20-22"		Sample time 0945
21			
22			
23	End of Test Pit BG-2 - Total Depth: 23"		
24			
25	Notes:		
26	[1]GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.		
27	[2]All information is transcribed from field notebooks.		
28			
29			
30			

TABLE B-2
Soils XRF and Analytical Data

2010 Bullion Mine Soil Sampling Results (Analytical)

Site	Date Sample Collected	Metals (mg/kg)					pH
		As	Cd	Cu	Pb	Zn	
Bullion Test Pit 1: 6-8"	8/4/2010	2.5	0.062	26.4	18.5	42.3	7.5
Bullion Test Pit 2: 15-17"	8/4/2010	1770	23.3	205	236	458	7.0
Bullion Test Pit 3: 7-9"	8/4/2010	200	2.4	32.8	97.7	65.5	6.8
Bullion Test Pit 4: 13-15"	8/4/2010	5.1	<0.05	27.9	18.5	36.9	6.7
Bullion Test Pit 5: 4-6"	8/5/2010	19.3	1.5	20.3	22.0	177	7.1
Bullion Test Pit 6: 14-16"	8/5/2010	6.2	0.075	31.3	19.3	38.3	7.2
Bullion Test Pit 7: 22-23"	8/5/2010	2810	33.7	116	292	268	7.2
Bullion Test Pit 8: 7-9"	8/5/2010	23.4	0.36	28.4	22.7	275	7.5
Bullion Test Pit 9: 11-13"	8/5/2010	324	5.4	64.6	135	274	7.6
Bullion Test Pit 10: 4-6"	8/5/2010	15.7	0.28	27.4	24.7	39.2	7.7
Bullion Test Pit 11: 18-21"	8/6/2010	3090	45.1	887	2870	854	4.2
Bullion Background-1: 10-12"	8/16/2010	28.2	0.49	10.9	29.3	48.3	6.9
Bullion Background-2: 4-6"	8/16/2010	17.5	0.40	13.9	17.5	63.2	6.9
Bullion Background-2: 4-6" Dup	8/16/2010	18.1	0.40	18.7	17.0	63.1	7.1

TABLE B-2
Soils XRF and Analytical Data

2010 Bullion Mine XRF Sampling Results

Site	Date Sample Collected	Metals				
		As	Cd	Cu	Pb	Zn
Bullion Test Pit 1: 0-2"	8/7/2010	58	<45	30	39	62
Bullion Test Pit 1: 6-8"	8/7/2010	<16	<57	41	36	53
Bullion Test Pit 1: 12-13"	8/7/2010	835	<61	178	240	263
Bullion Test Pit 1: 14-15"	8/7/2010	1146	<45	158	252	310
Bullion Test Pit 1: 22-24"	8/7/2010	1290	<47	190	266	437
Bullion Test Pit 2: 0-2"	8/7/2010	475	<55	103	95	227
Bullion Test Pit 2: 8-10"	8/7/2010	1496	<45	223	192	469
Bullion Test Pit 2: 15-17"	8/7/2010	1655	<55	185	218	549
Bullion Test Pit 2: 18-19"	8/7/2010	554	<48	304	164	469
Bullion Test Pit 2: 22-24"	8/7/2010	2079	<46	284	293	867
Bullion Test Pit 3: 0-2"	8/7/2010	338	<44	49	128	124
Bullion Test Pit 3: 4-6"	8/7/2010	212	<43	38	111	89
Bullion Test Pit 3: 7-9"	8/7/2010	475	<44	47	174	95
Bullion Test Pit 3: 11-13"	8/7/2010	968	<46	90	268	160
Bullion Test Pit 3: 22-24"	8/7/2010	364	<46	61	144	154
Bullion Test Pit 4: 0-2"	8/7/2010	61	<42	40	49	157
Bullion Test Pit 4: 8-10"	8/7/2010	21	<43	55	31	52
Bullion Test Pit 4: 13-15"	8/7/2010	10	<44	27	26	43
Bullion Test Pit 4: 18-20"	8/7/2010	11	<44	32	30	60
Bullion Test Pit 4: 25-27"	8/7/2010	260	<44	43	67	101
Bullion Test Pit 5: 0-2"	8/7/2010	60	<53	110	49	209
Bullion Test Pit 5: 0-2" Dup	8/7/2010	57	<43	110	45	191
Bullion Test Pit 5: 4-6"	8/7/2010	28	<45	35	39.0	286
Bullion Test Pit 5: 9-11"	8/7/2010	25	<41	29	27.0	229
Bullion Test Pit 5: 12-14"	8/7/2010	17	<42	32	27.0	103
Bullion Test Pit 5: 22-24"	8/7/2010	131	<43	194	81.0	399
Bullion Test Pit 6: 0-2"	8/7/2010	204	<45	88	147.0	215
Bullion Test Pit 6: 7-9"	8/7/2010	<18	<44	37	32.0	63
Bullion Test Pit 6: 14-16"	8/7/2010	<17	<44	29	31.0	64
Bullion Test Pit 6: 17-19"	8/7/2010	<19	<48	30	28.0	56
Bullion Test Pit 6: 23-25"	8/7/2010	59	<44	34	45	126
Bullion Test Pit 7: 0-2"	8/7/2010	105	<59	42	94.0	89
Bullion Test Pit 7: 0-2" Dup	8/7/2010	126	<44	47	111.0	104
Bullion Test Pit 7: 8-10"	8/7/2010	245	<42	59	64.0	110
Bullion Test Pit 7: 12-14"	8/7/2010	1616	<45	91	223.0	148

TABLE B-2
Soils XRF and Analytical Data

Bullion Test Pit 7: 16-18"	8/7/2010	2955	<45	78	318	126
Bullion Test Pit 7: 22-24"	8/7/2010	2198	<45	100	247	245
Bullion Test Pit 8: 0-2"	8/7/2010	45	<56	<36	23	1442
Bullion Test Pit 8: 4-6"	8/7/2010	21	<51	38	34	992
Bullion Test Pit 8: 7-9"	8/7/2010	41	<41	32	90	260
Bullion Test Pit 8: 10-12"	8/7/2010	43	<60	30	31	104
Bullion Test Pit 8: 17-19"	8/7/2010	58	<64	38	40	115
Bullion Test Pit 9: 0-2"	8/7/2010	19	<44	50	46	133
Bullion Test Pit 9: 4-6"	8/7/2010	<20	<44	35	34	70
Bullion Test Pit 9: 7-9"	8/7/2010	17	<50	34	28	62
Bullion Test Pit 9: 11-13"	8/7/2010	429	<45	90	185	380
Bullion Test Pit 9: 20-23"	8/7/2010	339	<44	91	131	309
Bullion Test Pit 10: 0-2"	8/7/2010	15	<44	<46	31	55
Bullion Test Pit 10: 4-6"	8/7/2010	26	<42	26	40	56
Bullion Test Pit 10: 10-12"	8/7/2010	98	<57	72	86	67
Bullion Test Pit 10: 14-16"	8/7/2010	15	<44	<35	40	66
Bullion Test Pit 10: 20-23"	8/7/2010	<17	<44	45	28	46
Bullion Test Pit 11: 0-2"	8/7/2010	205	<59	95	143	152
Bullion Test Pit 11: 8-10"	8/7/2010	351	<44	259	188	211
Bullion Test Pit 11: 14-16"	8/7/2010	655	<55	73	506	243
Bullion Test Pit 11: 18-21"	8/7/2010	2290	<48	1167	1992	707
Bullion Test Pit 11: 20-23"	8/7/2010	255	<40	90	60	1127
Bullion Background-1: 0-2"	8/16/2010	97	<38	40	64	150
Bullion Background-1: 4-6"	8/16/2010	26	<40	<36	30	95
Bullion Background-1: 10-12"	8/16/2010	34	<43	24	36	67
Bullion Background-1: 16-18"	8/16/2010	30	<42	<42	29	44
Bullion Background-1: 24-26"	8/16/2010	38	<41	<31	26	36
Bullion Background-2: 0-2"	8/16/2010	107	<38	37	38	95
Bullion Background-2: 4-6"	8/16/2010	24	<40	26	43	109
Bullion Background-2: 8-10"	8/16/2010	17	<44	<LOD	32	71
Bullion Background-2: 14-16"	8/16/2010	16	<44	<LOD	33	47
Bullion Background-2: 20-22"	8/16/2010	21	<44	37	38	65
Bullion Background-2: 20-22" Dup	8/16/2010	30	<44	39	32	61
Bullion drill 1	8/16/2010	871	<54	195	512	324
Bullion drill 2	8/16/2010	399	<43	46	187	100
Bullion drill 3	8/16/2010	657	<44	80	274	485
Bullion drill 4	8/16/2010	689	<54	138	397	273
Bullion drill 5	8/16/2010	261	<46	195	145	392

Appendix C
Soil Arsenic and Lead Bioavailability Technical Memorandum

Data Summary of the Bioavailability of Arsenic and Lead in Soil in Areas Potentially Affected by Former Bullion Mine, Jefferson County, Montana

PREPARED FOR: Kristine Edwards/U.S. Environmental Protection Agency

PREPARED BY: Mike Wirtz, P.E./CH2M HILL
Dennis Smith/CH2M HILL

DATE: December 4, 2012

This *Data Summary Memorandum of the Bioavailability of Arsenic and Lead in Soil in Areas Potentially Affected by Former Bullion Mine, Jefferson County, Montana* has been prepared by CH2M HILL for the U.S. Environmental Protection Agency (EPA). The objectives of this memorandum are to summarize the sampling and analytical findings for soils collected and analyzed for mine-specific arsenic and lead bioavailability at the Bullion Mine.

Background

EPA listed the Basin Mining Area to the Superfund National Priorities List on October 22, 1999, because of mining-waste problems in the watershed and mining waste in the Town of Basin. The mining area includes the watersheds of Basin and Cataract Creek and portions of the Boulder River below the confluence with these heavily impacted streams. Listing allows EPA to look at the watersheds in a comprehensive way in cooperation with other agencies and community groups. The Site is divided into several Operable Units (OUs): including the town of Basin, the Basin Watershed OU2, Crystal Mine OU5, and Bullion Mine OU6.

Working in partnership with the U.S. Forest Service, the EPA conducted some cleanup of the mining wastes at the Buckeye/Enterprise, Crystal and Bullion Mines located in the Basin Creek and Cataract Watersheds. The clean-ups were completed in 2002. Field work and preparation of Draft Remedial Investigations/Feasibility Studies at the Bullion Mine occurred in 2010-2011 in support of a forthcoming Final Record of Decision. The human health and ecological risk assessments undertaken for the Draft RI in 2011 revealed that arsenic and lead in soil are the primary risk contributors. As directed by EPA, a mine-specific bioavailability study was conducted to provide a better understanding of the bioavailability of the metal forms in site soils. This information will be used to more accurately assess the potential risk to human and ecological receptors. In addition, the site-specific bioavailability data are expected to support decisions on the selection of appropriate cleanup levels.

2010 Investigation

In 2010, as part of a remedial investigation, soil profile sampling and analysis was conducted at the Bullion Mine. Table 1 presents a representative subset of soil sampling locations from the original field work. Arsenic and lead concentrations measured from the surface soil sampling interval, utilizing X-ray fluorescence (XRF) analyses, are presented. Each of these locations was selected as sample locations for the bioavailability testing. The soil test pit sampling locations are illustrated on Figure 1.

TABLE 1
2010 Remedial Investigation Soil Sample Results (surface interval) and Locations
Bullion Mine, Jefferson County, Montana

Sample Identifier	Arsenic Concentration [1] (mg/kg)	Lead Concentration [2] (mg/kg)	GPS [3] Northing (ft)	GPS [3] Easting (ft)	Laboratory Analysis
Bullion Background 1	97	67	780163.15	1263950.09	EPA 6010
Bullion Test Pit 1	58	39	779677.81	1264305.28	EPA 6010
Bullion Test Pit 2	475	95	779977.28	1263709.38	EPA 6010
Bullion Test Pit 3	338	128	780331.01	1263196.64	EPA 6010
Bullion Test Pit 5	60	49	780580.18	1263137.59	EPA 6010
Bullion Test Pit 6	204	147	780738.07	1263137.46	EPA 6010
Bullion Test Pit 8	45	23	780900.51	1262920.95	EPA 6010
Bullion Test Pit 10	15	31	781167.60	1262572.04	EPA 6010

Notes:
[1] This sample is selected because it is within the area of interest; its arsenic concentration is well-spaced between other samples being tested; and it has sufficient arsenic concentration for IVBA testing.
[2] This sample is selected because it is within the area of interest; its lead concentration is well-spaced between other samples being tested; and it has sufficient lead concentration for IVBA testing.
[3] GPS coordinates are Montana State Plane, NAV 83, corrected to NAV 96.

Field Sampling Methods and Sample Handling

Field sampling methodology and sample handling followed the surface soil sampling methodologies described in the *Plan for Assessing the Bioavailability of Arsenic and Lead in Soil in Areas Potentially Affected by Former Bullion Mine, Jefferson County, Montana* (CH2MHILL, 2012).

Method of Collection and Locations

In accordance with the FSP, surface soil samples were collected from the top 2 inches of the soil. Samples were collected with a plastic spoon that was decontaminated prior to use. A minimum of 50 grams (approximately 1.5 cups) of soil was collected, placed into re-sealable bags, and labeled on the outside of the bags. Large debris (e.g., large rocks and sticks) was removed from the sample. Each sample was double bagged prior to shipment. All applicable information (e.g., date/time of collection) was recorded on the chain-of-custody (COC) form. GPS coordinates were collected and recorded in the field notebook along with observations and photos of the samples.

Sampling Locations

Table 2 provides the coordinates for the actual sample locations for the 2012 bioavailability investigation at the Bullion Mine. The soil sampling locations were very close and are presented on Figure 1.

TABLE 2
Actual Surface Soil Sample Locations
Bullion Mine, Jefferson County, Montana

Sample Identifier	GPS [1] Latitude	GPS [1] Longitude
Bullion TP #01	46.35418	-112.29071
Bullion TP #02	46.35479	-112.29308
Bullion TP #03	46.35579	-112.29524
Bullion TP #05	46.35652	-112.29554
Bullion TP #06	46.35687	-112.29565
Bullion TP #06 FD	46.35687	-112.29565
Bullion TP #08	46.35736	-112.29647
Bullion TP #10	46.35833	-112.29794
Bullion Background	46.35543	-112.29224

Notes:
[1] GPS coordinates are Latitude and Longitude, NAD 1983.

Analytical Methods

The laboratory analysis used to estimate the bioavailability of the arsenic and lead in soil was the In Vitro Bioaccessibility Procedure (IVBA) for arsenic and lead. These test procedures provide a tool to measure the fraction of a metal that is absorbed by an organism through specific routes of exposure (e.g., incidental soil ingestion). The laboratory procedures for these analyses were provided in the Field Sampling and Analysis Plan (CH2M HILL August 22, 2012) as:

- Attachment A - Standard Operating Procedure In Vitro Bioaccessibility (IVBA) Procedure for Arsenic (June 2011)
- Attachment B - Standard Operating Procedure for an In Vitro Bioaccessibility Assay for Lead in Soil (April 2012)

The IVBA procedure used an in vitro test to measure the fraction of a chemical solubilized from a soil sample under simulated mammalian gastrointestinal conditions. The soil sample was first sieved through a 250-micron sieve. A portion of the soil that passes through the sieve was used to determine the total concentration of arsenic and lead. The in vitro test introduced an aqueous fluid into a portion of the soil sample that passed through the sieve. The chemical solubilized from the soil sample is representative of the fraction of arsenic and lead potentially absorbed by a mammal under physiologically relevant conditions simulating gastric pH, buffering, and temperature. Upon completion of this extraction, the filtered extract solution was analyzed for arsenic and lead. The mass of the arsenic and lead found in the filtered extract was compared to the mass introduced into the test. The fraction liberated into the aqueous phase is defined as the bioaccessable fraction of arsenic and lead in that soil sample and is presented in Table 3. The bioaccessable fraction determined in this in vitro test predicts the site-specific gastrointestinal bioavailability of metals in for the sample.

The University of Colorado's Laboratory for Environmental and Geologic Studies (LEGS), under the oversight of John Drexler PhD, performed the sample analyses.

Sampling Results

Soil samples were collected at seven sample locations at the Bullion Mine (one duplicate sample was also collected) and one background location for the mine-specific arsenic and lead bioavailability analysis. Results of the 2012 bioavailability sampling are presented in Table 3.

The laboratory data as received from LEGS in presented in Appendix A.

The range of variability for As and Pb bioavailability is high. A 60 percent bioavailability default value was assumed for both arsenic and lead during the risk assessment prepared for the Draft RI. As shown in Table 3, sample-specific bioavailability factors are below the default values at all locations. The mine-specific mean bioavailability factors of 22 and 19 percent for arsenic and lead, respectively, would be expected to provide more realistic of the exposure and risk to receptors at the Bullion Mine.

Summary

The results of bioavailability studies confirm the previous assertion that the relative amount of arsenic and lead available for potential adverse effects in humans and mammals is lower than assumptions used in the risk assessment prepared for the Draft RI. The human health and ecological risk assessments should be revisited and results adjusted to account for this confirmatory information.

TABLE 3
Results of AS and Pb Bioavailability Analyses
Bullion Mine, Montana

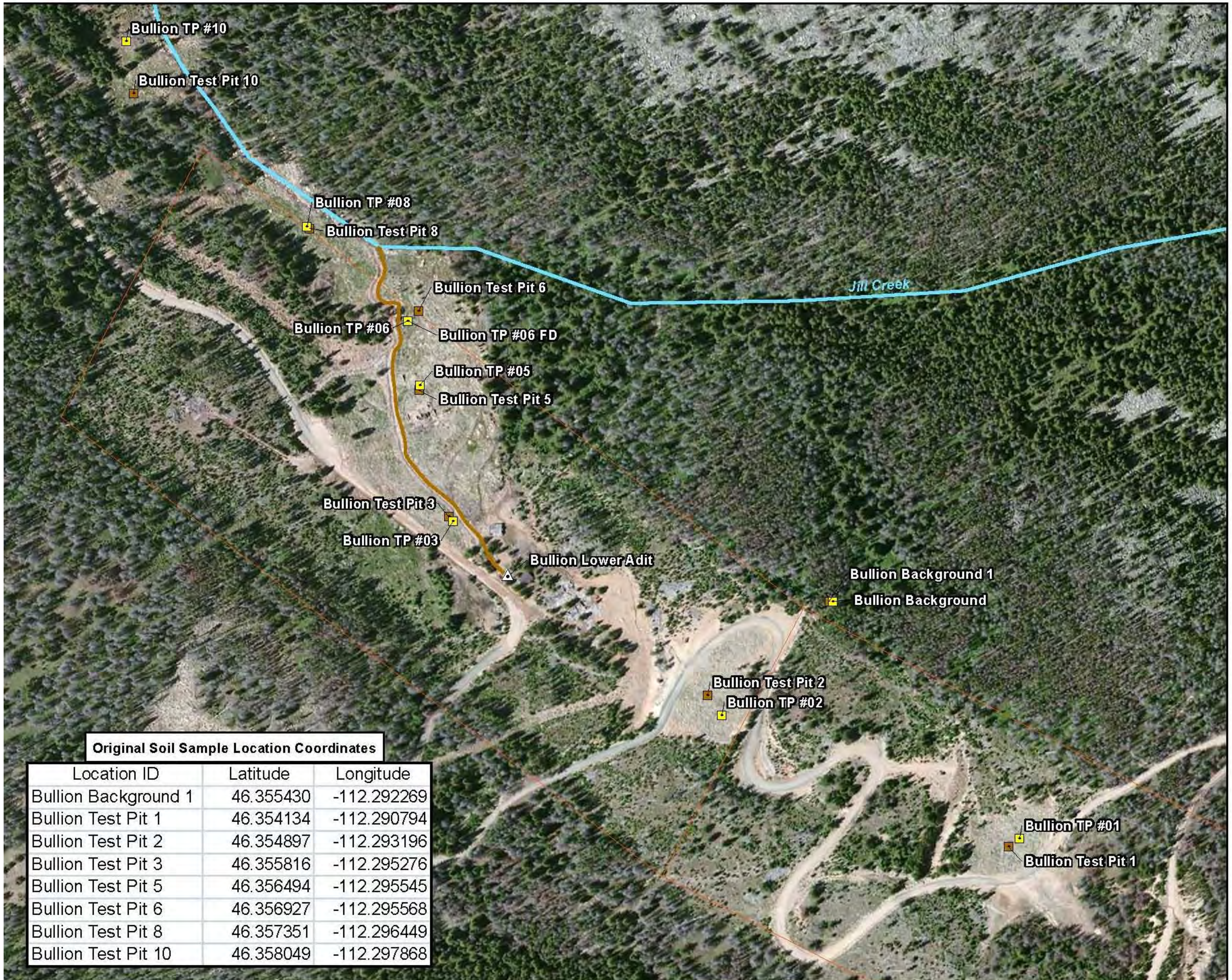
Sample Identifier	Lab ID	% Arsenic IVBA	% Lead IVBA	% Lead RBA Predicted [1]
Bullion TP #01	TL-18	6	9	8
Bullion TP #02	TL-14	33	13	11
Bullion TP #03	TL-8	26	20	18
Bullion TP #05	TL-5	22	23	20
Bullion TP #06	TL-4	17	14	12
Bullion TP #06 FD	TL-19	17	16	14
Bullion TP #08	TL-17	48	54	47
Bullion TP #10	TL-13	4	13	11
Bullion Background	TL-6	18	9	37
Minimum[2]		4	9	8
Maximum[2]		48	54	47
Mean[2]		21.8	19.4	18.1

Notes:
[1] % RBA Pb predicted value based on Drexler and Brattin (2007)
[2] Does not include FDs or background
FD = field duplicate
IVBA = in vitro bioaccessibility
RBA = relative bioavailability

References

CH2M HILL 2012. *Plan for Assessing the Bioavailability of Arsenic and Lead in Soil in Areas Potentially Affected by Former Bullion Mine, Jefferson County, Montana*. July.

Drexler, J. and Brattin, W. 2007. An ***In Vitro*** Procedure for Estimation of Lead Relative Bioavailability: With Validation. Human and Ecological Risk Assessment. 13(2), pp. 383-401.



Original Soil Sample Location Coordinates

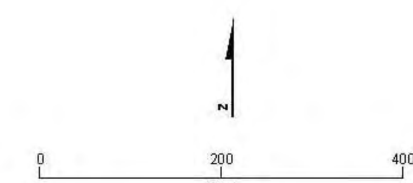
Location ID	Latitude	Longitude
Bullion Background 1	46.355430	-112.292269
Bullion Test Pit 1	46.354134	-112.290794
Bullion Test Pit 2	46.354897	-112.293196
Bullion Test Pit 3	46.355816	-112.295276
Bullion Test Pit 5	46.356494	-112.295545
Bullion Test Pit 6	46.356927	-112.295568
Bullion Test Pit 8	46.357351	-112.296449
Bullion Test Pit 10	46.358049	-112.297868

VICINITY MAP

LEGEND

- Bioavailability Test Pit 2012
- Bullion Lower Adit
- Soil Sample Location (0-2")
- Adit Discharge Channel
- Mine Claim Boundary

Note:
1. Bing Maps aerial imagery web mapping service



Bullion Mine
FIGURE 1
Soil Sample Locations for Bioavailability Analysis (As, Pb)
Bullion Mine OU6 Remedial Investigation

BOI \\OWL\PROJ\EPA\408158BULLIONMINE\GIS\MAPFILES\2012\BIOAVAILABILITYANALYSIS.MXD JCARR3 11/2/2012 10:14:42 AM

CH2MHILL

Appendix A
As and Pb Bioavailability Laboratory Data

Soils Arsenic - Preliminary Summary Of In Vitro Bioassay Results

Sample ID and Laboratory ID Cross reference

BULLION MINE (As Bioavailability)

2012_AUG_Soils_Basin Mining_DG-337

Sample #	Location	Drexler's Lab ID	As in <250 bulk Soil (Ug/Kg)	Mass soil (g)	Calc As #1	ICP As (ug/L)	Solutions (l)	% As IVBA
08K5-001	Bullion TP #01	TL-18	435,594	1.005	437.77	277	0.1	6
08K5-003	Bullion TP #02	TL-14	1,762,638	1.0025	1767.04	5801	0.1	33
08K5-004	Bullion TP #03	TL-8	323,960	1.00295	324.92	834	0.1	26
08K5-005	Bullion TP #05	TL-5	41,371	1.00432	41.55	90	0.1	22
08K5-006	Bullion TP #06	TL-4	264,452	0.99887	264.15	456	0.1	17
08K5-007	Bullion TP #06 FD	TL-19	248,229	0.98714	245.04	410	0.1	17
08K5-008	Bullion TP #08	TL-17	437,331	1.01419	443.54	2134	0.1	48
08K5-009	Bullion TP #10	TL-13	3,689,344	1.00037	3690.71	1316	0.1	4
08K5-010	Bullion TP #Background	TL-6	200,542	1.01126	202.80	370	0.1	18
NIST-2711			107,000	1.0215	109.30	595	0.1	54

Bioavailability QA/QC

	As Analyses
TL-10	497
TL-10-DUP	350
RPD	34.7
TL-10	497
TL-10-SPK	2902
% Recovery	96
BLANK-1	0
BLANK-SPI	2716
% Recovery	109
TL-21	2702
TL-21-DUP	2677
RPD	0.9
TL-21	2702
TL-21-SPK	4595
% Recovery	76
BLANK-2	0
BLANK-SPI	2797
% Recovery	112
NIST-2711	595
NIST-2711-/	578
Machine Detection Limit	**0.175**

Soils Lead - Preliminary Summary Of In Vitro Bioassay Results
Sample ID and Laboratory ID Cross reference

BULLION MINE (As Bioavailability)
2012_AUG_Soils_Basin Mining_DG-337

Sample #	Location	Drexler's Lab ID	Pb in <250 bulk Soil (ug/kg)	Mass soil (g)	Calc Pb #1	ICP Pb (ug/L)	Solutions (l)	% Pb IVBA	% RBA Predicted based on Drexler and Brattin, 2007
08K5-001	Bullion TP #01	TL-18	253,991	1.005	255.26	232	0.1	9	**8**
08K5-003	Bullion TP #02	TL-14	237,593	1.0025	238.19	312	0.1	13	**11**
08K5-004	Bullion TP #03	TL-8	126,560	1.00295	126.93	259	0.1	20	**18**
08K5-005	Bullion TP #05	TL-5	47,805	1.00432	48.01	112	0.1	23	**20**
08K5-006	Bullion TP #06	TL-4	94,682	0.99887	94.57	128	0.1	14	**12**
08K5-007	Bullion TP #06 FD	TL-19	89,576	0.98714	88.42	140	0.1	16	**14**
08K5-008	Bullion TP #08	TL-17	127,387	1.01419	129.19	697	0.1	54	**47**
08K5-009	Bullion TP #10	TL-13	851,914	1.00037	852.23	1071	0.1	13	**11**
08K5-010	Bullion TP #Background	TL-6	106,873	1.01126	108.08	453	0.1	42	**37**
NIST-2711			1,162,000	1.0215	1186.98	10253	0.1	86	**76**

Bioavailability QA/QC

	Pb Analyses
TL-10	1,425
TL-10-DUP	1,142
RPD	22
TL-10	1,425
TL-10-SPK	3,594
% Recovery	87
BLANK-1	(0)
BLANK-SPK-1	2,520
% Recovery	101
TL-21	3,549
TL-21-DUP	3,413
RPD	4
TL-21	3,549
TL-21-SPK	5,652
% Recovery	84
BLANK-2	(0)
BLANK-SPK-2	2,556
% Recovery	102
NIST-2711	10,253
NIST-2711-AD	9,905

Machine Detection Limit **0.018**

Appendix D
Sediment Sampling
Technical Memorandum

Data Summary – 2012 Stream Sediment Sampling, Bullion Mine, Jefferson County, Montana

PREPARED FOR: Kristine Edwards/U.S. Environmental Protection Agency

PREPARED BY: Dennis Smith/CH2M HILL

DATE: December 4, 2012

A summary of 2012 stream sediment sampling data from Jill and Jack Creeks at the Bullion Mine, Jefferson County, Montana was prepared by CH2M HILL for the U.S. Environmental Protection Agency (EPA). This memorandum provides a summary of the 2012 sediment sampling event and presents the analytical findings for sediment samples collected from strategic locations in Jill Creek and upstream and downstream of its confluence with Jack Creek. Jack Creek is a tributary to Basin Creek a major drainage within the Basin Watershed OU2.

Background

EPA listed the Basin Mining Area to the Superfund National Priorities List on October 22, 1999, because of mining-waste problems in the watershed and mining waste in the Town of Basin. The mining area includes the watersheds of Basin and Cataract Creek and portions of the Boulder River below the confluence with these heavily impacted streams. Listing allows EPA to look at the watersheds in a comprehensive way in cooperation with other agencies and community groups. The Site is divided into several Operable Units (OUs): including the town of Basin, the Basin Watershed OU2, Crystal Mine OU5, and Bullion Mine OU6.

Working in partnership with the U.S. Forest Service, the EPA conducted initial cleanup of the mining wastes at the Buckeye/Enterprise, Crystal and Bullion Mines located in the Basin Creek and Cataract Watersheds. The clean-ups were completed in 2002. Field work and preparation of a Draft Remedial Investigation/Feasibility Study (RI/FS) at the Bullion Mine occurred in 2010-2011 in support of a forthcoming Record of Decision. The Bullion Mine is thought to be a primary source for metalloid and trace metal contaminants and their transport down Jill Creek and Jack Creek, and into Basin Creek. Benthic macroinvertebrate community assessments in the streams (2010) revealed an adversely impacted aquatic environment. The information collected by the 2012 sampling will be used to more accurately assess the extent of the contamination and to provide additional lines of evidence to evaluate the potential risk to human and aquatic ecological receptors.

2010 Investigation

In 2010, as part of a remedial investigation, surface water and macroinvertebrate samples were collected along a reach of Jill Creek bracketing the lower portion of the Bullion Mine and extending down to its confluence with Jack Creek. Stream sediment data for this reach were not collected in 2010. Instead, because no activities have occurred at the site that would significantly alter instream conditions since the 2005 Basin Watershed OU2 RI (CDM), historical sediment data were used to represent nature and extent of sediment contamination in the draft RI/FS (CH2M HILL 2011). Sample analyses showed elevated trace metal concentrations in surface water from where Jill Creek intercepts the northwest corner (topographically downgradient) of the Bullion Mine site. Few macroinvertebrates were found in this reach and at the Jack Creek confluence. Agency review comments on the draft RI suggested that stream sediment be added to the recently sampled media to help provide a more current assessment of risk to aquatic and benthic receptors. The 2012 stream sediment sampling locations were co-located with the previous RI water quality and benthic macroinvertebrate sampling sites.

Field Sampling Methods and Sample Handling

Field sampling methodology and sample handling was described in the *2012 Sediment Sampling and Analysis Plan for the Bullion Mine* (CH2M HILL, July 2012).

Method of Collection and Locations

In accordance with the field sampling plan (FSP), surface sediment samples were collected from the top 10 centimeters of the sediment. Discrete grab sampling was implemented to avoid additional decontamination procedures and to reduce the potential for cross-contamination.

Sediment sampling methods employed are described below:

1. On arrival at the site, the "Dirty Hands" sample team member set up and organized sampling equipment near the first (farthest downstream) sampling location. Sample containers, sampling equipment, and decontaminated equipment were arranged on a plastic sheet. Sample containers remained in the re-sealable bag and were not directly handled during this process.
2. The "Clean Hands" sampler put on gloves prior to handling sampling bottles. At the edge of the surface water, while facing upstream, the unpreserved sample container was submerged into the substrate at several locations to fill the container.
3. Excess water was carefully decanted to avoid loss of fines, large debris (e.g., rocks and sticks) were removed by hand, and the lid was secured.
4. The outside of the container was wiped dry and the appropriate sample bottle label applied.
5. Each sample container was placed in a re-sealable bag and the outside of the bag was labeled.
6. All applicable information was recorded (e.g., date/time of collection) on the chain-of-custody (COC) form.
7. Samples were secured in a cooler.
8. GPS coordinates were recorded to mark each sampling location. Field observations were made in a field notebook.

Sampling Locations

The sample locations for the 2012 stream sediment collection at the Bullion Mine are presented in Figure 1. Six sampling sites were co-located with the previous 2010 RI macroinvertebrate survey sites.

Table 1 provides the coordinates for the actual sample locations for the 2012 sediment sampling along Jill and Jack Creeks.[1]

TABLE 1
Actual Stream Sediment Sample Locations – Jill Creek (Jill) and Jack Creek (Jack)
Bullion Mine, Jefferson County, Montana

Sample Identifier	GPS [1] Latitude	GPS [1] Longitude
Jill-1	46.35723	-112.29559
Jill-2	46.35723	-112.29597
Jill-3*	46.35736	-112.29619
Jill-4*	46.36022	-112.29798
Jack-1	46.36438	-112.30836
Jack-2	46.36454	-112.30980

Notes:
* field duplicate collected with sample
[1] GPS coordinates are Latitude and Longitude. NAD 1983

[1] It should be noted that sample locations in Jack Creek were intended to show potential impacts at its confluence with the first downstream receiving waters. Future remedial activities will be restricted to the Bullion Mine properties and associated mine discharge.

Analytical Methods

Target analytes included aluminum, antimony, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, thallium, and zinc. Upon receipt by the laboratory, sediment samples were first dried @ <40°C and sieved through a 10, 80 and 230 mesh to obtain 3 size fractions for analysis. The portions of the sediment that passes through the sieves were used to determine the total concentration of metals in each size fraction. Additionally, grain size distribution was evaluated to help with the characterization of sediments. The size fractions were identical to those obtained during the Basin Watershed OU2 RI. The sediment samples were analyzed by Pace Analytical Services, Inc. (PACE). Target detection limits for each analyte were established to achieve sediment quality benchmarks and are shown in Table 2. Following sample analysis, all data were assessed in terms of accuracy, precision, and completeness. Formal data validation (CH2M HILL October 2012) concluded that laboratory quality control data and field quality control procedures of the sample data collected, as specified in the SAP (CH2M HILL 2010) were acceptable. The precision (reproducibility), accuracy (correctness), representativeness (degree to which data accurately and precisely depict the characteristics of a population), comparability (confidence with which one data set can be compared to another data set), and completeness (percentage of valid results in the data set) objectives were met.

TABLE 2
Sample Analysis Summary and Required Detection Limits

Parameter	Analytical Method	Sediment Benchmark[a] (mg/kg)	PACE Method Detection Limit (mg/kg)	PACE Reporting Limit (mg/kg)
Aluminum (Al)	SW6010B	25.5	1.91	10
Antimony (Sb)	SW6010B	3.0	0.12	0.5
Arsenic (As)	SW6010B	5.9	0.12	0.5
Cadmium (Cd)	SW6010B	0.58	0.02	0.05
Copper (Cu)	SW6010B	16	0.04	0.5
Iron (Fe)	SW6010B	NA	1.21	2.5
Lead (Pb)	SW6010B	20000	0.05	0.3
Manganese (Mn)	SW6010B	400	0.83	25
Nickel (Ni)	SW6010B	16	0.04	1.0
Selenium (Se)	SW6010B	NA	0.17	0.75
Silver (Ag)	SW6010B	0.5	0.06	0.5
Thallium (Tl)	SW6010B	NA	0.16	0.75
Zinc (Zn)	SW6010B	98	0.14	1.0

[a] Lowest reported freshwater sediment benchmark from the NOAA Screening Quick Reference Tables (SQuiRTs) (Buchman et al., 2008)
NA = not available

Sampling Results

Stream sediment samples were collected at six sample locations (two duplicate samples were also collected) for the metals analysis. Results of the 2012 sampling are presented in Table 3. Considering the limited human health exposures identified in the draft RI, risks to ecological receptors (e.g. benthic macroinvertebrates) are expected to be the highest. Therefore, conservative Freshwater Sediments Screening Benchmarks obtained from EPA Region 3 were included for comparison purposes.

TABLE 3
Summary of Sediment Results (Dry Weight)
Bullion Mine Remedial Investigation

		JILL-01-SD			JILL-02-SD			JILL-03-SD			JILL-03-FD			EPA Region 3
		JILL-01-SD 10 MESH	JILL-01-SD 80 MESH	JILL-01-SD 230 MESH	JILL-02-SD 10 MESH	JILL-02-SD 80 MESH	JILL-02-SD 230 MESH	JILL-03-SD 10 MESH	JILL-03-SD 80 MESH	JILL-03-SD 230 MESH	JILL-03-FD 10 MESH	JILL-03-FD 80 MESH	JILL-03-FD 230 MESH	Freshwater Sediment Screening Benchmarks
Analyte	**Units**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	
Aluminum	mg/kg	2,210	2,220	10,700	1,430	4,280	7,260	3,250	2,520	10,100	4,590	2,900	8,850	
Antimony	mg/kg	0.37 J	0.22	0.94	8.4	6.4	7	0.083	0.12	0.09	0.53	0.1	0.51	2.0
Arsenic	mg/kg	33 J	47.3	235	1,800	1,320	1,840	112 J	58.5	288	19.5 J	36.8	265	9.8
Cadmium	mg/kg	1.3 J	1.4	7.3	25.4	18.6	25.7	2.9 J	2.2	12.7	1.5 J	1.8	10.7	0.99
Copper	mg/kg	21.6	18.2	137	64.3	68.2	110	42.9	54.7	474	47.6	42.9	347	31.6
Iron	mg/kg	7,200	6,070	27,400	118,000	70,800	124,000	9,160 J	7,630	48,100	150	7,020	39,500	20000
Lead	mg/kg	9.6 J	9.3	47.9	112	203	397	18.2 J	30.1 J	96.8	5,420 J	12.5 J	85.7	35.8
Manganese	mg/kg	313 J	264	693	253	556	332	382	263	1,590	8.1 J	261	1,250	460.0
Nickel	mg/kg	1.9	1.8	7.7	0.22	2.7	3.9	3.9	2.1	6.7	337	2.4	6.2	22.7
Selenium	mg/kg	0.84	0.3	1.4	0.15	0.14	0.17	0.59	0.57	0.37	2.6	0.24	1.1	2.0
Silver	mg/kg	0.045	0.047	0.053	0.052	0.34	1.5	0.041	0.059	0.045	0.76	0.051	0.06	1.0
Thallium	mg/kg	0.12	0.13	0.14	5.7	3.1	4.8	0.11	0.16	1.3	0.058	0.14	0.71	
Zinc	mg/kg	66.5	67.6	365	67.2	145	230	122	105	538	0.15	93.5	492	121.0
Percent Clay	% (w/w)	3.75			11.25			5			5			
Percent Sand	% (w/w)	92.5			75			92.5			92.5			
Percent Silt	% (w/w)	3.75			13.75			2.5			2.5			

TABLE 3
Summary of Sediment Results (Dry Weight)
Bullion Mine Remedial Investigation

		JILL-04-SD			JILL-04-FD			JACK-01-SD			JACK-02-SD			EPA Region 3
		JILL-04-SD 10 MESH	JILL-04-SD 80 MESH	JILL-04-SD 230 MESH	JILL-03-FD 10 MESH	JILL-03-FD 80 MESH	JILL-03-FD 230 MESH	JACK-01-SD 10 MESH	JACK-01-SD 80 MESH	JACK-01-SD 230 MESH	JACK-02-SD 10 MESH	JACK-02-SD 80 MESH	JACK-02-SD 230 MESH	Freshwater Sediment Screening Benchmarks
Analyte	**Units**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	**7/23/2012**	
Aluminum	mg/kg	3,460	4,390	11,200	3,110	4,820	11,000	2,610	3,260	6,690	2,230	3,610	7,690	
Antimony	mg/kg	1.2	2.4	6.4	0.48	3.9 J	5.4 J	0.1 UJ	0.09 UJ	0.76	0.1	2.1	4.9	2.0
Arsenic	mg/kg	104 J	395	836	930 J	448	759 J	23	47.1 J	129	18.3	346	470	9.8
Cadmium	mg/kg	2.5 J	8.9	21.6	17.3 J	10.2	20.5	0.73 J	1.2 J	3.2	1.7	8.3	14.6	0.99
Copper	mg/kg	60.3 J	159	505	255 J	168 J	521	12.5 J	18.1 J	45.8	34.7	86.9	176	31.6
Iron	mg/kg	7,210 J	14,300	37,600	29,600 J	15,500	34,300	6,440	8,430 J	26,500	22,200	12,100	26,600	20000
Lead	mg/kg	42.3 J	148	341	70.4 J	203	332	18.6 J	33.3 J	92	18.3	109	241	35.8
Manganese	mg/kg	276	548	1,220	313	548	1,120	200 J	287	583	385	660	1,280	460.0
Nickel	mg/kg	2.1	3.4	7.9	2	3.6	7.5	2 J	2.9	5.7	2.9	3.4	7.2	22.7
Selenium	mg/kg	0.54	0.92	1.6	0.95	0.97	1.5	0.61 J	0.48	1.8	2.6	1.4	2.3	2.0
Silver	mg/kg	0.057	0.21	1.7	0.059	0.44	2	0.051 UJ	0.23	0.058	0.05	0.14	1.4	1.0
Thallium	mg/kg	0.15	0.14	0.28	1.8 J	0.12	0.64	0.14 UJ	0.12	0.16	1.7	0.15	0.25	
Zinc	mg/kg	131 J	287	803	247 J	333	783	52.9	90.9 J	231	225	313	761	121.0
Percent Clay	% (w/w)	5			6.25			3.75			5			
Percent Sand	% (w/w)	88.75			88.75			95			95			
Percent Silt	% (w/w)	6.25			5			1.25			0			

Notes:

Data is from Bullion Mine OU6 RI/FS (CH2M HILL 2012)

CC = Cataract Creek

USG = Uncle Sam Gulch Creek

ND = no data

% (w/w) = percent wet weight

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

mg/kg = milligram per kilogram

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

Highlighting indicates exceeds EPA Reg 3 Freshwater Sediment Screening Benchmarks criteria

To facilitate clarity in assessing results, sediment values in the 3 size fractions that exceeded the conservative ecological benchmark criteria were shaded. The highest concentrations were generally observed in the smaller size fractions. However, for each sample, the smallest size fraction represents the smallest percentage by volume of the sample. The range of variability for many analytes from station Jill-1 to station Jack-2 is high.

Summary

The results of the sediment sampling confirm the findings from the previous Basin Watershed OU2 RI (CDM 2005) that enriched metalloid and trace metal concentrations occur in stream sediments from the Bullion Mine to its' confluence with Jack Creek. 2010 macroinvertebrate sampling results (CH2M HILL 2011) revealed impacts to aquatic invertebrates in this reach. The sediment sample results will be used in the evaluation of the fate and transport of source material and to provide additional lines of evidence to evaluate the potential risk to human and ecological receptors in the pending Final RI.

References

Buchman, M. F. 2008. *NOAA Screening Quick Reference Tables*. NOAA HAZMAT Report 99-1, Seattle, Washington, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration.

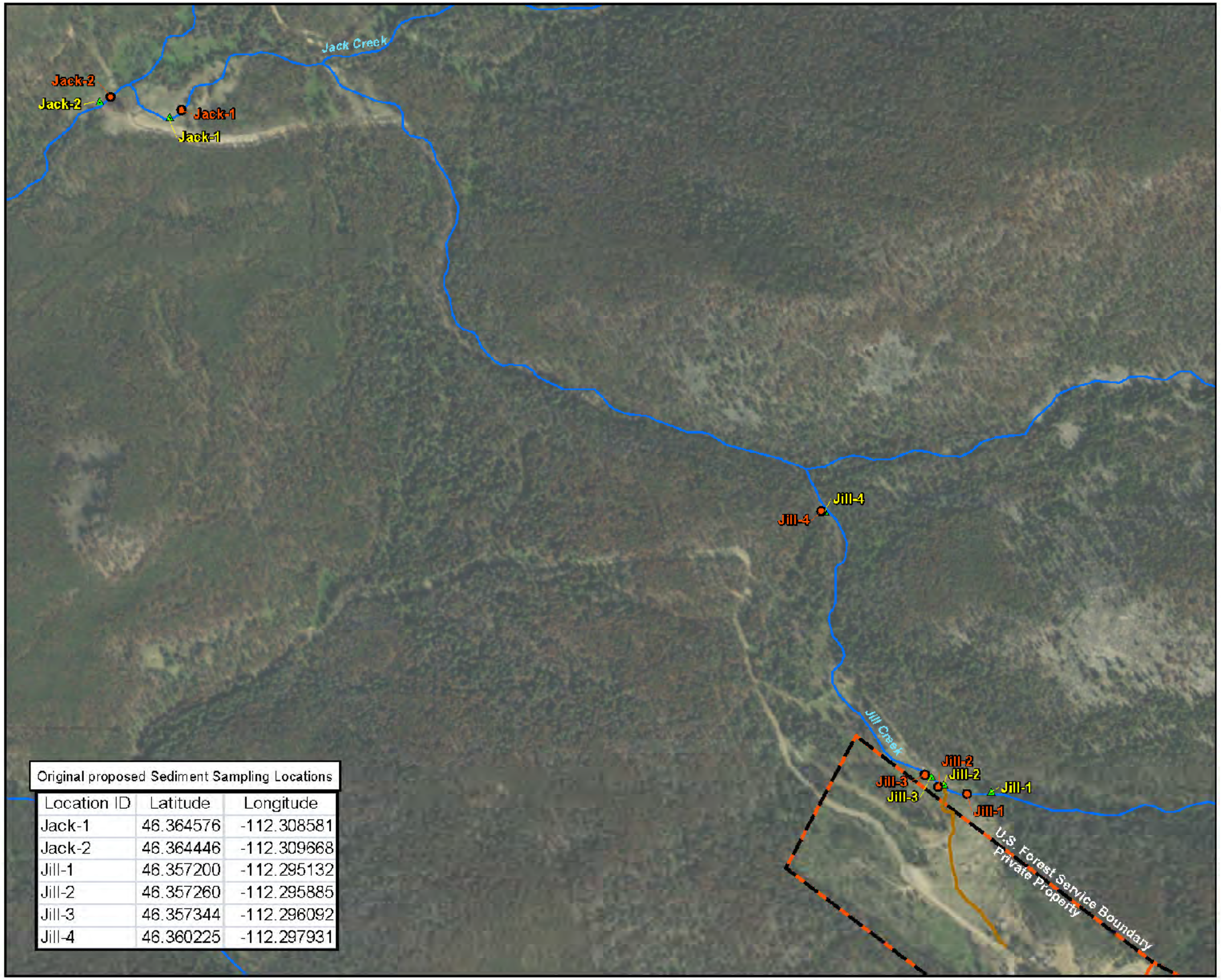
CDM, 2005. *Basin Mining Area Operable Unit 2, Jefferson County, Montana. Remedial Investigation Report Addendum. Volume 1. April*.

CH2M HILL, 2011. Bullion Mine OU6. Draft Focused Remedial Investigation, Jefferson County, Montana. May 2011.

CH2M HILL, 2012. *Sediment Sampling and Analysis Plan for the Bullion Mine* (CH2M HILL, July 2012).

CH2M HILL, 2012. *Chemical Data Quality Evaluation for Former Bullion Mine Sediment Sample Analyses – July 2012.*

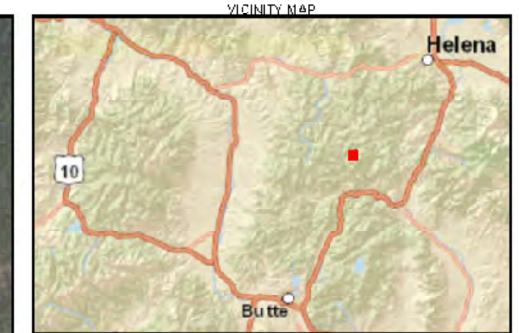
EPA, 2012. Freshwater Sediment Screening Benchmarks. U.S. Environmental Protection Agency – Region 3. Available at: www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm



Original proposed Sediment Sampling Locations

Location ID	Latitude	Longitude
Jack-1	46.364576	-112.308581
Jack-2	46.364446	-112.309668
Jill-1	46.357200	-112.295132
Jill-2	46.357260	-112.295885
Jill-3	46.357344	-112.296092
Jill-4	46.360225	-112.297931

VICINITY MAP



LEGEND
- 2012 Actual Sediment Sampling Location
- Proposed Sediment Sampling Location
- Adit Discharge Channel
- NHD Stream
- U.S. Forest Service Boundary
- Mine Claim Boundary

Notes:
1. 2009 NAIP Orthophoto

0 250 500
Feet

FIGURE 1
Actual Sediment Sampling Locations, July 2012
Bullion Mine OU3 Remedial Investigation

CH2MHILL

Appendix A
Laboratory Data

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

August 24, 2012

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

RE: Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Dear Dennis Smith:

Enclosed are the analytical results for sample(s) received by the laboratory on July 27, 2012. The results relate only to the samples included in this report. Results reported herein conform to the most current TNI standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

Samples were air dried prior to analysis.

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

Sincerely,

Samantha Rupe

samantha.rupe@pacelabs.com
Project Manager

Enclosures

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

CERTIFICATIONS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Minnesota Certification IDs

1700 Elm Street SE Suite 200, Minneapolis, MN 55414
A2LA Certification #: 2926.01
Alaska Certification #: UST-078
Alaska Certification #MN00064
Arizona Certification #: AZ-0014
Arkansas Certification #: 88-0680
California Certification #: 01155CA
EPA Region 8 Certification #: Pace
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Oklahoma Certification #: 9507
Oregon Certification #: MN200001
Pennsylvania Certification #: 68-00563
Puerto Rico Certification
Tennessee Certification #: 02818
Texas Certification #: T104704192
Virginia/DCLS Certification #: 002521
Virginia/VELAP Certification #: 460163
Washington Certification #: C754
Wisconsin Certification #: 999407970

Montana Certification IDs

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

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SAMPLE SUMMARY

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Lab ID	Sample ID	Matrix	Date Collected	Date Received
10200373001	**JILL-01-SD**	Solid	07/23/12 12:23	07/27/12 09:20
10200373002	**JILL-01-SD 10 MESH**	Solid	07/23/12 12:23	07/27/12 09:20
10200373003	**JILL-01-SD 80 MESH**	Solid	07/23/12 12:23	07/27/12 09:20
10200373004	**JILL-01-SD 230 MESH**	Solid	07/23/12 12:23	07/27/12 09:20
10200373005	**JILL-02-SD**	Solid	07/23/12 12:20	07/27/12 09:20
10200373006	**JILL-02-SD 10 MESH**	Solid	07/23/12 12:20	07/27/12 09:20
10200373007	**JILL-02-SD 80 MESH**	Solid	07/23/12 12:20	07/27/12 09:20
10200373008	**JILL-02-SD 230 MESH**	Solid	07/23/12 12:20	07/27/12 09:20
10200373009	**JILL-03-SD**	Solid	07/23/12 12:03	07/27/12 09:20
10200373010	**JILL-03-SD 10 MESH**	Solid	07/23/12 12:03	07/27/12 09:20
10200373011	**JILL-03-SD 80 MESH**	Solid	07/23/12 12:03	07/27/12 09:20
10200373012	**JILL-03-SD 230 MESH**	Solid	07/23/12 12:03	07/27/12 09:20
10200373013	**JILL-03-FD**	Solid	07/23/12 12:03	07/27/12 09:20
10200373014	**JILL-03-FD 10 MESH**	Solid	07/23/12 12:03	07/27/12 09:20
10200373015	**JILL-03-FD 80 MESH**	Solid	07/23/12 12:03	07/27/12 09:20
10200373016	**JILL-03-FD 230 MESH**	Solid	07/23/12 12:03	07/27/12 09:20
10200373017	**JILL-04-SD**	Solid	07/23/12 11:44	07/27/12 09:20
10200373018	**JILL-04-SD 10 MESH**	Solid	07/23/12 11:44	07/27/12 09:20
10200373019	**JILL-04-SD 80 MESH**	Solid	07/23/12 11:44	07/27/12 09:20
10200373020	**JILL-04-SD 230 MESH**	Solid	07/23/12 11:44	07/27/12 09:20
10200373021	**JILL-04-FD-MS/MSD**	Solid	07/23/12 11:44	07/27/12 09:20
10200373022	**JILL-04-FD-MS/MSD 10 MESH**	Solid	07/23/12 11:44	07/27/12 09:20
10200373023	**JILL-04-FD-MS/MSD 80 MESH**	Solid	07/23/12 11:44	07/27/12 09:20
10200373024	**JILL-04-FD-MS/MSD 230 MESH**	Solid	07/23/12 11:44	07/27/12 09:20
10200373025	**JACK-01-SD**	Solid	07/23/12 10:55	07/27/12 09:20
10200373026	**JACK-01-SD 10 MESH**	Solid	07/23/12 10:55	07/27/12 09:20
10200373027	**JACK-01-SD 80 MESH**	Solid	07/23/12 10:55	07/27/12 09:20
10200373028	**JACK-01-SD 230 MESH**	Solid	07/23/12 10:55	07/27/12 09:20
10200373029	**JACK-02-SD**	Solid	07/23/12 10:40	07/27/12 09:20
10200373030	**JACK-02-SD 10 MESH**	Solid	07/23/12 10:40	07/27/12 09:20
10200373031	**JACK-02-SD 80 MESH**	Solid	07/23/12 10:40	07/27/12 09:20
10200373032	**JACK-02-SD 230 MESH**	Solid	07/23/12 10:40	07/27/12 09:20

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SAMPLE ANALYTE COUNT

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
10200373001	**JILL-01-SD**	ASA 15-5 mod	DH1	4	PASI-MT
10200373002	**JILL-01-SD 10 MESH**	EPA 6010	IP	13	PASI-M
10200373003	**JILL-01-SD 80 MESH**	EPA 6010	IP	13	PASI-M
10200373004	**JILL-01-SD 230 MESH**	EPA 6010	IP	13	PASI-M
10200373005	**JILL-02-SD**	ASA 15-5 mod	DH1	4	PASI-MT
10200373006	**JILL-02-SD 10 MESH**	EPA 6010	IP	13	PASI-M
10200373007	**JILL-02-SD 80 MESH**	EPA 6010	IP	13	PASI-M
10200373008	**JILL-02-SD 230 MESH**	EPA 6010	IP	13	PASI-M
10200373009	**JILL-03-SD**	ASA 15-5 mod	DH1	4	PASI-MT
10200373010	**JILL-03-SD 10 MESH**	EPA 6010	IP	13	PASI-M
10200373011	**JILL-03-SD 80 MESH**	EPA 6010	IP	13	PASI-M
10200373012	**JILL-03-SD 230 MESH**	EPA 6010	IP	13	PASI-M
10200373013	**JILL-03-FD**	ASA 15-5 mod	DH1	4	PASI-MT
10200373014	**JILL-03-FD 10 MESH**	EPA 6010	IP	13	PASI-M
10200373015	**JILL-03-FD 80 MESH**	EPA 6010	IP	13	PASI-M
10200373016	**JILL-03-FD 230 MESH**	EPA 6010	IP	13	PASI-M
10200373017	**JILL-04-SD**	ASA 15-5 mod	DH1	4	PASI-MT
10200373018	**JILL-04-SD 10 MESH**	EPA 6010	IP	13	PASI-M
10200373019	**JILL-04-SD 80 MESH**	EPA 6010	IP	13	PASI-M
10200373020	**JILL-04-SD 230 MESH**	EPA 6010	IP	13	PASI-M
10200373021	**JILL-04-FD-MS/MSD**	ASA 15-5 mod	DH1	4	PASI-MT
10200373022	**JILL-04-FD-MS/MSD 10 MESH**	EPA 6010	IP	13	PASI-M
10200373023	**JILL-04-FD-MS/MSD 80 MESH**	EPA 6010	IP	13	PASI-M
10200373024	**JILL-04-FD-MS/MSD 230 MESH**	EPA 6010	IP	13	PASI-M
10200373025	**JACK-01-SD**	ASA 15-5 mod	DH1	4	PASI-MT
10200373026	**JACK-01-SD 10 MESH**	EPA 6010	IP	13	PASI-M
10200373027	**JACK-01-SD 80 MESH**	EPA 6010	IP	13	PASI-M
10200373028	**JACK-01-SD 230 MESH**	EPA 6010	IP	13	PASI-M
10200373029	**JACK-02-SD**	ASA 15-5 mod	DH1	4	PASI-MT
10200373030	**JACK-02-SD 10 MESH**	EPA 6010	IP	13	PASI-M
10200373031	**JACK-02-SD 80 MESH**	EPA 6010	IP	13	PASI-M
10200373032	**JACK-02-SD 230 MESH**	EPA 6010	IP	13	PASI-M

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PROJECT NARRATIVE

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Method: **EPA 6010**
Description: 6010 MET ICP
Client: CH2M Hill
Date: August 24, 2012

General Information:
24 samples were analyzed for EPA 6010. All samples were received in acceptable condition with any exceptions noted below.

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

Sample Preparation:
The samples were prepared in accordance with EPA 3050 with any exceptions noted below.

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

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

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

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

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

QC Batch: MPRP/34123

A matrix spike and matrix spike duplicate (MS/MSD) were performed on the following sample(s): 10200373002,10200373026

D6: The relative percent difference (RPD) between the sample and sample duplicate exceeded laboratory control limits.

- MSD (Lab ID: 1252895)
  - Antimony
  - Arsenic
  - Cadmium
  - Iron
  - Lead

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

- MS (Lab ID: 1252894)
  - Aluminum
  - Antimony
  - Arsenic
  - Iron
  - Lead
  - Manganese
  - Zinc
- MS (Lab ID: 1252896)
  - Antimony

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PROJECT NARRATIVE

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Method: **EPA 6010**
Description: 6010 MET ICP
Client: CH2M Hill
Date: August 24, 2012

QC Batch: MPRP/34123

A matrix spike and matrix spike duplicate (MS/MSD) were performed on the following sample(s): 10200373002,10200373026

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

- Cadmium
- Copper
- Lead
- Manganese
- Nickel
- Selenium
- Silver
- Thallium

- MSD (Lab ID: 1252895)
  - Aluminum
  - Arsenic
  - Cadmium
  - Iron
  - Manganese

QC Batch: MPRP/34124

A matrix spike and matrix spike duplicate (MS/MSD) were performed on the following sample(s): 10200373027

D6: The relative percent difference (RPD) between the sample and sample duplicate exceeded laboratory control limits.

- MSD (Lab ID: 1252900)
  - Arsenic

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

- MS (Lab ID: 1252899)
  - Antimony
  - Arsenic
  - Copper
  - Iron
  - Lead
  - Manganese
  - Zinc
- MSD (Lab ID: 1252900)
  - Antimony
  - Arsenic
  - Zinc

QC Batch: MPRP/34317

A matrix spike and matrix spike duplicate (MS/MSD) were performed on the following sample(s): 10200373022,10200373023,10200373024,10200394010,10200394011,10200394012

D6: The relative percent difference (RPD) between the sample and sample duplicate exceeded laboratory control limits.

- MSD (Lab ID: 1259400)
  - Arsenic
  - Lead
- MSD (Lab ID: 1259402)
  - Lead

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PROJECT NARRATIVE

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Method: **EPA 6010**
Description: 6010 MET ICP
Client: CH2M Hill
Date: August 24, 2012

QC Batch: MPRP/34317

A matrix spike and matrix spike duplicate (MS/MSD) were performed on the following sample(s):
10200373022,10200373023,10200373024,10200394010,10200394011,10200394012

D6: The relative percent difference (RPD) between the sample and sample duplicate exceeded laboratory control limits.

- MSD (Lab ID: 1259406)
  - Antimony
  - Copper
  - Iron
  - Zinc
- MSD (Lab ID: 1259408)
  - Arsenic
  - Lead

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

- MS (Lab ID: 1259399)
  - Aluminum
  - Arsenic
  - Cadmium
  - Copper
  - Iron
  - Manganese
  - Zinc
- MS (Lab ID: 1259401)
  - Aluminum
  - Antimony
  - Arsenic
  - Iron
  - Lead
  - Manganese
  - Zinc
- MS (Lab ID: 1259403)
  - Aluminum
  - Antimony
  - Arsenic
  - Copper
  - Iron
  - Lead
  - Manganese
- MS (Lab ID: 1259405)
  - Aluminum
  - Copper
  - Iron
  - Lead
  - Manganese
  - Zinc
- MS (Lab ID: 1259407)
  - Aluminum

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PROJECT NARRATIVE

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Method: **EPA 6010**
Description: 6010 MET ICP
Client: CH2M Hill
Date: August 24, 2012

QC Batch: MPRP/34317

A matrix spike and matrix spike duplicate (MS/MSD) were performed on the following sample(s): 10200373022,10200373023,10200373024,10200394010,10200394011,10200394012

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

- Antimony
- Arsenic
- Cadmium
- Copper
- Iron
- Lead
- Manganese
- Zinc
- MS (Lab ID: 1259409)
  - Aluminum
  - Antimony
  - Arsenic
  - Copper
  - Iron
  - Lead
  - Manganese
  - Zinc
- MSD (Lab ID: 1259400)
  - Aluminum
  - Arsenic
  - Copper
  - Iron
  - Lead
  - Manganese
  - Zinc
- MSD (Lab ID: 1259402)
  - Aluminum
  - Antimony
  - Copper
  - Iron
  - Lead
  - Manganese
  - Zinc
- MSD (Lab ID: 1259404)
  - Aluminum
  - Antimony
  - Arsenic
  - Iron
  - Manganese
- MSD (Lab ID: 1259406)
  - Aluminum
  - Antimony

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PROJECT NARRATIVE

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Method: **EPA 6010**
Description: 6010 MET ICP
Client: CH2M Hill
Date: August 24, 2012

QC Batch: MPRP/34317

A matrix spike and matrix spike duplicate (MS/MSD) were performed on the following sample(s): 10200373022,10200373023,10200373024,10200394010,10200394011,10200394012

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

- Arsenic
- Copper
- Iron
- Lead
- Manganese
- Zinc

- MSD (Lab ID: 1259408)
  - Aluminum
  - Antimony
  - Arsenic
  - Cadmium
  - Copper
  - Iron
  - Manganese
  - Zinc
- MSD (Lab ID: 1259410)
  - Aluminum
  - Antimony
  - Arsenic
  - Copper
  - Iron
  - Lead
  - Manganese
  - Zinc

Additional Comments:

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PROJECT NARRATIVE

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Method: **ASA 15-5 mod**
Description: PSA Percent Sand,Silt,Clay
Client: CH2M Hill
Date: August 24, 2012

General Information:
8 samples were analyzed for ASA 15-5 mod. All samples were received in acceptable condition with any exceptions noted below.

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

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

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

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

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

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

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

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

Additional Comments:

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

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-01-SD **Lab ID: 10200373001** Collected: 07/23/12 12:23 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
PSA Percent Sand,Silt,Clay	Analytical Method: ASA 15-5 mod								
Percent Clay	**3.75**	% (w/w)	0.10		1		08/03/12 17:58		
Percent Sand	**92.5**	% (w/w)	0.10		1		08/03/12 17:58		
Percent Silt	**3.75**	% (w/w)	0.10		1		08/03/12 17:58		
Texture	**Sand**				1		08/03/12 17:58		

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-01-SD 10 MESH **Lab ID: 10200373002** Collected: 07/23/12 12:23 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**2210**	mg/kg	7.5	1.4	1	08/03/12 14:47	08/06/12 12:41	7429-90-5	M1
Antimony	**0.37**	mg/kg	0.37	0.090	1	08/03/12 14:47	08/06/12 12:41	7440-36-0	M1
Arsenic	**33.0**	mg/kg	0.37	0.090	1	08/03/12 14:47	08/06/12 12:41	7440-38-2	M1
Cadmium	**1.3**	mg/kg	0.037	0.015	1	08/03/12 14:47	08/06/12 12:41	7440-43-9	M1
Copper	**21.6**	mg/kg	0.37	0.030	1	08/03/12 14:47	08/06/12 12:41	7440-50-8	
Iron	**7200**	mg/kg	1.9	0.90	1	08/03/12 14:47	08/06/12 12:41	7439-89-6	M1
Lead	**9.6**	mg/kg	0.22	0.037	1	08/03/12 14:47	08/06/12 12:41	7439-92-1	M1
Manganese	**313**	mg/kg	0.19	0.015	1	08/03/12 14:47	08/06/12 12:41	7439-96-5	M1
Nickel	**1.9**	mg/kg	0.75	0.030	1	08/03/12 14:47	08/06/12 12:41	7440-02-0	
Selenium	**0.84**	mg/kg	0.56	0.13	1	08/03/12 14:47	08/06/12 12:41	7782-49-2	
Silver	**0.045U**	mg/kg	0.37	0.045	1	08/03/12 14:47	08/06/12 12:41	7440-22-4	
Thallium	**0.12J**	mg/kg	0.75	0.12	1	08/03/12 14:47	08/06/12 12:41	7440-28-0	
Zinc	**66.5**	mg/kg	0.75	0.10	1	08/03/12 14:47	08/06/12 12:41	7440-66-6	M1

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-01-SD 80 MESH **Lab ID: 10200373003** Collected: 07/23/12 12:23 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**2220**	mg/kg	7.9	1.5	1	08/03/12 14:47	08/06/12 12:57	7429-90-5	
Antimony	**0.22J**	mg/kg	0.39	0.094	1	08/03/12 14:47	08/06/12 12:57	7440-36-0	
Arsenic	**47.3**	mg/kg	0.39	0.094	1	08/03/12 14:47	08/06/12 12:57	7440-38-2	
Cadmium	**1.4**	mg/kg	0.039	0.016	1	08/03/12 14:47	08/06/12 12:57	7440-43-9	
Copper	**18.2**	mg/kg	0.39	0.031	1	08/03/12 14:47	08/06/12 12:57	7440-50-8	
Iron	**6070**	mg/kg	2.0	0.95	1	08/03/12 14:47	08/06/12 12:57	7439-89-6	
Lead	**9.3**	mg/kg	0.24	0.039	1	08/03/12 14:47	08/06/12 12:57	7439-92-1	
Manganese	**264**	mg/kg	0.20	0.016	1	08/03/12 14:47	08/06/12 12:57	7439-96-5	
Nickel	**1.8**	mg/kg	0.79	0.031	1	08/03/12 14:47	08/06/12 12:57	7440-02-0	
Selenium	**0.30J**	mg/kg	0.59	0.13	1	08/03/12 14:47	08/06/12 12:57	7782-49-2	
Silver	**0.047U**	mg/kg	0.39	0.047	1	08/03/12 14:47	08/06/12 12:57	7440-22-4	
Thallium	**0.13U**	mg/kg	0.79	0.13	1	08/03/12 14:47	08/06/12 12:57	7440-28-0	
Zinc	**67.6**	mg/kg	0.79	0.11	1	08/03/12 14:47	08/06/12 12:57	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-01-SD 230 MESH **Lab ID: 10200373004** Collected: 07/23/12 12:23 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**10700**	mg/kg	8.8	1.7	1	08/03/12 14:47	08/06/12 13:06	7429-90-5	
Antimony	**0.94**	mg/kg	0.44	0.11	1	08/03/12 14:47	08/06/12 13:06	7440-36-0	
Arsenic	**235**	mg/kg	0.44	0.11	1	08/03/12 14:47	08/06/12 13:06	7440-38-2	
Cadmium	**7.3**	mg/kg	0.044	0.018	1	08/03/12 14:47	08/06/12 13:06	7440-43-9	
Copper	**137**	mg/kg	0.44	0.035	1	08/03/12 14:47	08/06/12 13:06	7440-50-8	
Iron	**27400**	mg/kg	11.0	5.3	5	08/03/12 14:47	08/06/12 16:36	7439-89-6	
Lead	**47.9**	mg/kg	0.26	0.044	1	08/03/12 14:47	08/06/12 13:06	7439-92-1	
Manganese	**693**	mg/kg	0.22	0.018	1	08/03/12 14:47	08/06/12 13:06	7439-96-5	
Nickel	**7.7**	mg/kg	0.88	0.035	1	08/03/12 14:47	08/06/12 13:06	7440-02-0	
Selenium	**1.4**	mg/kg	0.66	0.15	1	08/03/12 14:47	08/06/12 13:06	7782-49-2	
Silver	**0.053U**	mg/kg	0.44	0.053	1	08/03/12 14:47	08/06/12 13:06	7440-22-4	
Thallium	**0.14U**	mg/kg	0.88	0.14	1	08/03/12 14:47	08/06/12 13:06	7440-28-0	
Zinc	**365**	mg/kg	0.88	0.12	1	08/03/12 14:47	08/06/12 13:06	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-02-SD **Lab ID: 10200373005** Collected: 07/23/12 12:20 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
PSA Percent Sand,Silt,Clay	Analytical Method: ASA 15-5 mod								
Percent Clay	**11.25**	% (w/w)	0.10		1		08/03/12 18:28		
Percent Sand	**75**	% (w/w)	0.10		1		08/03/12 18:28		
Percent Silt	**13.75**	% (w/w)	0.10		1		08/03/12 18:28		
Texture	**Sandy Loam**				1		08/03/12 18:28		

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-02-SD 10 MESH **Lab ID: 10200373006** Collected: 07/23/12 12:20 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**1430**	mg/kg	8.6	1.6	1	08/03/12 14:47	08/06/12 13:12	7429-90-5	
Antimony	**8.4**	mg/kg	0.43	0.10	1	08/03/12 14:47	08/06/12 13:12	7440-36-0	
Arsenic	**1800**	mg/kg	0.86	0.21	2	08/03/12 14:47	08/06/12 16:41	7440-38-2	
Cadmium	**25.4**	mg/kg	0.043	0.017	1	08/03/12 14:47	08/06/12 13:12	7440-43-9	
Copper	**64.3**	mg/kg	0.43	0.034	1	08/03/12 14:47	08/06/12 13:12	7440-50-8	
Iron	**118000**	mg/kg	43.1	20.9	20	08/03/12 14:47	08/08/12 18:43	7439-89-6	
Lead	**112**	mg/kg	0.26	0.043	1	08/03/12 14:47	08/06/12 13:12	7439-92-1	
Manganese	**253**	mg/kg	0.22	0.017	1	08/03/12 14:47	08/06/12 13:12	7439-96-5	
Nickel	**0.22J**	mg/kg	0.86	0.034	1	08/03/12 14:47	08/06/12 13:12	7440-02-0	
Selenium	**0.15U**	mg/kg	0.65	0.15	1	08/03/12 14:47	08/06/12 13:12	7782-49-2	
Silver	**0.052U**	mg/kg	0.43	0.052	1	08/03/12 14:47	08/06/12 13:12	7440-22-4	
Thallium	**5.7**	mg/kg	0.86	0.14	1	08/03/12 14:47	08/06/12 13:12	7440-28-0	
Zinc	**67.2**	mg/kg	0.86	0.12	1	08/03/12 14:47	08/06/12 13:12	7440-66-6	

REPORT OF LABORATORY ANALYSIS

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-02-SD 80 MESH **Lab ID: 10200373007** Collected: 07/23/12 12:20 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**4280**	mg/kg	8.1	1.5	1	08/03/12 14:47	08/06/12 13:24	7429-90-5	
Antimony	**6.4**	mg/kg	0.40	0.097	1	08/03/12 14:47	08/06/12 13:24	7440-36-0	
Arsenic	**1320**	mg/kg	0.81	0.19	2	08/03/12 14:47	08/06/12 16:51	7440-38-2	
Cadmium	**18.6**	mg/kg	0.040	0.016	1	08/03/12 14:47	08/06/12 13:24	7440-43-9	
Copper	**68.2**	mg/kg	0.40	0.032	1	08/03/12 14:47	08/06/12 13:24	7440-50-8	
Iron	**70800**	mg/kg	20.2	9.8	10	08/03/12 14:47	08/06/12 16:57	7439-89-6	
Lead	**203**	mg/kg	0.24	0.040	1	08/03/12 14:47	08/06/12 13:24	7439-92-1	
Manganese	**556**	mg/kg	0.20	0.016	1	08/03/12 14:47	08/06/12 13:24	7439-96-5	
Nickel	**2.7**	mg/kg	0.81	0.032	1	08/03/12 14:47	08/06/12 13:24	7440-02-0	
Selenium	**0.14U**	mg/kg	0.60	0.14	1	08/03/12 14:47	08/06/12 13:24	7782-49-2	
Silver	**0.34J**	mg/kg	0.40	0.048	1	08/03/12 14:47	08/06/12 13:24	7440-22-4	
Thallium	**3.1**	mg/kg	0.81	0.13	1	08/03/12 14:47	08/06/12 13:24	7440-28-0	
Zinc	**145**	mg/kg	0.81	0.11	1	08/03/12 14:47	08/06/12 13:24	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-02-SD 230 MESH **Lab ID: 10200373008** Collected: 07/23/12 12:20 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**7260**	mg/kg	9.8	1.9	1	08/03/12 14:47	08/06/12 13:30	7429-90-5	
Antimony	**7.0**	mg/kg	0.49	0.12	1	08/03/12 14:47	08/06/12 13:30	7440-36-0	
Arsenic	**1840**	mg/kg	0.98	0.24	2	08/03/12 14:47	08/06/12 17:02	7440-38-2	
Cadmium	**25.7**	mg/kg	0.049	0.020	1	08/03/12 14:47	08/06/12 13:30	7440-43-9	
Copper	**110**	mg/kg	0.49	0.039	1	08/03/12 14:47	08/06/12 13:30	7440-50-8	
Iron	**124000**	mg/kg	49.0	23.7	20	08/03/12 14:47	08/08/12 18:49	7439-89-6	
Lead	**397**	mg/kg	0.29	0.049	1	08/03/12 14:47	08/06/12 13:30	7439-92-1	
Manganese	**332**	mg/kg	0.25	0.020	1	08/03/12 14:47	08/06/12 13:30	7439-96-5	
Nickel	**3.9**	mg/kg	0.98	0.039	1	08/03/12 14:47	08/06/12 13:30	7440-02-0	
Selenium	**0.17U**	mg/kg	0.74	0.17	1	08/03/12 14:47	08/06/12 13:30	7782-49-2	
Silver	**1.5**	mg/kg	0.49	0.059	1	08/03/12 14:47	08/06/12 13:30	7440-22-4	
Thallium	**4.8**	mg/kg	0.98	0.16	1	08/03/12 14:47	08/06/12 13:30	7440-28-0	
Zinc	**230**	mg/kg	0.98	0.14	1	08/03/12 14:47	08/06/12 13:30	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-03-SD **Lab ID: 10200373009** Collected: 07/23/12 12:03 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
PSA Percent Sand,Silt,Clay	Analytical Method: ASA 15-5 mod								
Percent Clay	**5**	% (w/w)	0.10		1		08/03/12 17:42		
Percent Sand	**92.5**	% (w/w)	0.10		1		08/03/12 17:42		
Percent Silt	**2.5**	% (w/w)	0.10		1		08/03/12 17:42		
Texture	**Sand**				1		08/03/12 17:42		

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012

Pace Project No.: 10200373

Sample: JILL-03-SD 10 MESH **Lab ID: 10200373010** Collected: 07/23/12 12:03 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**3250**	mg/kg	6.9	1.3	1	08/03/12 14:47	08/06/12 13:36	7429-90-5	
Antimony	**0.083U**	mg/kg	0.34	0.083	1	08/03/12 14:47	08/06/12 13:36	7440-36-0	
Arsenic	**112**	mg/kg	0.34	0.083	1	08/03/12 14:47	08/06/12 13:36	7440-38-2	
Cadmium	**2.9**	mg/kg	0.034	0.014	1	08/03/12 14:47	08/06/12 13:36	7440-43-9	
Copper	**42.9**	mg/kg	0.34	0.028	1	08/03/12 14:47	08/06/12 13:36	7440-50-8	
Iron	**9160**	mg/kg	3.4	1.7	2	08/03/12 14:47	08/06/12 17:20	7439-89-6	
Lead	**18.2**	mg/kg	0.21	0.034	1	08/03/12 14:47	08/06/12 13:36	7439-92-1	
Manganese	**382**	mg/kg	0.17	0.014	1	08/03/12 14:47	08/06/12 13:36	7439-96-5	
Nickel	**3.9**	mg/kg	0.69	0.028	1	08/03/12 14:47	08/06/12 13:36	7440-02-0	
Selenium	**0.59**	mg/kg	0.52	0.12	1	08/03/12 14:47	08/06/12 13:36	7782-49-2	
Silver	**0.041U**	mg/kg	0.34	0.041	1	08/03/12 14:47	08/06/12 13:36	7440-22-4	
Thallium	**0.11U**	mg/kg	0.69	0.11	1	08/03/12 14:47	08/06/12 13:36	7440-28-0	
Zinc	**122**	mg/kg	0.69	0.097	1	08/03/12 14:47	08/06/12 13:36	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-03-SD 80 MESH **Lab ID: 10200373011** Collected: 07/23/12 12:03 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**2520**	mg/kg	9.8	1.9	1	08/03/12 14:47	08/06/12 13:41	7429-90-5	
Antimony	**0.12U**	mg/kg	0.49	0.12	1	08/03/12 14:47	08/06/12 13:41	7440-36-0	
Arsenic	**58.5**	mg/kg	0.49	0.12	1	08/03/12 14:47	08/06/12 13:41	7440-38-2	
Cadmium	**2.2**	mg/kg	0.049	0.020	1	08/03/12 14:47	08/06/12 13:41	7440-43-9	
Copper	**54.7**	mg/kg	0.49	0.039	1	08/03/12 14:47	08/06/12 13:41	7440-50-8	
Iron	**7630**	mg/kg	2.5	1.2	1	08/03/12 14:47	08/06/12 13:41	7439-89-6	
Lead	**30.1**	mg/kg	0.29	0.049	1	08/03/12 14:47	08/06/12 13:41	7439-92-1	
Manganese	**263**	mg/kg	0.25	0.020	1	08/03/12 14:47	08/06/12 13:41	7439-96-5	
Nickel	**2.1**	mg/kg	0.98	0.039	1	08/03/12 14:47	08/06/12 13:41	7440-02-0	
Selenium	**0.57J**	mg/kg	0.74	0.17	1	08/03/12 14:47	08/06/12 13:41	7782-49-2	
Silver	**0.059U**	mg/kg	0.49	0.059	1	08/03/12 14:47	08/06/12 13:41	7440-22-4	
Thallium	**0.16U**	mg/kg	0.98	0.16	1	08/03/12 14:47	08/06/12 13:41	7440-28-0	
Zinc	**105**	mg/kg	0.98	0.14	1	08/03/12 14:47	08/06/12 13:41	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-03-SD 230 MESH **Lab ID: 10200373012** Collected: 07/23/12 12:03 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**10100**	mg/kg	7.5	1.4	1	08/03/12 14:47	08/06/12 13:46	7429-90-5	
Antimony	**0.090U**	mg/kg	0.38	0.090	1	08/03/12 14:47	08/06/12 13:46	7440-36-0	
Arsenic	**288**	mg/kg	0.38	0.090	1	08/03/12 14:47	08/06/12 13:46	7440-38-2	
Cadmium	**12.7**	mg/kg	0.038	0.015	1	08/03/12 14:47	08/06/12 13:46	7440-43-9	
Copper	**474**	mg/kg	0.38	0.030	1	08/03/12 14:47	08/06/12 13:46	7440-50-8	
Iron	**48100**	mg/kg	18.8	9.1	10	08/03/12 14:47	08/06/12 17:25	7439-89-6	
Lead	**96.8**	mg/kg	0.23	0.038	1	08/03/12 14:47	08/06/12 13:46	7439-92-1	
Manganese	**1590**	mg/kg	1.9	0.15	10	08/03/12 14:47	08/06/12 17:25	7439-96-5	
Nickel	**6.7**	mg/kg	0.75	0.030	1	08/03/12 14:47	08/06/12 13:46	7440-02-0	
Selenium	**0.37J**	mg/kg	0.56	0.13	1	08/03/12 14:47	08/06/12 13:46	7782-49-2	
Silver	**0.045U**	mg/kg	0.38	0.045	1	08/03/12 14:47	08/06/12 13:46	7440-22-4	
Thallium	**1.3**	mg/kg	0.75	0.12	1	08/03/12 14:47	08/06/12 13:46	7440-28-0	
Zinc	**538**	mg/kg	0.75	0.11	1	08/03/12 14:47	08/06/12 13:46	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-03-FD **Lab ID: 10200373013** Collected: 07/23/12 12:03 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
PSA Percent Sand,Silt,Clay	Analytical Method: ASA 15-5 mod								
Percent Clay	**5**	% (w/w)	0.10		1		08/03/12 17:32		
Percent Sand	**92.5**	% (w/w)	0.10		1		08/03/12 17:32		
Percent Silt	**2.5**	% (w/w)	0.10		1		08/03/12 17:32		
Texture	**Sand**				1		08/03/12 17:32		

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-03-FD 10 MESH **Lab ID: 10200373014** Collected: 07/23/12 12:03 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**4590**	mg/kg	9.6	1.8	1	08/03/12 14:47	08/06/12 13:52	7429-90-5	
Antimony	**0.53**	mg/kg	0.48	0.12	1	08/03/12 14:47	08/06/12 13:52	7440-36-0	
Arsenic	**19.5**	mg/kg	0.48	0.12	1	08/03/12 14:47	08/06/12 13:52	7440-38-2	
Cadmium	**1.5**	mg/kg	0.048	0.019	1	08/03/12 14:47	08/06/12 13:52	7440-43-9	
Copper	**47.6**	mg/kg	0.48	0.038	1	08/03/12 14:47	08/06/12 13:52	7440-50-8	
Iron	**5420**	mg/kg	2.4	1.2	1	08/03/12 14:47	08/06/12 13:52	7439-89-6	
Lead	**8.1**	mg/kg	0.29	0.048	1	08/03/12 14:47	08/06/12 13:52	7439-92-1	
Manganese	**337**	mg/kg	0.24	0.019	1	08/03/12 14:47	08/06/12 13:52	7439-96-5	
Nickel	**2.6**	mg/kg	0.96	0.038	1	08/03/12 14:47	08/06/12 13:52	7440-02-0	
Selenium	**0.76**	mg/kg	0.72	0.16	1	08/03/12 14:47	08/06/12 13:52	7782-49-2	
Silver	**0.058U**	mg/kg	0.48	0.058	1	08/03/12 14:47	08/06/12 13:52	7440-22-4	
Thallium	**0.15U**	mg/kg	0.96	0.15	1	08/03/12 14:47	08/06/12 13:52	7440-28-0	
Zinc	**150**	mg/kg	0.96	0.13	1	08/03/12 14:47	08/06/12 13:52	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012

Pace Project No.: 10200373

Sample: JILL-03-FD 80 MESH **Lab ID: 10200373015** Collected: 07/23/12 12:03 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**2900**	mg/kg	8.5	1.6	1	08/03/12 14:47	08/06/12 13:57	7429-90-5	
Antimony	**0.10U**	mg/kg	0.42	0.10	1	08/03/12 14:47	08/06/12 13:57	7440-36-0	
Arsenic	**36.8**	mg/kg	0.42	0.10	1	08/03/12 14:47	08/06/12 13:57	7440-38-2	
Cadmium	**1.8**	mg/kg	0.042	0.017	1	08/03/12 14:47	08/06/12 13:57	7440-43-9	
Copper	**42.9**	mg/kg	0.42	0.034	1	08/03/12 14:47	08/06/12 13:57	7440-50-8	
Iron	**7020**	mg/kg	2.1	1.0	1	08/03/12 14:47	08/06/12 13:57	7439-89-6	
Lead	**12.5**	mg/kg	0.25	0.042	1	08/03/12 14:47	08/06/12 13:57	7439-92-1	
Manganese	**261**	mg/kg	0.21	0.017	1	08/03/12 14:47	08/06/12 13:57	7439-96-5	
Nickel	**2.4**	mg/kg	0.85	0.034	1	08/03/12 14:47	08/06/12 13:57	7440-02-0	
Selenium	**0.24J**	mg/kg	0.64	0.14	1	08/03/12 14:47	08/06/12 13:57	7782-49-2	
Silver	**0.051U**	mg/kg	0.42	0.051	1	08/03/12 14:47	08/06/12 13:57	7440-22-4	
Thallium	**0.14U**	mg/kg	0.85	0.14	1	08/03/12 14:47	08/06/12 13:57	7440-28-0	
Zinc	**93.5**	mg/kg	0.85	0.12	1	08/03/12 14:47	08/06/12 13:57	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-03-FD 230 MESH **Lab ID: 10200373016** Collected: 07/23/12 12:03 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**8850**	mg/kg	10.0	1.9	1	08/03/12 14:47	08/06/12 14:02	7429-90-5	
Antimony	**0.51**	mg/kg	0.50	0.12	1	08/03/12 14:47	08/06/12 14:02	7440-36-0	
Arsenic	**265**	mg/kg	0.50	0.12	1	08/03/12 14:47	08/06/12 14:02	7440-38-2	
Cadmium	**10.7**	mg/kg	0.050	0.020	1	08/03/12 14:47	08/06/12 14:02	7440-43-9	
Copper	**347**	mg/kg	0.50	0.040	1	08/03/12 14:47	08/06/12 14:02	7440-50-8	
Iron	**39500**	mg/kg	12.5	6.0	5	08/03/12 14:47	08/06/12 17:30	7439-89-6	
Lead	**85.7**	mg/kg	0.30	0.050	1	08/03/12 14:47	08/06/12 14:02	7439-92-1	
Manganese	**1250**	mg/kg	1.2	0.10	5	08/03/12 14:47	08/06/12 17:30	7439-96-5	
Nickel	**6.2**	mg/kg	1.0	0.040	1	08/03/12 14:47	08/06/12 14:02	7440-02-0	
Selenium	**1.1**	mg/kg	0.75	0.17	1	08/03/12 14:47	08/06/12 14:02	7782-49-2	
Silver	**0.060U**	mg/kg	0.50	0.060	1	08/03/12 14:47	08/06/12 14:02	7440-22-4	
Thallium	**0.71J**	mg/kg	1.0	0.16	1	08/03/12 14:47	08/06/12 14:02	7440-28-0	
Zinc	**492**	mg/kg	1.0	0.14	1	08/03/12 14:47	08/06/12 14:02	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-04-SD **Lab ID: 10200373017** Collected: 07/23/12 11:44 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
PSA Percent Sand,Silt,Clay	Analytical Method: ASA 15-5 mod								
Percent Clay	**5**	% (w/w)	0.10		1		08/03/12 18:18		
Percent Sand	**88.75**	% (w/w)	0.10		1		08/03/12 18:18		
Percent Silt	**6.25**	% (w/w)	0.10		1		08/03/12 18:18		
Texture	**Sand**				1		08/03/12 18:18		

REPORT OF LABORATORY ANALYSIS

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-04-SD 10 MESH **Lab ID: 10200373018** Collected: 07/23/12 11:44 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**3460**	mg/kg	9.5	1.8	1	08/03/12 14:47	08/06/12 14:15	7429-90-5	
Antimony	**1.2**	mg/kg	0.48	0.11	1	08/03/12 14:47	08/06/12 14:15	7440-36-0	
Arsenic	**104**	mg/kg	0.48	0.11	1	08/03/12 14:47	08/06/12 14:15	7440-38-2	
Cadmium	**2.5**	mg/kg	0.048	0.019	1	08/03/12 14:47	08/06/12 14:15	7440-43-9	
Copper	**60.3**	mg/kg	0.48	0.038	1	08/03/12 14:47	08/06/12 14:15	7440-50-8	
Iron	**7210**	mg/kg	2.4	1.2	1	08/03/12 14:47	08/06/12 14:15	7439-89-6	
Lead	**42.3**	mg/kg	0.29	0.048	1	08/03/12 14:47	08/06/12 14:15	7439-92-1	
Manganese	**276**	mg/kg	0.24	0.019	1	08/03/12 14:47	08/06/12 14:15	7439-96-5	
Nickel	**2.1**	mg/kg	0.95	0.038	1	08/03/12 14:47	08/06/12 14:15	7440-02-0	
Selenium	**0.54J**	mg/kg	0.71	0.16	1	08/03/12 14:47	08/06/12 14:15	7782-49-2	
Silver	**0.057U**	mg/kg	0.48	0.057	1	08/03/12 14:47	08/06/12 14:15	7440-22-4	
Thallium	**0.15U**	mg/kg	0.95	0.15	1	08/03/12 14:47	08/06/12 14:15	7440-28-0	
Zinc	**131**	mg/kg	0.95	0.13	1	08/03/12 14:47	08/06/12 14:15	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-04-SD 80 MESH **Lab ID: 10200373019** Collected: 07/23/12 11:44 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**4390**	mg/kg	9.0	1.7	1	08/03/12 14:47	08/06/12 14:20	7429-90-5	
Antimony	**2.4**	mg/kg	0.45	0.11	1	08/03/12 14:47	08/06/12 14:20	7440-36-0	
Arsenic	**395**	mg/kg	0.45	0.11	1	08/03/12 14:47	08/06/12 14:20	7440-38-2	
Cadmium	**8.9**	mg/kg	0.045	0.018	1	08/03/12 14:47	08/06/12 14:20	7440-43-9	
Copper	**159**	mg/kg	0.45	0.036	1	08/03/12 14:47	08/06/12 14:20	7440-50-8	
Iron	**14300**	mg/kg	4.5	2.2	2	08/03/12 14:47	08/06/12 17:35	7439-89-6	
Lead	**148**	mg/kg	0.27	0.045	1	08/03/12 14:47	08/06/12 14:20	7439-92-1	
Manganese	**548**	mg/kg	0.23	0.018	1	08/03/12 14:47	08/06/12 14:20	7439-96-5	
Nickel	**3.4**	mg/kg	0.90	0.036	1	08/03/12 14:47	08/06/12 14:20	7440-02-0	
Selenium	**0.92**	mg/kg	0.68	0.15	1	08/03/12 14:47	08/06/12 14:20	7782-49-2	
Silver	**0.21J**	mg/kg	0.45	0.054	1	08/03/12 14:47	08/06/12 14:20	7440-22-4	
Thallium	**0.14U**	mg/kg	0.90	0.14	1	08/03/12 14:47	08/06/12 14:20	7440-28-0	
Zinc	**287**	mg/kg	0.90	0.13	1	08/03/12 14:47	08/06/12 14:20	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-04-SD 230 MESH **Lab ID: 10200373020** Collected: 07/23/12 11:44 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**11200**	mg/kg	9.4	1.8	1	08/03/12 14:47	08/06/12 14:25	7429-90-5	
Antimony	**6.4**	mg/kg	0.47	0.11	1	08/03/12 14:47	08/06/12 14:25	7440-36-0	
Arsenic	**836**	mg/kg	0.47	0.11	1	08/03/12 14:47	08/06/12 14:25	7440-38-2	
Cadmium	**21.6**	mg/kg	0.047	0.019	1	08/03/12 14:47	08/06/12 14:25	7440-43-9	
Copper	**505**	mg/kg	0.47	0.038	1	08/03/12 14:47	08/06/12 14:25	7440-50-8	
Iron	**37600**	mg/kg	11.8	5.7	5	08/03/12 14:47	08/06/12 17:41	7439-89-6	
Lead	**341**	mg/kg	0.28	0.047	1	08/03/12 14:47	08/06/12 14:25	7439-92-1	
Manganese	**1220**	mg/kg	1.2	0.094	5	08/03/12 14:47	08/06/12 17:41	7439-96-5	
Nickel	**7.9**	mg/kg	0.94	0.038	1	08/03/12 14:47	08/06/12 14:25	7440-02-0	
Selenium	**1.6**	mg/kg	0.71	0.16	1	08/03/12 14:47	08/06/12 14:25	7782-49-2	
Silver	**1.7**	mg/kg	0.47	0.057	1	08/03/12 14:47	08/06/12 14:25	7440-22-4	
Thallium	**0.28J**	mg/kg	0.94	0.15	1	08/03/12 14:47	08/06/12 14:25	7440-28-0	
Zinc	**803**	mg/kg	0.94	0.13	1	08/03/12 14:47	08/06/12 14:25	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-04-FD-MS/MSD **Lab ID: 10200373021** Collected: 07/23/12 11:44 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
PSA Percent Sand,Silt,Clay	Analytical Method: ASA 15-5 mod								
Percent Clay	**6.25**	% (w/w)	0.10		1		08/03/12 17:47		
Percent Sand	**88.75**	% (w/w)	0.10		1		08/03/12 17:47		
Percent Silt	**5**	% (w/w)	0.10		1		08/03/12 17:47		
Texture	**Sand**				1		08/03/12 17:47		

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-04-FD-MS/MSD 10 MESH **Lab ID: 10200373022** Collected: 07/23/12 11:44 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**3110**	mg/kg	9.8	1.9	1	08/07/12 11:13	08/08/12 20:27	7429-90-5	M1
Antimony	**0.48J**	mg/kg	0.49	0.12	1	08/07/12 11:13	08/08/12 20:27	7440-36-0	
Arsenic	**930**	mg/kg	0.49	0.12	1	08/07/12 11:13	08/08/12 20:27	7440-38-2	M1
Cadmium	**17.3**	mg/kg	0.049	0.020	1	08/07/12 11:13	08/08/12 20:27	7440-43-9	M1
Copper	**255**	mg/kg	0.49	0.039	1	08/07/12 11:13	08/08/12 20:27	7440-50-8	M1
Iron	**29600**	mg/kg	12.3	5.9	5	08/07/12 11:13	08/09/12 15:53	7439-89-6	M1
Lead	**70.4**	mg/kg	0.29	0.049	1	08/07/12 11:13	08/08/12 20:27	7439-92-1	M1
Manganese	**313**	mg/kg	0.25	0.020	1	08/07/12 11:13	08/08/12 20:27	7439-96-5	M1
Nickel	**2.0**	mg/kg	0.98	0.039	1	08/07/12 11:13	08/08/12 20:27	7440-02-0	
Selenium	**0.95**	mg/kg	0.74	0.17	1	08/07/12 11:13	08/08/12 20:27	7782-49-2	
Silver	**0.059U**	mg/kg	0.49	0.059	1	08/07/12 11:13	08/08/12 20:27	7440-22-4	
Thallium	**1.8**	mg/kg	0.98	0.16	1	08/07/12 11:13	08/08/12 20:27	7440-28-0	
Zinc	**247**	mg/kg	0.98	0.14	1	08/07/12 11:13	08/08/12 20:27	7440-66-6	M1

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-04-FD-MS/MSD 80 MESH **Lab ID: 10200373023** Collected: 07/23/12 11:44 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**4820**	mg/kg	7.2	1.4	1	08/07/12 11:13	08/08/12 20:42	7429-90-5	M1
Antimony	**3.9**	mg/kg	0.36	0.086	1	08/07/12 11:13	08/08/12 20:42	7440-36-0	M1
Arsenic	**448**	mg/kg	0.36	0.086	1	08/07/12 11:13	08/08/12 20:42	7440-38-2	M1
Cadmium	**10.2**	mg/kg	0.036	0.014	1	08/07/12 11:13	08/08/12 20:42	7440-43-9	
Copper	**168**	mg/kg	0.36	0.029	1	08/07/12 11:13	08/08/12 20:42	7440-50-8	M1
Iron	**15500**	mg/kg	9.0	4.4	5	08/07/12 11:13	08/09/12 16:09	7439-89-6	M1
Lead	**203**	mg/kg	0.22	0.036	1	08/07/12 11:13	08/08/12 20:42	7439-92-1	M1
Manganese	**548**	mg/kg	0.18	0.014	1	08/07/12 11:13	08/08/12 20:42	7439-96-5	M1
Nickel	**3.6**	mg/kg	0.72	0.029	1	08/07/12 11:13	08/08/12 20:42	7440-02-0	
Selenium	**0.97**	mg/kg	0.54	0.12	1	08/07/12 11:13	08/08/12 20:42	7782-49-2	
Silver	**0.44**	mg/kg	0.36	0.043	1	08/07/12 11:13	08/08/12 20:42	7440-22-4	
Thallium	**0.12U**	mg/kg	0.72	0.12	1	08/07/12 11:13	08/08/12 20:42	7440-28-0	
Zinc	**333**	mg/kg	0.72	0.10	1	08/07/12 11:13	08/08/12 20:42	7440-66-6	M1

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JILL-04-FD-MS/MSD 230 MESH **Lab ID: 10200373024** Collected: 07/23/12 11:44 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**11000**	mg/kg	8.8	1.7	1	08/07/12 11:13	08/08/12 20:58	7429-90-5	M1
Antimony	**5.4**	mg/kg	0.44	0.11	1	08/07/12 11:13	08/08/12 20:58	7440-36-0	M1
Arsenic	**759**	mg/kg	0.44	0.11	1	08/07/12 11:13	08/08/12 20:58	7440-38-2	M1
Cadmium	**20.5**	mg/kg	0.044	0.018	1	08/07/12 11:13	08/08/12 20:58	7440-43-9	
Copper	**521**	mg/kg	0.44	0.035	1	08/07/12 11:13	08/08/12 20:58	7440-50-8	M1
Iron	**34300**	mg/kg	11.1	5.4	5	08/07/12 11:13	08/08/12 22:34	7439-89-6	M1
Lead	**332**	mg/kg	0.27	0.044	1	08/07/12 11:13	08/08/12 20:58	7439-92-1	M1
Manganese	**1120**	mg/kg	1.1	0.088	5	08/07/12 11:13	08/08/12 22:34	7439-96-5	M1
Nickel	**7.5**	mg/kg	0.88	0.035	1	08/07/12 11:13	08/08/12 20:58	7440-02-0	
Selenium	**1.5**	mg/kg	0.66	0.15	1	08/07/12 11:13	08/08/12 20:58	7782-49-2	
Silver	**2.0**	mg/kg	0.44	0.053	1	08/07/12 11:13	08/08/12 20:58	7440-22-4	
Thallium	**0.64J**	mg/kg	0.88	0.14	1	08/07/12 11:13	08/08/12 20:58	7440-28-0	
Zinc	**783**	mg/kg	0.88	0.12	1	08/07/12 11:13	08/08/12 20:58	7440-66-6	

REPORT OF LABORATORY ANALYSIS

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JACK-01-SD **Lab ID: 10200373025** Collected: 07/23/12 10:55 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
PSA Percent Sand,Silt,Clay	Analytical Method: ASA 15-5 mod								
Percent Clay	**3.75**	% (w/w)	0.10		1		08/03/12 18:03		
Percent Sand	**95**	% (w/w)	0.10		1		08/03/12 18:03		
Percent Silt	**1.25**	% (w/w)	0.10		1		08/03/12 18:03		
Texture	**Sand**				1		08/03/12 18:03		

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JACK-01-SD 10 MESH **Lab ID: 10200373026** Collected: 07/23/12 10:55 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**2610**	mg/kg	8.5	1.6	1	08/03/12 14:47	08/06/12 14:47	7429-90-5	
Antimony	**0.10U**	mg/kg	0.43	0.10	1	08/03/12 14:47	08/06/12 14:47	7440-36-0	M1
Arsenic	**23.0**	mg/kg	0.43	0.10	1	08/03/12 14:47	08/06/12 14:47	7440-38-2	
Cadmium	**0.73**	mg/kg	0.043	0.017	1	08/03/12 14:47	08/06/12 14:47	7440-43-9	M1
Copper	**12.5**	mg/kg	0.43	0.034	1	08/03/12 14:47	08/06/12 14:47	7440-50-8	M1
Iron	**6440**	mg/kg	2.1	1.0	1	08/03/12 14:47	08/06/12 14:47	7439-89-6	
Lead	**18.6**	mg/kg	0.26	0.043	1	08/03/12 14:47	08/06/12 14:47	7439-92-1	M1
Manganese	**200**	mg/kg	0.21	0.017	1	08/03/12 14:47	08/06/12 14:47	7439-96-5	M1
Nickel	**2.0**	mg/kg	0.85	0.034	1	08/03/12 14:47	08/06/12 14:47	7440-02-0	M1
Selenium	**0.61J**	mg/kg	0.64	0.15	1	08/03/12 14:47	08/06/12 14:47	7782-49-2	M1
Silver	**0.051U**	mg/kg	0.43	0.051	1	08/03/12 14:47	08/06/12 14:47	7440-22-4	M1
Thallium	**0.14U**	mg/kg	0.85	0.14	1	08/03/12 14:47	08/06/12 14:47	7440-28-0	M1
Zinc	**52.9**	mg/kg	0.85	0.12	1	08/03/12 14:47	08/06/12 14:47	7440-66-6	

REPORT OF LABORATORY ANALYSIS

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JACK-01-SD 80 MESH **Lab ID: 10200373027** Collected: 07/23/12 10:55 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**3260**	mg/kg	7.5	1.4	1	08/03/12 14:38	08/06/12 18:56	7429-90-5	
Antimony	**0.090U**	mg/kg	0.37	0.090	1	08/03/12 14:38	08/06/12 18:56	7440-36-0	M1
Arsenic	**47.1**	mg/kg	0.37	0.090	1	08/03/12 14:38	08/06/12 18:56	7440-38-2	M1
Cadmium	**1.2**	mg/kg	0.037	0.015	1	08/03/12 14:38	08/06/12 18:56	7440-43-9	M1
Copper	**18.1**	mg/kg	0.37	0.030	1	08/03/12 14:38	08/06/12 18:56	7440-50-8	M1
Iron	**8430**	mg/kg	1.9	0.90	1	08/03/12 14:38	08/06/12 18:56	7439-89-6	M1
Lead	**33.3**	mg/kg	0.22	0.037	1	08/03/12 14:38	08/06/12 18:56	7439-92-1	M1
Manganese	**287**	mg/kg	0.19	0.015	1	08/03/12 14:38	08/06/12 18:56	7439-96-5	M1
Nickel	**2.9**	mg/kg	0.75	0.030	1	08/03/12 14:38	08/06/12 18:56	7440-02-0	
Selenium	**0.48J**	mg/kg	0.56	0.13	1	08/03/12 14:38	08/06/12 18:56	7782-49-2	
Silver	**0.23J**	mg/kg	0.37	0.045	1	08/03/12 14:38	08/06/12 18:56	7440-22-4	
Thallium	**0.12U**	mg/kg	0.75	0.12	1	08/03/12 14:38	08/06/12 18:56	7440-28-0	
Zinc	**90.9**	mg/kg	0.75	0.10	1	08/03/12 14:38	08/06/12 18:56	7440-66-6	M1

REPORT OF LABORATORY ANALYSIS

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JACK-01-SD 230 MESH **Lab ID: 10200373028** Collected: 07/23/12 10:55 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**6690**	mg/kg	9.7	1.9	1	08/03/12 14:38	08/06/12 19:12	7429-90-5	
Antimony	**0.76**	mg/kg	0.49	0.12	1	08/03/12 14:38	08/06/12 19:12	7440-36-0	
Arsenic	**129**	mg/kg	0.49	0.12	1	08/03/12 14:38	08/06/12 19:12	7440-38-2	
Cadmium	**3.2**	mg/kg	0.049	0.019	1	08/03/12 14:38	08/06/12 19:12	7440-43-9	
Copper	**45.8**	mg/kg	0.49	0.039	1	08/03/12 14:38	08/06/12 19:12	7440-50-8	
Iron	**26500**	mg/kg	12.1	5.9	5	08/03/12 14:38	08/08/12 19:53	7439-89-6	
Lead	**92.0**	mg/kg	0.29	0.049	1	08/03/12 14:38	08/06/12 19:12	7439-92-1	
Manganese	**583**	mg/kg	0.24	0.019	1	08/03/12 14:38	08/06/12 19:12	7439-96-5	
Nickel	**5.7**	mg/kg	0.97	0.039	1	08/03/12 14:38	08/06/12 19:12	7440-02-0	
Selenium	**1.8**	mg/kg	0.73	0.17	1	08/03/12 14:38	08/06/12 19:12	7782-49-2	
Silver	**0.058U**	mg/kg	0.49	0.058	1	08/03/12 14:38	08/06/12 19:12	7440-22-4	
Thallium	**0.16U**	mg/kg	0.97	0.16	1	08/03/12 14:38	08/06/12 19:12	7440-28-0	
Zinc	**231**	mg/kg	0.97	0.14	1	08/03/12 14:38	08/06/12 19:12	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JACK-02-SD **Lab ID: 10200373029** Collected: 07/23/12 10:40 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
PSA Percent Sand,Silt,Clay	Analytical Method: ASA 15-5 mod								
Percent Clay	**5**	% (w/w)	0.10		1		08/03/12 16:57		
Percent Sand	**95**	% (w/w)	0.10		1		08/03/12 16:57		
Percent Silt	**0**	% (w/w)	0.10		1		08/03/12 16:57		
Texture	**Sand**				1		08/03/12 16:57		

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Sample: JACK-02-SD 10 MESH **Lab ID: 10200373030** Collected: 07/23/12 10:40 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**2230**	mg/kg	8.4	1.6	1	08/03/12 14:39	08/06/12 19:18	7429-90-5	
Antimony	**0.10U**	mg/kg	0.42	0.10	1	08/03/12 14:39	08/06/12 19:18	7440-36-0	
Arsenic	**18.3**	mg/kg	0.42	0.10	1	08/03/12 14:39	08/06/12 19:18	7440-38-2	
Cadmium	**1.7**	mg/kg	0.042	0.017	1	08/03/12 14:39	08/06/12 19:18	7440-43-9	
Copper	**34.7**	mg/kg	0.42	0.034	1	08/03/12 14:39	08/06/12 19:18	7440-50-8	
Iron	**22200**	mg/kg	10.5	5.1	5	08/03/12 14:39	08/08/12 19:59	7439-89-6	
Lead	**18.3**	mg/kg	0.25	0.042	1	08/03/12 14:39	08/06/12 19:18	7439-92-1	
Manganese	**385**	mg/kg	0.21	0.017	1	08/03/12 14:39	08/06/12 19:18	7439-96-5	
Nickel	**2.9**	mg/kg	0.84	0.034	1	08/03/12 14:39	08/06/12 19:18	7440-02-0	
Selenium	**2.6**	mg/kg	0.63	0.14	1	08/03/12 14:39	08/06/12 19:18	7782-49-2	
Silver	**0.050U**	mg/kg	0.42	0.050	1	08/03/12 14:39	08/06/12 19:18	7440-22-4	
Thallium	**1.7**	mg/kg	0.84	0.13	1	08/03/12 14:39	08/06/12 19:18	7440-28-0	
Zinc	**225**	mg/kg	0.84	0.12	1	08/03/12 14:39	08/06/12 19:18	7440-66-6	

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ANALYTICAL RESULTS

Project: 406950 Bullion Mine July 2012

Pace Project No.: 10200373

Sample: JACK-02-SD 80 MESH **Lab ID: 10200373031** Collected: 07/23/12 10:40 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**3610**	mg/kg	9.3	1.8	1	08/03/12 14:39	08/06/12 19:23	7429-90-5	
Antimony	**2.1**	mg/kg	0.46	0.11	1	08/03/12 14:39	08/06/12 19:23	7440-36-0	
Arsenic	**346**	mg/kg	0.46	0.11	1	08/03/12 14:39	08/06/12 19:23	7440-38-2	
Cadmium	**8.3**	mg/kg	0.046	0.019	1	08/03/12 14:39	08/06/12 19:23	7440-43-9	
Copper	**86.9**	mg/kg	0.46	0.037	1	08/03/12 14:39	08/06/12 19:23	7440-50-8	
Iron	**12100**	mg/kg	4.6	2.2	2	08/03/12 14:39	08/08/12 20:05	7439-89-6	
Lead	**109**	mg/kg	0.28	0.046	1	08/03/12 14:39	08/06/12 19:23	7439-92-1	
Manganese	**660**	mg/kg	0.23	0.019	1	08/03/12 14:39	08/06/12 19:23	7439-96-5	
Nickel	**3.4**	mg/kg	0.93	0.037	1	08/03/12 14:39	08/06/12 19:23	7440-02-0	
Selenium	**1.4**	mg/kg	0.69	0.16	1	08/03/12 14:39	08/06/12 19:23	7782-49-2	
Silver	**0.14J**	mg/kg	0.46	0.056	1	08/03/12 14:39	08/06/12 19:23	7440-22-4	
Thallium	**0.15U**	mg/kg	0.93	0.15	1	08/03/12 14:39	08/06/12 19:23	7440-28-0	
Zinc	**313**	mg/kg	0.93	0.13	1	08/03/12 14:39	08/06/12 19:23	7440-66-6	

REPORT OF LABORATORY ANALYSIS

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ANALYTICAL RESULTS

Project:	406950 Bullion Mine July 2012
Pace Project No.:	10200373

Sample: JACK-02-SD 230 MESH **Lab ID: 10200373032** Collected: 07/23/12 10:40 Received: 07/27/12 09:20 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050								
Aluminum	**7690**	mg/kg	9.8	1.9	1	08/03/12 14:39	08/06/12 19:28	7429-90-5	
Antimony	**4.9**	mg/kg	0.49	0.12	1	08/03/12 14:39	08/06/12 19:28	7440-36-0	
Arsenic	**470**	mg/kg	0.49	0.12	1	08/03/12 14:39	08/06/12 19:28	7440-38-2	
Cadmium	**14.6**	mg/kg	0.049	0.020	1	08/03/12 14:39	08/06/12 19:28	7440-43-9	
Copper	**176**	mg/kg	0.49	0.039	1	08/03/12 14:39	08/06/12 19:28	7440-50-8	
Iron	**26600**	mg/kg	12.3	5.9	5	08/03/12 14:39	08/06/12 19:34	7439-89-6	
Lead	**241**	mg/kg	0.29	0.049	1	08/03/12 14:39	08/06/12 19:28	7439-92-1	
Manganese	**1280**	mg/kg	1.2	0.098	5	08/03/12 14:39	08/06/12 19:34	7439-96-5	
Nickel	**7.2**	mg/kg	0.98	0.039	1	08/03/12 14:39	08/06/12 19:28	7440-02-0	
Selenium	**2.3**	mg/kg	0.74	0.17	1	08/03/12 14:39	08/06/12 19:28	7782-49-2	
Silver	**1.4**	mg/kg	0.49	0.059	1	08/03/12 14:39	08/06/12 19:28	7440-22-4	
Thallium	**0.25J**	mg/kg	0.98	0.16	1	08/03/12 14:39	08/06/12 19:28	7440-28-0	
Zinc	**761**	mg/kg	0.98	0.14	1	08/03/12 14:39	08/06/12 19:28	7440-66-6	

REPORT OF LABORATORY ANALYSIS

QUALITY CONTROL DATA

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

QC Batch: MPRP/34123 Analysis Method: EPA 6010
QC Batch Method: EPA 3050 Analysis Description: 6010 MET
Associated Lab Samples: 10200373002, 10200373003, 10200373004, 10200373006, 10200373007, 10200373008, 10200373010, 10200373011, 10200373012, 10200373014, 10200373015, 10200373016, 10200373018, 10200373019, 10200373020, 10200373026

METHOD BLANK: 1252892 Matrix: Solid
Associated Lab Samples: 10200373002, 10200373003, 10200373004, 10200373006, 10200373007, 10200373008, 10200373010, 10200373011, 10200373012, 10200373014, 10200373015, 10200373016, 10200373018, 10200373019, 10200373020, 10200373026

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Aluminum	mg/kg	1.8U	9.2	08/06/12 12:34	
Antimony	mg/kg	0.11U	0.46	08/06/12 12:34	
Arsenic	mg/kg	0.11U	0.46	08/06/12 12:34	
Cadmium	mg/kg	0.018U	0.046	08/06/12 12:34	
Copper	mg/kg	0.14J	0.46	08/06/12 12:34	
Iron	mg/kg	1.1U	2.3	08/06/12 12:34	
Lead	mg/kg	0.046U	0.28	08/06/12 12:34	
Manganese	mg/kg	0.018U	0.23	08/06/12 12:34	
Nickel	mg/kg	0.037U	0.92	08/06/12 12:34	
Selenium	mg/kg	0.16U	0.69	08/06/12 12:34	
Silver	mg/kg	0.055U	0.46	08/06/12 12:34	
Thallium	mg/kg	0.15U	0.92	08/06/12 12:34	
Zinc	mg/kg	0.31J	0.92	08/06/12 12:34	

LABORATORY CONTROL SAMPLE: 1252893

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum	mg/kg	476	399	84	80-120	
Antimony	mg/kg	47.6	41.2	87	80-120	
Arsenic	mg/kg	47.6	43.3	91	80-120	
Cadmium	mg/kg	47.6	40.6	85	80-120	
Copper	mg/kg	47.6	41.0	86	80-120	
Iron	mg/kg	476	413	87	80-120	
Lead	mg/kg	47.6	41.4	87	80-120	
Manganese	mg/kg	47.6	42.1	89	80-120	
Nickel	mg/kg	47.6	41.6	87	80-120	
Selenium	mg/kg	47.6	41.8	88	80-120	
Silver	mg/kg	23.8	20.3	85	80-120	
Thallium	mg/kg	47.6	41.7	87	80-120	
Zinc	mg/kg	47.6	41.4	87	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1252894 1252895

Parameter	Units	10200373002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/kg	2210	472	435	3240	2480	218	62	75-125	27	30	M1

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QUALITY CONTROL DATA

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1252894 1252895

Parameter	Units	10200373002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Antimony	mg/kg	0.37	47.2	43.5	35.1	48.9	74	112	75-125	33	30	D6,M1
Arsenic	mg/kg	33.0	47.2	43.5	113	1460	170	3280	75-125	171	30	D6,M1
Cadmium	mg/kg	1.3	47.2	43.5	41.5	57.0	85	128	75-125	31	30	D6,M1
Copper	mg/kg	21.6	47.2	43.5	57.8	56.4	77	80	75-125	2	30	
Iron	mg/kg	7200	472	435	6520	16300	-144	2090	75-125	86	30	D6,M1
Lead	mg/kg	9.6	47.2	43.5	127	50.9	249	95	75-125	86	30	D6,M1
Manganese	mg/kg	313	47.2	43.5	238	215	-158	-226	75-125	10	30	M1
Nickel	mg/kg	1.9	47.2	43.5	42.3	38.0	86	83	75-125	11	30	
Selenium	mg/kg	0.84	47.2	43.5	41.3	39.2	86	88	75-125	5	30	
Silver	mg/kg	0.045U	23.6	21.7	19.9	17.9	84	82	75-125	10	30	
Thallium	mg/kg	0.12J	47.2	43.5	38.4	36.8	81	84	75-125	4	30	
Zinc	mg/kg	66.5	47.2	43.5	100	116	72	114	75-125	15	30	M1

MATRIX SPIKE SAMPLE: 1252896

Parameter	Units	10200373026 Result	Spike Conc.	MS Result	MS % Rec	% Rec Limits	Qualifiers
Aluminum	mg/kg	2610	664	3160	83	75-125	
Antimony	mg/kg	0.10U	66.4	34.3	52	75-125	M1
Arsenic	mg/kg	23.0	66.4	73.5	76	75-125	
Cadmium	mg/kg	0.73	66.4	40.2	59	75-125	M1
Copper	mg/kg	12.5	66.4	48.9	55	75-125	M1
Iron	mg/kg	6440	664	7070	94	75-125	
Lead	mg/kg	18.6	66.4	56.9	58	75-125	M1
Manganese	mg/kg	200	66.4	311	166	75-125	M1
Nickel	mg/kg	2.0	66.4	42.1	60	75-125	M1
Selenium	mg/kg	0.61J	66.4	42.1	63	75-125	M1
Silver	mg/kg	0.051U	33.2	18.9	57	75-125	M1
Thallium	mg/kg	0.14U	66.4	39.1	59	75-125	M1
Zinc	mg/kg	52.9	66.4	106	79	75-125	

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QUALITY CONTROL DATA

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

QC Batch: MPRP/34124 Analysis Method: EPA 6010
QC Batch Method: EPA 3050 Analysis Description: 6010 MET
Associated Lab Samples: 10200373027, 10200373028, 10200373030, 10200373031, 10200373032

METHOD BLANK: 1252897 Matrix: Solid
Associated Lab Samples: 10200373027, 10200373028, 10200373030, 10200373031, 10200373032

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Aluminum	mg/kg	1.9U	9.9	08/06/12 18:49	
Antimony	mg/kg	0.12U	0.50	08/06/12 18:49	
Arsenic	mg/kg	0.12U	0.50	08/06/12 18:49	
Cadmium	mg/kg	0.020U	0.050	08/06/12 18:49	
Copper	mg/kg	0.059J	0.50	08/06/12 18:49	
Iron	mg/kg	1.2U	2.5	08/06/12 18:49	
Lead	mg/kg	0.050U	0.30	08/06/12 18:49	
Manganese	mg/kg	0.020U	0.25	08/06/12 18:49	
Nickel	mg/kg	0.040U	0.99	08/06/12 18:49	
Selenium	mg/kg	0.17U	0.74	08/06/12 18:49	
Silver	mg/kg	0.059U	0.50	08/06/12 18:49	
Thallium	mg/kg	0.16U	0.99	08/06/12 18:49	
Zinc	mg/kg	0.20J	0.99	08/06/12 18:49	

LABORATORY CONTROL SAMPLE: 1252898

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum	mg/kg	485	445	92	80-120	
Antimony	mg/kg	48.5	44.9	92	80-120	
Arsenic	mg/kg	48.5	47.9	99	80-120	
Cadmium	mg/kg	48.5	43.8	90	80-120	
Copper	mg/kg	48.5	42.1	87	80-120	
Iron	mg/kg	485	464	96	80-120	
Lead	mg/kg	48.5	46.0	95	80-120	
Manganese	mg/kg	48.5	44.6	92	80-120	
Nickel	mg/kg	48.5	45.0	93	80-120	
Selenium	mg/kg	48.5	48.2	99	80-120	
Silver	mg/kg	24.3	21.0	87	80-120	
Thallium	mg/kg	48.5	46.1	95	80-120	
Zinc	mg/kg	48.5	47.4	98	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1252899 1252900

Parameter	Units	10200373027 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/kg	3260	476	446	3740	3780	101	117	75-125	1	30	
Antimony	mg/kg	0.090U	47.6	44.6	34.8	32.2	73	72	75-125	8	30	M1
Arsenic	mg/kg	47.1	47.6	44.6	77.7	106	64	133	75-125	31	30	D6,M1
Cadmium	mg/kg	1.2	47.6	44.6	44.0	41.7	90	91	75-125	5	30	
Copper	mg/kg	18.1	47.6	44.6	52.6	60.3	72	95	75-125	14	30	M1

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QUALITY CONTROL DATA

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1252899 1252900

Parameter	Units	10200373027 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Iron	mg/kg	8430	476	446	7280	8810	-240	87	75-125	19	30	M1
Lead	mg/kg	33.3	47.6	44.6	68.1	73.9	73	91	75-125	8	30	M1
Manganese	mg/kg	287	47.6	44.6	321	327	72	90	75-125	2	30	M1
Nickel	mg/kg	2.9	47.6	44.6	45.9	43.4	90	91	75-125	6	30	
Selenium	mg/kg	0.48J	47.6	44.6	46.7	44.5	97	99	75-125	5	30	
Silver	mg/kg	0.23J	23.8	22.3	20.6	19.1	86	85	75-125	7	30	
Thallium	mg/kg	0.12U	47.6	44.6	42.2	39.6	89	89	75-125	6	30	
Zinc	mg/kg	90.9	47.6	44.6	121	153	64	139	75-125	23	30	M1

REPORT OF LABORATORY ANALYSIS

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QUALITY CONTROL DATA

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

QC Batch: MPRP/34317 Analysis Method: EPA 6010
QC Batch Method: EPA 3050 Analysis Description: 6010 MET
Associated Lab Samples: 10200373022, 10200373023, 10200373024

METHOD BLANK: 1259397 Matrix: Solid
Associated Lab Samples: 10200373022, 10200373023, 10200373024

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Aluminum	mg/kg	1.6U	8.5	08/08/12 20:18	
Antimony	mg/kg	0.10U	0.42	08/08/12 20:18	
Arsenic	mg/kg	0.10U	0.42	08/08/12 20:18	
Cadmium	mg/kg	0.017U	0.042	08/08/12 20:18	
Copper	mg/kg	0.034U	0.42	08/08/12 20:18	
Iron	mg/kg	1.0U	2.1	08/08/12 20:18	
Lead	mg/kg	0.042U	0.25	08/08/12 20:18	
Manganese	mg/kg	0.017U	0.21	08/08/12 20:18	
Nickel	mg/kg	0.034U	0.85	08/08/12 20:18	
Selenium	mg/kg	0.14U	0.64	08/08/12 20:18	
Silver	mg/kg	0.051U	0.42	08/08/12 20:18	
Thallium	mg/kg	0.14U	0.85	08/08/12 20:18	
Zinc	mg/kg	0.21J	0.85	08/08/12 20:18	

LABORATORY CONTROL SAMPLE: 1259398

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum	mg/kg	472	463	98	80-120	
Antimony	mg/kg	47.2	44.1	93	80-120	
Arsenic	mg/kg	47.2	44.6	95	80-120	
Cadmium	mg/kg	47.2	44.8	95	80-120	
Copper	mg/kg	47.2	46.7	99	80-120	
Iron	mg/kg	472	480	102	80-120	
Lead	mg/kg	47.2	46.1	98	80-120	
Manganese	mg/kg	47.2	46.2	98	80-120	
Nickel	mg/kg	47.2	46.2	98	80-120	
Selenium	mg/kg	47.2	44.2	94	80-120	
Silver	mg/kg	23.6	22.3	95	80-120	
Thallium	mg/kg	47.2	45.3	96	80-120	
Zinc	mg/kg	47.2	46.7	99	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1259399 1259400

Parameter	Units	10200373022 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/kg	3110	413	413	4000	4220	214	268	75-125	5	30	M1
Antimony	mg/kg	0.48J	41.3	41.3	34.5	37.8	82	90	75-125	9	30	
Arsenic	mg/kg	930	41.3	41.3	147	806	-1890	-300	75-125	138	30	D6,M1
Cadmium	mg/kg	17.3	41.3	41.3	42.7	52.2	61	84	75-125	20	30	M1
Copper	mg/kg	255	41.3	41.3	128	125	-306	-314	75-125	3	30	M1

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QUALITY CONTROL DATA

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1259399 1259400

Parameter	Units	10200373022 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Iron	mg/kg	29600	413	413	9520	8960	-4870	-5010	75-125	6	30	M1
Lead	mg/kg	70.4	41.3	41.3	105	159	83	214	75-125	41	30	D6,M1
Manganese	mg/kg	313	41.3	41.3	485	425	417	271	75-125	13	30	M1
Nickel	mg/kg	2.0	41.3	41.3	43.6	42.0	101	97	75-125	4	30	
Selenium	mg/kg	0.95	41.3	41.3	40.1	39.9	95	94	75-125	.5	30	
Silver	mg/kg	0.059U	20.7	20.7	19.8	19.7	96	95	75-125	.9	30	
Thallium	mg/kg	1.8	41.3	41.3	38.8	38.3	89	88	75-125	1	30	
Zinc	mg/kg	247	41.3	41.3	180	187	-161	-143	75-125	4	30	M1

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1259401 1259402

Parameter	Units	10200373023 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/kg	4820	360	347	5780	6730	268	551	75-125	15	30	M1
Antimony	mg/kg	3.9	36	34.7	24.8	23.5	58	56	75-125	6	30	M1
Arsenic	mg/kg	448	36	34.7	414	474	-92	77	75-125	13	30	M1
Cadmium	mg/kg	10.2	36	34.7	42.2	44.0	89	97	75-125	4	30	
Copper	mg/kg	168	36	34.7	206	241	107	210	75-125	15	30	M1
Iron	mg/kg	15500	360	347	15300	17700	-51	630	75-125	14	30	M1
Lead	mg/kg	203	36	34.7	152	217	-141	41	75-125	35	30	D6,M1
Manganese	mg/kg	548	36	34.7	611	618	176	200	75-125	1	30	M1
Nickel	mg/kg	3.6	36	34.7	37.2	37.1	93	96	75-125	.3	30	
Selenium	mg/kg	0.97	36	34.7	34.8	34.1	94	95	75-125	2	30	
Silver	mg/kg	0.44	18	17.4	17.4	17.5	95	98	75-125	.009	30	
Thallium	mg/kg	0.12U	36	34.7	32.0	30.9	89	89	75-125	3	30	
Zinc	mg/kg	333	36	34.7	351	463	49	375	75-125	28	30	M1

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1259403 1259404

Parameter	Units	10200373024 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/kg	11000	481	463	13700	13100	562	450	75-125	5	30	M1
Antimony	mg/kg	5.4	48.1	46.3	33.0	26.5	57	46	75-125	22	30	M1
Arsenic	mg/kg	759	48.1	46.3	820	844	127	183	75-125	3	30	M1
Cadmium	mg/kg	20.5	48.1	46.3	66.7	64.6	96	95	75-125	3	30	
Copper	mg/kg	521	48.1	46.3	589	574	142	114	75-125	3	30	M1
Iron	mg/kg	34300	481	463	35900	36800	335	543	75-125	2	30	M1
Lead	mg/kg	332	48.1	46.3	410	381	163	107	75-125	7	30	M1
Manganese	mg/kg	1120	48.1	46.3	1190	1230	135	226	75-125	3	30	M1
Nickel	mg/kg	7.5	48.1	46.3	53.7	49.4	96	91	75-125	8	30	
Selenium	mg/kg	1.5	48.1	46.3	49.4	45.1	100	94	75-125	9	30	
Silver	mg/kg	2.0	24	23.1	26.5	23.8	102	94	75-125	11	30	
Thallium	mg/kg	0.64J	48.1	46.3	43.9	39.8	90	85	75-125	10	30	
Zinc	mg/kg	783	48.1	46.3	835	825	110	91	75-125	1	30	

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QUALITY CONTROL DATA

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1259405 1259406

Parameter	Units	10200394010 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/kg	964	459	439	2800	2280	401	300	75-125	21	30	M1
Antimony	mg/kg	9.7	45.9	43.9	53.6	115	96	241	75-125	73	30	D6,M1
Arsenic	mg/kg	317	45.9	43.9	1120	691	1750	853	75-125	47	30	M1
Cadmium	mg/kg	8.7	45.9	43.9	62.1	52.9	116	101	75-125	16	30	
Copper	mg/kg	260	45.9	43.9	226	164	-74	-220	75-125	32	30	D6,M1
Iron	mg/kg	10400	459	439	22500	11400	2630	228	75-125	65	30	D6,M1
Lead	mg/kg	316	45.9	43.9	1180	919	1880	1380	75-125	25	30	M1
Manganese	mg/kg	618	45.9	43.9	503	572	-251	-104	75-125	13	30	M1
Nickel	mg/kg	0.63J	45.9	43.9	44.5	42.8	96	96	75-125	4	30	
Selenium	mg/kg	1.3	45.9	43.9	44.7	42.2	95	93	75-125	6	30	
Silver	mg/kg	0.69	22.9	21.9	25.8	25.0	110	111	75-125	3	30	
Thallium	mg/kg	1.5	45.9	43.9	44.0	41.2	93	91	75-125	7	30	
Zinc	mg/kg	412	45.9	43.9	543	334	285	-178	75-125	48	30	D6,M1

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1259407 1259408

Parameter	Units	10200394011 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/kg	1630	388	342	3310	3260	433	476	75-125	2	30	M1
Antimony	mg/kg	49.6	38.8	34.2	47.5	48.6	-5	-3	75-125	2	30	M1
Arsenic	mg/kg	1870	38.8	34.2	725	1060	-2960	-2380	75-125	37	30	D6,M1
Cadmium	mg/kg	32.0	38.8	34.2	51.6	53.3	51	62	75-125	3	30	M1
Copper	mg/kg	269	38.8	34.2	239	226	-77	-125	75-125	5	30	M1
Iron	mg/kg	17300	388	342	13900	11300	-859	-1740	75-125	21	30	M1
Lead	mg/kg	1160	38.8	34.2	539	1190	-1600	90	75-125	75	30	D6,M1
Manganese	mg/kg	891	38.8	34.2	808	604	-214	-838	75-125	29	30	M1
Nickel	mg/kg	1.2	38.8	34.2	37.9	34.2	95	96	75-125	10	30	
Selenium	mg/kg	1.8	38.8	34.2	38.9	34.2	96	95	75-125	13	30	
Silver	mg/kg	4.5	19.4	17.1	21.8	20.6	89	94	75-125	6	30	
Thallium	mg/kg	2.2	38.8	34.2	37.5	33.7	91	92	75-125	11	30	
Zinc	mg/kg	580	38.8	34.2	486	435	-241	-422	75-125	11	30	M1

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1259409 1259410

Parameter	Units	10200394012 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/kg	5510	495	407	8300	9410	563	959	75-125	13	30	M1
Antimony	mg/kg	65.3	49.5	40.7	94.7	84.5	60	47	75-125	11	30	M1
Arsenic	mg/kg	3830	49.5	40.7	3810	3900	-49	164	75-125	2	30	M1
Cadmium	mg/kg	67.9	49.5	40.7	118	106	102	94	75-125	11	30	
Copper	mg/kg	817	49.5	40.7	899	874	165	140	75-125	3	30	M1
Iron	mg/kg	33700	495	407	46400	46100	2560	3060	75-125	.5	30	M1
Lead	mg/kg	2160	49.5	40.7	2340	2230	373	183	75-125	5	30	M1
Manganese	mg/kg	2220	49.5	40.7	2200	2200	-51	-62	75-125	.01	30	M1

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QUALITY CONTROL DATA

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1259409 1259410

Parameter	Units	10200394012 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Nickel	mg/kg	3.5	49.5	40.7	50.1	41.4	94	93	75-125	19	30	
Selenium	mg/kg	4.1	49.5	40.7	50.6	41.2	94	91	75-125	20	30	
Silver	mg/kg	11.8	24.8	20.3	36.5	31.4	100	96	75-125	15	30	
Thallium	mg/kg	4.5	49.5	40.7	48.8	40.1	90	88	75-125	20	30	
Zinc	mg/kg	1460	49.5	40.7	1570	1470	222	37	75-125	6	30	M1

REPORT OF LABORATORY ANALYSIS

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QUALIFIERS

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

DEFINITIONS

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

ND - Not Detected at or above adjusted reporting limit.

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

MDL - Adjusted Method Detection Limit.

PRL - Pace Reporting Limit.

RL - Reporting Limit.

S - Surrogate

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

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

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

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

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

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

TNI - The NELAC Institute.

LABORATORIES

PASI-M	Pace Analytical Services - Minneapolis
PASI-MT	Pace Analytical Services - Montana

ANALYTE QUALIFIERS

D6	The relative percent difference (RPD) between the sample and sample duplicate exceeded laboratory control limits.
M1	Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.

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QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: 406950 Bullion Mine July 2012
Pace Project No.: 10200373

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
10200373002	**JILL-01-SD 10 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373003	**JILL-01-SD 80 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373004	**JILL-01-SD 230 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373006	**JILL-02-SD 10 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373007	**JILL-02-SD 80 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373008	**JILL-02-SD 230 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373010	**JILL-03-SD 10 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373011	**JILL-03-SD 80 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373012	**JILL-03-SD 230 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373014	**JILL-03-FD 10 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373015	**JILL-03-FD 80 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373016	**JILL-03-FD 230 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373018	**JILL-04-SD 10 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373019	**JILL-04-SD 80 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373020	**JILL-04-SD 230 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373022	**JILL-04-FD-MS/MSD 10 MESH**	EPA 3050	MPRP/34317	EPA 6010	ICP/14009
10200373023	**JILL-04-FD-MS/MSD 80 MESH**	EPA 3050	MPRP/34317	EPA 6010	ICP/14009
10200373024	**JILL-04-FD-MS/MSD 230 MESH**	EPA 3050	MPRP/34317	EPA 6010	ICP/14009
10200373026	**JACK-01-SD 10 MESH**	EPA 3050	MPRP/34123	EPA 6010	ICP/13985
10200373027	**JACK-01-SD 80 MESH**	EPA 3050	MPRP/34124	EPA 6010	ICP/13986
10200373028	**JACK-01-SD 230 MESH**	EPA 3050	MPRP/34124	EPA 6010	ICP/13986
10200373030	**JACK-02-SD 10 MESH**	EPA 3050	MPRP/34124	EPA 6010	ICP/13986
10200373031	**JACK-02-SD 80 MESH**	EPA 3050	MPRP/34124	EPA 6010	ICP/13986
10200373032	**JACK-02-SD 230 MESH**	EPA 3050	MPRP/34124	EPA 6010	ICP/13986
10200373001	**JILL-01-SD**	ASA 15-5 mod	MT/9614		
10200373005	**JILL-02-SD**	ASA 15-5 mod	MT/9614		
10200373009	**JILL-03-SD**	ASA 15-5 mod	MT/9614		
10200373013	**JILL-03-FD**	ASA 15-5 mod	MT/9614		
10200373017	**JILL-04-SD**	ASA 15-5 mod	MT/9614		
10200373021	**JILL-04-FD-MS/MSD**	ASA 15-5 mod	MT/9614		
10200373025	**JACK-01-SD**	ASA 15-5 mod	MT/9614		
10200373029	**JACK-02-SD**	ASA 15-5 mod	MT/9614		

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CHAIN-OF-CUSTODY / Analytical Request Document

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

Page: of

1496770

Section A Required Client Information:	Section B Required Project Information:	Section C Invoice Information:
Company: CH2M HILL	Report To: DENNIS SMITH	Attention: DENNIS SMITH
Address: 322 EAST FRONT ST	Copy To: JEFF SCHUT	Company Name: CH2M HILL
BOISE ID 83702	MIKE WIRTZ	Address: 322 EAST FRONTST SUITE 200
Email To:	Purchase Order No.:	Pace Quote Reference:
Phone: 208-345-5310 Fax: 2083455315	Project Name: BILLION MINE JULY 2012	Pace Project Manager:
Requested Due Date/TAT:	Project Number: 406950	Pace Profile #:

REGULATORY AGENCY: ☐ NPDES ☐ GROUND WATER ☐ DRINKING WATER ☐ UST ☐ RCRA ☐ OTHER ______

Site Location STATE: MT

Section D Required Client Information

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

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

Requested Analysis Filtered (Y/N)

Analysis Tests: (A) Al, Sb, As, Cd, Co, Fe — N; (B) Pb, Mn, Ni, Se, Ag — N; (C) Tl, Zn — N; (D) MATRIX SPIKE — N

ITEM #	SAMPLE ID	MATRIX CODE	SAMPLE TYPE (G=GRAB C=COMP)	COMPOSITE START DATE	COMPOSITE START TIME	COMPOSITE END/GRAB DATE	COMPOSITE END/GRAB TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Unpreserved	H_2SO_4	HNO_3	HCl	NaOH	$Na_2S_2O_3$	Methanol	Other	Al, Sb, As, Cd, Co, Fe	Pb, Mn, Ni, Se, Ag	Tl, Zn	MATRIX SPIKE	Residual Chlorine (Y/N)	Pace Project No./ Lab I.D. 10200323
1	JILL-01-SD	SL	G			7/23/12	1223		1	X								X	X	X		N	001,002,003,004
2	JILL-02-SD	SL	G			7/23/12	1220		1	X								X	X	X		N	005,006,007,008
3	JILL-03-SD	SL	G			7/23/12	1203		1	X								X	X	X		N	009,010,011,012
4	JILL-03-FD	SL	G			7/23/12	1203		1	X								X	X	X		N	013,014,015,016
5	JILL-04-SD	SL	G			7/23/12	1144		1	X								X	X	X		N	017,018,019,020
6	JILL-04-FD-MS/MSD	SL	G			7/23/12	1144		1	X								X	X	X	X	N	021,022,023,024
7	JACK-01-SD	SL	G			7/23/12	1055		1	X								X	X	X		N	025,026,027,028
8	JACK-02-SD	SL	G			7/23/12	1040		1	X								X	X	X		N	029,030,031,032
9																							
10																							
11																							
12																							

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME
EMAIL RESULTS TO	[signature] CH2M	7/26/12	1600			
DENNIS.SMITH@CH2M.COM	FedEX	7/27/12	9:20	Sherri Cline Pace	7/27/12	9:20
JEFF.SCHUTT@CH2M.COM						
MIKE.WIRTZ@CH2M.COM						

SAMPLE CONDITIONS

Temp in °C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)
2.8	Y	Y	Y

ORIGINAL

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: MICHAEL WIRTZ

SIGNATURE of SAMPLER: [signature] DATE Signed (MM/DD/YY): 07/26/12

*Important Note: By signing this form you are accepting Pace's NET 30 day payment terms and agreeing to late charges of 1.5% per month for any invoices not paid within 30 days.

F-ALL-Q-020rev.07, 15-May-2007

Pace Analytical®	Document Name: **Sample Condition Upon Receipt Form**	Revised Date: 01Nov2011 Page 1 of 1
	Document Number: **F-MT-C-184 Rev.00**	Issuing Authority: Pace Minnesota Quality Office

Sample Condition Upon Receipt

Client Name: CH2M Hill Bullion Mine

Project # 10200323

Optional
Proj. Due Date:
Proj. Name:

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

Tracking #: 5370 1150 8507

Custody Seal on Cooler/Box Present: ☒ yes ☐ no Seals intact: ☒ yes ☐ no

Packing Material: ☐ Bubble Wrap ☒ Bubble Bags ☐ None ☐ Other ________ Temp Blank: Yes X No ____

Thermometer Used 1383045 or 135 **Type of Ice:** (Wet) Blue None ☐ Samples on ice, cooling process has begun

Cooler Temperature 2.8 **Biological Tissue is Frozen:** Yes (No)

Temp should be above freezing to 6°C

Date and Initials of person examining contents: 7/27/12 SC

		Comments:
Chain of Custody Present:	☒Yes ☐No ☐N/A	1.
Chain of Custody Filled Out:	☒Yes ☐No ☐N/A	2.
Chain of Custody Relinquished:	☒Yes ☐No ☐N/A	3.
Sampler Name & Signature on COC:	☒Yes ☐No ☐N/A	4.
Samples Arrived within Hold Time:	☒Yes ☐No ☐N/A	5.
Short Hold Time Analysis (<72hr):	☐Yes ☒No ☐N/A	6.
Rush Turn Around Time Requested:	☐Yes ☒No ☐N/A	7.
Sufficient Volume:	☒Yes ☐No ☐N/A	8.
Correct Containers Used:	☒Yes ☐No ☐N/A	9.
-Pace Containers Used:	☒Yes ☐No ☐N/A	
Containers Intact:	☒Yes ☐No ☐N/A	10.
Filtered volume received for Dissolved tests	☐Yes ☒No ☐N/A	11.
Sample Labels match COC:	☒Yes ☐No ☐N/A	12.
-Includes date/time/ID/Analysis Matrix: Soil		
All containers needing acid/base preservation have been checked. Noncompliance are noted in 13.	☐Yes ☐No ☒N/A	13. ☐ HNO3 ☐ H2SO4 ☐ NaOH ☐ HCl Samp #
All containers needing preservation are found to be in compliance with EPA recommendation.	☐Yes ☐No ☒N/A	
Exceptions: VOA,Coliform, TOC, Oil and Grease, WI-DRO (water)	☐Yes ☒No	Initial when completed / Lot # of added preservative
Samples checked for dechlorination:	☐Yes ☐No ☒N/A	14.
Headspace in VOA Vials (>6mm):	☐Yes ☐No ☒N/A	15.
Trip Blank Present:	☐Yes ☐No ☒N/A	16.
Trip Blank Custody Seals Present	☐Yes ☐No ☒N/A	
Pace Trip Blank Lot # (if purchased): ________		

Client Notification/ Resolution: Field Data Required? Y / N

Person Contacted: ____________________ Date/Time: ____________

Comments/ Resolution: ____________________

Project Manager Review: [signature] **Date:** 7-27-12

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

Appendix E
Geology Technical Memorandum

Bullion Mine Geology Report

PREPARED FOR: Dennis Smith/CH2M HILL

PREPARED BY: Greg Warren/CH2M HILL

DATE: July 15, 2011

Scope of Geologic/Drilling Investigation

This report summarizes the preliminary geologic exploration that was conducted for the Crystal Mine remedial investigation. The purpose of the geologic exploration was to gather subsurface information at the site and provide basic geologic and hydrogeologic data to assist in evaluating remedial alternatives to reduce acid mine drainage (AMD). The geologic investigation scope of this project included the following:

- Drilling a vertical boring to intercept the lower adit tunnel
- Video logging the adit intercept boring
- Drilling vertical soil borings
- Installing monitoring wells and piezometers to measure groundwater levels
- Logging the borings and evaluating subsurface conditions
- Conducting a geophysical investigation
- Conducting general site geologic reconnaissance and observations
- Preparing this technical memorandum to report the findings of the investigation.

Drilling Investigation

The drilling and geologic exploration was conducted in August 2010 by a CH2M HILL engineering geologist. The borings were drilled by Axis Drilling, Inc. of Belgrade, Montana, under subcontract to CH2M HILL. The borings were advanced using track-mounted drilling equipment, equipped with a Tubex 3-7/8- or 5-7/8-inch-diameter downhole hammer. Standard penetration tests (SPTs) were conducted during the drilling in accordance with ASTM D1586—*Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*. The SPT samplers were driven using a 140-pound hammer free falling for 30 inches, for a total penetration of 1.5 feet. The number of blows required for each 6 inches was recorded during the driving of the sample, and is collectively referred to as "blow counts." The sum of the blow counts for the last 1 foot of the driving distance is the "N-value." "Refusal" is the condition in which the sampler is driven less than 6 inches after 50 blows, or less than 12 inches after 100 blows. After the sampler was driven and the blow counts were recorded, the sampler was withdrawn from the borehole for recovery of the disturbed soil sample. If the drilling indicated hard rock, then no attempt to drive an SPT was made and the cuttings only were logged.

The soil borings were logged by a CH2M HILL engineering geologist in accordance with ASTM 5434 *Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock*. Soil and rock samples were examined in the field and were visually classified in accordance with ASTM D2488, *Description and Identification of Soils (Visual-Manual Procedure)*. The soil boring logs are contained in Attachment 1.

Soil Borings and Monitoring Well Installation

The soil borings were located in order to install monitoring wells in position to evaluate an upgradient to downgradient hydrogeologic section. Originally the intent was to determine the presence of shallow groundwater at the soil/bedrock interface. However, the depth to rock was very shallow in most areas (within a few feet of ground surface) and at the time of drilling this interface was dry. Therefore, the borings were drilled to depths between 25 and 60 feet, deep enough to encounter the first water-bearing zones actually within weathered and fractured bedrock.

The monitoring wells were drilled and completed in compliance with the ASTM D5092 *Standard Practice for design and Installation of Ground Water Monitoring Wells in Aquifers* and Administrative Rules of Montana *(ARM 36.21.8)*

The monitoring well casings and screens consisted of threaded, flush-jointed, 2-inch-diameter, Schedule 40 polyvinyl chloride (PVC). The well screens and casings were installed inside the 6-inch steel casing to center the well and allow placement of annular materials. A 10-foot section of factory-slotted screen was installed at the bottom of each well. Colorado silica sand (10-20 gradation) was placed around the screen to act as a filter pack. The filter pack extended approximately 1 to 2 feet above the top of the well screen. No PVC glues or solvents were used. Bentonite chips were placed on top of the sand pack to provide a seal. Bentonite chips were placed in the boring annulus and hydrated to provide a seal from the top of the sand pack to within 2 feet of the ground surface. The filter sand and bentonite were slowly poured into the borehole while the steel casing was retracted to prevent bridging. The levels of the sand and bentonite were continuously tagged with a weighted tape to ensure proper placement.

The wells were finished using an aboveground monument that consists of a 6-inch-diameter steel casing with approximately 2.0 to 3.0 feet of stickup and a locking cover. The steel pipe was set approximately 2.5 feet below ground surface (bgs) and held in place by Redi-mix concrete. A J plug was installed on the top of the PVC well casing.

Piezometer Installation

Standpipe drive-point piezometers were installed below the lower Bullion Adit and along Jill Creek in order to measure shallow groundwater levels and collect groundwater samples. These were installed in place of monitoring wells because: (1) the steep terrain precluded drill rig access; (2) on the basis of geophysics results, bedrock was very shallow (less than 10 feet bgs); and (3) based on the prevalence of seeps and springs, it was anticipated that groundwater was very near the surface.

The piezometers consisted of 3/4-inch-diameter, Soloinst® Model 615N stainless steel drive point piezometers. The screened portions consist of 1-foot-long, stainless steel 50 mesh, and attached to a 3/4-inch-diameter, 5-foot-long steel threaded riser pipes. The piezometers were installed by hand using a slide hammer to drive the points until refusal. The piezometers were driven to depths between approximately 7 and 11 feet bgs.

The wells and piezometers were surveyed by CH2M HILL surveyors, using Leica survey-grade global positioning system (GPS) units. The datum is a local modified Montana State Plane (NAD83) coordinate system with NAVD 88 elevations. Figure 1 shows the locations of monitoring wells and piezometers and groundwater contours. The well construction diagrams are contained in Attachment 2. Table 1 shows the borehole, well construction, and piezometer details. Attachment 3 contains photographs of site activities and drilling.

Monitoring Well Development

The new monitoring wells were developed after the wells were fully constructed. The wells were developed by a combination of surging and bailing to remove the sandy material and develop the filter pack within the annulus. Depth to water and drawdown were recorded during well development for future reference. Because of low well productivity, thin saturated zone, and the low-yield, weathered, clayey nature of the surrounding granitic bedrock, the wells were typically bailed dry and allowed to recover rather than pumped. Therefore it was difficult to remove enough water to reduce the turbidity and clean the annular sand pack. The piezometers were pumped using a peristaltic pump and Teflon/plastic tubing.

Vertical Adit Intercept Boring

The vertical adit intercept boring was drilled to a depth of approximately 80 feet deep in order to intercept the lower Bullion Adit, evaluate mine flooding and groundwater inflow, collect water samples, and video log the borehole and adit. The drilling was conducted using a Tubex downhole hammer with 4-inch casing of the first 13 feet, then 3-7/8-inch open hole until intercepting the adit. The borehole was drilled at a surveyed location above the adit location based on previous subsurface mapping. This boring intercepted the adit at a depth of approximately 74 feet bgs and touched the bottom at 80 feet bgs (elevations that correspond with 7317.69 and 7311.69 respectively). The boring intercepted the adit approximately 280 feet up-adit from the portal.

A 2-inch PVC casing was temporarily installed in the open borehole to prevent incidental caving of the borehole until video logging. Prior to video logging, the PVC pipe was removed and the hole was left open for future sampling and video logging, and protected with an aboveground steel monument cemented into the ground surface with a locking cover to prevent vandalism.

Geophysical Investigation

A geophysical exploration was conducted in order to determine P-Wave structure in the shallow subsurface, depth to rock, and seismic velocity of the sediments and rock in the shallow subsurface (0 to 50 feet). The primary goals of the geophysical investigation for this project were to determine: (1) subsurface profile down to bedrock and estimate seismic velocities in the area along Jill Creek at the proposed groundwater cutoff wall; and (2) to evaluate depth to rock and seismic velocity along a profile above the Bullion Mine to assist in scoping the drilling and groundwater investigation.

TABLE 1
Borehole, Well Construction, and Piezometer Details

Well ID	Installation Date	Latitude (d-m-s.ss)	Longitude (d-m-s.ss)	Ground Elev. (ft amsl)	M.P. Elev. (ft amsl)	Borehole Depth (ft bgs)	Borehole Dia. (inches)	Casing Dia. (inches)	Screen Length (ft)	Screen Slot Size	Screen Depth (ft bgs)		Sand Filter Mesh	Sand Pack Interval (ft bgs)		Water Levels	
											Top	Bottom		Top	Bottom	DTW[a] (ft bgs)	Water Elevation (ft amsl)
BM-B-1[b]	8/18/2010	46-21-18.61	112-17-38.61	7391.69	N/A	80.5	3.8 / 4	---	---	---	---	---	---	---	---	48.5	7343.19
BM-MW-1	8/28/2010	46-21-13.29	112-17-24.18	7701.55	7704.05	60	6	2	10	0.02”	49.5	59.5	10-20	48	60	54.38	7649.67
BM-MW-2	8/27/2010	46-21-15.65	112-17-28.47	7581.98	7584.48	50	6	2	10	0.02”	40	50	10-20	38	50	47.35	7537.13
BM-MW-3	8/26/2010	46-21-15.50	112-17-31.38	7558.84	7561.34	45	6	2	10	0.02”	34	44	10-20	32.5	44	35.93	7525.41
BM-MW-4	8/25/2010	46-21-17.10	112-17-34.62	7469.17	7471.68	25	6	2	10	0.02”	14	24	10-20	12.8	24	16.68	7455.00
P-1		46-21-22.25	112-17-43.16	7260.57	7262.59	9.0	1.0	¾	1	0.01”	8.0	9.0	---	---	---	8.14	7254.45
P-2		46-21-23.08	112-17-42.20	7247.58	7249.43	7.2	1.0	¾	1	0.01”	6.2	7.2	---	---	---	7.31	7242.12
P-3		46-21-21.37	112-17-42.13	7283.10	7284.83	7.3	1.0	¾	1	0.01”	6.3	7.3	---	---	---	4.88	7279.95
P-4		46-21-25.80	112-17-45.63	7143.58	7145.40	7.2	1.0	¾	1	0.01”	6.2	7.2	---	---	---	2.59	7142.81
P-5		46-21-26.56	112-17-48.29	7119.15	7120.95	7.2	1.0	¾	1	0.01”	6.2	7.2	---	---	---	4.78	7116.17
P-6		46-21-29.57	112-17-51.27	7084.77	7087.75	6.0	1.0	¾	1	0.01”	5.0	6.0	---	---	---	4.61	7083.14

Notes:
amsl = above mean sea level
bgs = below ground surface
DTW = depth to water below measuring point
ft = feet
ID = identification
in = inches
MP = measuring point

[a] Depth to Water measured on September 24 and 30, 2010

[b] No PVC monitoring well was installed in BM-B-1; only a protective steel surface casing

The field geophysical exploration program consisted of P-Wave Seismic Refraction Surveys and was conducted by Sage Earth Science (Sage) of Idaho Falls, Idaho, under contract to CH2M HILL. Sage used seismic refraction techniques in accordance with ASTM 5777-00 *"Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation."* Depth-to-rock calculations were made along a profile on 16.4-foot (5-meter) spacing. Based on anticipated conditions that exist at the site, Sage used a 378-foot seismic spread with 24-channel engineering seismograph (Bison Model 9024) and sledge hammer to create waves. At each spread location, a fully-reversed profile to account for dipping or sloping interfaces was conducted. Sage prepared profiles that included seismic compression wave velocities and depth to the first refractive horizon (that is, rock).

Sage conducted a total of approximately 3,150 feet of continuous P wave refraction profile, beginning below the Bullion Mine along Jill Creek all the way to above the uppermost Bullion adit. In addition, at select locations a perpendicular seismic profile was conducted to cross-check the seismic velocities and depth to rock calculations.

Figure 2 shows the locations of the geophysical survey lines. The findings of the geophysical survey are summarized in a following section.

General Geologic Setting – Bullion Mine Vicinity

The Bullion Mine vicinity is underlain by bedrock geologic units including granitic rocks and volcanic rocks, and unconsolidated surficial geologic units including colluvial, glacial, and alluvial deposits. The following sections provide more detailed discussion of the bedrock and surficial geologic units in the vicinity of the Bullion Mine.

Bedrock Geologic Units

Bedrock geologic units in the Bullion Mine vicinity include extrusive volcanic rocks of the Middle Member of the Elkhorn Mountains Volcanics and intrusive rocks of the Butte Pluton. The Elkhorn Mountains Volcanics represent magma that reached the surface and erupted to form a volcanic and volcanogenic layered sequence. The Butte Pluton represents the parent magma that crystallized underground and intruded beneath the Elkhorn Mountains Volcanics.

Elkhorn Mountains Volcanics

The Middle member of the Elkhorn Mountain Volcanics is described as "dacitic welded tuff, and also includes lapilli tuff, tuff breccias, and minor volcanic sandstone and conglomerate." The groundmass is very fine grained with plagioclase phenocrysts. The color ranges from greenish-gray, gray, brownish-gray to reddish-gray. This unit is between approximately 73 and 78 million years in age and may be as much as 8,200 feet thick. The lower part of the middle member experienced contact metamorphism where the Butte Pluton intruded, and has been altered to hornfels facies, which is a dense, impermeable rock. The Elkhorn Mountains Volcanics are mapped near the upper portions of the Bullion Mine.

Butte Pluton

The rock that comprises the Butte Pluton of the Boulder Batholith was previously classified as quartz monzonite (Becraft et al., 1963; Ruppel, 1963). However, using a newer classification system that uses the modal distribution of minerals, the rocks typically plot as granite or granodiorite (Streckeisen, 1976). For simplicity, the rocks of the Butte Pluton will be referred to in this report as “granite,” because this appears to be the most common classification of the Butte Pluton rocks. The Butte Pluton was emplaced between approximately 82 and 74 million years ago. This rock unit includes three textural phases, including fine grained, medium- to coarse-grained, and the aplite and porphyry phase. However, these phases are similar chemically, and also not all three phases have been distinguished throughout the area because of gradational contacts. The three units are described in the following text.

The medium- to coarse-grained phase is light-to dark-gray, with potassium feldspar, plagioclase, hornblende and biotite. This unit underlies as much as 90 percent of the Basin Creek area and numerous outcrops of this rock type were observed in the vicinity of the Bullion Mine. The fine-grained phase includes light- and dark-gray and pinkish-gray varieties and is both porphyritic and equigranular. This unit is most abundant in the Basin Creek area in the vicinity of Jack Mountain and is generally most commonly found at higher elevations in the Butte Pluton. This phase forms a “chill margin” to the rest of the pluton, where it crystallized before the coarse-grained phases. The aplite and porphyry unit is similar in texture to the fine-grained unit but is distinguished by a very low mafic content. The aplite and porphyry units form tabular bodies and dikes throughout the area. These typically have northeast trends and formed in steep joints.

Surficial Geologic Units

Surficial geologic units in the Bullion Mine vicinity include Quaternary-age (less than 1.6 million years) glacial till, alluvial deposits, and colluvial deposits. The glacial till deposits are the most extensive surficial deposits in the Basin Creek watershed and consist primarily of morainal deposits that cover slopes and valley bottoms. The till is interpreted to be primarily Bull-Lake in age (ca 120,000 years old) and comprised mainly of locally-derived plutonic and volcanic rocks. The till is typically deeply weathered, and smaller clasts are poorly preserved and most have disintegrated into unsorted sand- and fine gravel-sized grains that now form the interstitial matrix for larger, less-weathered boulders. At the Bullion Mine, the glacial till has been deposited downslope along the valley walls and bottom of Jill Creek and mantles the lower portion of the mine vicinity, primarily below the lower adit.

Other surficial deposits in the vicinity include alluvial deposits along Jill Creek that consist of rounded sand, gravel and boulders; and colluvium on slopes that consists of locally-derived, weakly-stratified silt, sand and gravel deposited by gravity processes.

Structural Geology

Geologic structures in the area consist of faults/shear zones, joints, fractures, and lineaments. The geologic structure is important because it influenced the orientation and location of the ore bodies and polymetallic quartz veins. The veins developed in east-trending fractures and shear zones formed by tectonic stresses that appear to be related to emplacement of the crystalline rocks. In addition, the orientation and density geologic structure and fractures play a major role in influencing groundwater flow in the vicinity of the Bullion Mine.

The volcanic rocks typically underlie topographically higher areas above the Bullion Mine and are generally highly-fractured with many open and intersecting fractures. In contrast, the plutonic rocks have fracturing and near-surface weathering but the fracturing and weathering typically decreases with depth. The exposed portions of the Butte Pluton are cut by fracture systems that formed during cooling of the pluton (nondiastrophic fractures), and those that developed during emplacement of the batholith because of tectonic stresses (diastrophic fractures).

The nondiastrophic fractures in the Butte Pluton include cross joints, longitudinal joints, and flat-lying joints. Cross joints are steep to nearly vertical, east-trending fractures spaced from approximately 5 to 10 feet. Longitudinal joints trend north and generally dip steeply west with spacing from 1 to 5 feet. Flat-lying joints dip southward at low angles. These joint systems are evident in granitic outcrops in the vicinity of the Bullion Mine.

The diastrophic factures are very important because some of these consist of shear zones that contain quartz veins and polymetallic mineral deposits. The most important of these fracture systems, based on economic significance, is marked by east-trending shear zones as much as 6 miles long. These shear zones have slicken-sided surfaces that indicate oblique-slip movement, and most zones dip steeply north.

The Bullion vein is formed in one of the most prominent east-trending shear zones. This zone trends approximately 110 degrees (azimuth direction) and dips 50 to 70 degrees northeast. This vein is part of a major east-trending structural lineament known to extend more than 3.5 miles in length from the Bullion Mine on the west to the Eva May Mine on the east. The vein is offset in several places by north-trending cross faults and joint sets in the Butte Pluton. Faults are reported to cross the mineralized vein at the Moccasin claim (which is immediately east of the Bullion Mine).

Hydrogeology

Two general aquifers exist in the Basin Watershed: a shallow, unconfined alluvial aquifer found in stream alluvium and thick colluvial deposits, and a deeper aquifer within fractured bedrock. Both aquifers are reserved for or are used as potable water sources for residents of the watershed and the town of Basin.

Groundwater recharge in the vicinity of the Bullion Mine occurs as infiltration of snowmelt and precipitation at topographic highs. Recharge is greatest in areas with higher hydraulic conductivity, such as zones of densely fractured rock and collapsed shafts and raises. Groundwater discharge occurs as numerous small springs and seeps in topographic lows, slope breaks, at geologic contacts with changes in hydraulic conductivity, and where adits daylight. Typically, crystalline bedrock aquifers have low hydraulic conductivity, except where secondary fracture permeability exists. However, along fault zones, mineralized zones, and large fractures, the hydraulic conductivity may be comparatively high.

Contour maps generated by McDougal et al. (2004) as part of the lineament analysis show the greatest occurrences of linear feature spatial frequency, length, and intersection frequency. Two things are significant on these contour maps: (1) a high linear feature spatial frequency is indicated in the watershed near the Bullion Mine, and (2) longer linear features also occur near Crystal and Bullion Mines. The implication of these contour maps is that fracture frequency, fracture length, and frequency of fracture intersections are higher near the Crystal and Bullion Mines—corresponding with the occurrence of mineralized zones and also correlates with more permeable fracture zones that could experience greater recharge and preferred groundwater movement. The predominant east-west orientation of linear features may have a significant influence on structurally-controlled shallow ground water flow directions. The polymetallic vein systems are up to 50 feet wide, and along with old mine workings can act as groundwater conduits.

In the immediate vicinity of the Bullion Mine, it appears that groundwater inflow into the tunnels and adits comes primarily from infiltration of surface water from saturated areas, fractured rocks, and old collapsed shafts and open trenches above the extensive mine workings. No groundwater discharge is currently emanating from the middle and upper bullion adits. In contrast, the lower Bullion adit is a primary point of groundwater discharge. Numerous springs were observed and have been inventoried in the vicinity of the Bullion Mine. Several of these springs are mapped upslope from the uppermost Bullion adit and tunnel, indicating that the subsurface may be saturated along the length of the slope.

Seepage from the adit and springs drains into Jill Creek, which flows westward towards Jack Creek. Groundwater seeps and groundwater infiltration downgradient of the Bullion Mine site contribute to the total metal load in Jill Creek downstream of Bullion Mine. The local hydrogeologic conditions and groundwater levels are described in more detail below under *Subsurface Conditions*.

Mine Workings and Mineral Deposits

The Bullion Mine was worked periodically from 1897 to 1955, with some surface mining occurring in 1963. The mine consists of three adits on three different levels, connected by stopes and inclines. Numerous vertical “discovery shafts” and exploratory trenches cut perpendicular to the direction of the vein were excavated at the surface. On the basis of historical information and mine maps, the main (lower) adit is the longest and extends at least 2,600 feet to the east-southeast. The middle adit and upper adit extend approximately 800 and 200 feet, respectively. The total mine workings are estimated to be approximately 4,500 feet. Ore has been mined by stoping between the lower, middle, and upper adit. The mined zone is up to 16 feet wide in the lower workings. The mine maps and long profiles show that there are several cross-cuts and raises between the levels.

Mineralization

The Bullion vein is contiguous with the Crystal vein to the east. The Bullion vein trends N70W (110 degrees) and dips between 50 and 70 degrees to the northeast. The vein consists of quartz, pyrite, tetrahedrite, galena, sphalerite, chalcopyrite, arsenopyrite, and siderite. The mine produced approximately 30,000 tons of ore containing 3,500 oz of gold, 250,000 oz of silver, 300 tons of copper, 1000 tons of lead, and 1000 tons of zinc.

Subsurface Geologic Conditions

Soil Borings and Monitoring Wells

Four soil borings were advanced into the soil and weathered rock above the Bullion Mine. These borings were drilled primarily directly above the Bullion vein and near old mine workings and thus encountered moderately to highly weathered and altered granitic bedrock. BM-MW-1 was drilled highest upslope above the inferred location of the uppermost adit and is intended to act as an upgradient, or "background" well. This boring encountered mostly light-gray to yellowish, iron-stained, slightly to moderately weathered, fine-grained aplite or volcanic rock that broke down to silty sand or clayey sand. In this boring, the rock was too hard below a depth of 20 feet to collect split spoon samples and therefore the cuttings were logged. No groundwater was found in the boring at the time of drilling, and the boring was terminated at 60 feet and a well installed. However, groundwater flowed into the well within several days after well completion.

BM-MW-2 was drilled next in line near a human-made exploratory trench and encountered bedrock at 1 foot bgs. This boring encountered brownish, iron-stained, slightly to moderately weathered granitic rock. The rock was too hard to collect split spoon samples and, therefore, the cuttings only were logged. The drilling action and rate indicated alternating harder and softer (more weathered) zones within the granite. Very little groundwater was found in the fractured granite in the boring at the time of drilling, and the boring was terminated at 50 feet and a well installed. However, groundwater flowed into the well the day following well completion.

BM-MW-3 was drilled third in line near the edge of the existing road, and encountered bedrock at approximately 5 feet bgs, beneath road fill. This boring encountered primarily orange-brown, iron-stained, moderately- to highly-weathered granitic rock that broke down to silty to clayey sand. From 43 feet to the bottom of the boring at 45 feet no SPTs were attempted because of hard drilling conditions. The cuttings indicated gray, hard granite. The drilling action and rate indicated alternating harder and softer (more weathered) zones within the granite. Groundwater was measured at 36.5 feet bgs, and a well was installed in the borehole.

BM-MW-4 was drilled lowest downslope of the four borings and drilled immediately below the inferred location of the second adit. This boring encountered orange-brown, iron-stained, highly weathered and altered granitic rock that broke down to silty sand. Groundwater was observed flowing into the boring at 20 feet bgs, the boring was drilled to 25 feet in depth, and a well was completed in this interval.

Vertical Adit Intercept Boring

Boring BM-B-1 was drilled vertically to intercept the lower Bullion adit, as previously described. Because the rock was too hard to collect SPTs, only the cuttings were logged. However, the subsequent downhole video camera enabled visual logging of the granitic rock in the boring. This boring indicated that the rock above the adit consists of moderately to highly weathered granite, sand, and clay in the upper 13 feet. Below that, the rock consisted primarily of grayish, medium- to coarse-grained granitic rock with occasional more weathered layers. The lower adit was intercepted at 74 feet bgs and the bottom of the adit was measured to be 80.5 feet bgs.

A downhole video log was conducted in order to evaluate present conditions of the lower adit (caving/stability etc.), and observe groundwater inflow or mine flooding. The downhole video logging was conducted by personnel from the Montana Bureau of Mine and Geology with assistance from CH2M HILL and Axis Drilling. The video logging was conducted using a color GeoVision, JR. ™ Borehole Video System Model GVCJRM1. The camera has a built in light emitting diode (LED) light source and a tilting mechanism for side viewing and panning. To increase the viewing range underground, a separate small LED flashlight was affixed to the camera. The borehole videolog was recorded onto a digital video disk (DVD) for future reference. The camera and steel cable reel were attached to a 1-inch PVC pipe and lowered down inside the open 4-inch borehole. As the camera was lowered downhole, successive 10-foot pieces of PVC pipe were attached for stability and to also enable tilting and rotating the camera.

The video log showed gray to orange-gray granitic rock in the upper 74 feet, consistent with the drill cuttings. The camera entered water at approximately 42 feet bgs, which limited the visibility because of the particulates in the water. The borehole penetrated the adit very close to the adit wall (interpreted to be the northern wall based on mapping); however, by panning the camera around, the adit appeared to be open but flooded in that particular location. Because of the poor water quality and limited light, the camera was not able to penetrate very far into the void of the adit.

Groundwater Measurements/Local Groundwater Movement

In the immediate vicinity of the Bullion Mine, it appears that groundwater inflow into the tunnels and adits comes primarily from infiltration of surface water from saturated areas, fractured rocks, and collapsed shafts and open trenches above the extensive mine workings. Groundwater discharge occurs as springs, seeps, diffuse seepage into Jill Creek, and discharge from the lower Bullion Mine adit.

The monitoring wells were located to evaluate an upgradient to downgradient hydrogeologic section. Above the lower draining adit, no groundwater was present at the soil/bedrock interface at the time of drilling. On the basis of the geophysical investigation, the depth to rock was very shallow in most areas (within a few feet of ground surface) and, therefore, this subsurface situation was not conducive to groundwater movement. In contrast, the soil borings indicated that the first water-bearing zones were actually located within weathered and fractured bedrock.

Boring BM-B-1 directly intercepted the lower adit and allowed for direct depth to water measurements. The most recent water level was measured at 48.5 feet bgs, which indicates that the mine is flooded and there is approximately 25.5 feet of hydrostatic head in the mine adit at that location (approximately 280 feet up-adit from the portal). On the basis of site knowledge and observations, it appears that most of the lower and possibly portions of the intermediate mine workings are flooded.

No groundwater was observed discharging from the middle and upper Bullion adits during the investigation. Numerous springs were observed in the vicinity of the Bullion Mine. These springs were inventoried, and discharge measurements collected in the early summer; however, by the fall many of these had dried up—indicating that these are likely fed by snowmelt and precipitation. Several springs are mapped upslope from the uppermost Bullion adit and tunnel, both in native ground and also at old closed mine portals. The presence of these springs indicates that the shallow subsurface may be saturated higher above the Bullion Mine and likely receives recharge from snowmelt at higher elevations.

Groundwater measurements were collected from the monitoring wells and piezometers to evaluate the groundwater occurrence and movement in the vicinity. Table 2 provides a summary of the groundwater measurements conducted in the late summer and fall of 2010. Figure 1 shows a groundwater contour map. Groundwater levels measured in the monitoring wells declined as much as 2 to 4 feet between installation at the end of August and the latest measurement at the end of September. The declining water levels indicate a decrease in the amount of saturation in the subsurface and diminished spring flows.

TABLE 2-
Groundwater Elevations – Bullion Mine Monitoring Wells and Piezometers

Date	P-1	P-2	P-3	P-4	P-5	P-6	MW-1	MW-2	MW-3	MW-4	BM-B-1
8/29/10							(dry)	7541.11	7528.99	7457.88	7349.3
9/22/10									7526.37		7343.6
9/23/10							7650.95	7538.21		7455.63	
9/24/10		7242.16	7281.85		7116.41	7083.77					
9/30/10	7254.45	7242.12	7279.95	7142.81	7116.17	7083.14	7649.67	7537.13	7525.41	7455.00	7343.2

Groundwater elevations in feet amsl.

Geophysics Investigation Findings and Discussion

The geophysical investigation indicated that the subsurface conditions in the vicinity of the Bullion Mine consist of two basic layers that include unconsolidated sediments overlying slightly- to moderately-weathered bedrock. Figures in the geophysics report show the results of each velocity profile. Each figure consists of a graph with three lines. The vertical axes of the graph are “depth below grade (in feet)” on the left side, and “velocity (feet per second)” on the right side. The horizontal axis is distance (in feet) along the spread. The black line represents depth to the refractive layer (top of rock), the red line represents seismic velocity of the upper sediments, and the blue line represents seismic velocity of the underlying bedrock.

In general, when interpreting the results of a seismic investigation, it is important to consider both the depth of the refractor and the velocity of the refractor. Sediments typically exhibit a P wave velocity of less than 1,000 to 2,000 feet per second (fps). Weathered rock, or possibly very dense saturated sediments with exhibit P wave velocities between 3,000 and 4,000 fps. A refractor P wave velocity higher than 6,000 fps is typically considered to be “rock” material.

Two general areas were investigated and the results of each are described in the following text.

Groundwater Cutoff Wall Area

Seismic refraction spreads A-A′ and B-B′ were located in the proposed groundwater cutoff wall area in the floodplain adjacent to Jill Creek (Figure 3). This part of the seismic refraction survey was conducted in this vicinity in order to: (1) evaluate the thickness of sediments and depth to bedrock that would serve as a cutoff, and (2) evaluate the amount of weathering in the underlying bedrock to determine whether the rock is competent enough to serve as an effective cutoff (highly weathered or fractured rock may not serve as an effective cutoff to groundwater flow). The results of the seismic survey indicated that the depth to bedrock ranged from approximately 10 feet bgs near the northwest end of the A-A′ spread to approximately 5 feet bgs at the southeast end. These depths can be considered consistent with the valley configuration, where the valley was wider with more apparent sediment infill under the northern portion of the spread, and a much narrower valley with less alluvial fill under the southern end of the spread (closer to A′). Seismic spread B-B′ crossed perpendicular through spread A-A′ and confirmed the depth to rock and the seismic velocities.

The seismic P wave velocities of the underlying granitic bedrock layer in this area range from approximately 8,000 to 13,000 fps. Typical seismic P wave velocities in granitic rock range from 15,000 to 19,000 fps. The variability is due to the degree of weathering, fracturing, and saturation of the rock mass. The P wave velocities observed at this site indicate that the granitic rock is likely to be moderately weathered and fractured. However, the weathering and fracturing may decrease with depth. Rock with P waves in this range still represents fairly high-quality rock mass that would likely be of low permeability.

Bullion Mine long Profile

Seismic refraction spreads C-C′ and D-D′ were located along a profile parallel to the trend of the Bullion vein and mine workings. The seismic refraction spreads along this path were conducted in order to: (1) evaluate the thickness of sediments and depth to bedrock underlying the length of the Bullion Mine to refine the monitoring well and piezometer installation (to see the sediment/rock interface in the proposed piezometer locations), and (2) evaluate the amount of weathering and fracturing in the underlying bedrock. Because spread C-C′ was 2,400 feet long and crossed a variety of terrain, there are many variations in the seismic velocities and depth to rock. One item to consider when viewing the depth to rock is that this spread crossed the road switchbacks in six locations, skirted the human-made trench, and also traversed several areas of cuts and fills. Therefore, when viewing the "depth to rock", it should be considered that the ground surface is shown as being flat on the graphs and consequently the depth to rock appears "wavy." In reality the rock profile is likely more planar and the variations in "depth to rock" actually represent irregularities (highs and lows, cuts and fills, etc) in the present ground surface.

The results of this portion of the seismic survey could be divided into two general sections: (1) from the beginning of the line (Spreads 5 through 9), and (2) the remainder of the line (Spreads 10 through 20). Spreads 5 through 9 traversed from the north side of Jill Creek, across the floodplain, and up the slope below the discharging lower Bullion Adit. This area is underlain by sand, silt, and gravel (primarily colluvium and glacial till) and has also been reworked by previous mine reclamation activities. In addition, this area appears to be quite saturated, based on the preponderance of springs and seepage. The seismic spread in this area indicated that the depth to bedrock ranged from approximately 8 feet bgs under the Jill Creek floodplain, between 10 and 15 feet bgs up the slope below the Bullion adit, to as shallow as 5 feet near the lower Bullion adit portal. These depths can be considered consistent with the slope configuration, where the rock is slightly deeper under the filled/disturbed portions of the slope. The seismic P wave velocities of the underlying granitic bedrock layer along this spread range from approximately 6,000 to 9,000 fps, indicating that the granitic rock under this area is likely to be moderately weathered and fractured.

Spreads 10 through 20 traversed from the discharging lower Bullion Adit along the trend of the Bullion vein to above the uppermost adit. This area is underlain by a veneer of sediment (primarily colluvium) and has also been reworked and regraded by previous mine excavations, reclamation activities, and road building. Thus the topography is irregular and contains several cuts and fills. The seismic spreads across this area indicated that the depth to bedrock ranged from approximately 5 feet bgs to as much as 20 feet bgs. These depths can be considered consistent with the slope configuration, where the rock is slightly deeper under the filled or disturbed portions of the slope. The seismic P wave velocities of the underlying granitic bedrock layer along this spread are typically in the range of 5,000 fps, which indicates that the granitic rock under this area is likely to be moderately to highly weathered and fractured and is generally poor rock mass. The length of this spread overlies the Bullion vein and therefore it was anticipated that the rock mass may be poor. These results are consistent with the information gained during drilling.

References

Becraft, G.T., D.M Pinckney, Sam Rosenblum. 1963. *Geology and Mineral Deposits of the Jefferson County City Quadrangle, Jefferson and Lewis and Clark Counties, Montana*. U.S. Geological Survey Professional Paper 428. 101 p. 18 plates.

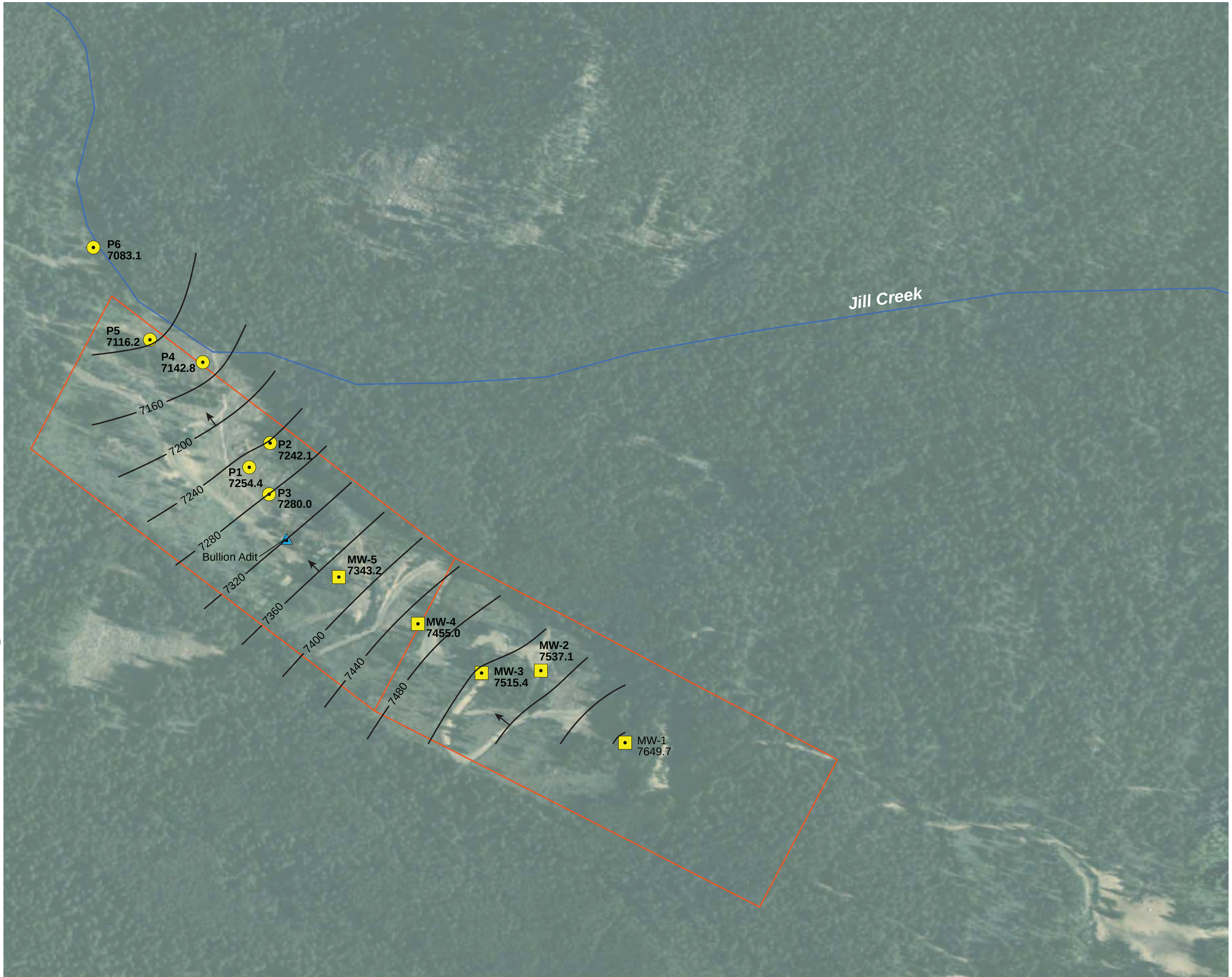
McDougal, R. R., Cannon, M. R., Smith, B. D., and Ruppert, D. A., 2004. *"Hydrogeology of the Boulder River Watershed Study Area and Examination of the Regional Ground-Water Flow System Using Interpreted Fracture Mapping from Remote Sensing Data"* in *Integrated Investigation of Environmental Effects of Historical Mining in the Basin and Boulder Mining Districts, Boulder River Watershed, Jefferson County, Montana*. U. S. Geological Survey Professional Paper 1652, Nimick, D. A., Church, S. E., and Finger, S. E., eds., pp. 341-368.

O'Neill, J. M., Lund, K., Van Gosen, B. S., Desborough, G. A., Sole, T. C., and DeWitt, E. H., 2004. "Geologic Framework" in *Integrated Investigation of Environmental Effects of Historical Mining in the Basin and Boulder Mining Districts, Boulder River Watershed, Jefferson County, Montana*. U. S. Geological Survey Professional Paper 1652, Nimick, D. A., Church, S. E., and Finger, S. E., eds., pp. 53-88.

Ruppel, E. T. 1963. *Geology of the Basin Quadrangle, Jefferson, Lewis and Clark, and Powell Counties, Montana*. U.S. Geological Survey Bulletin 1151, 121 p. 7 plate.

Streckeisen, A. L., 1976. *Classification of the Common Igneous Rocks by Means of Their Chemical Composition: A Provisional Attempt.* Neues Jahrbuch for Mineralogie, Monatshefte, 1976, H. 1, 1-15.

Figures



VICINITY MAP

LEGEND

- Piezometer
- Monitoring Well
- Adit
- NHD Stream
- Mine Claim Boundary
- Groundwater Contours (elevations in feet)
- Groundwater Flow Direction

Notes:
1. Area of interest subject to change.
2. 2009 NAIP Orthophotography
3. BM-B-1 completed open-hole in adit intercept boring.

N

0 250 500
Feet

FIGURE 1
GROUNDWATER CONTOUR MAP
Bullion Mine OU6 Remedial Investigation

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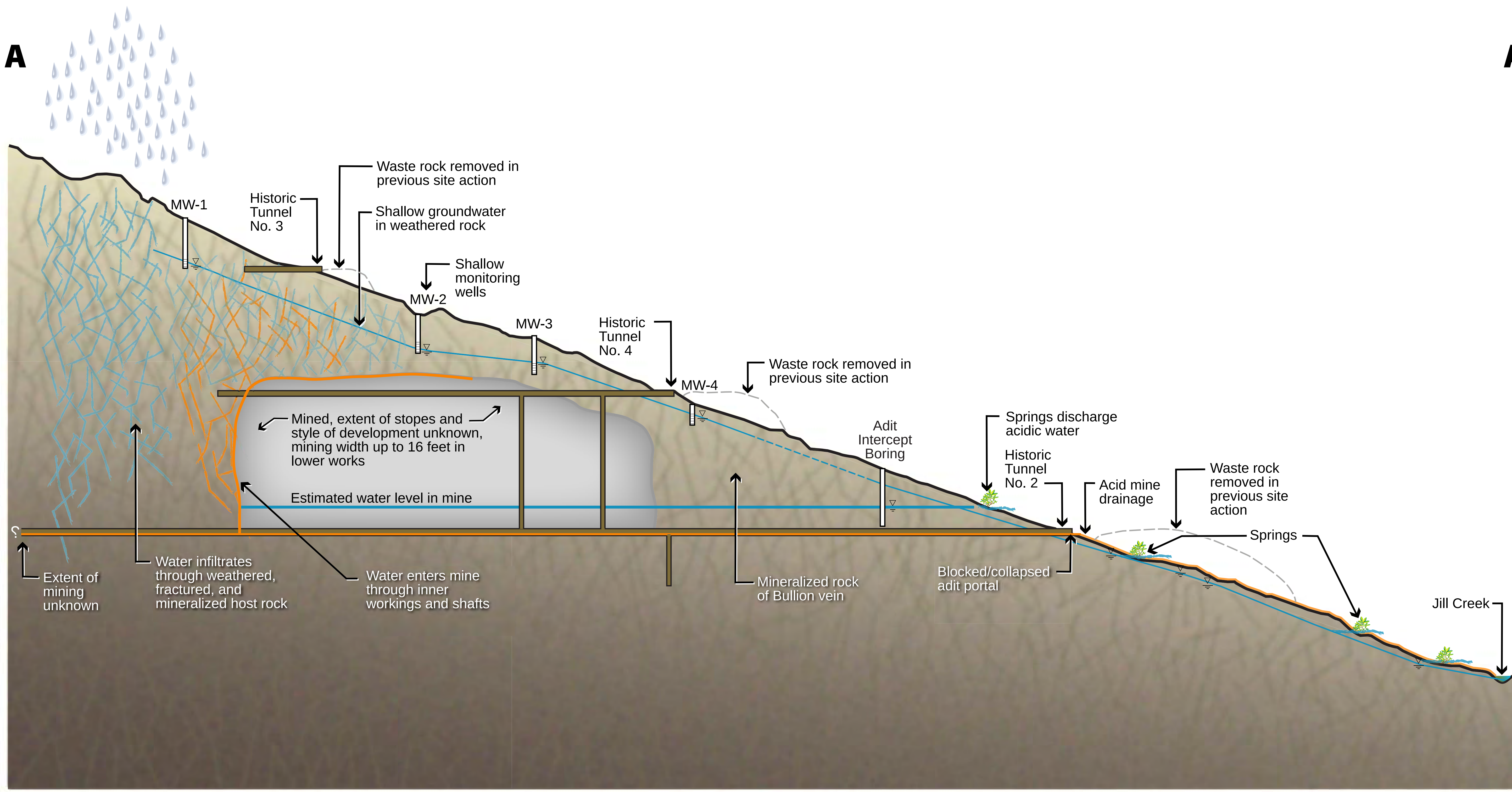
ES060711213019BOI Fig3-10_GroundwaterContourMap_v3.ai



LEGEND

Groundwater Level

FIGURE 2
BULLION MINE PROFILE
Bullion Mine OU6 Remedial Investigation

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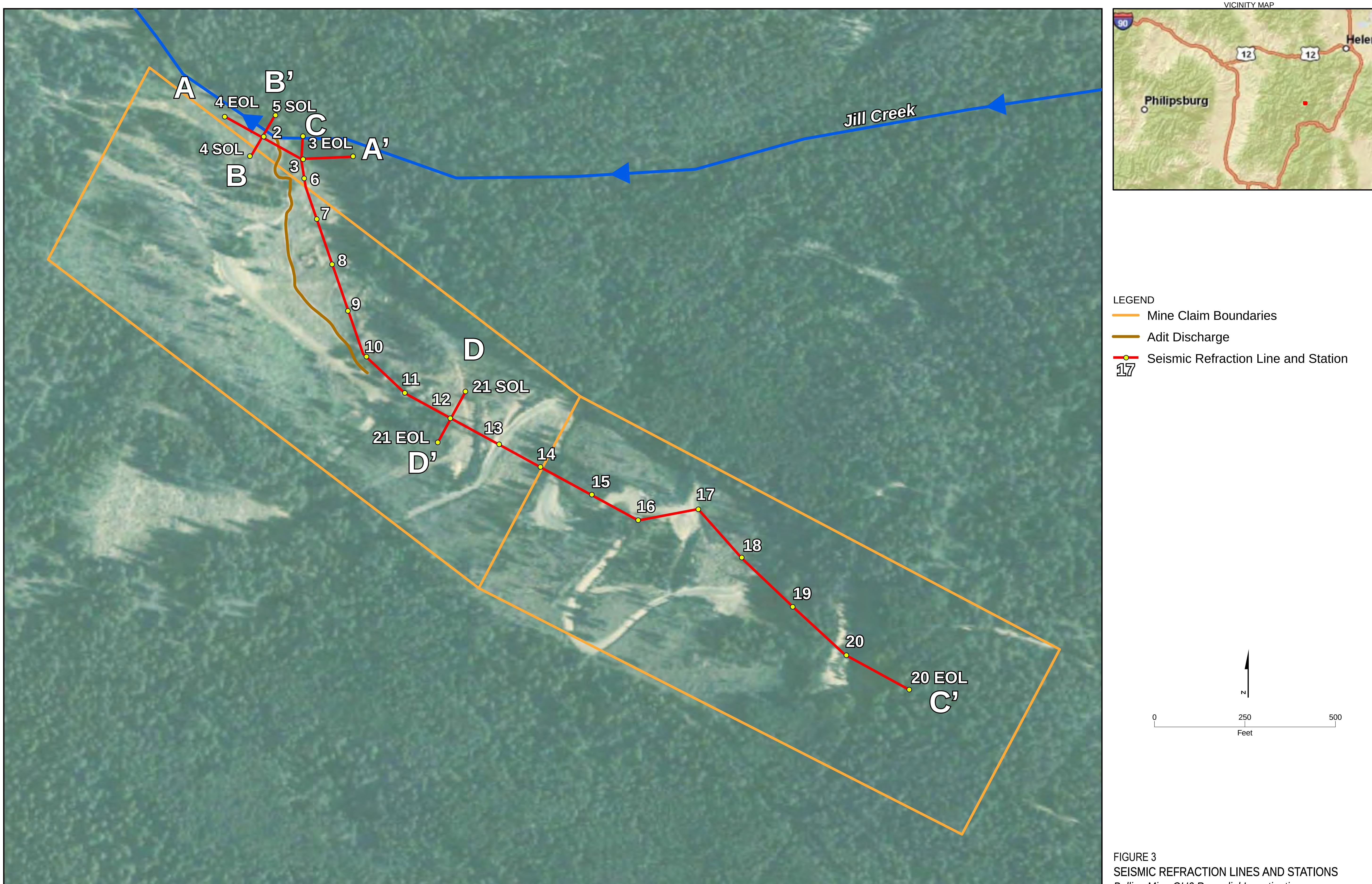


FIGURE 3
SEISMIC REFRACTION LINES AND STATIONS
Bullion Mine OU6 Remedial Investigation

Attachment 1

Soil Boring Logs

CH2MHILL

PROJECT NUMBER	BORING NUMBER:
408158.FI.02	BM-B-1 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Bullion Mine, Adit Intercept Boring

LOCATION : LAT 46° 21' 18.6056", LONG -112° 17' 38.6133"

ELEVATION : 7391.7

DRILLING CONTRACTOR : Axis

DRILLING METHOD AND EQUIPMENT : Davey-Kent 200, Track Mounted, 6" Diameter ODEX

WATER LEVELS : 48.5 ft bgs START: 8/18/2010 END: 8/18/2010 LOGGER : G. Warren, P.G.

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (In.)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
					Weathered granitic rock, breaks down to sand and clay	No SPT samples in weathered bedrock
10						
					Harder granitic bedrock, alternating weaker weathered layers	Drill 6 inch steel casing to 13 feet bgs, then drill open hole with hammer to bottom of boring.
20						
30					Hard gray granitic rock	30 feet - TWA on data ram = 0.06 mg/m^3
40						
					Continued hard granitic rock, smooth drilling	45 feet - conc = 0.08 mg/m^3
50						50 feet - TWA = 0.06 mg/m^3 Hole making water at approximately 50 feet
60						
70					Continued hard granitic rock	70 feet - TWA = 0.05 mg/m^3
						74 feet - contact #2 Tunnel
80						Bottom of Tunnel at 80.5 feet
90						
100						

PROJECT NUMBER	BORING NUMBER:
408158.FI.02	BM-MW-1 SHEET 1 OF 2

SOIL BORING LOG

PROJECT : Bullion Mine, Adit Intercept Boring | LOCATION : LAT 46° 21' 13.2947", LONG -112° 17' 24.1772"

ELEVATION : 7704.1 | DRILLING CONTRACTOR : Axis

DRILLING METHOD AND EQUIPMENT : Davey-Kent 200, Track Mounted, 6" Diameter ODEX

WATER LEVELS : 54.4 ft bgs | START: 8/27/2010 | END: 8/27/2010 | LOGGER : G. Warren, P.G.

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (In.)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
						2 inch split spoon, 140 lb hammer with cathead and rope. Drill with tubex and 6 inch casing.
5	5.0 – 6.5		SS-1	6-8-6 (14)	Highly weathered granite to silty to clayey sand (SM), light brown with some orange ferrous oxide staining, dry, stiff, slightly cohesive, fine to medium-grained	
10	10.0 – 11.5		SS-2	11-12-13 (25)	Like above but more clayey and cohesive	
15	15.0 – 16.5		SS-3	14-13-14 (27)	Highly weathered and altered fine-grained granite, green-gray, breaks down to sandy clay and clayey sand, moist, very stiff	
20	20.0 / 20.1		SS-4	50/1" (50/1")	Harder rock - gray weathered/altered granite or volcanic rock	
25	25.0 – 25.4		SS-5	50/5" (50/5")	Silty fine sand (SM), yellow to gray with minor ferrous oxide stain, dry, very dense (alteration of granite or volcanic)	
30					Continued weathered fine-grained , aplite phase granite with alterations	30 feet - No SPT, pretty hard drilling in rock
35						

PROJECT NUMBER	BORING NUMBER:
408158.FI.02	BM-MW-1 SHEET 2 OF 2

SOIL BORING LOG

PROJECT : Bullion Mine, Adit Intercept Boring

LOCATION : LAT 46° 21' 13.2947", LONG -112° 17' 24.1772"

ELEVATION : 7704.1

DRILLING CONTRACTOR : Axis

DRILLING METHOD AND EQUIPMENT : Davey-Kent 200, Track Mounted, 6" Diameter ODEX

WATER LEVELS : 54.4 ft bgs

START: 8/27/2010

END: 8/27/2010

LOGGER : G. Warren, P.G.

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (In.)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
					Harder rock	35 feet - No SPT, hard drilling in rock
40					Rock, even harder and dry, fractured fine-grained gray bedrock (volcanic or aplite)	40 feet - No SPT, hard rock
45						
50					Continued hard/fractured gray rock, fine-grained (aplite or volcanic)	50 feet - No SPT, hard rock
55						
60						Bottom of Boring at 60 feet Install monitoring well
65						
70						

CH2MHILL

PROJECT NUMBER	BORING NUMBER:
408158.FI.02	BM-MW-2 SHEET 1 OF 2

SOIL BORING LOG

PROJECT : Bullion Mine, Adit Intercept Boring LOCATION : LAT 46° 21' 15.6498", LONG -112° 17' 28.4670"

ELEVATION : 7584.5 DRILLING CONTRACTOR : Axis

DRILLING METHOD AND EQUIPMENT : Davey-Kent 200, Track Mounted, 6" Diameter ODEX

WATER LEVELS : 47.4 ft bgs START: 8/26/2010 END: 8/27/2010 LOGGER : G. Warren, P.G.

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (In.)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
					Bedrock at 1 foot, granite, hard, brownish, slightly to moderately weathered	2 inch split spoon, 140 lb hammer with cathead and rope.l Drill with tubex and 6 inch casing. Weathered granite exposed in trench wall above boring
5	5.0		SS-1	50/1" (50/1")		Hard steady drilling
10					Slightly easier drilling Continued granite to slightly weathered granite	No sample (SPT) at 10 feet
15						
20					Continued granite to slightly weathered granite	20 feet - hard drilling, no SPT
25					Continued weathered granite	25 feet - slightly easier drilling
30	30.0		SS-2	50/0" (50/0")	Continued granite, hard, occasional softer slightly weathered silty to clayey sand zones.	
35						

CH2MHILL

PROJECT NUMBER	BORING NUMBER:
408158.FI.02	BM-MW-2 SHEET 2 OF 2

SOIL BORING LOG

PROJECT : Bullion Mine, Adit Intercept Boring   LOCATION : LAT 46° 21' 15.6498", LONG -112° 17' 28.4670"

ELEVATION : 7584.5   DRILLING CONTRACTOR : Axis

DRILLING METHOD AND EQUIPMENT : Davey-Kent 200, Track Mounted, 6" Diameter ODEX

WATER LEVELS : 47.4 ft bgs   START: 8/26/2010   END: 8/27/2010   LOGGER : G. Warren, P.G.

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (In.)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
40					Continued granite with occasional weathered zones	
45						
50					Continued material as above	Bottom of Boring at 50 feet Install monitoring well Very little water in massive granite
55						
60						
65						
70						

CH2MHILL

PROJECT NUMBER	BORING NUMBER:
408158.FI.02	BM-MW-3 SHEET 1 OF 2

SOIL BORING LOG

PROJECT : Bullion Mine, Adit Intercept Boring — LOCATION : LAT 46° 21' 15.5025", LONG -112° 17' 31.3844"

ELEVATION : 7561.3 — DRILLING CONTRACTOR : Axis

DRILLING METHOD AND EQUIPMENT : Davey-Kent 200, Track Mounted, 6" Diameter ODEX

WATER LEVELS : 35.9 ft bgs — START: 8/25/2010 — END: 8/26/2010 — LOGGER : G. Warren, P.G.

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (In.)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
					Road fill from 0 to 5 feet	2 inch split spoon, 140 lb hammer with cathead and rope. Drill with tubex and 6 inch casing.
5						
10	10.0 – 11.5		SS-1	9-14-13 (27)	Highly weathered granite/clayey sand (SC), orange to light brown, dry, medium dense, slightly plastic	Data RAM TWA = 0.01 mg/m^3
15	15.0 – 16.5		SS-2	17-23-21 (44)	Continued highly weathered granite, weathered to silty sand (SM-SP), dry, orange to light brown, dense, ferrous oxide alteration	
20	20.0 – 21.4		SS-3	15-34-50/5" (84/11")	Continued highly weathered granite/clayey to silty sand (SM to SC), light orange to brown, dry, very dense, cohesive	
25	25.0 – 26.3		SS-4	15-30-50/3.5" (80/9.5")	Continued highly weathered granite/silty to clayey sand (SM to SC), greenish-gray, dry with trace moisture, very dense, cohesive	
30	30.0 – 31.3		SS-5	19-43-50/3.5" (93/9.5")	Continued highly weathered granite/slightly to clayey sand (same as above)	
35						

CH2MHILL

PROJECT NUMBER	BORING NUMBER:
408158.FI.02	BM-MW-3 SHEET 2 OF 2

SOIL BORING LOG

PROJECT : Bullion Mine, Adit Intercept Boring   LOCATION : LAT 46° 21' 15.5025", LONG -112° 17' 31.3844"

ELEVATION : 7561.3   DRILLING CONTRACTOR : Axis

DRILLING METHOD AND EQUIPMENT : Davey-Kent 200, Track Mounted, 6" Diameter ODEX

WATER LEVELS : 35.9 ft bgs   START: 8/25/2010   END: 8/26/2010   LOGGER : G. Warren, P.G.

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (In.)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
					Cuttings are the same material, grayish weathered granite, clayey to silty sand, dry	No SPT at 35 feet
						38 feet - Cuttings are changing to orange color
40	40.0 41.5		SS-6		Highly weathered granite/sandy clay (CL), gray with orange mottling and ferrous oxide stain, stiff, slightly moist, plastic	Sampler wet, measure water at 36.5 feet below ground surface, drill to 45 feet
					Cuttings are gray, much harder rock	
45						No SPT, harder rock Bottom of Boring at 45 feet Install monitoring well
50						
55						
60						
65						
70						

CH2MHILL

PROJECT NUMBER	BORING NUMBER:
408158.FI.02	BM-MW-4 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Bullion Mine, Adit Intercept Boring LOCATION : LAT 46° 21' 17.1000", LONG -112° 17' 34.6207"

ELEVATION : 7471.7 DRILLING CONTRACTOR : Axis

DRILLING METHOD AND EQUIPMENT : Davey-Kent 200, Track Mounted, 6" Diameter ODEX

WATER LEVELS : 16.7 ft bgs START: 8/20/2010 END: 8/20/2010 LOGGER : G. Warren, P.G.

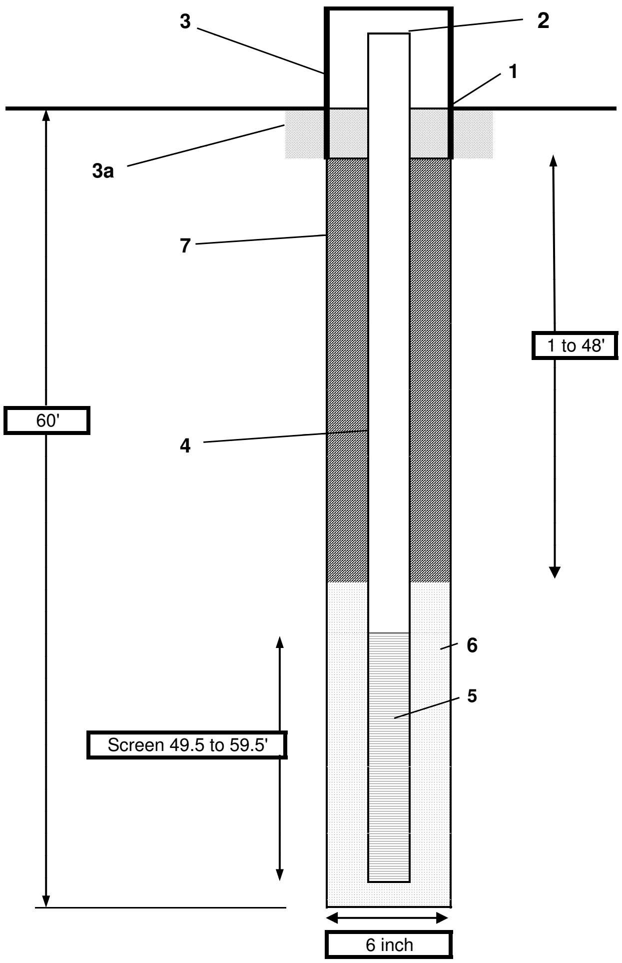
DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (In.)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
						2 inch split spoon, 140 lb hammer with cathead and rope. Drill with tubex and 6 inch casing.
5	5.0 6.5		SS-1	6-19-21 (40)	Highly weathered granite/orange silty sand (SM-SW), brown, dry, dense, fine to medium-grained, oxidation staining, feldspar weathered to clay	
10	10.0 10.5		SS-2	50/5.5" (50/5.5")	Continued highly weathered granite/silty sand (SM-SP), dark brown, dry, very dense fine to medium-grained, lots of black minerals	Data Ram TWA = 0.003 mg/m^3
15	15.0 16.5		SS-3	15-22-23 (45)	Continued highly weathered granite/silty sand (SP-SM), orange to brown and black, dry, dense, alteration, minerals, heavily oxidized	Sampler wet but sample is dry
20	20.0 20.8		SS-4	29-50/4" (50/4")	Continued highly weathered and altered granite, like above.	Water coming in bottom of hole
25					Clayey material on drill bit, no SPT at 25 feet	Bottom of Boring at 25 feet Install monitoring well
30						
35						

Attachment 2

Well Construction Diagrams

WELL NUMBER
BM-MW-1 SHEET 1 OF 1

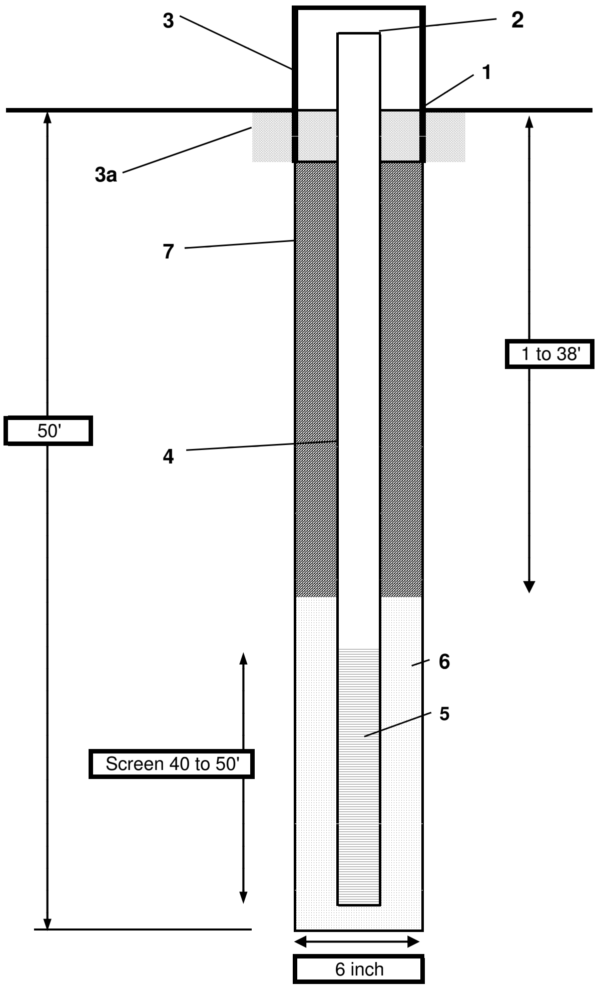
PROJECT : Bullion Mine; Basin Creek, MT	LOCATION (Lat/Long): 46-21-13.2947 112-17-24.1772
DRILLING CONTRACTOR : Axis Drilling	
DRILLING METHOD AND EQUIPMENT USED : Tubex, air-rotary w/ downhole hammer; 6-inch steel casing	
WATER LEVELS: 54.38 (9/30/2010) ft. bmp	INSTALL DATE : 8/28/2010 LOGGER : Greg Warren, P. G.



1- Ground elevation at well	7701.55'
2- Top of PVC casing elevation	7704.05'
a) casing plug	J-Plug
3- Wellhead protection cover type	Steel 6-inch riser set in concrete with padlock
a) concrete pad dimensions	2-feet round
4- Dia./type of well casing	2-inch Sched 40 PVC
5- Type/slot size of screen	2-inch PVC, 0.020-inch slot
6- Type screen filter	10-20 Silica sand
a) Quantity used	
7- Annular Seal	Holeplug: bentonite
Development method	Surge and bail
Notes:	Makes very little water
Development volume:	Bail 5 gallons until dry; let recover for 3 hours, and only 1 foot of recovery; very slow to recover

WELL NUMBER		
BM-MW-2	SHEET 1	OF 1

PROJECT : Bullion Mine; Basin Creek, MT LOCATION (Lat/Long): 46-21-15.6498 112-17-28.4670
DRILLING CONTRACTOR : Axis Drilling
DRILLING METHOD AND EQUIPMENT USED : Tubex, air-rotary w/ downhole hammer; 6-inch steel casing
WATER LEVELS: 47.35 (9/30/2010) ft. bmp INSTALL DATE: 8/27/2010 LOGGER : Greg Warren, P. G.



1- Ground elevation at well	7581.98'
2- Top of PVC casing elevation	7584.48'
a) casing plug	J-Plug
3- Wellhead protection cover type	Steel 6-inch riser set in concrete with padlock
a) concrete pad dimensions	2-feet round
4- Dia./type of well casing	2-inch Sched 40 PVC
5- Type/slot size of screen	2-inch PVC, 0.020-inch slot
6- Type screen filter	10-20 Silica sand
a) Quantity used	
7- Annular Seal	Holeplug: bentonite
Development method	Surge and bail
Notes:	Makes very little water, dirty (high turbidity)
Development volume:	Bail 3 gallons, water level drops from 43.37' below top of casing to 51.40' below top of casing; very slow to recover

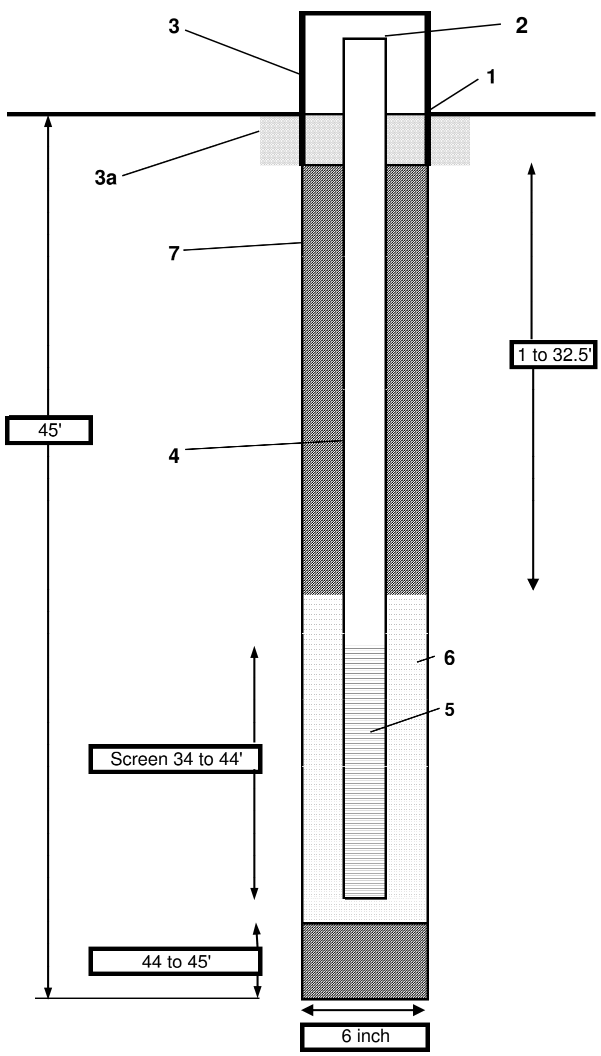
WELL NUMBER		
BM-MW-3	SHEET 1	OF 1

PROJECT : Bullion Mine; Basin Creek, MT — LOCATION (Lat/Long): 46-21-15.5025 112-17-31.3844

DRILLING CONTRACTOR : Axis Drilling

DRILLING METHOD AND EQUIPMENT USED : Tubex, air-rotary w/ downhole hammer; 6-inch steel casing

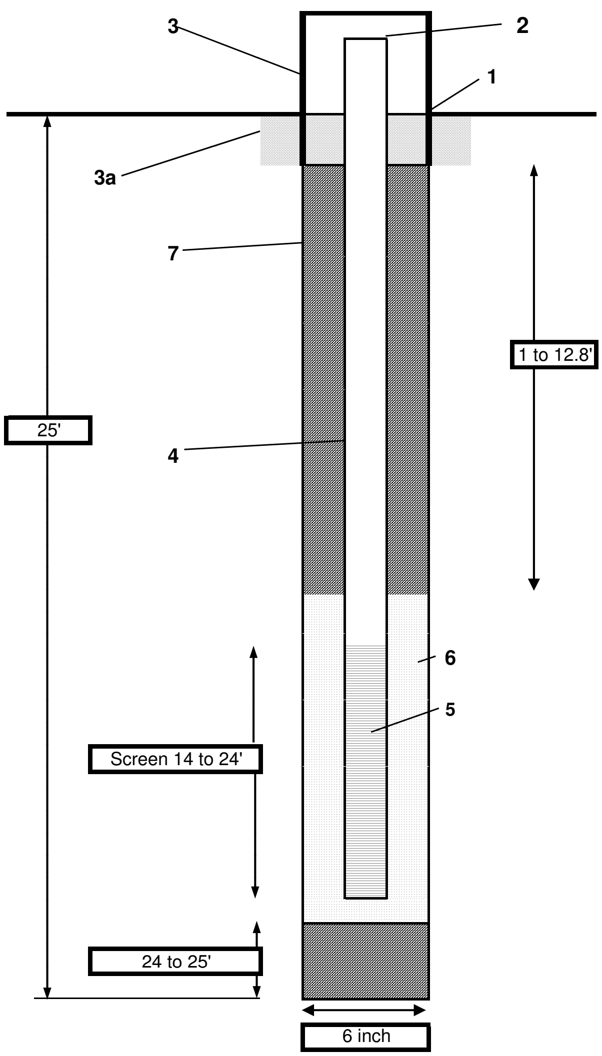
WATER LEVELS: 35.93 (9/30/2010) ft. bmp — INSTALL DATE : 8/26/2010 — LOGGER : Greg Warren, P. G.



1- Ground elevation at well	7558.84'
2- Top of PVC casing elevation	7561.34'
a) casing plug	J-Plug
3- Wellhead protection cover type	Steel 6-inch riser set in concrete with padlock
a) concrete pad dimensions	2-feet round
4- Dia./type of well casing	2-inch Sched 40 PVC
5- Type/slot size of screen	2-inch PVC, 0.020-inch slot
6- Type screen filter	10-20 Silica sand
a) Quantity used	
7- Annular Seal	Holeplug: bentonite
Development method	Surge and bail
Notes:	Makes ok water, dirty (high turbidity)
Development volume:	Bail 4 gallons, water level drops from 32.35' below top of casing to 38.25' below top of casing

WELL NUMBER		
BM-MW-4	SHEET 1	OF 1

PROJECT : Bullion Mine; Basin Creek, MT LOCATION (Lat/Long): 46-21-17.1000 112-17-34.6207
DRILLING CONTRACTOR : Axis Drilling
DRILLING METHOD AND EQUIPMENT USED : Tubex, air-rotary w/ downhole hammer; 6-inch steel casing
WATER LEVELS: 16.68 (9/30/2010) ft. bmp INSTALL DATE : 8/25/2010 LOGGER : Greg Warren, P. G.



1- Ground elevation at well	7469.17'
2- Top of PVC casing elevation	7471.67'
a) casing plug	J-Plug
3- Wellhead protection cover type	Steel 6-inch riser set in concrete with padlock
a) concrete pad dimensions	2-feet round
4- Dia./type of well casing	2-inch Sched 40 PVC
5- Type/slot size of screen	2-inch PVC, 0.020-inch slot
6- Type screen filter	10-20 Silica sand
a) Quantity used	
7- Annular Seal	Holeplug: bentonite
Development method	Surge and bail
Notes:	Makes ok water, dirty (high turbidity)
Development volume:	Bail 5 gallons, water level drops from 13.80' below top of casing to 17.60' below top of casing; recharges quickly

Attachment 3

Photographs

Running seismic refraction lines along Jill Creek floodplain

Drill rig setup on vertical adit intercept boring BM-B-1

Drill rig set up and well installation at BM-MW-4

Drill rig set up and well installation at BM-MW-3

Drill accessing BM-MW-1 location

Appendix F
Seismic Refraction Report

SAGE EARTH SCIENCE
GEOPHYSICAL SURVEYS

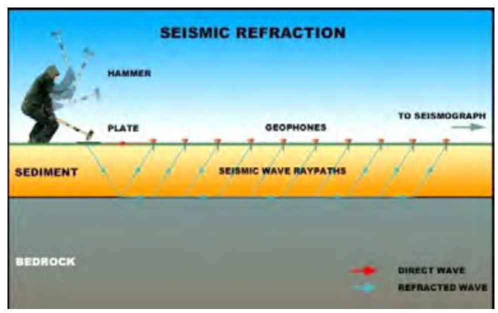
August 12, 2010

RE: COMPRESSION WAVE SEISMIC REFRACTIONROFILE SURVEY, BULLION MINE SITE

Based on the project objective and site conditions, Sage Earth Science conducted a compression (p-wave) seismic refraction survey at the Western Montana site. The objective of the survey is to determine P-wave structure in the shallow subsurface, depth to rock, and seismic velocity of the sediments and underlying rock. The field work was performed on June 27th and June 28th, 2010

P-wave survey (surface refraction)

Given a physical setting of increasing density/velocity with depth, and by measuring the travel time of a compression wave (*P-wave*) between known points, the seismic refraction method can be used to determine the depth to a refracting horizon, the seismic velocity of the refracting horizon, as well as thickness and velocities of the overlying materials.



Scope P-wave survey (refraction)

Aproximately 3,150 feet of P-wave refraction profile were acquired. Data were obtained in accordance with ASTM standard, **ASTM D 5777-00** *Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation.* Velocity calculations were made on a 75 foot station spacing

Sage Earth Science used a 24-channel engineering seismograph and sledge hammer to perform the acoustic travel time measurements. The survey is designed for a maximum depth of investigation of 50 feet depending on the subsurface setting. At each location, a fully reversed profile to account for dipping/sloping interfaces was performed. Profiles of the seismic compression wave velocities were prepared.

2184 Channing Way, Suite 110, Idaho Falls, ID 83404
telephone: (208)522-5049, Fax: (208)528-6200, email: sageearthscience@yahoo.com
http://www.sageearthscience.com

Table 1 Survey parameters

recording instrument	Bison 9024 s/n 6-93913
geophone	Mark products – 4 hz. vertical
Geophone/station spacing	6.56 feet (2 meters)
number of channels	24
sample rate	1.0 millisecond
number of samples	1000
record length	1 second
low pass filter	120 hz
low cut filter	4 hz
seismic source	12 pound sledge hammer
source locations	Channels 1,24 and offset as appropriate
data reduction method	Generalized reciprocal method (GRM)

Discussion

The following figures show the results of each seismic velocity profile. Each figure consists of three lines. The black line at the top of each figure represents the depth to the refracting horizon beneath the existing ground surface. The red line shows the seismic velocity of refracting horizon. The blue line represents the seismic velocity of the overlying sediments.

It is important to consider both the depth of the refractor and the velocity of the refractor. Sediments will typically exhibit a p-wave velocity less than 1,000-2000 feet per second. Weathered rock or in some cases a very dense saturated sediment will exhibit a p-wave velocity from 3,000-4,000 feet per second. A refractor p-wave velocity above 6,000 feet per second can typically considered a rock material.

The refractor velocity exhibited at this site ranges from 5,000 fps to 10,000 fps. Based on the observed velocity, it is assumed that the refractor is a rock surface, but is significantly weathered. Over large portions of the survey, the refractor should be considered very weathered. Although the P-wave velocity can be a good indicator of the type of soil or rock, it is not a unique indicator. Each type of sediment or rock has a wide range of seismic velocities. These ranges significantly overlap especially depending on the degree of weathering, fracturing and saturation. Experience shows, near surface weathered rocks often exhibit velocities significantly lower than common publish values.

Quoting from the ASTM standard, **ASTM D 5777-00** *Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation*

> *The seismic refraction method provides the velocity of compressional P-waves in subsurface materials. Although the P-wave velocity can be a good indicator of the type of soil or rock, it is not a unique indicator. Table 1 shows that each type of sediment or rock has a wide range of seismic velocities, and many of these ranges overlap. While the seismic refraction technique measures the seismic velocity of seismic waves in earth materials, it is the interpreter who based on*

knowledge of the local conditions or other data, or both, must interpret the seismic refraction data and arrive at a geologically reasonable solution

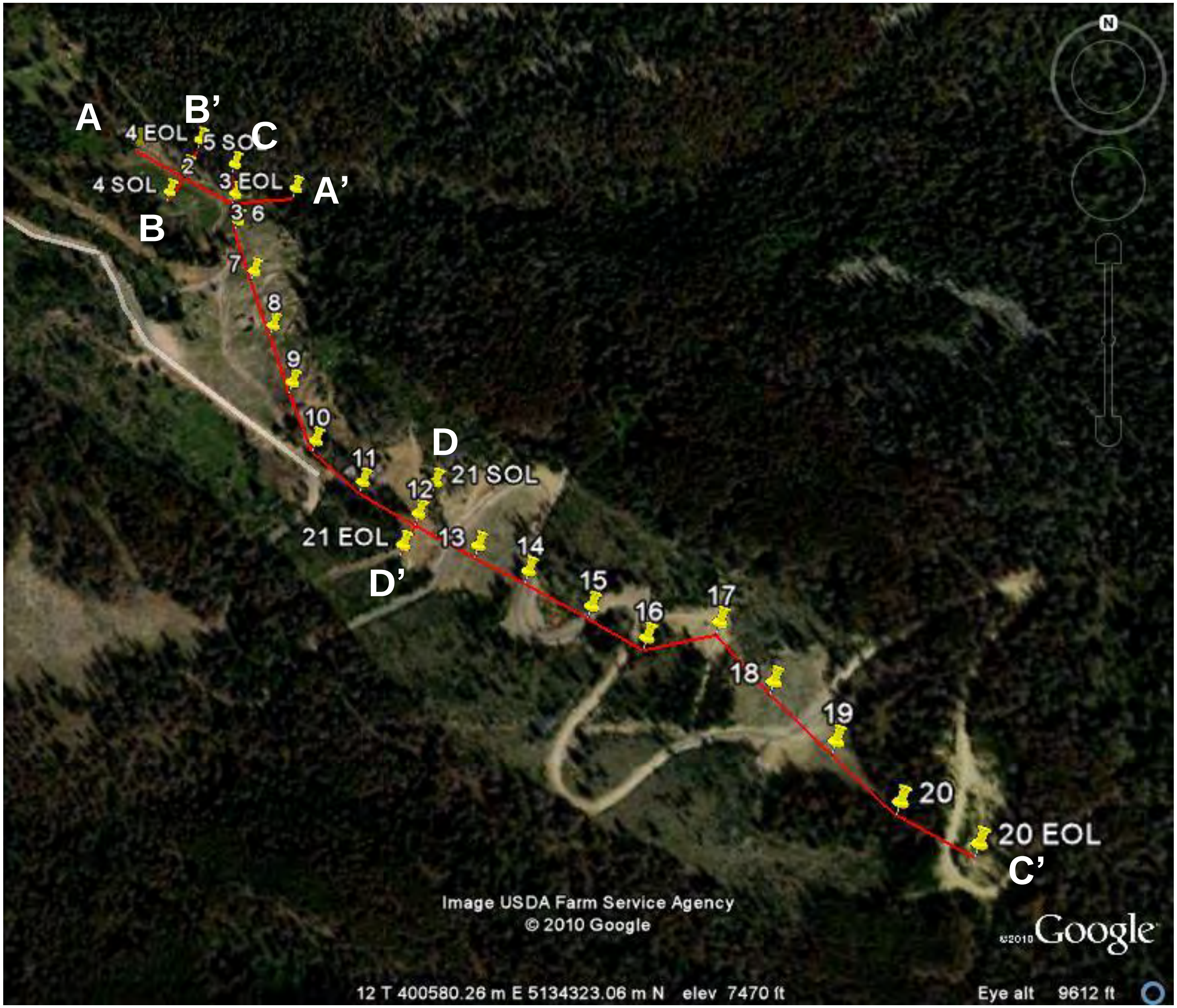
Table 3

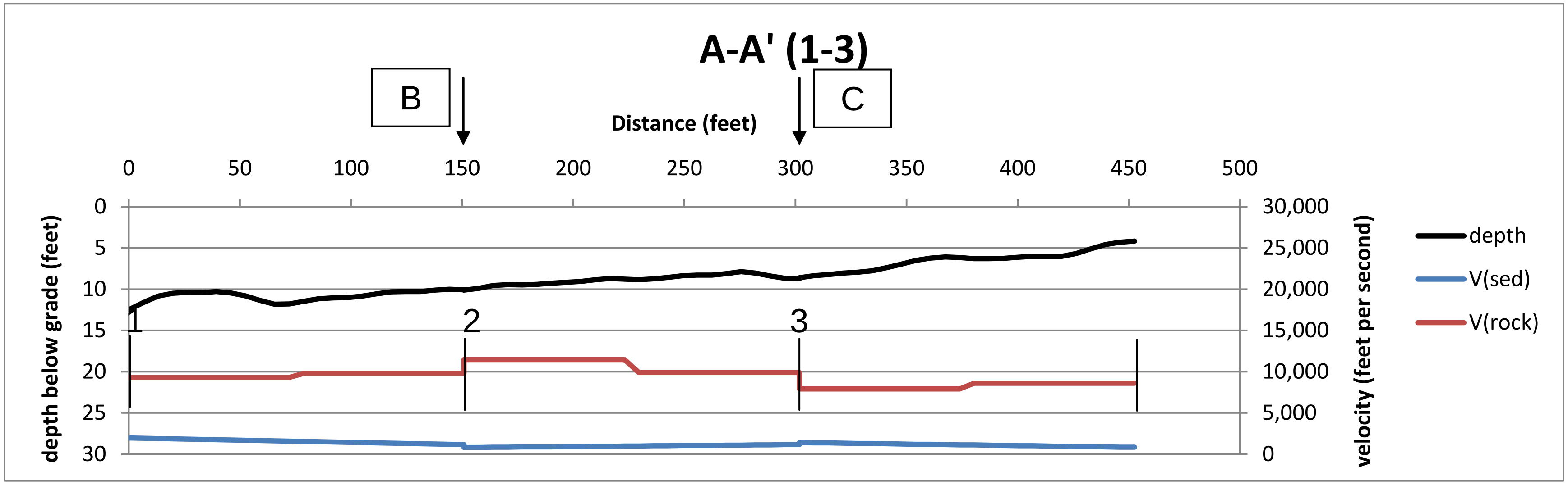
Material	***wave velocity V_p feet/second***
Weathered surface material	*800-2,000*
Gravel or dry sand	*1,500-3,000*
Sand (saturated)	*4,000-6,000*
Clay (saturated)	*3,000-9,000*
Sandstone	*6,000-13,000*
Shale	*9,000-14,000*
Chalk	*6,000-13,000*
Limestone	*7,000-20,000*
Granite	*15,000-19,000*
Metamorphic rock	*10,000-23,000*

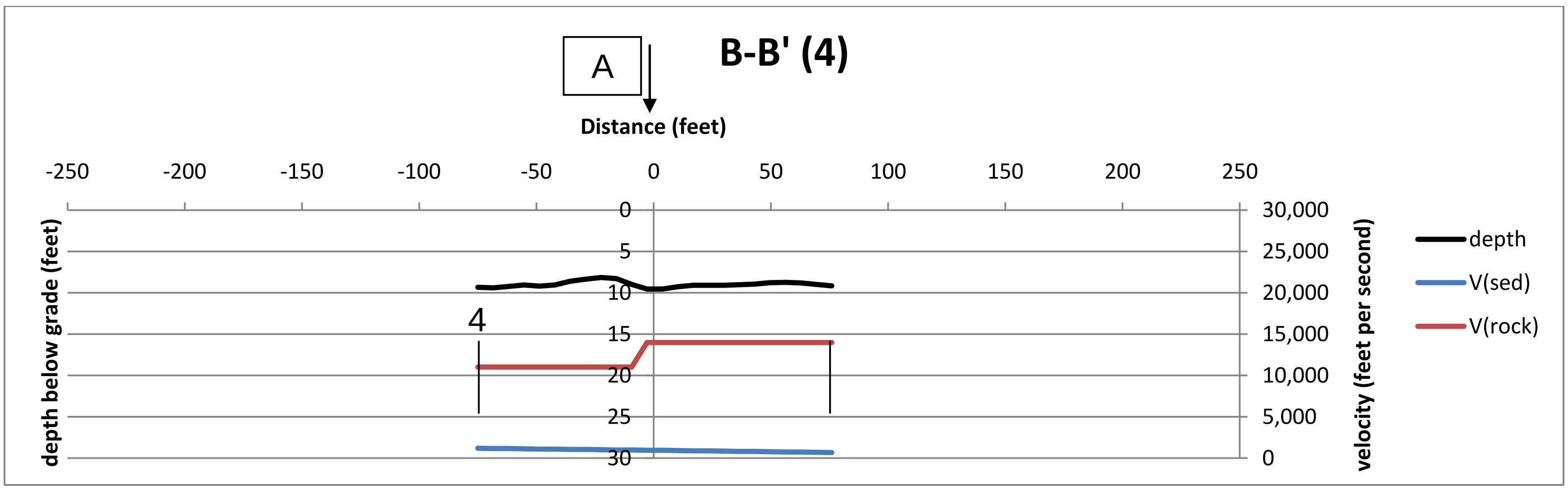
5.2.2. According to Mooney (8), P-wave velocities are generally greater for:

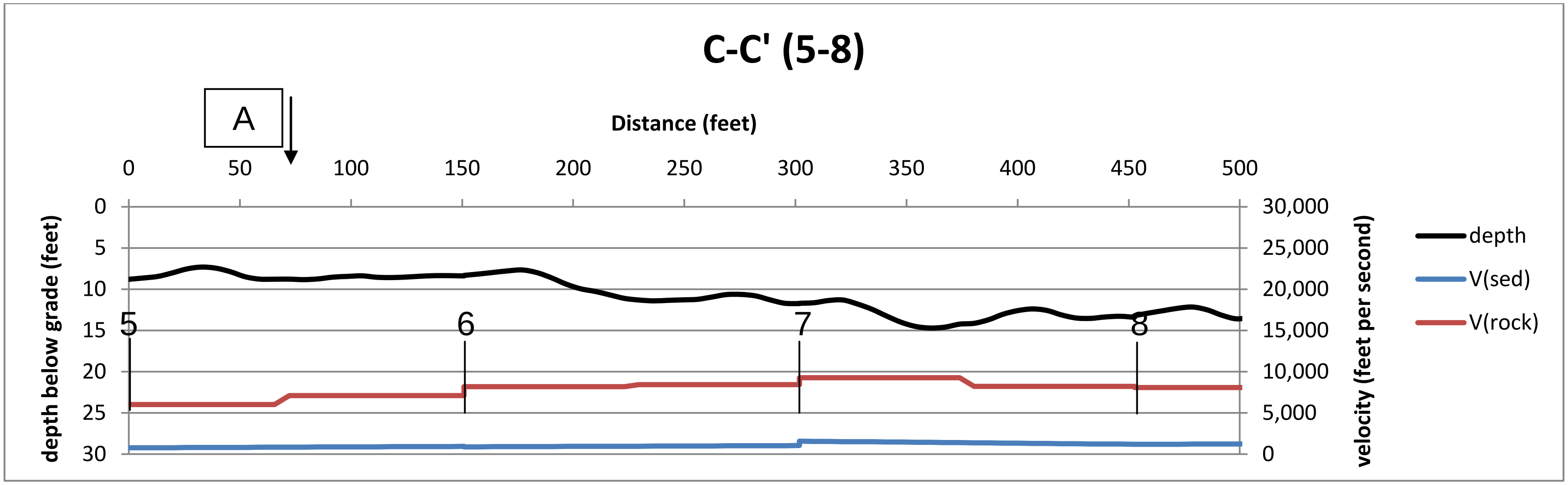
1. *Denser rocks than lighter rocks*
2. *Older rocks than younger rocks*
3. *Igneous rocks than sedimentary rocks*
4. *Solid rocks than rocks with crack and fractures*
5. *Unweathered rocks than weathered rocks*
6. *Consolidated sediments than unconsolidated sediments*
7. *Water saturated rocks/sediments than unsaturated rocks/sediments*
8. *Wet soils than dry soils*

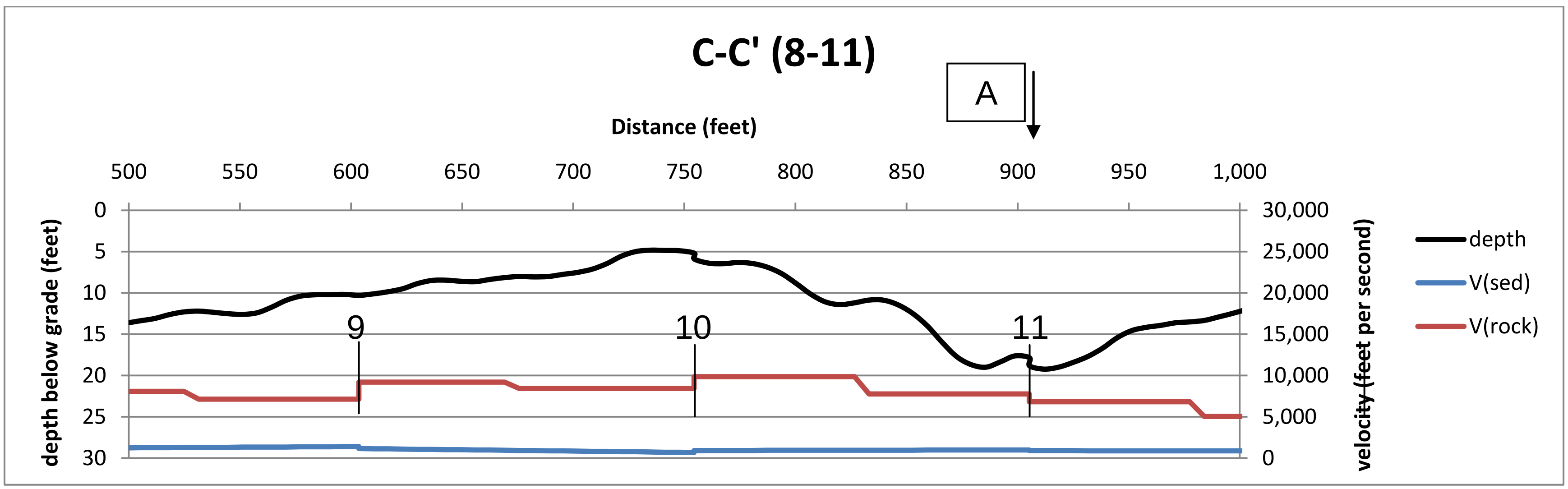
Glen Carpenter / principal

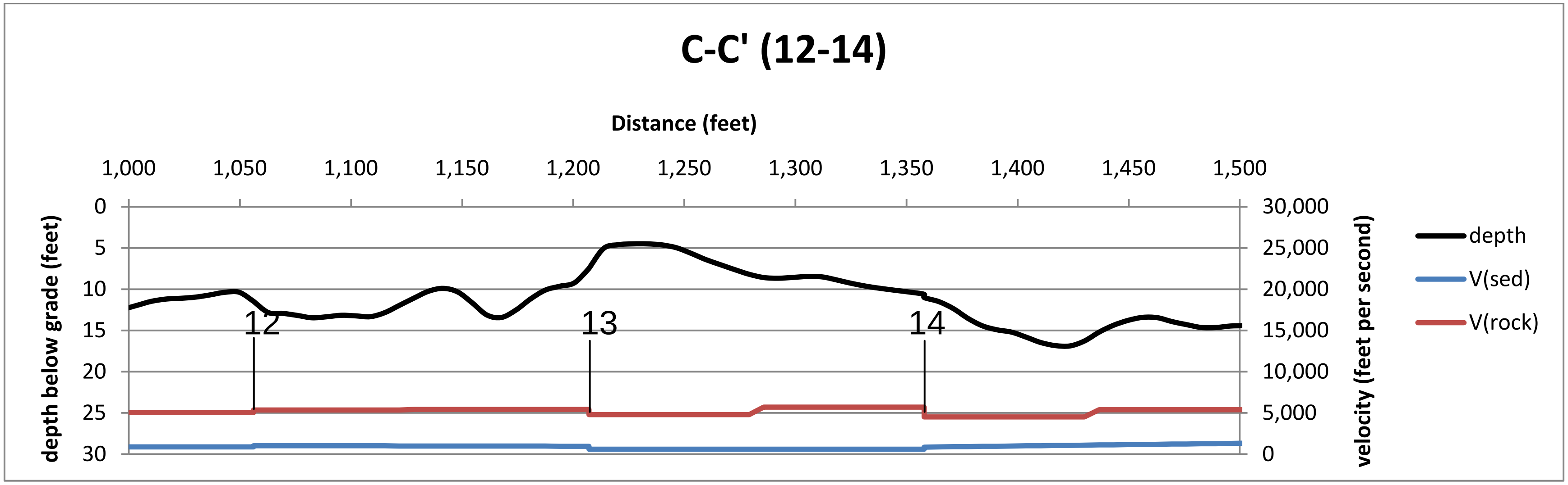

A
B'
4 EOL
5 SOL
C
2
4 SOL
3 EOL
A'
3
6
B
7
8
9
10
D
11
21 SOL
12
21 EOL
13
14
D'
15
16
17
18
19
20
20 EOL
C'
Image USDA Farm Service Agency
© 2010 Google
©2010 Google
12 T 400580.26 m E 5134323.06 m N elev 7470 ft
Eye alt 9612 ft

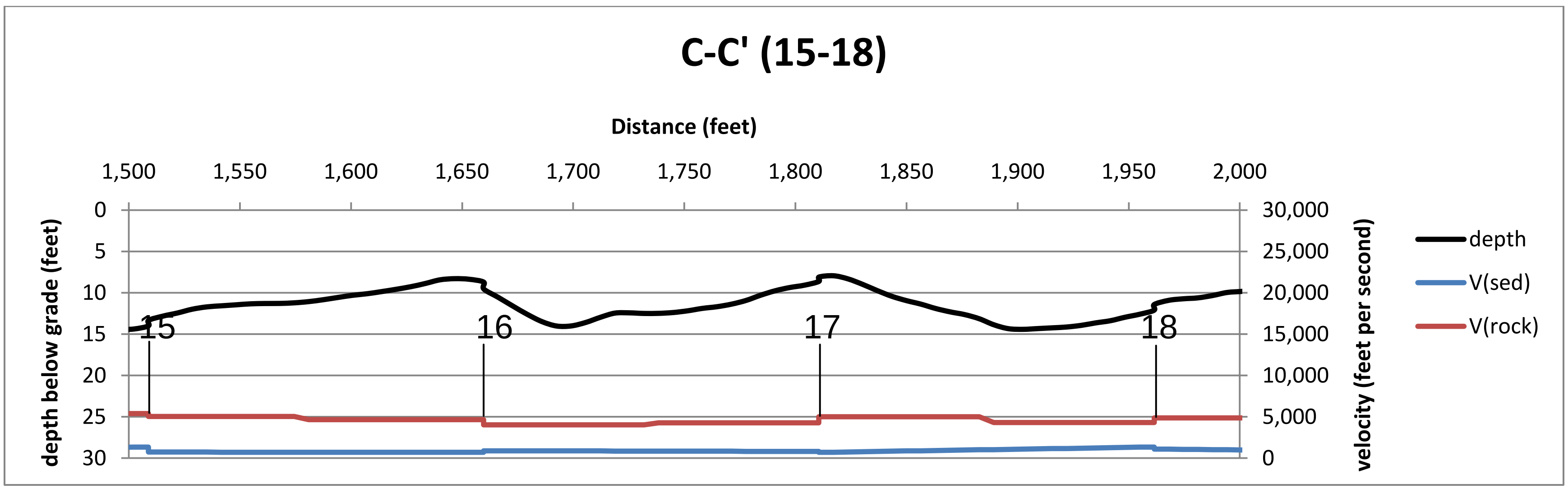

A-A' (1-3)
B
C
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
depth below grade (feet)
0
5
10
15
20
25
30
velocity (feet per second)
30,000
25,000
20,000
15,000
10,000
5,000
0
1
2
3
depth
V(sed)
V(rock)

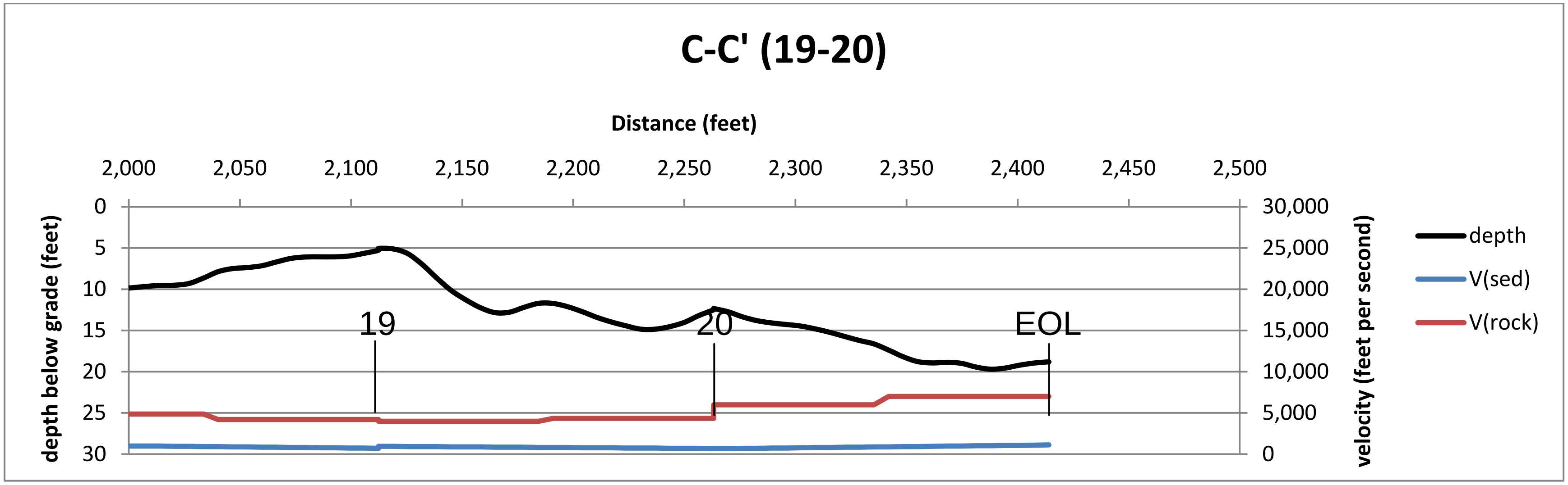

B-B' (4)
A
Distance (feet)
-250
-200
-150
-100
-50
0
50
100
150
200
250
depth below grade (feet)
0
5
10
15
20
25
30
velocity (feet per second)
30,000
25,000
20,000
15,000
10,000
5,000
0
4
depth
V(sed)
V(rock)

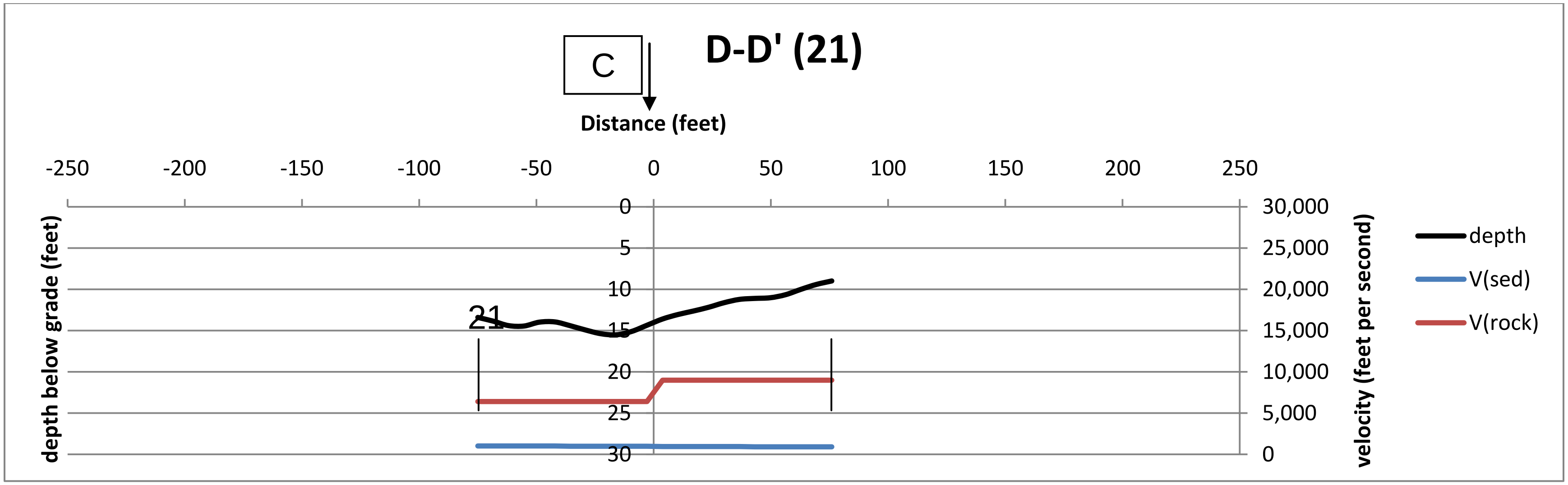

C-C' (5-8)
A
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
0
5
10
15
20
25
30
depth below grade (feet)
30,000
25,000
20,000
15,000
10,000
5,000
0
velocity (feet per second)
5
6
7
8
depth
V(sed)
V(rock)


C-C' (8-11)
A
Distance (feet)
500
550
600
650
700
750
800
850
900
950
1,000
0
5
10
15
20
25
30
depth below grade (feet)
30,000
25,000
20,000
15,000
10,000
5,000
0
velocity (feet per second)
9
10
11
depth
V(sed)
V(rock)


C-C' (12-14)
Distance (feet)
1,000
1,050
1,100
1,150
1,200
1,250
1,300
1,350
1,400
1,450
1,500
depth below grade (feet)
0
5
10
15
20
25
30
velocity (feet per second)
30,000
25,000
20,000
15,000
10,000
5,000
0
12
13
14
depth
V(sed)
V(rock)


C-C' (15-18)
Distance (feet)
1,500
1,550
1,600
1,650
1,700
1,750
1,800
1,850
1,900
1,950
2,000
depth below grade (feet)
0
5
10
15
20
25
30
velocity (feet per second)
30,000
25,000
20,000
15,000
10,000
5,000
0
15
16
17
18
depth
V(sed)
V(rock)


C-C' (19-20)
Distance (feet)
2,000
2,050
2,100
2,150
2,200
2,250
2,300
2,350
2,400
2,450
2,500
depth below grade (feet)
0
5
10
15
20
25
30
velocity (feet per second)
30,000
25,000
20,000
15,000
10,000
5,000
0
19
20
EOL
depth
V(sed)
V(rock)


D-D' (21)
C
Distance (feet)
-250
-200
-150
-100
-50
0
50
100
150
200
250
depth below grade (feet)
0
5
10
15
20
25
30
velocity (feet per second)
30,000
25,000
20,000
15,000
10,000
5,000
0
21
depth
V(sed)
V(rock)

Appendix G
Macroinvertebrate Survey Report

Report

An Assessment of Aquatic Macroinvertebrates near the Bullion Mine, Jefferson County, MT

Submitted to

U.S. Environmental Protection Agency Region 8

March 2011

Prepared by

Daniel L. McGuire
McGuire Consulting

Prepared for

CH2MHILL

Boise, Idaho

Contents

Tables

Figures

Appendix

Summary

Historic mining has degraded water quality and aquatic habitat in much of the upper Boulder River Drainage, Jefferson County, Montana. The Bullion Mine has been identified as a major source of acid mine drainage and metals in the Basin Creek sub-basin. Aquatic macroinvertebrates were surveyed in 2010 to assess impacts to Jill and Jack Creeks.

Essentially no macroinvertebrates were found in Jill Creek downstream from the Bullion Mine adit discharge. The macroinvertebrate assemblage in Jack Creek downstream from the confluence with Jill Creek was also impaired.

Sparse, but relatively healthy macroinvertebrate communities were present in Jill Creek above the mine discharge and in Jack Creek above the confluence of Jill Creek (Jack-6). While these sites are relatively sterile and less than pristine, they, along with other least-impaired sites in the region, provide a basis for evaluating biological responses to remediation actions.

1.0 Introduction

Historic mining has degraded aquatic habitat and water quality in much of the upper Boulder River Drainage, Jefferson County, Montana. To facilitate cleanup, the U.S. Environmental Protection Agency (EPA) added the Basin Mining Area to the Superfund National Priorities List in 1999. Numerous abandoned mines and mining wastes are present within the Basin Watershed Operable Unit 2 (OU2). The Bullion Mine has been identified as a major source of acid mine drainage (AMD), metals, and arsenic within the Basin Creek watershed. Initial cleanup of the mine site was completed in 2004. Actions included tailings and contaminant removal, site contouring and revegetation, and stream channel stabilization. However, AMD continues to degrade water quality and impair aquatic life.

The EPA is conducting a remedial investigation to characterize the extent of contamination and identify viable remedial cleanup options for the Bullion Mine site. CH2M HILL contracted with McGuire Consulting to conduct aquatic macroinvertebrate-based biological monitoring of streams adjacent to and downstream from the Bullion Mine.

2.0 Study Area

The Bullion Mine is located on the west slope of Jack Mountain near the head of the Jill Creek watershed. From the top of the mine site, the stream flows through approximately two kilometers of constructed stream channel to its confluence with Jack Creek. Monitoring stations were established at four sites on Jill Creek and at two sites on Jack Creek that bracket the Jill Creek confluence (Figure 1).

Above the mine site (Jill-1), the stream channel was entrenched, typically less than 0.5 meter wide, and lined with alders. The stream flows over predominately coarse sand and gravel and, at base flow, was generally less than five centimeters deep. Small quantities of aquatic moss grew on a alder roots and few highly embedded boulders.

Within and downstream from the mine site, the channel has been stabilized and lined with limestone boulders. Water depth was typically a few centimeters in the high gradient channel. Monitoring sites were located immediately above (Jill-2) and below (Jill-3) the mine adit confluence. Jill-4 was located approximately 600 meters downstream from the adit.

Monitoring sites were established on Jack Creek above (Jack-6) and below (Jack-5) the Jill Creek confluence. In this reach, Jack Creek has a gradient of less than one percent. Riffles and pools were generally associated with woody debris, and the substrate was predominately gravel, sand, and fines. Tailings and metallic precipitants were evident throughout the stream channel and floodplain.

TABLE 1
Macroinvertebrate Sampling Locations in the Jack Creek Drainage Associated with the Bullion Mine

Site	Lat/Long	Description
Jill-1	46.3572 -112.2951	Above mine, tailings, and constructed channel
Jill-2	46.3573 -112.2959	In constructed channel, above adit inflow
Jill-3	46.3573 -112.2961	In constructed channel, below adit inflow
Jill-4	46.3602 -112.2979	In constructed channel, below mine
Jack-5	46.3645 -112.3103	~30 m below Jill Creek confluence
Jack-6	46.3643 -112.3089	~50 m above Jill Creek confluence

FIGURE 1
Macroinvertebrate Monitoring Sites near the Bullion Mine

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

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

0 250 500
Feet

FIGURE 1
Benthic Macro-Invertebrate Monitoring Locations
Bullion Mine OU6 Remedial Investigation

3.0 Methods

Benthic macroinvertebrates were collected at six sites during late August and September 2010. Four quantitative samples were collected at each site. Standard quantitative samplers (Hess or Surber) were precluded by minimal water depths and large, highly embedded substrates. Rather, a standard sampling area was delineated and boulders, cobbles and large gravels were hand-picked and brushed to dislodge organisms. The remaining substrate was raked with a garden claw to a depth of 2-4 cm. Macroinvertebrates were collected in a rectangular net (18 inches W: mesh 1000 micron) held immediately downstream from the sample area. Due to low catch rates, sampling effort (area sampled) was 0.2 square meters. Samples were preserved in 95 percent ETOH and delivered to the lab in Espanola.

In the laboratory, samples were rinsed in a U.S. Standard 30 sieve to remove the preservative. All macroinvertebrates were removed from the sample, identified to the lowest level practical, usually genus or species, and enumerated. Data were entered into spreadsheets, which calculated a variety of metrics and summary statistics.

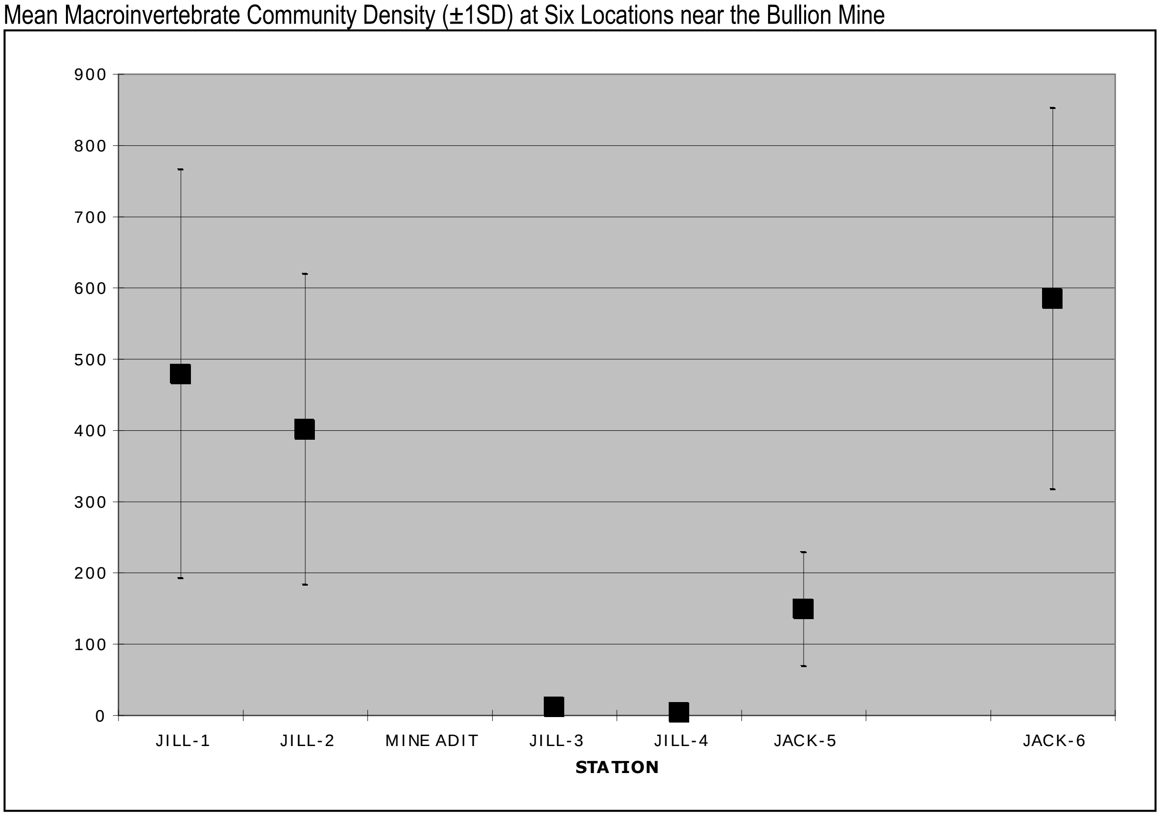
4.0 Results

Data (identifications, counts, metric values, and descriptive statistics) are presented in Appendix A.

4.1 Community Density

Relatively few macroinvertebrates were present in these streams. Catch rates varied from zero to 167 organisms per 0.2 square meter sample. Density estimates ranged from 4 to 585 organisms per square meter (Figure 2). Density estimates were similar for Jill Creek sites above the mine adit (Jill-1 and Jill-2) and Jack Creek upstream from the Jill Creek confluence (Jack-6). Several hundred macroinvertebrates per square meter were present at these sites. Community density was significantly lower in Jill Creek below the adit (Jill-3 and Jill-4) and in Jack Creek below the Jill Creek confluence (Jack-5).

FIGURE 2
Mean Macroinvertebrate Community Density (±1SD) at Six Locations near the Bullion Mine



4.2 Macroinvertebrate Taxa Richness

A total of 58 macroinvertebrate taxa were identified from the study sites (Table 2). Mayflies, stoneflies, and caddisflies (collectively EPT) accounting for 61 percent of the taxa collected. For all samples combined, individual sites yielded from 3 to 40 taxa (Figure 3). Mean taxa richness ranged from 21.75 at Jill-1 to 0.75 at Jill-4 (Figure 4) and was significantly higher at sites above the mine discharge than below. In Jack Creek, mean taxa richness and EPT richness (Figure 5) were significantly higher above the Jill Creek confluence than below.

FIGURE 3
Total Number of Macroinvertebrate Taxa Collected at Six Locations near the Bullion Mine

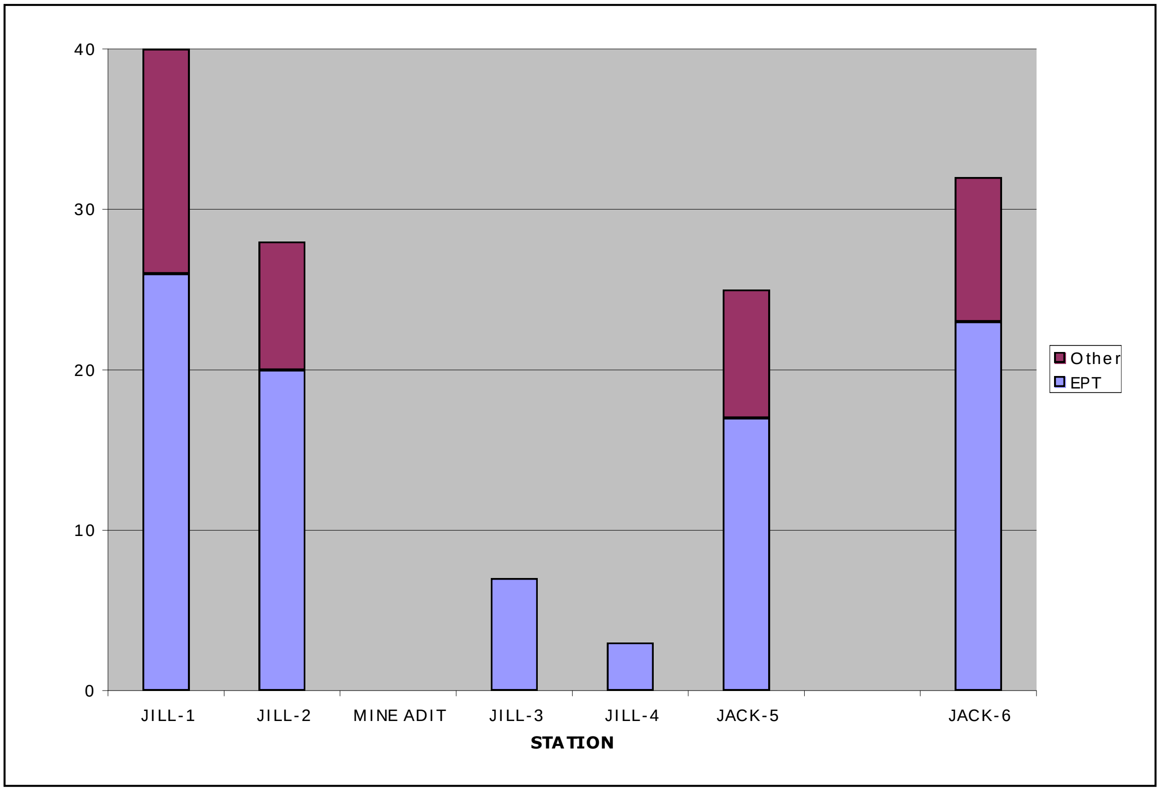


FIGURE 4
Mean Macroinvertebrate Taxa Richness (±1SD) at Six Locations near the Bullion Mine

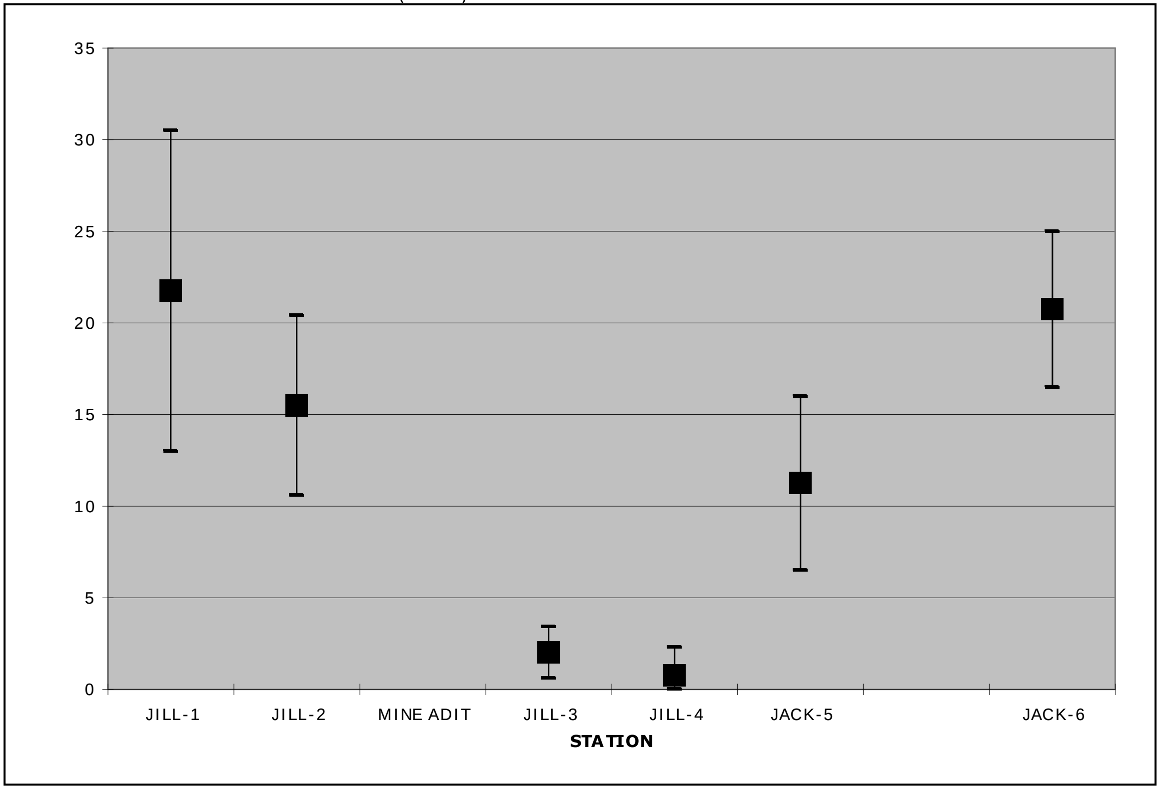
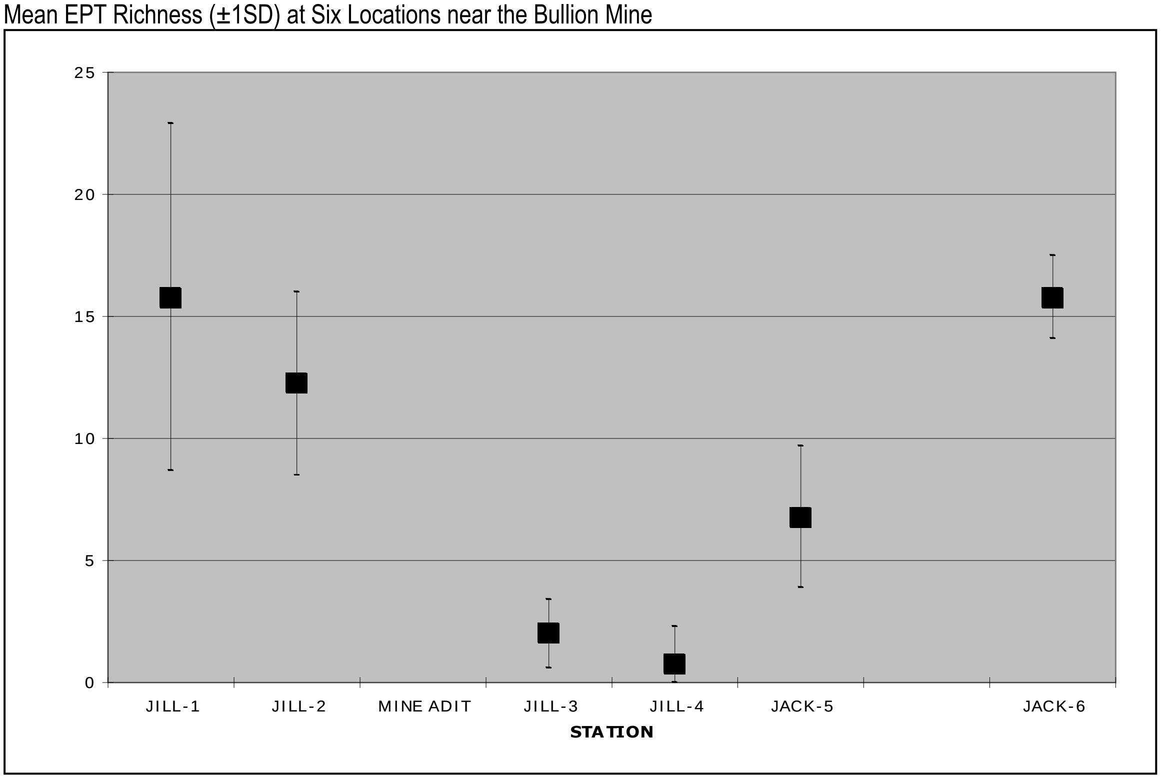


FIGURE 5
Mean EPT Richness (±1SD) at Six Locations near the Bullion Mine



4.3 Macroinvertebrate Community Composition

The late summer macroinvertebrate fauna in upper Jill Creek and Jack Creek was dominated by stoneflies (Figure 6). Mayflies were abundant at three sites but were relatively scarce at the downstream Jack Creek site (Jack-5). Dipterans replaced mayflies as the second most abundant taxonomic group at this site. Community composition analyses were not warranted for Jill Creek sites downstream from the mine adit discharge (Jill-3 and 4). Only 12 macroinvertebrates were collected from these sites.

Differences in the relative abundances of major groups reflected shifts in taxonomic composition among stations. Heptageniid mayflies were common in Jill Creek above the mine adit (Jill-1 and 2) and in Jack Creek above Jill Creek (Jack-6). *Diamesa*, a metals-tolerant chironomid, was present in each sample from lower Jack Creek (Jack-5), but was not collected at any other site. *Zapada columbiana* was the most abundant taxon at each site.

FIGURE 6
Relative Abundance (%) of Major Macroinvertebrate Taxonomic Groups at Four Locations near the Bullion Mine

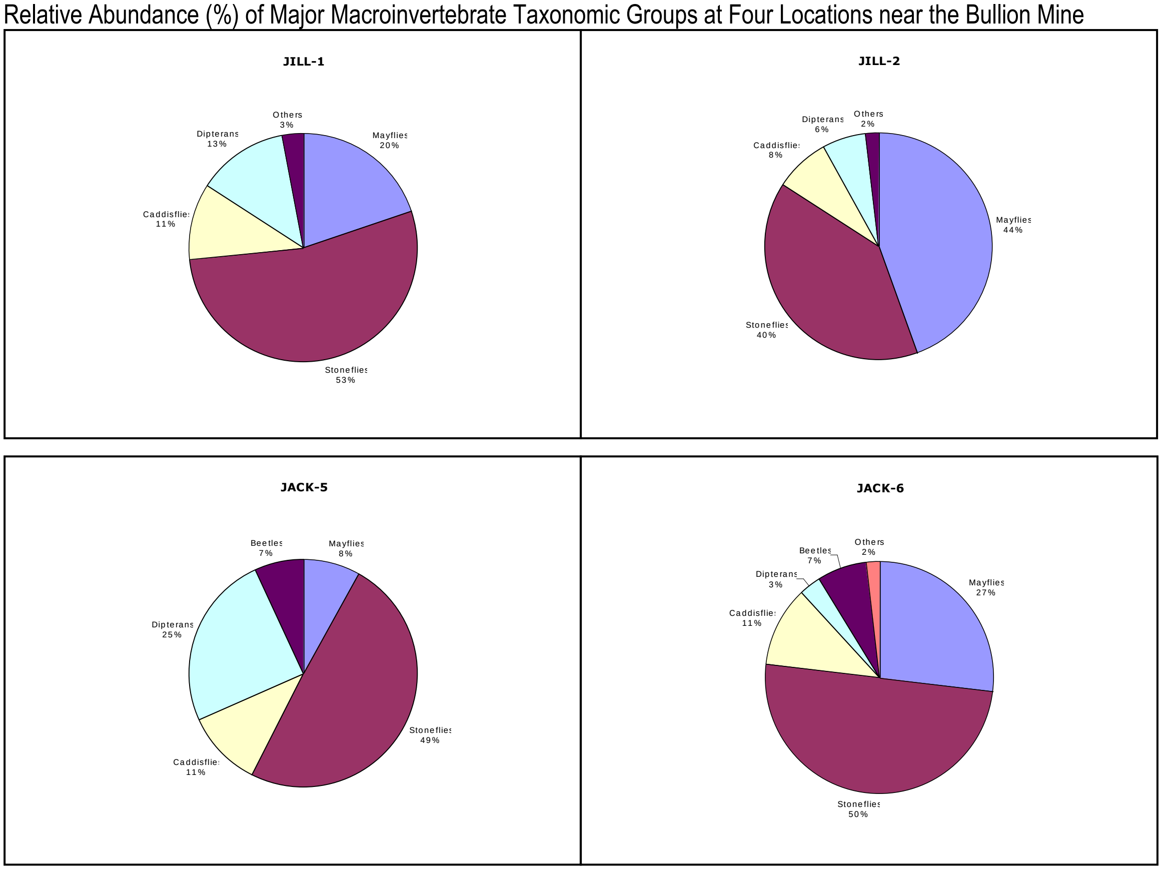


TABLE 2
Checklist of Macroinvertebrate Taxa Identified at Six Locations near the Bullion Mine, August/September 2010

Taxon	JILL-1	JILL-2	JILL-3	JILL-4	JACK-5	JACK-6
COLEOPTERA						
Heterlimnius corpulentus					X	X
Optioservus sp.					X	X
DIPTERA						
Thienemannimyia gp.	X					
Diamesa sp.					X	
Pagastia sp.	X	X			X	X
Brillia sp.	X				X	X
Cricotopus nostocladius	X					X
Eukiefferiella sp.					X	
Orthocladius sp.					X	
Parametriocnemus sp.		X				
Paraphaenocladius sp.	X					
Rheocricotopus sp.	X	X				
Tvetenia sp.	X	X				
Stempellinella sp.	X					
Micropsectra sp.	X	X				X
Dicranota sp.		X				X
Hexatoma sp.					X	
Limnophila sp.	X					
Tipulidae nr Ormosia	X					
Chelifera sp.	X					
Prosimulium sp.	X	X				
EPHEMEROPTERA	X					
Baetis bicaudatus	X	X		X		
Baetis tricaudatus					X	X
Drunella coloradensis	X	X				
Drunella doddsi					X	X
Drunella spinifera					X	X
Cinygma sp.	X				X	
Cinygmula spp.	X	X	X			X
Epeorus deceptivus	X					
Epeoris grandis		X			X	X
Rhithrogena sp.	X	X				X
Paraleptophlebia sp.	X					
Ameletus sp.	X	X			X	X
PLECOPTERA						
Leuctridae	X					X
Visoka cataractae	X	X	X		X	X
Zapada oregenensis gp.	X	X				
Zapada columbiana	X	X	X	X	X	X
Yoraperla sp.	X	X	X			X
Sweltsa sp.	X	X				X
Megarcys sp.	X	X			X	X
Isoperla sp.	X					
Setvena bradleyi						X
Doroneuria sp.	X	X			X	x
TRICHOPTERA						
Arctopsyche sp.					X	
Parapsyche sp.	X	X	X		X	X
Dicosmoecus sp.					X	
Psychoglypha sp.	X	X				
Chryptochia sp.	X			X		
Lepidostoma sp.	X					X
Glossosoma sp.						X
Rhyacophila betteni gp.	X					X
Rhyacophila brunnea gp.	X	X			X	X
Rhyacophila hyalinata gp.		X	X		X	X
Rhyacophila iranda gp.	X	X	X		X	X
Rhyacophila sibirica gp.	X	X			X	X
Rhyacophila verrula	X					
ANNELIDA						
Enchytraeidae						X
TURBELLARIA						
Polycelis sp.	X	X				X
TOTAL TAXA (58)	40	28	7	3	25	32
EPT TAXA (35)	26	20	7	3	17	23

5.0 Discussion

These data clearly show impacts from AMD and toxic pollutants originating from the Bullion Mine. A sparse, but relatively diverse macroinvertebrate assemblage was present above the mine. Downstream from the mine discharge, Jill Creek was essentially devoid of life. The few macroinvertebrates collected downstream from the adit had probably recently drifted into the reach from upstream. Measurable impacts extended downstream into Jack Creek.

Both Jack and Jill Creeks are sterile streams with poor to fair benthic habitat. Macroinvertebrates were scarce throughout the study area; only 1,301 organisms were collected during this survey. Nevertheless, several hundred macroinvertebrates were collected at each site in upper Jill Creek and in Jack Creek above the Jill Creek confluence. These sites supported diverse assemblages dominated by stoneflies and mayflies. Taxa considered sensitive to AMD were present at each site. In contrast, only 12 macroinvertebrates were collected from Jill Creek downstream from the Bullion Mine discharge. Impacts from AMD were also evident in Jack Creek below the confluence of Jill Creek. Macroinvertebrate density and taxa richness were reduced, and community composition shifted to more tolerant species in Jack Creek below Jill Creek compared to the site approximately 80 m upstream.

Data from Jill-1, Jill-2 and Jack-6 can be used as references for evaluating biological recovery at downstream sites. While these sites are not pristine, they support relatively robust macroinvertebrate faunas that are characteristic of least impaired streams in the region (Table 3).

TABLE 3
Metrics Characterizing Macroinvertebrate Assemblages in Least-Impaired Stream reaches in the Upper Boulder River and Tenmile Creek Drainages

	Jack Creek Drainage			Cataract Creek Drainage[1]		Tenmile Creek Drainage[2]	
Metric	Jill-1	Jill-2	Jack-6	USG-1	CC-5	Banner Ck	Monitor Ck
Density	479	401	585	600	340	213 to 620	147 to 577
Total Taxa	40	28	32	26	35	37 to 39	33 to 44
Percent Mayfly	20	45	27	45	29	36 to 63	20 to 42
Percent Stonefly	54	40	50	26	33	20 to 32	16 to 30

[1] - McGuire (2011). Stations Ji-1: Uncle Sam Gulch above Crystal Mine; CC-5: Cataract Creek above USG.
[2] - Skaar and McGuire (2008). Annual mean values from a three year study.

6.0 Literature Cited

McGuire, D. L. 2011. An Assessment of Aquatic Macroinvertebrates near the Crystal Mine, Jefferson County, MT. CH2MHILL. Boise, Idaho.

Skaar, D. and D. McGuire. 2008. Aquatic Health Status of the Upper Tenmile Creek Drainage, Montana 1997-2001. Impacts of Abandoned Mines and Municipal Water Diversions. Montana Fish Wildlife & Parks , Helena, MT.

APPENDIX A

Data

Bullion Mine Biomonitoring Jefferson County, MT
Jack Creek – Site 6 Above Jill Creek Confluence
LAT: 46.3643
LONG: -112.309
September 28, 2010

Standardized Sample (0.2m2):

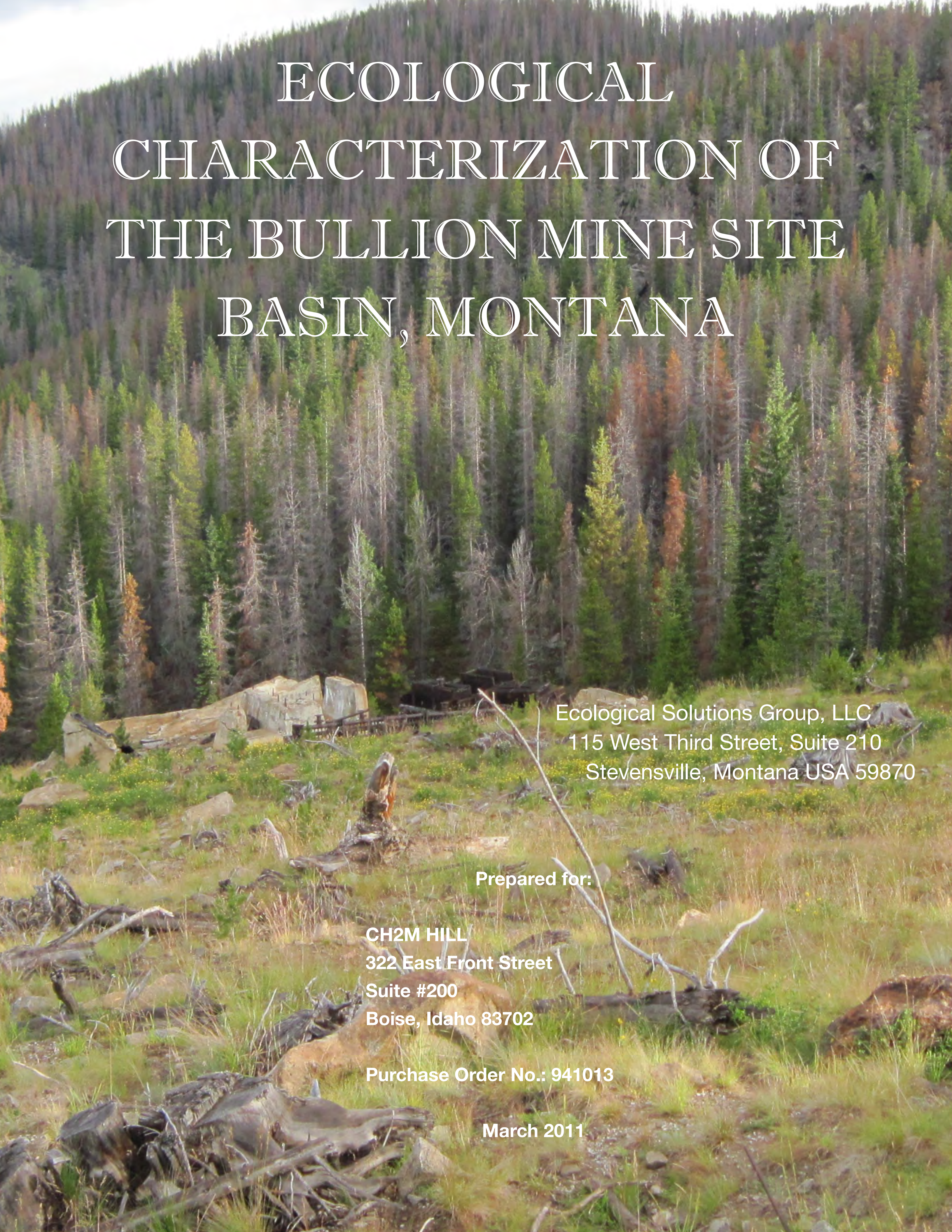
Taxon	1	2	3	4	MEAN	ST. DEV.	TOT #	%RA
COLEOPTERA					**8**		**31**	**7%**
Heterlimnius corpulentus	5	10	11	3	7.3	3.9	29	6.2%
Optioservus sp.	0	1	1	0	0.5	0.6	2	0.4%
DIPTERA					**4**		**16**	**3%**
Pagastia sp.	0	0	1	0	0.3	0.5	1	0.2%
Brillia sp.	0	1	2	1	1.0	0.8	4	0.9%
Cricotopus nostocladius	0	0	1	0	0.3	0.5	1	0.2%
Micropsectra sp.	1	4	3	1	2.3	1.5	9	1.9%
Dicranota sp.	0	0	1	0	0.3	0.5	1	0.2%
EPHEMEROPTERA					**32**		**126**	**27%**
Baetis tricaudatus	0	0	0	2	0.5	1.0	2	0.4%
Drunella doddsi	1	1	2	0	1.0	0.8	4	0.9%
Drunella spinifera	0	2	1	1	1.0	0.8	4	0.9%
Cinygmula spp.	5	12	1	1	4.8	5.2	19	4.1%
Epeorus grandis	8	18	27	4	14.3	10.3	57	12%
Rhithrogena sp.	7	3	10	9	7.3	3.1	29	6.2%
Ameletus sp.	3	6	1	1	2.8	2.4	11	2.4%
PLECOPTERA					**58**		**232**	**50%**
Leuctridae	0	0	1	1	0.5	0.6	2	0.4%
Visoka cataractae	2	10	0	0	3.0	4.8	12	2.6%
Zapada columbiana	36	63	72	18	47.3	24.8	189	41%
Yoraperla sp.	0	0	3	2	1.3	1.5	5	1.1%
Sweltsa sp.	0	0	1	0	0.3	0.5	1	0.2%
Megarcys sp.	3	1	1	3	2.0	1.2	8	1.7%
Setvena bradleyi	0	1	2	0	0.8	1.0	3	0.6%
Doroneuria sp.	3	7	1	1	3.0	2.8	12	2.6%
TRICHOPTERA					**13**		**52**	**11%**
Parapsyche sp.	0	1	2	1	1.0	0.8	4	0.9%
Lepidostoma sp.	1	0	0	0	0.3	0.5	1	0.2%
Glossosoma sp.	0	0	1	0	0.3	0.5	1	0.2%
Rhyacophila betteni gp.	2	3	6	3	3.5	1.7	14	3.0%
Rhyacophila brunnea gp.	4	7	7	3	5.3	2.1	21	4.5%
Rhyacophila hyalinata gp.	0	1	3	0	1.0	1.4	4	0.9%

Standardized Sample (0.2m2):								
Taxon	**1**	**2**	**3**	**4**	**MEAN**	**ST. DEV.**	**TOT #**	**%RA**
Rhyacophila iranda gp.	1	0	0	0	0.3	0.5	1	0.2%
Rhyacophila sibirica gp.	1	4	0	1	1.5	1.7	6	1.3%
ANNELIDA					**2**		**7**	**2%**
Enchytraeidae	3	0	4	0	1.8	2.1	7	1.5%
OTHER					**1**		**2**	**0%**
Turbellaria	0	0	1	1	0.5	0.6	2	0.4%

Standardized Sample (0.2m2):							
Taxon	**1**	**2**	**3**	**4**	**MEAN**	**ST. DEV.**	**TOT #**
TOTAL ORGANISMS	86	156	167	57	117	53.5	466
TAXA RICHNESS	17	20	27	19	20.8	4.3	32
EPT RICHNESS	14	16	18	15	15.8	1.7	23
BIOTIC INDEX	1.35	1.26	1.50	1.30	1.35	0.10	1.37
% DOMINANT TAXON	42%	40%	43%	32%	39%	5%	41%
% COLLECTORS (g+f)	14%	14%	14%	14%	14%	0%	14%
% SCRAPER+SHREDDER	70%	71%	72%	65%	69%	3%	70%
%EPT	90%	90%	85%	89%	88%	2%	88%
SHANNON DIVERSITY	3.12	3.16	3.14	3.47	3.22	0.17	3.40
EPT/(EPT + Chironomidae)	0.99	0.97	0.95	0.96	0.97	0.01	0.98
% COLLECTOR-GATHERERS	14%	13%	13%	12%	13%	1%	13%
% SHREDDERS	45%	47%	47%	39%	45%	4%	46%
% SCRAPERS	24%	23%	25%	26%	25%	1%	24%
% FILTERERS	0%	1%	1%	2%	1%	1%	1%
% PREDATORS	16%	15%	14%	21%	17%	3%	16%
% CHIRONOMIDAE	1%	3%	4%	4%	3%	1%	3%
% TANYTARSINI	1%	3%	2%	2%	2%	1%	2%
Baetidae/EPHEMEROPTERA	0%	0%	0%	11%	3%	6%	2%
METALS TOLERANCE INDEX	1.08	0.97	1.16	1.42	1.16	0.19	1.11

NOTES:
Each sample was ~0.2 meter square
Cobbles were scrubbed and finer substrates raked into a downstream net
Net was 45 cm wide by 25 mm high; 900 micron mesh
IDs by D. McGuire

Appendix H
Wetlands Inventory, Health Assessment, and T&E Species Survey



ECOLOGICAL CHARACTERIZATION OF THE BULLION MINE SITE BASIN, MONTANA

Ecological Solutions Group, LLC
115 West Third Street, Suite 210
Stevensville, Montana USA 59870

Prepared for:

CH2M HILL
322 East Front Street
Suite #200
Boise, Idaho 83702

Purchase Order No.: 941013

March 2011

AUTHORS

The authors of this document are the following:

Paul L. Hansen, Vegetation Ecologist

J. Gant Massey, Vegetation Ecologist

Tom Keith, Database Design and Management

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INTRODUCTION

Background

The Basin Watershed Operable Unit (OU) 2 consists of surface water, stream bed sediments, tailings, impacted soils, groundwater, aquatic resources, terrestrial resources, sediment deposition and contaminated property located within a 77 square mile watershed that is tributary to the Boulder River in Jefferson County, Montana (CH2M Hill 2010). Mining for gold, silver, copper, lead, and zinc began in the late 1800s in the watershed, producing a variety of wastes, including mine waste rock, mill tailings, and mill process waters that were and continue to be released into Basin/Cataract Creeks and associated tributaries (CH2M Hill 2010). The Basin OU 2 contains over 250 abandoned and/or inactive mine sites, including the Bullion Mine (Pioneer and others 1994).

In the face of these environmental issues, approximately 40,000 cubic yards of waste rock, tailings and smelter waste were removed from the Bullion Mine and nearby Crystal Mine and transported to the Luttrell Repository in 2001-2002 through a joint USFS and EPA removal action (CH2M Hill 2009). The removal action included recontouring and reseeding impacted slopes. Acid mine drainage associated with the Bullion Mine was directed to a constructed channel, but not mitigated at the time, in anticipation of additional remedial action through the CERCLA process by EPA in the future (CH2M Hill 2009).

In the meantime, according to the Remedial Investigation (CDM 2005a, CDM 2005b), seepage from from adits at the Bullion Mine continued to drain into Jill Creek. In addition, groundwater seeps and groundwater infiltration down-gradient of the Bullion Mine site also contribute to the total metal load in Jill Creek downstream of Bullion Mine. These discharges contain various concentrations of metals and arsenic which, in combination with a low pH, are detrimental to aquatic life and represent an ecological and human health risk. This risk has prompted EPA re-characterize the source of the acid mine drainage at the Bullion Mine and eventually mitigate the risk through some remedial action (CH2M Hill 2010).

In support of this initiative, CH2M Hill subcontracted with Ecological Solutions Group LLC (ESG) of Stevensville, Montana, to support the ecological characterization of the site. This work included conducting a literature search and interviews with knowledgeable State and Federal fish and wildlife personnel regarding threatened and endangered species that may occur at the Bullion Mine site. Further, ESG was subcontracted to conduct a vegetative survey across the reseeded face of the Bullion Mine to assess the progress of revegetation efforts. Finally, given the prevalence of water at the Bullion Mine site, and the elevated levels of trace element contamination in these waters, ESG was subcontracted to describe, delineate and map the extent of uplands and jurisdictional wetlands at the Bullion Mine.

This work included a field meeting on August 31, 2010, with Kris Edwards, the EPA's Remedial Project Manager for the site. During this field meeting, Kris Edwards identified areas for revegetation assessment and to delineate for jurisdictional wetlands, as well as providing additional background and directions for the field work. The field work was conducted from September 1 through September 3, 2010. Report writing occurred in the fall and winter of 2010. Report writing occurred in the fall and winter of 2010.

Scope of Work

The scope of work included the following four tasks:

1) Jurisdictional wetland survey;
2) Vegetation belt transect survey of 2001-2002 reclaimed mine site;
3) Threatened and Endangered species survey; and
4) Lotic wetland (i.e., riparian) health assessment.

LOCATION OF STUDY AREA

The Bullion Mine site is located in the Basin Creek drainage on the northwest slope of Jack Mountain, approximately 6 miles north-northwest of the town of Basin, Montana (CH2M Hill 2009). The site, which ranges in elevation from 7,100 ft to more than 7,700 ft, contains three adits (upper, middle, and lower) that are evenly distributed along the mine site, and seven foundations from mining structures, which are in various states of disrepair (CH2M Hill 2009).

Figures 1 and 2 show the location of the study area within the context of western Montana.

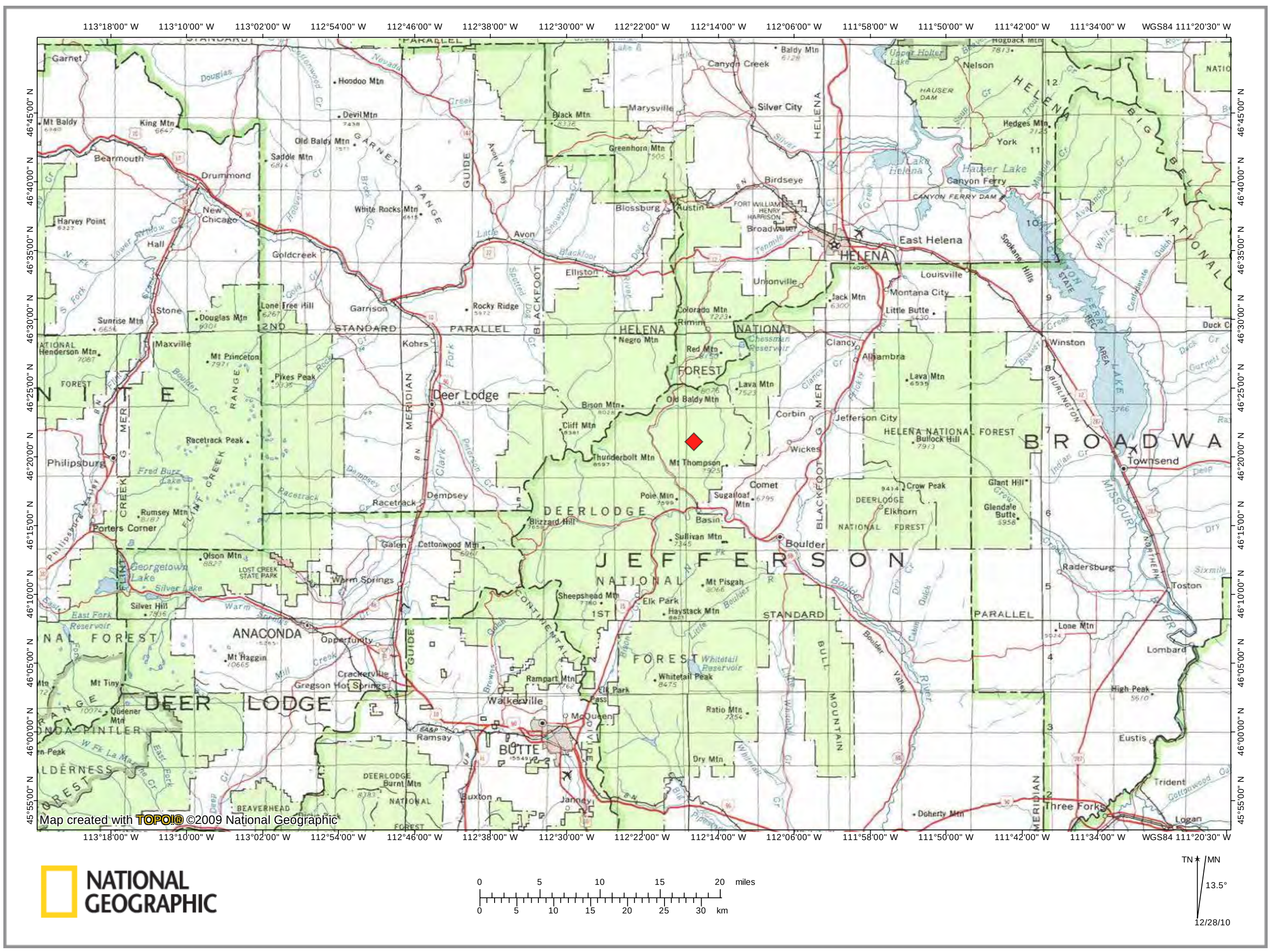


Figure 1. A red diamond marks the general location of the Bullion Mine site

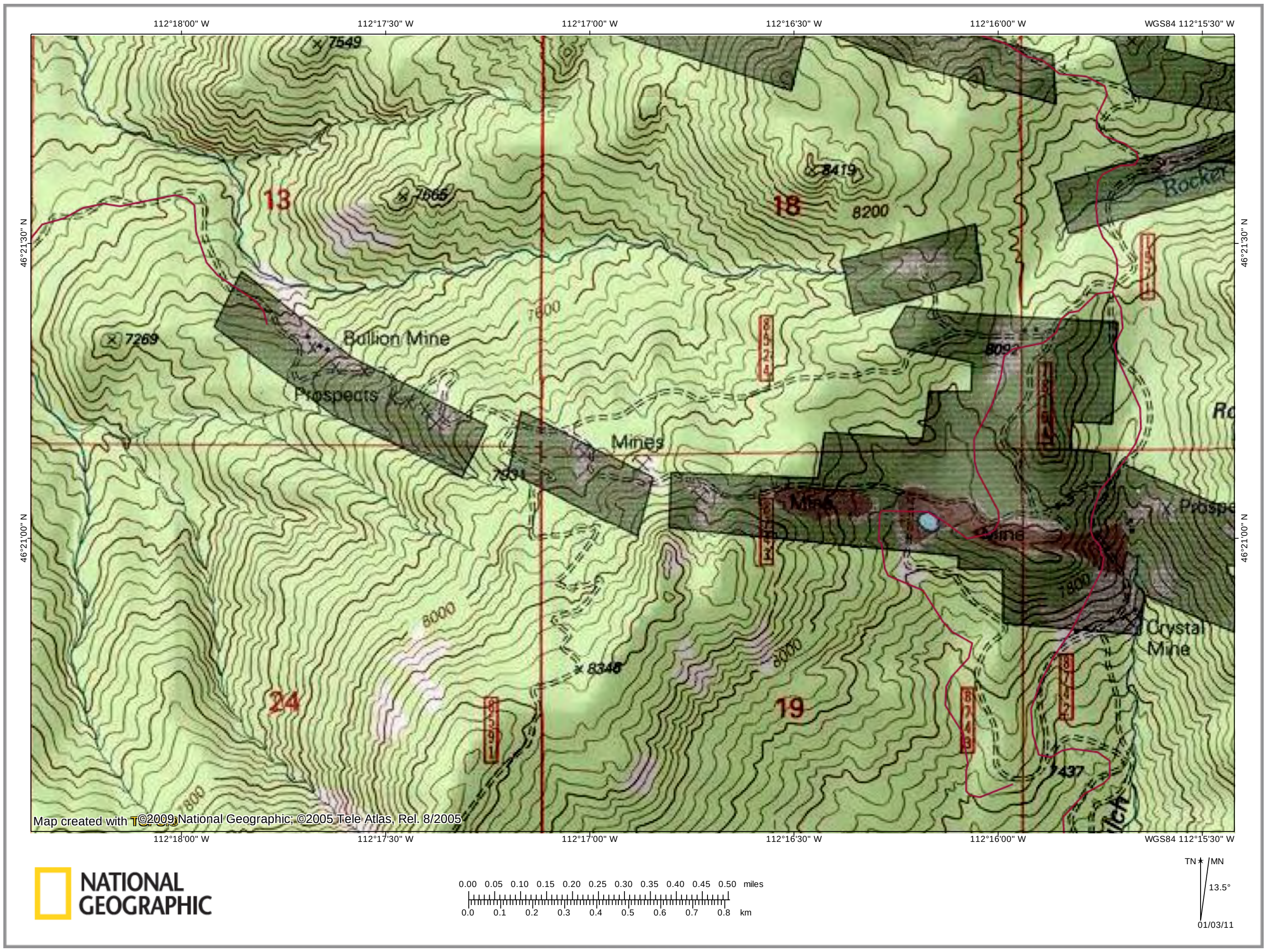


Figure 2. Location showing the Bullion Mine site (left) and Crystal Mine site (right) to the east (Jill Creek is located at the lower end of the mine site and flows to the northwest and is a tributary of Jack Creek)

PHYSIOGRAPHY AND GEOLOGY OF STUDY AREA

The Bullion Mine site shares common geology with the rest of the Basin watershed, which is comprised mostly of Elkhorn Mountains Volcanics (EMV), Granodioritic rocks, and surficial sedimentary deposits, all of which date to the Cretaceous period (Montana Bureau of Mines and Geology 2009). The Bullion Mine site is underlain by Butte Pluton, which consists of crystalline igneous rocks and assorted volcanic rocks, which are highly fractured. These fractures are important because the polymetallic quartz veins targeted for mining developed in east-trending fractures formed by tectonic stresses that appear to be related to emplacement of the crystalline rocks. Further, these fractures strongly influence groundwater movement through the rock (CH2M Hill 2009). Indeed, because of the steep grades of the land, groundwater seeps are common throughout the area, particularly along fault zones, mineralized zones and large fractures (USGS 2004). Near-surface groundwater is recharged through snowmelt and direct precipitation, which at high elevations can reach 20 to 30 inches per annum (Natural Resources and Conservation Service 2011b). Recharge is greatest in areas with higher hydraulic conductivity, such as zones of densely fractured rock (CH2M Hill 2009).

CLIMATE DATA

As shown in Table 1, there are three sites near the Bullion Mine at which weather data has been recorded:

Table 1. Weather records for sites near the Bullion Mine (7,650 ft in elevation)

Location	Distance from Bullion Mine	Elevation	Period of Record
Basin, Montana	5.5 air miles	5,350 ft	1944-1970
Frohner Meadows, Montana	7.5 air miles	6,480 ft	1989-present
Rocker Peak, Montana	0.5 air miles	8,000 ft	1979-present

Given its similar elevation to the Bullion Mine, the data from the Rocker Peak station probably gives the most representative data for weather conditions at the Bullion Mine. Nonetheless, given the relatively short period of record for the Rocker Peak station, weather information for all three sites are provided below in Tables 2 and 3 to give a regional perspective regarding weather patterns at and near the Bullion Mine.

As shown in Tables 2 and 3, the area near the the Bullion Mine is very cold in the winter and warmest mid-summer. Temperature extremes range from average lows well below freezing from November through February, with average highs near 80°F in July. Average precipitation increases with elevation, although the wettest months are consistently May and June at all three weather data collection locations. February is the driest month at Basin and Frohner Meadows, and the second driest month at Rocker Peak, with October the driest month at that location.

Table 2. Weather records for sites near the Bullion Mine

Location	Average Temp	Average Monthly Low Temp (Month)	Average Monthly High Temp (Month)	Historic Low Temp (Year)	Historic High Temp (Year)	Annual Precipitation
Basin[1]	42.4° F	10° F (Jan)	82° F (Jul)	-42° F (1990)	101° F (2002)	11.5 inches
Frohner Meadow[2]	37.5° F	8° F (Jan)	84° F (Jul)	-54° F (1990)	90° F (1990)	22.9 inches
Rocker Peak[3]	32.8° F	-21° F (Dec/Feb)	77° F (Jul)	-42° F (1990)	84° F (2008)	29.1 inches

Source: [1]The Weather Channel 2011, [2]Natural Resources and Conservation Service 2011a, [3]Natural Resources and Conservation Service 2011b

Table 3. Monthly temperature and precipitation averages for sites near the Bullion Mine

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (˚F)												
Basin[1]	22	27	33	41	50	58	65	64	54	44	30	23
Frohner Meadow[2]	23	23	28	34	42	49	58	57	48	38	29	22
Rocker Peak[3]	19	19	23	29	37	44	53	52	44	33	23	17
Precipitation (inches)												
Basin[1]	0.4	0.3	0.5	0.8	2.0	1.9	1.5	1.4	1.1	0.6	0.6	0.4
Frohner Meadow[2]	1.6	1.4	1.5	2.2	2.7	3.6	2.4	1.5	1.8	0.9	1.7	1.7
Rocker Peak[3]	2.2	1.9	2.3	3.2	3.5	4.2	2.7	1.7	2.0	1.0	2.1	2.3

Source: [1]The Weather Channel 2011, [2]Natural Resources and Conservation Service 2011a, [3]Natural Resources and Conservation Service 2011b

PHOTOGRAPHS OF STUDY AREA

The following photographs show the overall landscape of the mine site, interesting geologic features, and interesting plants.

Photo 1. Looking northeast across the face of the 2001-2002 reclaimed mine site. Notice concrete foundations in the center of the photo

Photo 2. Healthy, robust specimen of *Deschampsia cespitosa* (tufted hairgrass), an acid mine-tolerant grass species

Photo 3. One of five vegetation belt transects established across the 2001-2002 reclaimed mine site. The yellow flowered forb is *Lotus corniculatus* (birds-foot trefoil), and introduced forb

Photo 4. Looking east across one of the five vegetation belt transects across the 2001-2002 reclaimed mine site. Notice the concrete foundation in the upper right

Photo 5. The lower vegetation belt transects established across the 2001-2002 reclaimed mine site. The constructed channel that carries the acid mine drainage from the adit is present in the photo

Photo 6. Looking to the west from above the 2001-2002 reclaimed floodplain of Jill Creek

Photo 7. Relatively undisturbed portion of Jill Creek, east (upstream) of the 2001-2002 reclaimed floodplain section

Photo 8. Another photo of the relatively undisturbed floodplain of Jill Creek. Notice the abundant woody vegetation along the creek

Photo 9. Dense, diverse vegetation dominates the relatively undisturbed section of Jill Creek located east (upstream) of the 2001-2002 reclaimed floodplain

Photo 10. Jill Creek on the eastern edge of the 2001-2002 reclaimed floodplain prior to the confluence with the acid mine drainage from the adit. Notice the water clarity

Photo 11. Jill Creek upstream of the confluence with the mine adit

Photo 12. Constructed channel containing the acid mine drainage from the adit just above the confluence with Jill Creek. Notice the color of the water

Photo 13. Confluence of the adit and Jill Creek. Notice the water clarity change when the streams meet

Photo 14. Immediately downstream of the confluence of the adit and Jill Creek. Notice the water clarity change and the staining of the channel materials

Photo 15. Looking upstream of Jill Creek showing the confluence with the adit. The streambanks are engineered with rock, logs, and coir fabric

Photo 16. Downstream of confluence showing engineered streambanks, drop structures, and stained streambed

Photo 17. Looking upstream near the lower end of the study area. Notice the faint yellow line in the upper center representing a line transect tape used in determining jurisdictional wetlands

Photo 18. Reconstructed streambank (2001-2002) with logs and coir fabric

Photo 19. Notice the reconstructed streambanks and stream channel with energy-dissipating log drop structures. Notice the cloudy water and stained streambed and log structures

Photo 20. Near the lower end of the study area. Notice the rock and log-lined streambanks

Photo 21. Looking downstream (west) of Jill Creek showing the constructed streambanks and channel

Photo 22. Looking upstream (southeast) back towards the 2001-2002 reclaimed mine site

Photo 23. Lower end of the study area showing the energy dissipating drop structures placed throughout the stream channel

METHODS

Jurisdictional Wetland Survey

The 1987 U.S. Army Corps of Engineers Manual and Regional Supplement for Western Mountains, Valleys, and Coast Region (2010) provide for methods to be used when there has been natural or human-induced alterations that have significantly changed the area soils, hydrology and/or vegetation, i.e., atypical situations. This is pertinent in that all three of the functional wetland criteria have been altered at the Bullion Mine. A significant portion of the soils at the site have been dug up, removed, moved and replaced during the course of mining, both from direct action, as well as from the the gravitational and alluvial movement of mine tailings. In addition, during efforts at site cleanup and restoration, site soils were significantly disturbed through removal and construction. Despite the efforts at reclamation, however, site soils still contain over three times the background concentrations for arsenic, cadmium, copper, lead, mercury, antimony, and zinc.

In addition, two adits are actively discharging mine-impacted water onto the site, which has a pH of 2.92. This adit water contains concentrations of arsenic, cadmium, copper, nickel, and antimony that exceed acceptable Federal Safe Drinking Water Act (SDWA) maximum contaminant levels/maximum contaminant level goals (MCL/MCLG). Further, the sampled adit discharge exceeded fresh water chronic and acute aquatic life criteria presented in the Montana Numeric Water Quality Standards, Circular WQB-7, for arsenic, cadmium, copper, lead, and zinc. In addition, both the streams issuing from the adit and side streams have been placed in rock channels, and the streambanks of Jill Creek have been completely reconstructed using log revetments and erosion fabric. Also, it appears that the removal of contaminated soils from selected sections of the site have lowered the soil level relative to the water table, significantly increasing the number of springs and the flow of surface water.

Finally, during site cleanup and restoration, the site was seeded with a grass and forb mix, and then planted with tree and shrub seedlings. While both the seeding and herbaceous plant palettes were designed to match site conditions and to encourage rapid revegetation, this effort complicated wetland determination in two ways. First, the revegetation mix introduced some non-native species, such as *Lotus corniculatus* (birds-foot trefoil) to the site. Second, the plants now on site represent a man-made construct that mimics nature, but may not match pre-disturbance conditions.

Given these factors, what wetlands occur at the Bullion Mine are man-induced, i.e., they have been purposely or incidentally created by human activities. As the atypical situation that these man-induced changes have created are now the “normal circumstances” for the area, the Bullion Mine was examined as it currently is for jurisdictional and/or functional wetland status, not as it might have been pre-disturbance.

The wetlands at the Bullion Mine were jurisdictionally delineated through the routine methods defined in the 1987 U.S. Army Corps of Engineers (USACE) Manual and the Regional Supplement for Western Mountains, Valleys, and Coast Region (2010). The area of functional wetlands were delineated using similarly-based methods. The purpose of the mapping was to establish a baseline from which to help gauge the overall effect of remedial activities at the Bullion Mine on the wetlands of the site.

The USACE Manual (1987) states that, “[S]ite-specific conditions may require modification of field procedures. For example, slope configuration in a complex area may necessitate modification of the baseline and transect positions. . . However, the basic approach for making jurisdictional wetlands determinations should not be altered (i.e., the determination should be based on the dominant plant species, soil characteristics, and hydrologic characteristics of the area in question). The user should document reasons for using a different characterization procedure than described in the manual." Given the size and shape of the site, as well as other project considerations, the USACE methods were slightly altered in the following manner at the Bullion Mine.

From the top to the bottom of its major watercourses, the Bullion Mine site is approximately a half-mile in length (approx. 2,400 ft) and averages a tenth of a mile in width (approx. 600 ft) (Fig. 3). The red line represents the area where the surveys were conducted. Jill Creek runs along the northern boundary of the survey area. On areas over 5 acres in size but less than a mile in length, the USACE Manual (1987) calls for the establishment of three transects perpendicular to a baseline that lies parallel the major watercourse. In addition to its wetlands work, however, the contract requires a separate vegetative survey to be performed on five transects perpendicular to the vertical face of the mine. The area covered by the vegetative survey overlays part of the area covered by the wetlands survey. We therefore co-located five of its wetlands transects with the five vegetative transects. In addition, we added a sixth and seventh wetlands transect in an area not covered by the vegetative survey. The yellow lines represent the five transects across the face of the reclaimed area, while the blue lines represent the additional wetlands assessed in the lower portion of the survey area.

Figure 3. Bullion Mine project area and transects

Additionally, the U.S. Army Corps of Engineers Manual (1987) calls for the use of a 30 ft radius quadrat to capture herbaceous overstory data, a 10 ft radius quadrat to capture herbaceous understory and herbaceous vine data, and a 1.64 ft radius quadrat to capture herbaceous plant data. Protocol calls for these co-located plots to be placed along each transect at spots indicative of each unique plant community found. Given that this site has only recently been revegetated and that mature plant communities have yet to take hold, ESG instead investigated wetland patterns in a 1 meter wide band along each transect, making breaks between investigative quadrats based upon observable changes in hydrologic patterns (i.e., the presence of inundated conditions versus dry conditions) and in vegetation (i.e., the presence of upland species such as *Festuca idahoensis* [Idaho fescue] versus wetland species such as *Juncus balticus* [Baltic rush]).

Given the extreme level of soil disturbance, soil horizon characteristics were not considered either in making breaks between investigative quadrats or for wetland characterizations. Hydrologic characterization followed the USACE Manual (1987). Vegetative information was collected using plant cover per Daubenmire (1959) for the herbaceous layer, and plant counts for the herbaceous understory and overstory layers (USACE 1987). No vines were found within the study area. Dominance by canopy position was determined through the standard 50/20 rule (USACE 1987). The ends of each transect and the position of breaks between investigative quadrats were collected using Wide Area Augmentation System (WAAS) compatible, Garmin eTrex Vista HCx Global Positioning System (GPS) units, with a position accuracy of ± 3 m, utilizing the World Geodetic System 84 (WGS 84) reference system. All coordinates in the report are presented as decimal degrees.

Vegetation Belt Transect Survey

Five vegetation belt transects were established across the 2001-2002 revegetated reclaimed mine site to assess the success of the revegetation effort (Fig. 3). The total area of the reclaimed mine site is approx. 2.2 acres. The belt transects were 3 ft wide and varied in length due to the irregular shape of the reclaimed mine site. All plants with canopy cover in the belt transect were recorded along with their canopy cover class. Additional vegetation and site information was also collected. The data was then cleaned and analyzed with tools ESG has developed over the years. The data sheets along with a summary of the five transects is presented in Appendices A and B.

Threatened and Endangered Species Survey

The review of threatened and endangered species potentially present at the Bullion Mine site was conducted in September 2010. This work included a review of current lists of endangered, threatened, proposed, and candidate species from the USDI Fish and Wildlife Service, the State of Montana Department of Fish, Wildlife and Parks, and the Montana Natural Heritage Program. The review also included direct interviews with technical experts at the State of Montana's Department of Fish, Wildlife and Parks, and the Montana Natural Heritage Program.

Lotic Wetland (i.e., Riparian) Health Assessment

Polygon Location—Stream reaches were delineated to determine the overall health of particular reach. A reference reach was used to relate a particular stream reach to a relatively undisturbed reach within the immediate area. The reference reach was located on Upper Jill Creek.

Factors of the Lotic Wetland Health Assessment—Any rating of riparian site health necessarily combines the assessment of a variety of vegetation and physical factors that determine hydrologic and edaphic function. The several factors comprising the riparian health rating are all interrelated, but are understood to have individual importance reflected by the weight given to each item on the Lotic Wetland Health Assessment form. The factor breakout groupings and point weighting in the evaluation are not based on quantitative studies so much as they were subjectively determined, using the collective experience and collaboration of an array of riparian scientists, hydrologists, range professionals, and land managers working together in a reiterative process (called the "Delphi" approach), coordinated and directed by the Riparian and Wetland Research Program at the University of Montana (Hansen and others 2000).

Following is a list of the items scored on the health assessment, including a brief discussion of each item to inform the reader of its ecological importance. Details of the scoring thresholds and instructions for how the observer is to rate each item are provided in the Lotic Wetland Health Assessment for Streams and Small Rivers (Survey) field form and User Manual as a separate document accompanying the final report. The User Manual also includes a discussion of the background and development of this methodology, as well as instructions in its application and utility. The short discussions given below of the assessment items are excerpted from the detailed treatment provided in the User Manual.

Some factors do not apply on every site. For example, factors concerning trees and shrubs are not rated on sites having no potential for woody species. Vegetative site potential can be determined by using a key to site type (e.g., Hansen and others 1995, 2008; Hansen and Hall 2002; Thompson and Hansen 2001, 2002, 2003, or another appropriate publication). On severely disturbed sites, vegetation potential may be difficult to determine. On such sites, clues to potential may be sought on nearby sites having similar landscape position.

Most of the factors in this evaluation are rated by ocular estimations. Such estimation can be challenging on large, brushy sites with limited visibility; however, extreme precision is not necessary. Although the rating categories are broad, evaluators are required to calibrate their eye with practice. It is important to remember that a health rating is not an absolute numerical value. The factor breakout groupings and point weighting in the evaluation are somewhat subjective and are not grounded in quantitative science so much as in the collective experience of an array of collaborating riparian scientists, range professionals, and land managers.

1. Vegetative cover of floodplain and streambanks (6 of 60 total points = 10 percent of the total score)—
Vegetation cover helps to stabilize streambanks, control nutrient cycling, reduce water velocity, provide fish cover and food, trap sediments, reduce erosion, and reduce the rate of evaporation (Platts and others 1987). On most streams the area of the channel bottom is excluded from the polygon. (***Note:*** *The whole channel width extends from right bankfull stage to left bankfull stage; however we need to include the lower streambanks in all polygons, therefore consider for exclusion ONLY the relatively flat and lowest area of the channel—the "bottom."*) This allows data to be collected on the riparian area while excluding the aquatic zone, or open water, of the stream. The aquatic zone is the area covered by water and lacking persistent emergent vegetation. Persistent emergent vegetation consists of perennial wetland species that normally remain standing at least until the beginning of next growing season, e.g., *Typha* species (cattails), *Scirpus* species (bulrushes), *Carex* species (sedges), and other perennial graminoids.

In many systems, large portions of the channel bottom may become exposed due to seasonal irrigation use, hydroelectric generation, and natural seasonal changes such as are found in many prairie ecosystems. In these cases, especially the prairie streams, the channel bottom may have varying amounts of herbaceous vegetation, and the channel area is ***included*** in the polygon as area to be inventoried. Typically these are the "pooled channel" stream type that has scour pools scattered along the length, interspersed with reaches of grass, bulrush, or sedge-covered channel bottom. If over half (>50 percent) the channel bottom area has a canopy cover of persistent vegetation cover (perennial species), taken over the entire length of the polygon as a whole, then it qualifies for inclusion within the inventoried polygon area. If you are in doubt whether to include the channel bottom in the polygon, then leave it out, but be sure to indicate this in the comment section. This is important so that future assessments of the polygon will be looking at the same area of land.

2. Invasive plant species (weeds) (6 of 60 total points = 10 percent of the total score)—Invasive plants (weeds) are alien species whose introduction does or is likely to cause economic or *environmental* harm. Whether the disturbance that allowed their establishment is natural or human-caused, weed presence indicates a degrading ecosystem. While some of these species may contribute to some riparian functions, their negative impacts reduce overall site health. This item assesses the degree and extent to which the site is infested by invasive plants. The severity of the problem is a function of the density/distribution (pattern of occurrence), as well as canopy cover (abundance) of the weeds. In determining the health score, all invasive species are considered collectively, not individually. A standard weed list should be used for the locality to indicate the species being considered.

3. Disturbance-increaser undesirable herbaceous species (3 of 60 total points = 5 percent of the total score)—A large cover of disturbance-increaser undesirable herbaceous species, native or exotic, indicates displacement from the potential natural community (PNC) and a reduction in riparian health. These species generally are less productive, have shallow roots, and poorly perform most riparian functions. They usually result from some disturbance, which removes more desirable species. Invasive species considered in the previous item are not reconsidered here. A partial list of undesirable herbaceous species appropriate for use in follows. A list should be used that is standard for the locality and that indicates which species are being considered. The evaluator should list any additional species included.

Amaranthus spp. (pigweed)	*Antennaria* spp. (pussy-toes)	*Brassicaceae* (mustards)
Fragaria spp. (strawberries)	*Kochia scoparia* (kochia; fire-weed)	*Medicago lupulina* (black medic)
Plantago spp. (plantains)	*Poa pratensis* (Kentucky bluegrass)	*Potentilla anserina* (silverweed)
Taraxacum spp. (dandelion)	*Salsola iberica* (Russian thistle)	*Trifolium* spp. (clovers)

4. Preferred tree and shrub establishment and/or regeneration (6 of 60 total points = 10 percent of the total score)—(*Skip this item if the site lacks potential for trees or shrubs; for example, the site is a herbaceous wet meadow or marsh.*) Not all riparian areas can support trees and/or shrubs. However, on those sites where such species do belong, they play important roles. The root systems of woody species are excellent streambank stabilizers, while their spreading canopies provide protection to soil, water, wildlife, and livestock. Young age classes of woody species are important for the continued presence of woody communities not only at a given moment but into the future. Woody species potential can be determined by using a key to site type (Hansen and others 1995, 2008; Hansen and Hall 2002; Thompson and Hansen 2001, 2002, 2003, etc.). On severely disturbed sites, the evaluator should seek clues to potential by observing nearby sites with similar landscape position. (***Note:*** Vegetation potential is commonly underestimated on sites with a long history of disturbance.)

The following species are excluded from the evaluation:

- *Artemisia cana* (silver sagebrush), including subsp. *cana* and *viscidula;*
- *Artemisia frigida* (fringed sagewort);

- *Crataegus* species (hawthorn);
- *Elaeagnus angustifolia* (Russian olive);
- *Gutierrezia sarothrae* (broom snakeweed);
- *Rosa* species (rose);
- *Sarcobatus vermiculatus* (black greasewood);
- *Symphoricarpos* spp. (snowberry);
- *Tamarix* species (saltcedar; tamarisk); and
- Non native species.

These are species that may reflect long-term disturbance on a site, that are generally less palatable to browsers, and that tend to increase under long-term moderate-to-intense grazing pressure; ***AND*** for which there is rarely any problem in maintaining presence on site. Examples of the latter include *Artemisia cana* (silver sagebrush) and *Sarcobatus vermiculatus* (black greasewood). Both are considered climax species in many riparian situations and rarely have any problem maintaining a presence on a site. Only under extreme long-term grazing pressures will these species be eliminated from a site. On the other hand, *Elaeagnus angustifolia* (Russian olive) and *Tamarix* spp. (saltcedar; tamarisk) are especially aggressive, undesirable exotic plants.

The main reason for excluding these plants is that they are far more abundant on many sites than are species of greater concern (i.e., *Salix* species [willows], *Cornus stolonifera* [red-osier dogwood], *Amelanchier alnifolia* [Saskatoon serviceberry], and many other taller native riparian species), and they may mask the ecological significance of a small amount of a species of greater concern. ***FOR EXAMPLE:*** A polygon may have *Symphoricarpos occidentalis* (western snowberry) with 30 percent canopy cover showing young plants for replacement of older ones, while also having a trace of *Salix exigua* (sandbar willow) present, but represented only by older mature individuals. We feel that the failure of the willow to regenerate (even though there is only a small amount) is very important in the health evaluation, but by including the snowberry and willow together on this polygon, the condition of the willow would be hidden (overwhelmed by the larger amount of snowberry).
5a. Browse utilization of available preferred trees and shrubs (3 of 60 total points = 5 percent of the total score) —(*Skip this item if the site lacks trees or shrubs; for example, the site is a herbaceous wet meadow or cattail marsh, or all woody plants have already been removed.*) Livestock and/or wildlife browse many riparian woody species. Excessive browsing can eliminate these important plants from the community and result in their replacement by undesirable invaders. With excessive browsing, the plant loses vigor, is prevented from flowering, or is killed. Utilization in small amounts is normal and not a health concern, but concern increases with greater browse intensity.

The following species are excluded from the evaluation:

- *Artemisia cana* (silver sagebrush), including subsp. *cana* and *viscidula;*
- *Artemisia frigida* (fringed sagewort);
- *Crataegus* species (hawthorn);
- *Elaeagnus angustifolia* (Russian olive);
- *Gutierrezia sarothrae* (broom snakeweed);
- *Rosa* species (rose);
- *Sarcobatus vermiculatus* (black greasewood);
- *Symphoricarpos* spp. (snowberry);

- *Tamarix* species (saltcedar; tamarisk); and
- Non native species.

These are species that may reflect long-term disturbance on a site, that are generally less palatable to browsers, and that tend to increase under long-term moderate-to-intense grazing pressure; ***AND*** for which there is rarely any problem in maintaining presence on site. Examples of the latter include *Artemisia cana* (silver sagebrush) and *Sarcobatus vermiculatus* (black greasewood). Both are considered climax species in many riparian situations and rarely have any problem maintaining a presence on a site. Only under extreme long-term grazing pressures will these species be eliminated from a site. On the other hand, *Elaeagnus angustifolia* (Russian olive) and *Tamarix* spp. (saltcedar; tamarisk) are especially aggressive, undesirable exotic plants.

The main reason for excluding these plants is that they are far more abundant on many sites than are species of greater concern (i.e., *Salix* species [willows], *Cornus stolonifera* [red-osier dogwood], *Amelanchier alnifolia* [Saskatoon serviceberry], and many other taller native riparian species), and they may mask the ecological significance of a small amount of a species of greater concern. ***FOR EXAMPLE:*** A polygon may have *Symphoricarpos occidentalis* (western snowberry) with 30 percent canopy cover showing young plants for replacement of older ones, while also having a trace of *Salix exigua* (sandbar willow) present, but represented only by older mature individuals. We feel that the failure of the willow to regenerate (even though there is only a small amount) is very important in the health evaluation, but by including the snowberry and willow together on this polygon, the condition of the willow would be hidden (overwhelmed by the larger amount of snowberry).

5b. Live woody vegetation removal by other than browsing (3 of 60 total points = 5 percent of the total score)— Excessive cutting or removing parts of plants or whole plants by agents other than browsing animals (e.g., human clearing, cutting, beaver activity, etc.) can result in many of the same negative effects to the community that are caused by excessive browsing. However, other effects from this kind of removal are direct and immediate, including reduction of physical community structure and wildlife habitat values.

Removal of woody vegetation may occur at once (timber harvest), or it may be cumulative over time (annual firewood cutting or beaver activity). This question is not so much to assess long term incremental harvest, as it is to assess the extent that the stand is lacking vegetation that would otherwise be there today. Give credit for re-growth. Consider how much the removal of a tree many years ago may have now been mitigated with young replacements.

Three non-native species or genera are excluded from consideration here because these are aggressive, invasive exotic plants that should be removed. They are *Elaeagnus angustifolia* (Russian olive), *Rhamnus cathartica* (common buckthorn), and *Tamarix* spp. (salt cedar).

6. Standing decadent and dead woody material (3 of 60 total points = 5 percent of the total score)—(*Skip this item if the site lacks trees or shrubs; for example, the site is a herbaceous wet meadow or cattail marsh.*) The amount of decadent and dead woody material on a site can be an indicator of the overall health of a riparian area. Large amounts of decadent and dead woody material may indicate a reduced flow of water through the stream (dewatering) due to either human or natural causes. Dewatering of a site, if severe enough, may change the site vegetation potential from riparian species to upland species. In addition, decadent and dead woody material may indicate severe stress from over browsing. Finally, large amounts of decadent and dead woody material may indicate climatic impacts, disease and insect damage. For instance, severe winters may cause extreme die back of trees and shrubs, and cyclic insect infestations may kill individuals in a stand. In all these cases, a high percentage of dead and decadent woody material reflects degraded vegetative health, which can lead to reduced streambank integrity, channel incisement, and excessive lateral cutting, besides reducing production and other wildlife values.

7. Streambank root mass protection (6 of 60 total points = 10 percent of the total score)—Vegetation along streambanks performs the primary physical functions of stabilizing the soil with a binding root mass and of filtering sediments from overland flow. Few studies have documented depth and extent of root systems of plant species found in wetlands. Despite this lack of documented evidence, some generalizations can be made. All tree and shrub species are considered to have deep, binding root masses. Among wetland herbaceous species, the first rule is that annual plants lack deep, binding roots. Perennial species offer a wide range of root mass qualities. Some rhizomatous species such as the deep rooted *Carex* species (sedges) are excellent streambank stabilizers. Others, such as *Poa pratensis* (Kentucky bluegrass), have only shallow roots and are poor streambank stabilizers. Still others, such as *Juncus balticus* (Baltic rush), are intermediate in their ability to stabilize streambanks. The size and nature of the stream will determine which herbaceous species can be effective.

8. Human-caused bare ground (6 of 60 total points = 10 percent of the total score)—Bare ground is soil not covered by plants, litter or duff, downed wood, or rocks larger than 6 cm (2.5 in). Hardened, impervious surfaces (e.g., asphalt, concrete, etc.) are not bare ground—these do not erode nor allow weeds sites to invade. Bare ground caused by human activity indicates a deterioration of riparian health. Sediment deposits and other natural bare ground are excluded as normal or probably beyond immediate management control. Human land uses causing bare ground include livestock grazing, recreation, roads, and industrial activities. The evaluator should consider the causes of all bare ground observed and estimate the fraction that is human-caused.

9. Streambank structurally altered by human activity (6 of 60 total points = 10 percent of the total score)—Altered streambanks are those having impaired structural integrity (strength or stability) usually due to human-causes. These streambanks are more susceptible to cracking and/or slumping. Count as streambank alteration such damage as livestock or wildlife hoof shear and concentrated trampling, vehicle or ATV tracks, and any other areas of human-caused disruption of streambank integrity, including rip-rap or use of fill. The basic criterion is any disturbance to streambank structure that increases erosion potential or streambank profile shape change. One large exception is lateral streambank cutting caused by stream flow, even if thought to result from upstream human manipulation of the flow. The intent of this item is to assess only direct, on-site mechanical or structural damage to the streambanks.

10. Human physical alteration to the rest of the polygon (3 of 60 total points = 5 percent of the total score)—Within the remainder of the polygon area, outside the streambank area that was addressed in the previous question, estimate the amount of area that has been physically altered by human-causes. The purpose of this question is to evaluate physical change to the soil, hydrology, etc. as it affects the ability of the natural system to function normally. Changes in soil structure will alter infiltration of water, increase soil compaction, and change the amount of sediment contributed to the water body. Every human activity in or around a natural site can alter that site. This question seeks to assess the accumulated effects of all human-caused change. Count such things as:

- **Soil Compaction.** This kind of alteration includes livestock-caused hummocking and pugging, recreational trails that obviously have compacted the soil, vehicle and machine tracks and ruts in soft soil, etc.
- **Plowing/Tilling.** This is disruption of the soil surface for cultivation purposes. It does not include the alteration of drainage or topographic pattern, which are included in the **Topographic Change** category.
- **Hydrologic Change.** Include in this category any area that is physically affected by removal or addition of water for human purpose. The physical effects to look for are erosion due to reduced or increased water, bared soil surface that had water cover removed, or flooded area that normally supports a drier vegetation type.
- **Human Impervious Surface.** This includes roofs, hardened surfaces like walkways and roads, boat launches, etc.
- **Topographic Change.** This is the deliberate alteration of terrain and/or drainage pattern for human purposes. It may be for aesthetic (landscaping) or other reasons, including such structures as water diversions ditches and canals.

11. Stream channel incisement (vertical stability) (9 of 60 total points = 15 percent of the total score)—An incised stream channel has vertically downcut its bed. Incisement can lower the water table enough to change vegetation site potential. It can also increase stream energy by reducing sinuosity, reducing water retention/storage, and increasing erosion. A stream becomes critically incised when downcutting lowers the channel bed so that the two-year flood event cannot overflow the streambanks. A severe disturbance can initiate downcutting, transforming the system from one having a high water table, appropriate floodplain, and high productivity to one of degraded water table, narrow (or no) active floodplain, and no productivity. Channel incisement is the most heavily weighted factor on the health assessment, which reflects the profound importance of maintaining the water table elevation. For the health assessment, this factor is assessed in terms of the stages of channel degradation and subsequent healing depicted in Schumm's model of channel evolution, as presented in Rosgen (2006) and adapted for the Lotic Wetland Health Assessment (Fig. 4).

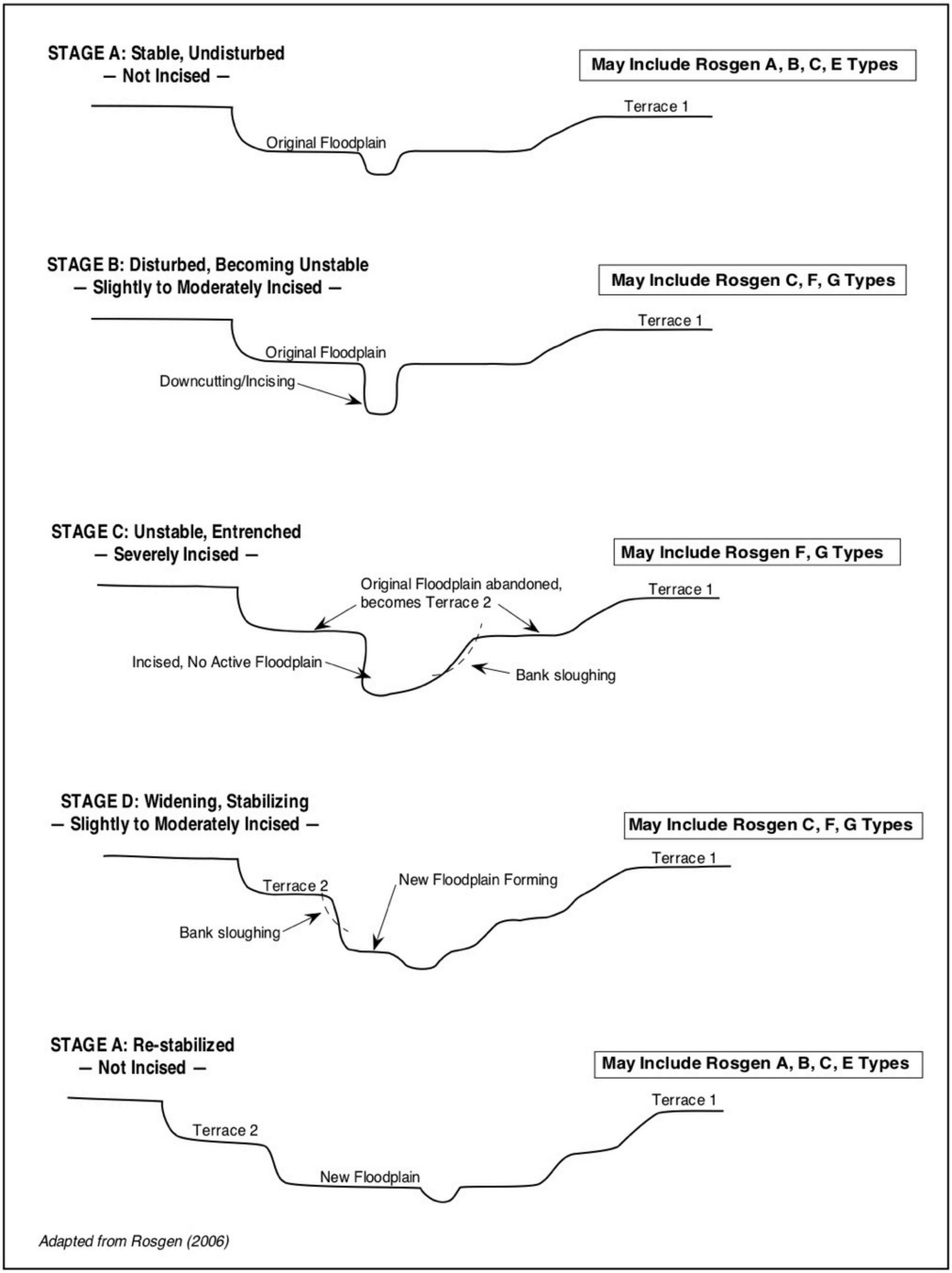


Figure 4. Stages of stream channel incisement and re-stabilization used in rating the degree of impaired health for the Lotic Wetland Health Assessment

RESULTS AND DISCUSSION

Jurisdictional Wetland Survey

Figure 5 once again shows the area that was assessed in the work. As discussed previously, from the top to the bottom of its major watercourses, the Bullion Mine site is approximately a half-mile in length (approx. 2,400 ft) and averages a tenth of a mile in width (approx. 600 ft). The red line represents the area where the surveys were conducted. Jill Creek runs along the northern boundary of the survey area. The yellow lines represent the five transects across the face of the reclaimed area, while the blue lines represent the additional wetlands assessed in the lower portion of the survey area.

Figure 5. Bullion Mine project area and transects

Table 4 shows jurisdictional wetland acres and the functional wetland ares observed on the Bullion Mine Survey Area. Based upon the transects, approximately 1.3 acres (37 percent) of the 3.6-acre Bullion Mine project site may be delineated as a jurisdictional wetland, 2.6 acres (73 percent) of the site as a functional wetland, and 1.0 acres (27 percent) of the site as an upland. Given the degree of historic disturbance of the site and the recent efforts at revegetation, however, the Bullion Mine is best characterized as a mixed matrix of wetlands and uplands, with wetland and upland status varying mostly due to subtle differences in elevation relative to groundwater.

Table 4. Jurisdictional wetland acres and the functional wetland acres observed on the Bullion Mine Survey Area

		Jurisdictional Wetland Acres	Functional Wetland Acres
Wetland along the reclaimed area		1.0	2.1
Jill Creek and lower seep area		0.3	0.5
	TOTAL	***1.3***	***2.6***

Figure 6 shows the outline of the reclaimed site. Within the reclaimed site (outlined by the red line), 1.0 acres represent jurisdictional wetlands scattered across the reclaimed hillside.

Figure 6. Reclaimed area at Bullion Mine

Figure 7 shows Jill Creek and the lower seep area. The red line represents functional wetlands only, while the purple line indicates the jurisdictional and functional wetland boundaries are the same.

Figure 7. Wetlands along Jill Creek and lower seep area

Thirty-one different plant species were found in the wetland transects of the Bullion Mine (Table 5). Nineteen species were rated as being facultative wetland plants (FAC, FACW, or OBL), nine species were rated as being upland plants (UPL), and two species were not rated. Seventeen species were woody (both overstory and understory), and fourteen species were herbaceous. Fifty-three percent of the herbaceous species were rated as facultative wetland plants (FAC, FACW, or OBL), forty-two percent of the herbaceous species were rated as upland plants (UPL), and six percent of the herbaceous species were not rated. Seventy-one percent of the herbaceous species were rated as facultative wetland plants (FAC, FACW, or OBL), twenty-one percent of the herbaceous species were rated as upland plants (UPL), and seven percent of the herbaceous species were not rated.

Among the dominant woody plants species present, *Pinus contorta* (lodgepole pine) had the greatest average cover, followed by *Picea glauca* (white spruce). Nonetheless, more *Picea glauca* (white spruce) plants were found than *Pinus contorta* (lodgepole pine). Among the dominant herbaceous species, *Deschampsia cespitosa* (tufted hairgrass) had the greatest overall presence at the Bullion Mine, particularly in wetland areas. *Festuca idahoensis* (Idaho fescue) and *Lotus corniculatus* (birds-foot trefoil) were dominant in upland areas.

Table 5. Dominant plant species by canopy position at the Bullion Mine

Lifeform Canopy Layer	Species	Wetland Status	Percent Canopy Cover: Jurisdictional Wetland	Upland	Average
Woody Overstory	*Abies lasiocarpa* (subalpine fir)	UPL	0.00	0.32	0.09
Woody Overstory	*Pinus contorta* (lodgepole pine)	FAC	0.00	0.32	0.09
Woody Understory	*Pinus contorta* (lodgepole pine)	FAC	3.02	1.01	1.93
Woody Understory	*Picea glauca* (white spruce)	FAC	1.33	0.48	0.70
Woody Understory	*Spiraea betulifolia* (shiny-leaf spiraea)	FACU	0.02	0.05	0.06
Woody Understory	*Salix bebbiana* (Bebb willow)	FACW	0.02	0.00	0.01
Woody Understory	*Abies lasiocarpa* (subalpine fir)	UPL	0.00	0.05	0.01
Woody Understory	*Ribes* spp. (currant bush)	FAC+	0.00	0.00	0.01
Woody Understory	*Rosa woodsii* (wood's rose)	FACU	0.00	0.00	0.04
Woody Understory	*Juniperus communis* (common juniper)	FACU	0.00	0.29	0.08
Herbaceous	*Deschampsia cespitosa* (tufted hairgrass)	FACW	29.02	4.13	13.42
Herbaceous	*Equisetum hyemale* (common scouring-rush)	FAC	7.46	0.00	2.76
Herbaceous	*Calamagrostis stricta* (narrow-spiked reedgrass)	FACW	5.72	0.00	2.12
Herbaceous	*Hordeum jubatum* (foxtail barley)	FAC-	5.72	0.00	2.12
Herbaceous	*Lotus corniculatus* (birds-foot trefoil)	FAC	3.73	13.02	8.89
Herbaceous	*Dactylis glomerata* (orchardgrass)	FACU	2.63	0.00	9.43
Herbaceous	*Agrostis scabra* (rough bentgrass)	FAC	2.40	0.00	3.24
Herbaceous	*Festuca idahoensis* (Idaho fescue)	FACU	1.16	17.42	7.14
Herbaceous	*Carex microptera* (small-winged sedge)	FAC+	0.06	0.00	0.02
Herbaceous	*Carex praticola* (meadow sedge)	FACW	0.01	0.00	0.00

Vegetation Belt Transect Survey

The 2001-2002 revegetation of the reclaimed site seems to be doing well. There still is some bare ground (approx. 20 percent) on the site. However, the slope seems to be stable with very little to no erosion. The slope has numerous springs located throughout. The springs are not directly associated with the rock lined ditch from the acid mine drainage farther upslope. The rocks of the channel associated with the ditch are colored orange.

The surrounding hillsides are dominated by the *Pinus contorta/Vaccinium scoparium* (lodgepole pine/ whortleberry) community type which is a late successional stage of the *Abies lasiocarpa/Vaccinium scoparium* (subalpine fir/whortleberry) habitat type. The wetter sites are occupied by either the *Abies lasiocarpa/ Calamagrostis canadensis* (subalpine fir/bluejoint reedgrass) habitat type, or the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador-tea) habitat type (Pfister and others 1977; Hansen and others 1995).

Photos 24-28 are of the five vegetation belt transects on the reclaimed site.

Photo 24. Transect #1—Looking east across the 2001-2002 reclaimed mine site. Transect #1 is located on the upper portion of the reclaimed site, while Transect #5 is at the lower portion, just uphill from Jill Creek

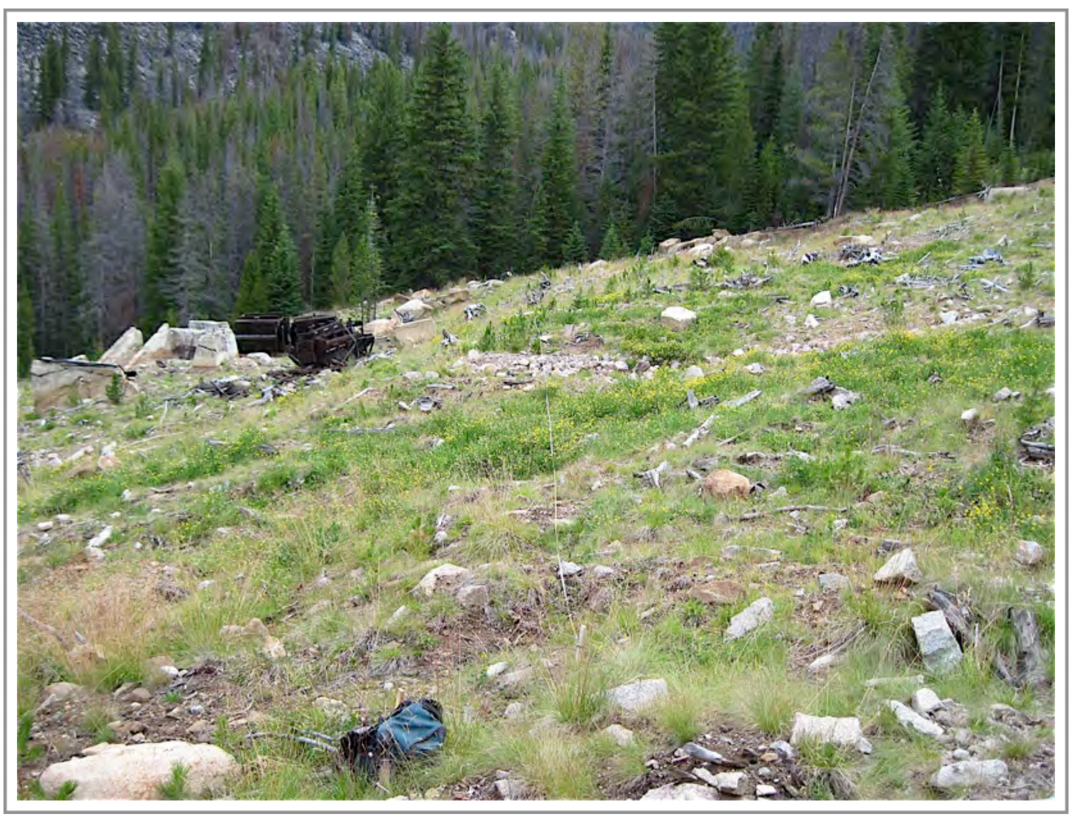


Photo 25. Transect #2—Looking east across the 2001-2002 reclaimed mine site. Transect #1 is located on the upper portion of the reclaimed site, while Transect #5 is at the lower portion, just uphill from Jill Creek

Photo 26. Transect #3—Looking east across the 2001-2002 reclaimed mine site. Transect #1 is located on the upper portion of the reclaimed site, while Transect #5 is at the lower portion, just uphill from Jill Creek

Photo 27. Transect #4—Looking east across the 2001-2002 reclaimed mine site. Transect #1 is located on the upper portion of the reclaimed site, while Transect #5 is at the lower portion, just uphill from Jill Creek

Photo 28. Transect #5—Looking east across the 2001-2002 reclaimed mine site. Transect #1 is located on the upper portion of the reclaimed site, while Transect #5 is at the lower portion, just uphill from Jill Creek

In a forested ecosystem, one measure of success is how fast the trees are re-establishing on a site. Table 6 shows the three trees species along with their seedling count. All vegetation belt transects were 3 ft wide. However, the length of each transect varied due to the irregularities within the reclamation site. Transect #1 is located on the upper portion of the reclaimed site, while Transect #5 is at the lower portion, just uphill from Jill Creek. A trend is seen showing that the farther down the slope the transect, the greater the number of tree seedlings. The reason for this increase down the slope is not apparent.

Table 6. Number of tree seedlings (by species) for the five vegetation belt transects on the Bullion Mine reclamation site (Note: each transect was 3 ft wide)

Species	Transect 1 (180 ft)	Transect 2 (263 ft)	Transect 3 (312 ft)	Transect 4 (269 ft)	Transect 5 (144 ft)
Abies lasiocarpa (subalpine fir)	6	21	33	142	38
Pinus contorta (lodgepole pine)	8	50	49	27	31
Pseudotsuga menziesii (Douglas fir)	0	0	4	13	1
TOTAL	***14***	***71***	***86***	***182***	***70***

Table 7 shows the average canopy cover, range of canopy cover, constancy, and prominence index for the five vegetation belt transects on the Bullion Mine reclamation site. Prominence index is an indication of importance on a site, and is the product of average canopy cover and constancy (frequency) values. Herbaceous species dominate the site, with *Deschampsia cespitosa* (tufted hairgrass; native) and *Dactylis glomerata* (orchard-grass; introduced) providing the greatest average canopy cover.

Table 7. Average canopy cover, range of canopy cover, constancy, and prominence index for the five vegetation belt transects on the Bullion Mine reclamation site (number = 5 transects)

Species	Percent Canopy Cover Average	Percent Canopy Cover Range	Constancy (Frequency)	Prom. Index[1]	Origin Status[2]
Trees (N = 3)					
Abies lasiocarpa (subalpine fir)	1.5	0.5-3	100	1.5	N
Pinus contorta (lodgepole pine)	2.5	0.5-3	100	2.5	N
Pseudotsuga menziesii (Douglas fir)	0.5	0-0.5	60	0.3	N
Shrubs (N = 8)					
Alnus incana (mountain alder)	0.5	0-0.5	20	0.1	N
Rosa woodsii (Woods rose)	0.5	0-0.5	60	0.3	N
Rubus idaeus (red raspberry)	0.5	0-0.5	20	0.1	N
Salix bebbiana (Bebb willow)	0.5	0-0.5	80	0.4	N
Salix boothii (Booth willow)	0.5	0-0.5	20	0.1	N
Salix drummondiana (Drummond willow)	0.5	0-0.5	40	0.2	N
Shepherdia canadensis (russet buffaloberry)	0.5	0-0.5	40	0.2	N
Spiraea betulifolia (shiny-leaf spiraea)	0.5	0.5-0.5	100	0.5	N
Graminoids (N = 16)					
Agropyron caninum (bearded wheatgrass)	1.3	0-3	60	0.8	N
Agrostis scabra (tickle-grass)	1.8	0-3	80	1.4	N
Bromus inermis (smooth brome)	0.5	0-0.5	20	0.1	Both
Calamagrostis canadensis (bluejoint reedgrass)	0.5	0-0.5	20	0.1	N
Calamagrostis stricta (narrow-spiked reedgrass)	1.8	0-3	40	0.7	N
Carex microptera (small-winged sedge)	6.5	0-10	80	5.2	N
Carex praegracilis (clustered field sedge)	0.5	0-0.5	60	0.3	N
Dactylis glomerata (orchard-grass)	26.0	20-40	100	26.0	I
Deschampsia cespitosa (tufted hairgrass)	32.0	30-40	100	32.0	N
Festuca idahoensis (Idaho fescue)	16.0	10-20	100	16.0	N
Festuca scabrella (rough fescue)	1.1	0-3	80	0.9	N
Hordeum jubatum (foxtail barley)	0.5	0-0.5	20	0.1	N
Juncus balticus (Baltic rush)	0.5	0-0.5	40	0.2	N
Phleum pratense (common timothy)	3.0	0-3	20	0.6	I
Sitanion hystrix (bottlebrush squirreltail)	0.5	0-0.5	20	0.1	N
Stipa viridula (green needlegrass)	0.5	0-0.5	20	0.1	N

Table 7 (cont.)

Species	Percent Canopy Cover Average	Percent Canopy Cover Range	Constancy (Frequency)	Prom. Index[1]	Origin Status[2]
Forbs (N = 15)					
Achillea millefolium var. *lanulosa* (common yarrow)	14.0	10-20	100	14.0	N
Antennaria microphylla (rosy pussy-toes)	0.5	0-0.5	20	0.1	N
Antennaria neglecta (field pussy-toes)	0.5	0-0.5	40	0.2	N
Astragalus spp. (milk-vetch)	0.5	0-0.5	80	0.4	Both
Cirsium arvense (Canada thistle)	0.5	0-0.5	60	0.3	I
Epilobium angustifolium (fireweed)	0.5	0-0.5	40	0.2	N
Epilobium ciliatum (common willow-herb)	0.5	0.5-0.5	100	0.5	N
Fragaria virginiana (Virginia strawberry)	0.5	0-0.5	80	0.4	N
Geum canadense (white avens)	0.5	0-0.5	40	0.2	N
Lotus corniculatus (birds-foot trefoil)	9.2	3-20	100	9.2	I
Lupinus argenteus (silvery lupine)	0.5	0.5-0.5	100	0.5	N
Pyrola spp. (wintergreen)	0.5	0-0.5	40	0.2	N
Rumex spp. (dock; sorrel)	0.5	0-0.5	60	0.3	Both
Trifolium repens (white clover)	0.5	0-0.5	60	0.3	I
Verbascum thapsus (common mullein)	0.5	0-0.5	20	0.1	I
Ferns and Allies (N = 1)					
Equisetum hyemale (common scouring-rush)	4.5	0-10	60	2.7	N

[1]Prominence Index is the product of average canopy cover and constancy (frequency) values.
[2]Origin Status: N = native to pre-Columbian North America; I = introduced by post-Columbian human immigrants; Both = contains native and introduced species. See Methods section for list of information sources.

Table 8 shows the total number of species by lifeform and by species origin (i.e., whether native, introduced, and both categories) for the five vegetation belt transects on the Bullion Mine reclamation site. There were a total 43 different plant species identified on the site, with 34 (79 percent) of the species being native. However, some of the introduced species are currently providing large amounts of canopy cover to the site (i.e., *Dactylis glomerata* [orchard-grass]).

Table 8. Total number of species by lifeform and by species origin (i.e., whether native, introduced, and both categories) for the five vegetation belt transects on the Bullion Mine reclamation site

Lifeform	Number of Species	Species in Each Origin Category		
		Native[1]	Introduced[2]	Both[3]
Trees	3	3	0	0
Shrubs	8	8	0	0
Graminoids	16	13	2	1
Forbs	15	9	4	2
Ferns and Allies	1	1	0	0
TOTAL	***43***	***34***	***6***	***3***

[1]***Native*** = native to pre-Columbian North America
[2]***Introduced*** = introduced by post-Columbian human immigrants
[3]***Both*** = species contains native and introduced elements (NOTE: Those plant specimens only identified to genus and the genus includes both native and introduced species, were identified as "Both.")

Table 9 shows the average number of species per belt transect by lifeform and by native, introduced, or both for the five vegetation belt transects on the Bullion Mine reclamation site. On average, each transect had approx. 25 different plant species. Of those, approx. 20 were native, while the rest were either introduced or both.

Table 9. Average number of species per belt transect by lifeform and by native, introduced, or both for the five vegetation belt transects on the Bullion Mine reclamation site

Lifeform	Species per Transect	Species per Polygon in Each Origin Category		
		Native[1]	Introduced[2]	Both[3]
Trees	2.6	2.6	0.0	0.0
Shrubs	3.8	3.8	0.0	0.0
Graminoids	8.6	7.2	1.2	0.2
Forbs	9.4	5.6	2.4	1.4
Ferns and Allies	0.6	0.6	0.0	0.0
TOTAL	***25.0***	***19.8***	***3.6***	***1.6***

[1]***Native*** = native to pre-Columbian North America
[2]***Introduced*** = introduced by post-Columbian human immigrants
[3]***Both*** = species contains native and introduced elements (NOTE: Those plant specimens only identified to genus and the genus includes both native and introduced species, were identified as "Both.")

Table 10 shows the average canopy cover by lifeform per polygon by lifeform and by native, introduced, or both for the five vegetation belt transects on the Bullion Mine reclamation site (total average canopy cover can be greater than 100 percent due to overlap of lifeform layers). The herbaceous layer (i.e., graminoids, forbs, ferns and allies) provide almost 95 percent of the total canopy cover to the site (114.2 percent canopy cover out of an average total of 120.4 percent). In addition, approx. 69 percent of the total canopy cover is provided by native species, with the remainder by introduced or both.

Table 10. Average canopy cover by lifeform per polygon by lifeform and by native, introduced, or both for the five vegetation belt transects on the Bullion Mine reclamation site (Total average canopy cover can be greater than 100 percent due to overlap of lifeform layers.)

Lifeform	Canopy Cover per Polygon	Canopy Cover per Polygon by Species Origin Category		
		Native[1]	Introduced[2]	Both[3]
Trees	4.3%	4.3%	0.0%	0.0%
Shrubs	1.9%	1.9%	0.0%	0.0%
Graminoids	84.6%	57.9%	26.6%	0.1%
Forbs	26.9%	16.3%	9.9%	0.7%
Ferns and Allies	2.7%	2.7%	0.0%	0.0%
TOTAL	***120.4***%	***83.1***%	***36.5***%	***0.8***%

[1]***Native*** = native to pre-Columbian North America
[2]***Introduced*** = introduced by post-Columbian human immigrants
[3]***Both*** = species contains native and introduced elements (NOTE: Those plant specimens only identified to genus and the genus includes both native and introduced species, were identified as "Both.")

Table 11 shows the most prominent plant species for the inventoried polygons on the five vegetation belt transects on the Bullion Mine reclamation site among the four main plant lifeforms. Once again, prominence index is an indication of importance on a site, and is the product of average canopy cover and constancy (frequency) values. The most prominent species is *Deschampsia cespitosa* (tufted hairgrass). However, the second and fifth most prominent species are introduced species (i.e., *Dactylis glomerata* [orchard-grass] and *Lotus corniculatus* [birds-foot trefoil]).

Table 11. The most prominent plant species for the inventoried polygons on the five vegetation belt transects on the Bullion Mine reclamation site among the four main plant lifeforms (For a complete table of prominence of all species, see Tables 9a and 9b in Appendix B.)

Species	Prominence Value[1]	Origin Status[2]
Trees		
Pinus contorta (lodgepole pine)	2.5	Native
Abies lasiocarpa (subalpine fir)	1.5	Native
Pseudotsuga menziesii (Douglas fir)	0.3	Native
Shrubs		
Spiraea betulifolia (shiny-leaf spiraea)	0.5	Native
Salix bebbiana (Bebb willow)	0.4	Native
Rosa woodsii (Woods rose)	0.3	Native
Salix drummondiana (Drummond willow)	0.2	Native
Shepherdia canadensis (russet buffaloberry)	0.2	Native
Graminoids		
Deschampsia cespitosa (tufted hairgrass)	32.0	Native
Dactylis glomerata (orchard-grass)	26.0	Introduced
Festuca idahoensis (Idaho fescue)	16.0	Native
Carex microptera (small-winged sedge)	5.2	Native
Agrostis scabra (tickle-grass)	1.4	Native
Forbs		
Achillea millefolium var. *lanulosa* (common yarrow)	14.0	Native
Lotus corniculatus (birds-foot trefoil)	9.2	Introduced
Epilobium ciliatum (common willow-herb)	0.5	Native
Lupinus argenteus (silvery lupine)	0.5	Native
Astragalus spp. (milk-vetch)	0.4	Both
Ferns and Allies		
Equisetum hyemale (common scouring-rush)	2.7	Native

[1]Prominence indicates species dominance on a site. Prominence value is the product of constancy (percent frequency of occurrence on polygons in the set) and average cover on those polygons in the set having it present.

[2]Origin Status: Native = native to pre-Columbian North America; Introduced = introduced by post-Columbian human immigrants; Both = contains native and introduced species

Threatened and Endangered Species Survey

While an enumeration of Threatened and Endangered plant and animal species potentially present near the Bullion Mine would seem to be a simple exercise, it is complicated by three issues. First, while the Bullion Mine lies in Jefferson County, Montana, the location is near the boundaries with two other Montana Counties, namely Lewis and Clark and Powell. For this reason, the Threatened and Endangered species of all three counties were considered as being potentially present near the project site (Table 12). Second, the USDI Fish and Wildlife Service (USFWS) maintains one list of Threatened and Endangered species probably present by Montana county, this list is different than the list attributed to the USFWS that is maintained by the Montana Natural Heritage Program (2010).

Table 12. Threatened and Endangered Species present at the Montana counties surrounding the Bullion Mine (Key: LE = Listed Endangered; LT = Listed Threatened; XN = Experimental Non-essential Population; DM = Recovered, delisted, and being monitored

Category Species Name	Jefferson County	Lewis and Clark County	Powell County
Mammal			
Black-footed Ferret	LE[1]	LE[1]	—
Canada Lynx	LT[1,2]	LT[1,2]	LT[1,2]
Gray Wolf	LE, XN[2]	LE, XN[2]	LE, XN[2]
Grizzly Bear	—	LT, XN[1,2]	LT, XN[1,2]
Bird			
Bald Eagle	—	DM[2]	DM[2]
Peregrin Falcon	DM[2]	DM[2]	DM[2]
Whooping Crane	LE[2]	—	—
Fish			
Bull Trout	—	LT[1,2]	LT[1,2]
Plants			
Ute Ladies Tresses	LT[1,2]	—	—

[1]Data source: USDI Fish and Wildlife Service (2009)
[2]Data source: Montana Natural Heritage Program (2010)

This difference is partially due to the fact that the USFWS has not updated its formal list of Threatened and Endangered species by Montana county since 2009, while the MNHP last updated its list on August 8, 2010. Therefore, the re-listing of the gray wolf in Montana that occurred in the first week of August 2010 is not reflected in the most current USFWS county list, but it is reflected on the MNHP list (Maxwell, pers. com. 2010). The other source of differences is that the USFWS relies on historic probable range data to determine the counties “where one would reasonably expect the species to occur (USFWS 2009).” The MNHP, however, relies upon recent, formally reported sitings of species to designate in which counties a species occurs (Maxwell, pers. com. 2010). For this reason, the USFWS lists the black footed ferret as occurring in Jefferson County and Lewis and Clark County, which are part of the species’ historic range, while the MNHP does not due to a lack of recent sightings in these counties. Conversely, the MNHP lists the whooping crane as occurring in Jefferson County due to a 1985 sighting of a single migrating bird 20 miles south of Boulder, Montana, while the USFWS does not list it as occurring in this county as the bird is not reasonably expected to be there.

The third factor complicating an enumeration of Threatened and Endangered species at the Bullion Mine is that while a species may be present in Jefferson, Lewis and Clark and/or Powell Counties, it’s range may not encompass the 7,700 ft elevation of the Bullion Mine. For instance, the black-footed ferret preys exclusively on prairie dogs, whose towns are found only in grasslands, steppe, and shrub steppe (Black-footed ferret [*Mustela nigripes*] 2010). Therefore, the black-footed ferret will not be found near the Bullion Mine. While bull trout do spawn in rocky tributary streams, the small size of the streams near the project area and the harsh winters at 8,000 ft, which would freeze the eggs and or fry, make it unlikely that bull trout would have been found historically near the Bullion Mine (Schmetterling, pers. com. 2010). Ute ladies tresses are restricted in area to alkaline wetlands in the valley bottoms, and are so will not be found at the Bullion Mine (Ute ladies tresses [*Spiranthes diluvialis*] 2010). For these reasons, only the following three, currently listed Threatened and Endangered species have a realistic potential of being at or near the Bullion Mine: Canada lynx (2010), gray wolf (2010), and grizzly bear (2010). Descriptions of these three species from the Montana Field Guides are included in Appendix G.

Lotic Wetland (i.e., Riparian) Health Assessment

A lotic wetland health assessment was conducted on three reaches of streams in the Bullion and Crystal Mine sites. The three reaches are:

- Lower Jill Creek (reconstructed/impacted) (Bullion Mine site), riparian health assessment conducted in 2010;
- Uncle Sam Gulch Creek (impacted) (Crystal Mine site), riparian health assessment conducted in 2010; and
- Upper Jill Creek (unimpacted) (Bullion Mine site), riparian health assessment conducted in 2010.

The three reaches were then compared to previous work on the following sites:

- Silver Bow Creek (LAO), riparian health assessment conducted in 2001;
- Clark For River Governor’s Demo (GDP), riparian health assessment conducted in 2001; and
- Coeur d’Alene Mining District in northern Idaho, riparian health assessment conducted in 2009.

Photo 29. Looking upstream on Lower Jill Creek showing the confluence with the adit. The streambanks are engineered with rock, logs, and coir fabric

Photo 30. Looking downstream on Lower Jill Creek showing engineered streambanks, drop structures, and stained streambed

Photo 31. Upper end of Uncle Sam Gulch Creek showing abandoned sediment drift fence material mostly covered by mine tailings

Photo 32. Downstream along Uncle Sam Gulch Creek looking upstream toward the Motor House (upper left)

Photo 33. Relatively undisturbed portion of Upper Jill Creek, east (upstream) of the 2001-2002 reclaimed floodplain section

Photo 34. Another photo of the relatively undisturbed floodplain of Upper Jill Creek. Notice the abundant woody vegetation along the creek

Lower Area One (LAO) is located on Silver Bow Creek just outside Butte, Montana on what was once the Butte Reduction Works Site and the Colorado Smelter Site lying between what is now Interstate 90 and Centennial Avenue (Photos 35 and 36) (Bitterroot Restoration, Inc. 2002). Between 1993 and 1998 phase one of the LAO clean-up plan was completed on the southern portion of the area. Treatment consisted of removal of contaminated materials, reconstruction of channel and floodplain from clean borrow material, and planting vegetation on the site (Vaughn and others 2000, Windell and Stilwell 2000). Since completion of initial work, some ongoing maintenance has been done on LAO, such as weed control. The lotic wetland health assessment was conducted in October of 2001.

Photo 35. A 2001 photo of grass and young willow on the floodplain within Lower Area One

Photo 36. A 2001 photo of young willow banks of Silver Bow Creek within Lower Area One

The Governor's Demonstration Project (GDP) is located along the Clark Fork River between Morel Road Bridge (Warm Springs Road) and Perkins Lane near Warm Springs, Montana (Bitterroot Restoration, Inc. 2002). It encompasses the river channel and floodplain downstream from the Warm Springs Ponds and the confluence of Silver Bow Creek and Warm Springs Creek (Photos 37 and 38).

On the GDP between 1990 and 1991, tailings-affected areas were treated using *in-situ* methods of amendment. These treatments consisted of deep plowing and conventional tillage techniques to mix lime amendments with contaminated substrates on the floodplain, some attempts at stabilization of eroding riverbanks, construction of channel modifications to reduce bank erosion, seeding of plowed areas, sprigging of willows on treated banks, construction of fence to control livestock grazing, and development of a grazing management plan (Schafer and Associates 1991). The lotic wetland health assessment was conducted in October of 2001.

Photo 37. A 2001 photo of shrubby banks of the Clark Fork River within the Governor's Demonstration Project

Photo 38. A 2001 photo of a well-vegetated riverbank along the Clark Fork River within the Governor's Demonstration Project

The Coeur d'Alene Mining District is located in northern Idaho. The 18 polygons represent lands administered by the USDI Bureau of Land Management and were sampled in 2009. They represent a cross-section of the landscape, including drainages with historic mining activity (Photos 39 and 40).

Photo 39. A 2009 photo of a typical small stream on the Coeur d'Alene Mining District in northern Idaho administered by the USDI Bureau of Land Management

Photo 40. A 2009 photo of a typical small stream on the Coeur d'Alene Mining District in northern Idaho administered by the USDI Bureau of Land Management

Table 13 represents a comparison of impacted/reconstructed reaches of Jill Creek and Uncle Sam Gulch Creek to a reference reach of Jill Creek (unimpacted), and a comparison to other streams in the region (health score values given as percent ratings, where 100 percent is perfect health). The table shows that the overall health score of Lower Jill Creek (reconstructed) and Uncle Sam Gulch Creek (impacted) is very low with each reach being nonfunctional. In fact, the value of 10 percent for the soil and hydrology portion of the assessment for Uncle Sam Gulch Creek is one of the lowest we have seen. (Since early 1990s, ESG has has conducted health assessments on over 9,000 miles of streams, rivers, lakeshores, ponds, and wet meadows throughout North America.) On the other hand, Upper Jill Creek (unimpacted) is adjacent to Lower Jill Creek and the overall health score is very high at 93 percent. For comparisons, the reconstructed Silver Bow Creek (LAO) is 84 percent while the *in-situ* treated Clark Fork River Governor's Demo is 73 percent. USDI Bureau of Land Management stream reaches in the Coeur d'Alene Mining District of northern Idaho scored an average of 94 percent.

A riparian health question arises pertaining to the length of time after treatment for the three mining sites. The longer the time frame, the longer the vegetation has had a chance to become established on a site. The following represent the number of years after the reclamation treatment when a riparian health assessment was conducted:

- Lower Jill Creek (reconstructed/impacted) (Bullion Mine site) = 8 years;
- Silver Bow Creek (LAO) (2001) = 3 years; and
- Clark For River Governor's Demo (GDP) (2001) = 10 years.

Even though Lower Jill Creek is at a higher elevation (approx. 7,180 ft) than Silver Bow Creek (LAO) (approx. 5,455 ft) and the Clark For River Governor's Demo (GDP) (approx. 4,765 ft), this does not account for the vast differences in riparian health scores. For example, even though Lower Jill Creek had eight years for vegetative growth (compared to three years for Silver Bow Creek [LAO] and 10 years for Clark For River Governor's Demo [GDP]), the health scores were extremely low. It is of our professional opinion that the main differences are related to the type of reclamation work conducted on Lower Jill Creek, along with the continuing acid mine drainage from the adit into the creek. Of the two, the greatest difference is related to the type of reclamation work conducted on Lower Jill Creek.

Table 13. Comparison of impacted/reconstructed reaches of Jill Creek and Uncle Sam Gulch Creek to a reference reach of Jill Creek (unimpacted), and a comparison to other streams in the region (health score values given as percent ratings, where 100 percent is perfect health)

Location	Number of Polygons	Health Rating (weighted average)			Overall Health Category[1]
		Vegetation	Soil/Hydr.	Overall	
Lower Jill Creek[2] (Reconstructed)	1	40%	27%	33%	NF
Uncle Sam Gulch Creek[3] (Impacted)	1	47%	10%	28%	NF
Upper Jill Creek[2] (Unimpacted)	1	87%	100%	93%	PFC
Silver Bow Creek (LAO) (2001)	6	73%	94%	84%	PFC
CFR Governor's Demo (GDP) (2001)	6	56%	88%	73%	FAR
CDA Northern Idaho (2009)	18	88%	100%	94%	PFC

[1]Health Categories:

PFC (Proper Functioning Condition [Healthy]) = score rating from 80 to 100 percent

FAR (Functional—At Risk [Healthy, but with problems]) = score rating from 60 to 80 percent

NF (Nonfunctional [Unhealthy]) = score rating below 60 percent

[2]Jill Creek is located on the Bullion Mine site

[3]Uncle Sam Gulch Creek is located on the Crystal Mine site

Table 14 shows the riparian vegetation health factors average weighted scores for the impacted/reconstructed reaches of Lower Jill Creek and Uncle Sam Gulch Creek to a reference reach of Upper Jill Creek (unimpacted), and a comparison to other streams in the region (see the Methods Section for a discussion of the various riparian health factors). Uncle Sam Gulch Creek scored a low 0 pts out of 6 pts for total vegetation cover, with Lower Jill Creek scoring 0 pts out of 3 pts due to the abundance of disturbance species. Other values are presented in the table.

Table 14. Comparison of riparian vegetation health factors average weighted scores for the impacted/ reconstructed reaches of Jill Creek and Uncle Sam Gulch Creek to a reference reach of Jill Creek (unimpacted), and a comparison to other streams in the region (see the Methods Section for a discussion of the various riparian health factors)

	Health Assessment Factors (total points for each factor in parentheses)							
Location[1]	Vegetation Cover (6 pts)	Weed Canopy Cover (3 pts)	Weed Density Distribution Category (3 pts)	Disturbance Species (3 pts)	Preferred Woody Establishment (6 pts)	Preferred Woody Browse (3 pts)	Live Woody Removal (3 pts)	Standing Dec./Dead Woody Veg. (3 pts)
LJC (N = 1)	4.0	2.0	2.0	0.0	2.0	1.0	0.0	1.0
USGC (N = 1)	0.0	3.0	3.0	2.0	2.0	3.0	0.0	1.0
UJC (N = 1)	6.0	3.0	3.0	3.0	4.0	2.0	3.0	2.0
LAO (N = 6)	4.7	1.2	0.7	2.0	6.0	2.5	NC[2]	2.7
GDP (N = 6)	2.9	1.2	0.2	3.0	3.7	2.5	NC[2]	1.6
CDA (N = 18)	6.0	1.9	1.1	2.6	6.0	2.8	2.9	3.0

[1]Location:

LJC = Lower Jill Creek (Reconstructed) (Bullion Mine site)

USGC = Uncle Sam Gulch Creek (Impacted) (Crystal Mine site)

UJC = Upper Jill Creek (Unimpacted) (Bullion Mine site)

LAO = Silver Bow Creek (LAO) (2001)

GDP = Clark For River Governor’s Demo (GDP) (2001)

CDA = CDA Northern Idaho (2009)

[2]NC means the factor was not collected in that survey, and the item is not factored in the rating that year

Finally, Table 15 shows the riparian soil/hydrology health factors average weighted scores for the impacted/ reconstructed reaches of Lower Jill Creek and Uncle Sam Gulch Creek to a reference reach of Upper Jill Creek (unimpacted), and a comparison to other streams in the region (see the Methods Section for a discussion of the various riparian health factors). The soil/hydrology health factors for Lower Jill Creek and Uncle Sam Gulch Creek scored very low. The only reason they did not score lower is that the sites have a lot of rock/bedrock associated with the streambed. This high level of streambed armoring restricted the incisement of each of the streams. Other values are presented in the table.

Table 15. Comparison of riparian soil/hydrology health factors average weighted scores for the impacted/ reconstructed reaches of Jill Creek and Uncle Sam Gulch Creek to a reference reach of Jill Creek (unimpacted), and a comparison to other streams in the region (see the Methods Section for a discussion of the various riparian health factors)

	Health Assessment Factors (total points for each factor in parentheses)				
Location[1]	Streambank Rootmass (6 pts)	Human-Caused Bare Ground (6 pts)	Human-Altered Stream Banks (6 pts)	Human-Altered Rest of Polygon (3 pts)	Channel Incisement Stage (9 pts)
LJC (N = 1)	0.0	2.0	0.0	0.0	6.0
USGC (N = 1)	0.0	0.0	0.0	0.0	6.0
UJC (N = 1)	6.0	6.0	6.0	3.0	9.0
LAO (N = 6)	4.3	6.0	6.0	3.0	9.0
GDP (N = 6)	4.8	4.4	5.2	3.0	9.0
CDA (N = 18)	6.0	6.0	6.0	3.0	9.0

[1]Location:

LJC = Lower Jill Creek (Reconstructed) (Bullion Mine site)
USGC = Uncle Sam Gulch Creek (Impacted) (Crystal Mine site)
UJC = Upper Jill Creek (Unimpacted) (Bullion Mine site)
LAO = Silver Bow Creek (LAO) (2001)
GDP = Clark For River Governor’s Demo (GDP) (2001)
CDA = CDA Northern Idaho (2009)

APPENDICES INFORMATION

The following is a list of appendices that are part of report:

- Appendix A: Bullion Mine Site Vegetation Transect Data
- Appendix B: Bullion Mine Site Vegetation Transect Data Set Summary
  Each Summary Data Set in Appendix B contains the following tables:
  - ❖ Table 1a. Transect Location Information—General
  - ❖ Table 1b. Transect Location Information—Latitude and Longitude
  - ❖ Table 2. Transect Administrative Information
  - ❖ Table 3. Invasive Plant Species (Weeds) and Acres (by Individual Species)
  - ❖ Table 4. Tree Species and Acres (by Individual Species)
  - ❖ Table 5. Shrub Species and Acres (by Individual Species)
  - ❖ Table 6. Graminoid Species and Acres (by Individual Species)
  - ❖ Table 7. Forb Species and Acres (by Individual Species)
  - ❖ Table 8. Ferns and Allies by Species and Acres (by Individual Species)
  - ❖ Table 9a. Species Dominance (Prominence Values) Sorted by Prominence Value
  - ❖ Table 9b. Species Dominance (Prominence Values) Sorted by Species Latin Name
  - ❖ Table 10. Summary Information by Lifeform
- Appendix C: Lotic Wetland Health Assessment Data
  - ❖ Jill Creek (Impacted/Reconstructed Reach, Unimpacted Reach)
  - ❖ Uncle Sam Gulch Creek
- Appendix D: Lotic Wetland Health Assessment (Survey) Polygon Data Set Summary
  Each Summary Data Set in Appendix D contains the following tables:
  - ❖ Table 1a. Polygon Location Information—General
  - ❖ Table 1b. Polygon Location Information—Latitude and Longitude
  - ❖ Table 2. Polygon Administrative Information
  - ❖ Table 3a. Proper Functioning Condition (Health or PFC) Lotic Summary
  - ❖ Table 3b. Comparison to Previous Health or PFC Sampling
  - ❖ Table 4a. Vegetation Characteristics
  - ❖ Table 4b. Soil/Hydrology Characteristics
  - ❖ Table 5. Riparian Zone and Polygon Dimensions
  - ❖ Table 6. Invasive Plant Species (Weeds) and Acres (by Individual Species)
  - ❖ Table 7. Habitat Types and Community Types
- Appendix E: Lotic Wetland Health Assessment for Streams and Small Rivers (Survey)
  - ❖ Blank Field Form
  - ❖ User Manual
- Appendix F: Development of Methodologies to Evaluate the Health of Riparian and Wetland Systems (reprint of 2000 publication)
- Appendix G: Threatened and Endangered Species Descriptions

LITERATURE CITED

Bitterroot Restoration, Inc. 2002. Riparian assessments of two Upper Clark Fork Basin Locations. Bitterroot Restoration, Inc., Corvallis, Montana, USA. 32 p.

Black-footed ferret (*Mustela nigripes*). 2010. *In:* Montana Field Guide. http://FieldGuide.mt.gov/detail_AMAJF02040.asp. September 15, 2010.

Canada lynx (*Lynx canadensis*). 2010. *In:* Montana Field Guide. http://fieldguide.mt.gov/detail_AMAJH03010.aspx. September 15, 2010.

CDM Federal Programs Corporation (CDM). 2005a. Draft Feasibility Study Basin Mining Area Superfund Site, Operable Unit, Jefferson County, Montana, USA. np.

CDM Federal Programs Corporation (CDM). 2005b. Remedial Investigation Report Addendum, Basin Mining Area Superfund Site, Operable Unit 2, Jefferson County, Montana, USA. np.

CH2M Hill. 2009. Basin Mining Area, Operable Unit 2, Engineering Evaluation/Cost Analysis, Bullion and Crystal Mines, Jefferson County, Montana. Prepared for U.S. Environmental Protection Agency, Region VIII, Helena, Montana, USA. 124 p.

CH2M Hill. 2010. Attachment A—Statement of Work, Subcontract No. 941012, Bullion Mine, Ecological Characterization. August 10, 2010. Boise, Idaho, USA. 140 p.

Daubenmire, R. D. 1959. A canopy-coverage method of vegetation analysis. Northwest Science 33: 43-66.

Gray wolf (*Canis lupus*). 2010. *In:* Montana Field Guide. http://fieldguide.mt.gov/detail_AMAJA01030.aspx. September 15, 2010.

Grizzly bear (*Ursus arctos*). 2010. *In:* Montana Field Guide. http://fieldguide.mt.gov/detail_AMAJB01020.aspx. September 15, 2010.

Hansen, Paul L. and James B. Hall. 2002. Classification and management of USDI Bureau of Land Management's riparian and wetland sites in eastern and southern Idaho. Bitterroot Restoration, Inc., Corvallis, Montana, USA. 304 p.

Hansen, Paul L., William H. Thompson, Robert C. Ehrhart, Dan K. Hinckley, Bill Haglan, and Karen Rice. 2000. Development of methodologies to evaluate the health of riparian and wetland areas. *In:* Proceedings of the Fifth International Symposium of Fish Physiology, Toxicology and Water Quality, November 10-13, 1998, Hong Kong, China. Vance Thurston, Editor. EPA/6000/R-00/015. United States Environmental Protection Agency, Office of Research and Development, Washington, DC, USA. 300 p.

Hansen, Paul L., Robert D. Pfister, Keith Boggs, Bradley J. Cook, John Joy, and Dan K. Hinckley. 1995. Classification and management of Montana's riparian and wetland sites. Miscellaneous Publication No 54. Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Missoula, Montana, USA. 646 p.

Hansen, Paul L., William H. Thompson, J. Gant Massey, and Max Thompson. 2008. Classification and management of upland, riparian, and wetland sites of USDI Bureau of Land Management's Miles City Field Office, eastern Montana USA. Prepared for the USDI Bureau of Land Management Miles City Field Office, Miles City, Montana, USA. 640 p. plus 91p. of Appendix B (Indicator Species).

Maxwell, Bryce. 2010. Zoologist, Montana Natural Heritage Program, Helena, Montana, USA. Personal communication.

Montana Bureau of Mines and Geology. 2009. http://www.mbmg.mtech.edu. March 27, 2009.

Montana Natural Heritage Program. 2010. http://mtnhp.org/SpeciesOfConcern/. September 15, 2010.

Natural Resources Conservation Service (NRCS) 2011a. SNOTEL site: Frohner Meadow, Montana. http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=487&state=mt. January 4, 2011.

Natural Resources Conservation Service (NRCS) 2011b. SNOTEL site: Rocker Peak, Montana. http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=722&state=mt. January 4, 2011.

Pioneer Technical Services, Inc. and Thomas, Dean and Hoskins, Inc. 1994. Summary Report: Hazardous Materials Inventory Site Summary (Red Book). Prepared for: Abandoned Mine Land Reclamation Bureau, Montana Department of State Lands, Helena, Montana, USA.

Pfister, Robert D., Bernard L. Kovalchik, Stephen F. Arno, and Richard C. Presby. 1977. Forest habitat types of Montana. USDA Forest Service General Technical Report INT-34. Intermountain Forest and Range Experiment Station, Ogden, Utah, USA. 175 p.

Rosgen, Dave. 2006. Watershed assessment of river stability and sediment supply (WARSSS). Wildland Hydrology. Pagosa Springs, Colorado, USA. 628 p.

Schafer and Associates. 1991. Final report of the Clark Fork River Demonstration Project, Warm Springs, Montana. Report submitted to the Office of the Governor, Capitol Station, Helena, Montana, USA.

Schmetterling, David. 2010. Fisheries Biologist, Montana Department of Fish, Wildlife and Parks, Missoula, Montana, USA. Personal communication.

Thompson, William H. and Paul L. Hansen. 2001. Classification and management of riparian and wetland sites of the Saskatchewan prairie ecozone and parts of adjacent subregions. Saskatchewan Wetland Conservation Corporation. Regina, Saskatchewan, Canada. 298 p.

Thompson, William H. and Paul L. Hansen. 2002. Classification and management of riparian and wetland sites of the Alberta Grassland Natural Region and adjacent subregions. Bitterroot Restoration, Inc. Prepared for the Alberta Riparian Habitat Management Program-Cows and Fish, Lethbridge, Alberta, Canada. 416 p.

Thompson, William H. and Paul L. Hansen. 2003. Classification and management of riparian and wetland sites in Alberta's Parkland Natural Region and Dry Mixedwood Natural Subregion. Bitterroot Restoration, Inc. Prepared for the Alberta Riparian Habitat Management Program-Cows and Fish, Lethbridge, Alberta, Canada. 340 p.

Ute ladies' tresses (*Spiranthes diluvialis*). 2010. *In:* Montana Field Guide. http://FieldGuide.mt.gov/detail_PMORC2B100.aspx. September 15, 2010.

US Army Corps of Engineers (USACE). 1987. Corps of Engineers Wetlands Delineation Manual Technical Report Y-87-1 [On-line edition]). U.S. Army Engineer Research and Development Center, Environmental Laboratory, Waterways Experiment Station, Vicksburg, Mississippi, USA. 143 p.

US Army Corps of Engineers (USACE). 2010. U.S. Army Corps of Engineers (USACE) Manual and the Regional Supplement for Western Mountains, Valleys, and Coast Region. (Version 2.0). U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, Mississippi, USA. 153 p.

US Geological Survey (USGS). 2004. The Boulder River Watershed Study, Jefferson County, Montana. Professional Paper 1652-B. Eds: Church, Stanley E., David A. Nimick, Susan E. Finger, and Michael O'Neill.

USDI Fish and Wildlife Service. 2009. Endangered, Threatened, proposed and candidate species in Montana counties, Endangered Species Act. Department of the Interior, Fish and Wildlife Service, Ecological Services, Montana Field Office, Helena, Montana, USA. Memorandum dated September, 2009. http://fwp.mt.gov/wildthings/tande/. September 15, 2010.

Vaughn, B., C. Hoschouer, R. Gleason, and C. Stilwell. 2000. An evaluation of revegetation success within a floodplain system impaired by sulfide mine waste. 2000 Billings Land Reclamation Symposium. Billings, Montana, USA. 11 p.

The Weather Channel. 2011. Monthly Averages for Basin, MT. http://www.weather.com/weather/wxclimatology/monthly/graph/USMT0017. January 4, 2011.

Windell, Jay, and Chuck Stilwell. 2000. Bioengineered streambank stabilization on Silver Bow Creek, Butte, Montana. 2000 Billings Land Reclamation Symposium. Billings, Montana Montana. 15 p.

APPENDIX A

BULLION MINE SITE VEGETATION TRANSECT DATA SET (N = 5)

ESG VEGETATION TRANSECT FORM

Record ID No: **2024099**

ADMINISTRATIVE DATA

A1. Field data collected by: **Ecological Solutions Group LLC (ESG)**

A2. Funding Agency/Organization: **EPA/CH2MHILL**

A3a. BLM State Office: ______ **A3b.** BLM Field Office/Field Station: ______

A4. USFWS Refuge: ______

A5. Reservation: ______

A6. NPS Park/NHS: ______

A7. USFS National Forest: **Beaverhead-Deerlodge National Forest**

A8. Other Location: **Bullion Mine Site Complex**

A9. Year: **2010** **A10.** Date field data collected: **9/1/2010** **A11.** Observers: **Paul Hansen and Gant Massey**

LOCATION DATA

B1. State/Province: **MT** **B2.** County/Municipal District: **Jefferson**

B3. Area name: **Bullion Mine 2001-2002 Reclamation Site**

B4. Transect number: **1**

B5. Location: 1/4 1/4 Sec: ______ 1/4 Sec: ______ Sec: **13**

Township (NS): **7N** Range (EW): **6W** **B6.** Elev. (ft): **7,318** ; (m): **2,231**

Aspect (Degree): **330** Slope (%): **10**

B7. Transect latitude/longitude coordinates: GPS Projection: **WGS 84**

		Deg	Min	Sec	N/S	Decimal		Deg	Min	Sec	E/W	Decimal	Accuracy +/- ft	Accuracy +/- m	Observer Initial & WPT
Start:	Lat:	46	21	21.1	N	46.355861	Lon:	112	17	43.8	W	-112.295500	8	2.4	P001
End:	Lat:	46	21	22.0	N	46.356111	Lon:	112	17	41.7	W	-112.294917	10	3.0	G006
Other:	Lat:				N		Lon:				W				

B8. Other Point Comments: ______

B9. Quad map(s): **Basin, Montana**

TRANSECT INFORMATION

C1. Belt transect dimensions: length (ft): **180.00** ; (m): **54.86** width (ft): **3.00** ; (m): **0.91**

C2. Belt transect size (acres): **0.01** ; (hect): **0.01**

C3. Number of acres each transect represents (acres): **0.44** ; (hect): **0.18**

VEGETATION DATA

Trees

D1a. Are trees present? (Yes; No): **Yes** **D1b.** Tree species by canopy cover (%) and percent age group (%)

SPECIES	COV (%)	SDLG	DEC	SPLG	DEC	POLE	DEC	MAT	DEC	DEAD
ABILAS	**0.5**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
PINCVL	**0.5**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Trees

SPECIES	**D2.** Regen. Category	**D3.** Age Group Dist. Category	**D4a.** Sdlg/Splg Browse Utilization	**D4b.** Browse Architecture Type	**D4c.** Browse Intensity
ABILAS	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**
PINCVL	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**

Shrubs

D5a. Are shrubs present? (Yes; No): **Yes**

D5b. Does the polygon have potential for preferred woody species ? (Yes; No; NC): **Yes**

D5c. Shrub species canopy cover (%), age/size groups (%), and utilization

SPECIES	COV (%)	SDLG-SPLG/UTIL		MATURE/UTIL		DEC-DEAD/UTIL		**D5d.** Shrub Growth Form (N,F,U,C)	**D5e.** Browse Architecture Type	**D5f.** Browse Intensity
SALBEB	**0.5**	**97.5**	**Light**	**0.0**	**NA**	**0.0**	**NA**	**N**	**Uninter.**	**Lt-Mod.**
SPIBET	**0.5**	**97.5**	**Light**	**0.0**	**NA**	**0.0**	**NA**	**N**	**Uninter.**	**Lt-Mod.**

Record ID No: **2024099**

D5g. Tree ***AND*** shrub removal by other than browse: None (0-5%); Light (6-25%); Moderate (26-50%); Heavy (>50%); NA; NC: **Heavy (>50%)**

D5h. Basis of Call: **The site was reclaimed and any trees or shrubs present were removed prior to the reclaiming of the site.**

D6. Graminoids Graminoids present? (Yes; No): **Yes**

SPECIES	COV (%)	SPECIES	COV (%)	SPECIES	COV (%)	SPECIES	COV (%)
DESCES	**30.0**	**AGRCAN**	**0.5**				
DACGLO	**20.0**	**CALSTR**	**0.5**				
FESIDA	**20.0**	**HORJUB**	**0.5**				
CARMIC	**3.0**	**JUNBAL**	**0.5**				
FESSCA	**3.0**	**STIVIR**	**0.5**				

D7. Forbs Forbs present? (Yes; No): **Yes**

SPECIES	COV (%)	SPECIES	COV (%)
ACHMVL	**20.0**		
EQUHYE	**10.0**		
LOTCOR	**3.0**		
CIRARV	**0.5**		
EPIANG	**0.5**		
EPICIL	**0.5**		
FRAVIR	**0.5**		
LUPARG	**0.5**		
TRIREP	**0.5**		

Weed Data

D12a. Are invasive species present? (Yes; No; NC): **Yes**

If ***Yes,*** **D12b.** Enter the canopy cover and the density/distribution class for each of the following invasive species:

	Canopy Cover (New Way)	Density/ Distribut. Class
bluebuttons (KNAARV):	**0.0**	**0**
Canada thistle (CIRARV):	**0.5**	**1**
cheatgrass (BROTEC):	**0.0**	**0**
common burdock (ARCMIN):	**0.0**	**0**
common cuprina (CRUVUL):	**0.0**	**0**
common hound's-tongue (CYNOFF):	**0.0**	**0**
common tansy (TANVUL):	**0.0**	**0**
dalmatian toadflax (LINDAL):	**0.0**	**0**
diffuse knapweed (CENDIF):	**0.0**	**0**
Dyer's woad (ISATIN):	**0.0**	**0**
field bindweed (CONARV):	**0.0**	**0**
field sow thistle (SONARV):	**0.0**	**0**
Japanese brome (BROJAP):	**0.0**	**0**
leafy spurge (EUPESU):	**0.0**	**0**
musk thistle (CARNUT):	**0.0**	**0**
orange hawkweed (HIEAUR):	**0.0**	**0**
oxeye daisy (CHRLEU):	**0.0**	**0**
perennial pepperweed (LEPLAT):	**0.0**	**0**
purple loosestrife (LYTSAL):	**0.0**	**0**
Russian knapweed (CENREP):	**0.0**	**0**
Russian olive (ELAANG):	**0.0**	**0**
saltcedar (tamarisk) (TAMARI):	**0.0**	**0**
Scotch thistle (ONOACA):	**0.0**	**0**
spotted knapweed (CENMAC):	**0.0**	**0**
St. John's wort (HYPPER):	**0.0**	**0**
sulphur cinquefoil (POTREC):	**0.0**	**0**
tall buttercup (RANACR):	**0.0**	**0**
teasel (DIPFUL):	**0.0**	**0**
whitetop (CARDRA):	**0.0**	**0**
yellow iris (IRIPSE):	**0.0**	**0**
yellow starthistle (CENSOL):	**0.0**	**0**
yellow toadflax (LINVUL):	**0.0**	**0**
Others: ______	**0.0**	**0**
Others: ______	**0.0**	**0**

Record ID No: **2024099**

D8. Plant Group by Canopy Cover (%)

Layer	Trees	Shrubs	Graminoids	Forbs
3 (>6.0 ft):	0.0	0.0	0.0	0.0
2 (>1.5 - 6.0 ft):	0.5	0.0	0.5	0.0
1 (0 - 1.5 ft):	0.5	0.5	70.0	30.0

D9. Total canopy cover (%) by lifeform:

Trees: **0.5** Shrubs: **0.5**

Graminoids: **70.0** Forbs: **30.0**

D10. Total canopy cover (%) by woody species: **0.5**

D11. Total canopy cover (%) by all plant lifeforms: **80.0**

D12c. Cumulative totals for all invasive species:

Canopy Cover (New Way)	Density/ Distribution Class
0.5	1

D13a. Are undesirable herbaceous species present? Yes; No; NC): **NC**

If ***Yes,*** **D13b.** Record the combined canopy cover (%) of all undesirable herbaceous species observed: ______

D14. Transect trend: Improving, Degrading, Static, or Status Unknown? **Improving**

D15. Explain trend description and give other comments:

The vegetation transect was a belt transect across the face of the 2001-2002 reclaimed site. The transect was 1 m wide and 55 m long.

Number of tree seedlings: PINCON (lodgepole pine) = 8; ABILAS (subalpine fir) = 6.

The 2001-2002 revegetation of the reclaimed site seems to be doing well. There still is some bare ground (approx. 20 percent) on the site. However, the slope seems to be stable with very little to no erosion. The slope has numerous springs located throughout. The springs are not directly associated with the rock lined ditch from the acid mine drainage farther upslope. The rocks of the channel associated with the ditch are colored orange.

The surrounding hillsides are dominated by the Pinus contorta/Vaccinium scoparium (lodgepole pine/whortleberry) community type which is a late successional stage of the Abies lasiocarpa/Vaccinium scoparium (subalpine fir/whortleberry) habitat type. The wetter sites are occupied by either the Abies lasiocarpa/Calamagrostis canadensis (subalpine fir/bluejoint reedgrass) habitat type, or the Abies lasiocarpa/Ledum glandulosum (subalpine fir/Labrador-tea) habitat type.

PHYSICAL SITE DATA

E1a. Is there exposed soil surface (bare ground)? (Yes; No; NC): **Yes** If ***No*** or ***NC,*** go to item **E2.**

E1b. Percent (%) of the polygon which is exposed soil surface (bare ground): **20.0**

E1c. Of this, how much is due to natural processes: **0.0** Human-caused disturbance: **97.5** (must approx. 100%)

E1d. Within ***each*** category (natural & human-caused), how much resulted from the listed processes?

NATURAL PROCESSES *(must approx. 100%)*

0.0	Erosional	0.0	Type Dependent
0.0	Depositional	0.0	Saline/Alkaline
0.0	Wildlife Use	0.0	Other

HUMAN-CAUSED PROCESSES *(must approx. 100%)*

0.0	Grazing	0.0	Construction
0.0	Timber Harvest	97.5	Mining
0.0	Cultivation	0.0	Recreation
0.0	Other		

Explain "Other": ______

E2. Non-vegetated ground cover. (***Note*****:** Bare ground and vascular plant cover recorded above.)

Rocks (>2.5 in.): **30.0** Moss: **30.0** Litter/Duff: **0.5** Wood: **20.0** Human Imperv. Surf.: **0.0** Other: **0.0**

E3. Detailed description of ends of the transects:

The transect start just east of the small parking lot and continue east across the face of the reclamation site to the edge of the conifer forest on the east side of the site. The entire transect lies within the 2001-2002 reclaimed site.

Record ID No: **2024099**

PHOTOGRAPH DATA

F1. Identification of photos:

Photographer: **Paul Hansen and Gant Massey**

Photo numbers: **2313, 2314, 2315, 2316**

F2. Description of views:

Looking along the belt transect from the west end of the transect. The view is towards the east.

ADDITIONAL DATA

G1. Vegetative use by animals (0-25%; 26-50%; 51-75%; 76-100%): **2 - 26-50%**

G2a. Break down the transect area into the land uses listed (must total to approx. 100%):

G2b. Break down the area adjacent to the transect into the land uses listed (must total to approx. 100%):

	G2a	G2b
No land use apparent:	**0.0**	**0.0**
Turf grass (lawn):	**0.0**	**0.0**
Tame pasture (grazing):	**0.0**	**0.0**
Native pasture (grazing):	**0.0**	**0.0**
Recreation (ATV paths, campsites, etc.):	**0.0**	**0.0**
Development (buildings, corrals, paved lots, etc.):	**0.0**	**0.0**
Tilled cropping:	**0.0**	**0.0**
Perennial forage (e.g., alfalfa hayland):	**0.0**	**0.0**
Roads:	**0.0**	**0.0**
Logging:	**0.0**	**0.0**
Mining:	**97.5**	**97.5**
Railroads:	**0.0**	**0.0**
Other:	**0.0**	**0.0**

Description of Other Usage Noted:

Description of Other Usage Noted:

G3. Adjacent uplands (Agriculture; Grassland; Shrubland; Forest; or Other): **Forest**

G4a. Were Category 2 (T & E) plant species observed? (Yes; No): **No** If **Yes, G4b.** Species:

G4c. Location(s):

WILDLIFE DATA

Threatened and Endangered Species Data

H1a. Were T & E animal species observed? (Yes; No; NC): **No**

If ***Yes,* H1b.** What species? Peregrine Falcon: ______ Bald Eagle: ______ Bull Trout: ______

Peregrine Falcon Nest: ______ Bald Eagle Nest: ______

Other T & E species observed: Species ______ Number ______ Species ______ Number ______

H1c. Location in transect where T & E animals or nests were sighted:

ESG VEGETATION TRANSECT FORM

Record ID No: 2024100

ADMINISTRATIVE DATA

A1. Field data collected by: **Ecological Solutions Group LLC (ESG)**

A2. Funding Agency/Organization: **EPA/CH2MHILL**

A3a. BLM State Office: ______ **A3b.** BLM Field Office/Field Station: ______

A4. USFWS Refuge: ______

A5. Reservation: ______

A6. NPS Park/NHS: ______

A7. USFS National Forest: **Beaverhead-Deerlodge National Forest**

A8. Other Location: **Bullion Mine Site Complex**

A9. Year: **2010** **A10.** Date field data collected: **9/1/2010** **A11.** Observers: **Paul Hansen and Gant Massey**

LOCATION DATA

B1. State/Province: **MT** **B2.** County/Municipal District: **Jefferson**

B3. Area name: **Bullion Mine 2001-2002 Reclamation Site**

B4. Transect number: **2**

B5. Location: 1/4 1/4 Sec: ______ 1/4 Sec: **NW** Sec: **13**

Township (NS): **7N** Range (EW): **6W** **B6.** Elev. (ft): **7,280** ; (m): **2,219**

Aspect (Degree): **330** Slope (%): **12**

B7. Transect latitude/longitude coordinates: GPS Projection: **WGS 84**

		Deg	Min	Sec	N/S	Decimal		Deg	Min	Sec	E/W	Decimal	Accuracy +/- ft	Accuracy +/- m	Observer Initial & WPT
Start:	Lat:	**46**	**21**	**21.9**	**N**	**46.356083**	Lon:	**112**	**17**	**45.2**	**W**	**-112.295889**	**8**	**2.4**	**P002**
End:	Lat:	**46**	**21**	**23.1**	**N**	**46.356417**	Lon:	**112**	**17**	**41.7**	**W**	**-112.294917**	**9**	**2.7**	**P003**
Other:	Lat:				**N**		Lon:				**W**				

B8. Other Point Comments: ______

B9. Quad map(s): **Basin, Montana**

TRANSECT INFORMATION

C1. Belt transect dimensions: length (ft): **262.00** ; (m): **79.86** width (ft): **3.00** ; (m): **0.91**

C2. Belt transect size (acres): **0.02** ; (hect): **0.01**

C3. Number of acres each transect represents (acres): **0.44** ; (hect): **0.18**

VEGETATION DATA

Trees

D1a. Are trees present? (Yes; No): **Yes** **D1b.** Tree species by canopy cover (%) and percent age group (%)

SPECIES	COV (%)	SDLG/DEC		SPLG/DEC		POLE/DEC		MAT/DEC		DEAD
PINCVL	**3.0**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
ABILAS	**0.5**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Trees

SPECIES	**D2.** Regen. Category	**D3.** Age Group Dist. Category	**D4a.** Sdlg/Splg Browse Utilization	**D4b.** Browse Architecture Type	**D4c.** Browse Intensity
PINCVL	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**
ABILAS	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**

Shrubs

D5a. Are shrubs present? (Yes; No): **Yes**

D5b. Does the polygon have potential for preferred woody species ? (Yes; No; NC): **Yes**

D5c. Shrub species canopy cover (%), age/size groups (%), and utilization

SPECIES	COV (%)	SDLG-SPLG/UTIL		MATURE/UTIL		DEC-DEAD/UTIL		**D5d.** Shrub Growth Form (N,F,U,C)	**D5e.** Browse Architecture Type	**D5f.** Browse Intensity
ALNINC	**0.5**	**97.5**	**Heavy**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Intense**
SALBEB	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Intense**
SPIBET	**0.5**	**97.5**	**Light**	**0.0**	**NA**	**0.0**	**NA**	**N**	**Uninter.**	**Lt-Mod.**

Record ID No: **2024100**

D5g. Tree ***AND*** shrub removal by other than browse: None (0-5%); Light (6-25%); Moderate (26-50%); Heavy (>50%); NA; NC: **Heavy (>50%)**

D5h. Basis of Call: **The site was reclaimed and any trees or shrubs present were removed prior to the reclaiming of the site.**

D6. Graminoids Graminoids present? (Yes; No): **Yes**

SPECIES	COV (%)	SPECIES	COV (%)	SPECIES	COV (%)	SPECIES	COV (%)
DESCES	**40.0**	**AGRSCA**	**3.0**	**SITHYS**	**0.5**		
DACGLO	**20.0**	**CALSTR**	**3.0**				
FESIDA	**20.0**	**PHLPRA**	**3.0**				
CARMIC	**10.0**	**CARPRA**	**0.5**				
AGRCAN	**3.0**	**FESSCA**	**0.5**				

D7. Forbs Forbs present? (Yes; No): **Yes**

SPECIES	COV (%)	SPECIES	COV (%)
ACHMVL	**10.0**		
LOTCOR	**10.0**		
ASTRAG	**0.5**		
CIRARV	**0.5**		
EPICIL	**0.5**		
EQUHYE	**0.5**		
FRAVIR	**0.5**		
GEUCAN	**0.5**		
LUPARG	**0.5**		
RUMEXX	**0.5**		

Weed Data

D12a. Are invasive species present? (Yes; No; NC): **Yes**

If ***Yes,*** **D12b.** Enter the canopy cover and the density/distribution class for each of the following invasive species:

	Canopy Cover (New Way)	Density/ Distribut. Class
bluebuttons (KNAARV):	**0.0**	**0**
Canada thistle (CIRARV):	**0.5**	**1**
cheatgrass (BROTEC):	**0.0**	**0**
common burdock (ARCMIN):	**0.0**	**0**
common cuprina (CRUVUL):	**0.0**	**0**
common hound's-tongue (CYNOFF):	**0.0**	**0**
common tansy (TANVUL):	**0.0**	**0**
dalmatian toadflax (LINDAL):	**0.0**	**0**
diffuse knapweed (CENDIF):	**0.0**	**0**
Dyer's woad (ISATIN):	**0.0**	**0**
field bindweed (CONARV):	**0.0**	**0**
field sow thistle (SONARV):	**0.0**	**0**
Japanese brome (BROJAP):	**0.0**	**0**
leafy spurge (EUPESU):	**0.0**	**0**
musk thistle (CARNUT):	**0.0**	**0**
orange hawkweed (HIEAUR):	**0.0**	**0**
oxeye daisy (CHRLEU):	**0.0**	**0**
perennial pepperweed (LEPLAT):	**0.0**	**0**
purple loosestrife (LYTSAL):	**0.0**	**0**
Russian knapweed (CENREP):	**0.0**	**0**
Russian olive (ELAANG):	**0.0**	**0**
saltcedar (tamarisk) (TAMARI):	**0.0**	**0**
Scotch thistle (ONOACA):	**0.0**	**0**
spotted knapweed (CENMAC):	**0.0**	**0**
St. John's wort (HYPPER):	**0.0**	**0**
sulphur cinquefoil (POTREC):	**0.0**	**0**
tall buttercup (RANACR):	**0.0**	**0**
teasel (DIPFUL):	**0.0**	**0**
whitetop (CARDRA):	**0.0**	**0**
yellow iris (IRIPSE):	**0.0**	**0**
yellow starthistle (CENSOL):	**0.0**	**0**
yellow toadflax (LINVUL):	**0.0**	**0**
Others:	**0.0**	**0**
Others:	**0.0**	**0**

Record ID No: **2024100**

D8. Plant Group by Canopy Cover (%)

Layer	Trees	Shrubs	Graminoids	Forbs
3 (>6.0 ft):	**0.0**	**0.0**	**0.0**	**0.0**
2 (>1.5 - 6.0 ft):	**0.5**	**0.0**	**0.5**	**3.0**
1 (0 - 1.5 ft):	**3.0**	**3.0**	**80.0**	**20.0**

D9. Total canopy cover (%) by lifeform:

Trees: **3.0** Shrubs: **3.0**

Graminoids: **80.0** Forbs: **20.0**

D10. Total canopy cover (%) by woody species: **10.0**

D11. Total canopy cover (%) by all plant lifeforms: **80.0**

D12c. Cumulative totals for all invasive species:

Canopy Cover (New Way)	Density/ Distribution Class
0.5	**1**

D13a. Are undesirable herbaceous species present? Yes; No; NC): **NC**

If ***Yes,* D13b.** Record the combined canopy cover (%) of all undesirable herbaceous species observed: ________

D14. Transect trend: Improving, Degrading, Static, or Status Unknown? **Improving**

D15. Explain trend description and give other comments:

The vegetation transect was a belt transect across the face of the 2001-2002 reclaimed site. The transect was 1 m wide and 80 m long.

Number of tree seedlings in belt transect: PINCON (lodgepole pine) = 50; ABILAS (subalpine fir) = 21.

The 2001-2002 revegetation of the reclaimed site seems to be doing well. There still is some bare ground (approx. 20 percent) on the site. However, the slope seems to be stable with very little to no erosion. The slope has numerous springs located throughout. The springs are not directly associated with the rock lined ditch from the acid mine drainage farther upslope. The rocks of the channel associated with the ditch are colored orange.

The surrounding hillsides are dominated by the Pinus contorta/Vaccinium scoparium (lodgepole pine/whortleberry) community type which is a late successional stage of the Abies lasiocarpa/Vaccinium scoparium (subalpine fir/whortleberry) habitat type. The wetter sites are occupied by either the Abies lasiocarpa/Calamagrostis canadensis (subalpine fir/bluejoint reedgrass) habitat type, or the Abies lasiocarpa/Ledum glandulosum (subalpine fir/Labrador-tea) habitat type.

PHYSICAL SITE DATA

E1a. Is there exposed soil surface (bare ground)? (Yes; No; NC): **Yes** If ***No*** or ***NC,*** go to item **E2.**

E1b. Percent (%) of the polygon which is exposed soil surface (bare ground): **20.0**

E1c. Of this, how much is due to natural processes: **0.0** Human-caused disturbance: **97.5** (must approx. 100%)

E1d. Within ***each*** category (natural & human-caused), how much resulted from the listed processes?

NATURAL PROCESSES *(must approx. 100%)*

0.0	Erosional	**0.0**	Type Dependent
0.0	Depositional	**0.0**	Saline/Alkaline
0.0	Wildlife Use	**0.0**	Other

HUMAN-CAUSED PROCESSES *(must approx. 100%)*

0.0	Grazing	**0.0**	Construction
0.0	Timber Harvest	**97.5**	Mining
0.0	Cultivation	**0.0**	Recreation
0.0	Other		

Explain "Other": ________

E2. Non-vegetated ground cover. (***Note*****:** Bare ground and vascular plant cover recorded above.)

Rocks (>2.5 in.): **30.0** Moss: **0.5** Litter/Duff: **0.5** Wood: **20.0** Human Imperv. Surf.: **0.0** Other: **0.0**

E3. Detailed description of ends of the transects:

The transect start just east of the small parking lot and continue east across the face of the reclamation site to the edge of the conifer forest on the east side of the site. The entire transect lies within the 2001-2002 reclaimed site.

Record ID No: **2024100**

PHOTOGRAPH DATA

F1. Identification of photos:

Photographer: **Paul Hansen and Gant Massey**

Photo numbers: **2319, 2320, 2321, 2322, 2323, 2324, 2325**

F2. Description of views:

Looking along the belt transect from the west end of the transect. The view is towards the east.

ADDITIONAL DATA

G1. Vegetative use by animals (0-25%; 26-50%; 51-75%; 76-100%): **2 - 26-50%**

G2a. Break down the transect area into the land uses listed (must total to approx. 100%):

G2b. Break down the area adjacent to the transect into the land uses listed (must total to approx. 100%):

	G2a	G2b
No land use apparent:	0.0	0.0
Turf grass (lawn):	0.0	0.0
Tame pasture (grazing):	0.0	0.0
Native pasture (grazing):	0.0	0.0
Recreation (ATV paths, campsites, etc.):	0.0	0.0
Development (buildings, corrals, paved lots, etc.):	0.0	0.0
Tilled cropping:	0.0	0.0
Perennial forage (e.g., alfalfa hayland):	0.0	0.0
Roads:	0.0	0.0
Logging:	0.0	0.0
Mining:	97.5	97.5
Railroads:	0.0	0.0
Other:	0.0	0.0

Description of Other Usage Noted:

Description of Other Usage Noted:

G3. Adjacent uplands (Agriculture; Grassland; Shrubland; Forest; or Other): **Forest**

G4a. Were Category 2 (T & E) plant species observed? (Yes; No): **No** If **Yes, G4b.** Species:

G4c. Location(s):

WILDLIFE DATA

Threatened and Endangered Species Data

H1a. Were T & E animal species observed? (Yes; No; NC): **No**

If ***Yes*, H1b.** What species? Peregrine Falcon: ____ Bald Eagle: ____ Bull Trout: ____

Peregrine Falcon Nest: ____ Bald Eagle Nest: ____

Other T & E species observed: Species ____ Number ____ Species ____ Number ____

H1c. Location in transect where T & E animals or nests were sighted:

ESG VEGETATION TRANSECT FORM

Record ID No: **2024101**

ADMINISTRATIVE DATA

A1. Field data collected by: **Ecological Solutions Group LLC (ESG)**

A2. Funding Agency/Organization: **EPA/CH2MHILL**

A3a. BLM State Office: ______ **A3b.** BLM Field Office/Field Station: ______

A4. USFWS Refuge: ______

A5. Reservation: ______

A6. NPS Park/NHS: ______

A7. USFS National Forest: **Beaverhead-Deerlodge National Forest**

A8. Other Location: **Bullion Mine Site Complex**

A9. Year: **2010** **A10.** Date field data collected: **9/1/2010** **A11.** Observers: **Paul Hansen and Gant Massey**

LOCATION DATA

B1. State/Province: **MT** **B2.** County/Municipal District: **Jefferson**

B3. Area name: **Bullion Mine 2001-2002 Reclamation Site**

B4. Transect number: **3**

B5. Location: 1/4 1/4 Sec: ______ 1/4 Sec: **NW** Sec: **13**

Township (NS): **7N** Range (EW): **6W** **B6.** Elev. (ft): **7,270** ; (m): **2,216**

Aspect (Degree): **330** Slope (%): **13**

B7. Transect latitude/longitude coordinates: GPS Projection: **WGS 84**

		Deg	Min	Sec	N/S	Decimal		Deg	Min	Sec	E/W	Decimal	Accuracy +/- ft	Accuracy +/- m	Observer Initial & WPT
Start:	Lat:	**46**	**21**	**22.6**	**N**	**46.356278**	Lon:	**112**	**17**	**45.9**	**W**	**-112.296083**	**8**	**2.4**	**P004**
End:	Lat:	**46**	**21**	**23.7**	**N**	**46.356583**	Lon:	**112**	**17**	**42.0**	**W**	**-112.295000**	**10**	**3.0**	**P005**
Other:	Lat:				**N**		Lon:				**W**				

B8. Other Point Comments: ______

B9. Quad map(s): **Basin, Montana**

TRANSECT INFORMATION

C1. Belt transect dimensions: length (ft): **312.00** ; (m): **95.10** width (ft): **3.00** ; (m): **0.91**

C2. Belt transect size (acres): **0.02** ; (hect): **0.01**

C3. Number of acres each transect represents (acres): **0.44** ; (hect): **0.18**

VEGETATION DATA

Trees

D1a. Are trees present? (Yes; No): **Yes** **D1b.** Tree species by canopy cover (%) and percent age group (%)

SPECIES	COV (%)	SDLG	DEC	SPLG	DEC	POLE	DEC	MAT	DEC	DEAD
PINCVL	**3.0**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
ABILAS	**0.5**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
PSEMEN	**0.5**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Record ID No: **2024101**

Trees

SPECIES	**D2.** Regen. Category	**D3.** Age Group Dist. Category	**D4a.** Sdlg/Splg Browse Utilization	**D4b.** Browse Architecture Type	**D4c.** Browse Intensity
PINCVL	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**
ABILAS	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**
PSEMEN	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**

Shrubs

D5a. Are shrubs present? (Yes; No): **Yes**

D5b. Does the polygon have potential for preferred woody species ? (Yes; No; NC): **Yes**

D5c. Shrub species canopy cover (%), age/size groups (%), and utilization

SPECIES	COV (%)	SDLG-SPLG/UTIL		MATURE/UTIL		DEC-DEAD/UTIL		**D5d.** Shrub Growth Form (N,F,U,C)	**D5e.** Browse Architecture Type	**D5f.** Browse Intensity
ROSWOO	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**N**	**Arrested**	**Lt-Mod.**
RUBIDA	**0.5**	**97.5**	**Light**	**0.0**	**NA**	**0.0**	**NA**	**N**	**Uninter.**	**Lt-Mod.**
SALBEB	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**
SHECAN	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**
SPIBET	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**

Record ID No: **2024101**

D5g. Tree ***AND*** shrub removal by other than browse: None (0-5%); Light (6-25%); Moderate (26-50%); Heavy (>50%); NA; NC: **Heavy (>50%)**

D5h. Basis of Call: **The site was reclaimed and any trees or shrubs present were removed prior to the reclaiming of the site.**

D6. Graminoids Graminoids present? (Yes; No): **Yes**

SPECIES	COV (%)	SPECIES	COV (%)	SPECIES	COV (%)	SPECIES	COV (%)
DACGLO	**40.0**	**CARPRA**	**0.5**				
DESCES	**30.0**	**FESSCA**	**0.5**				
FESIDA	**20.0**						
CARMIC	**3.0**						
AGRSCA	**0.5**						

D7. Forbs Forbs present? (Yes; No): **Yes**

SPECIES	COV (%)	SPECIES	COV (%)
ACHMVL	**10.0**		
LOTCOR	**3.0**		
ANTNEG	**0.5**		
ASTRAG	**0.5**		
CIRARV	**0.5**		
EPICIL	**0.5**		
FRAVIR	**0.5**		
GEUCAN	**0.5**		
LUPARG	**0.5**		
RUMEXX	**0.5**		
VERTHA	**0.5**		

Weed Data

D12a. Are invasive species present? (Yes; No; NC): **Yes**

If ***Yes,*** **D12b.** Enter the canopy cover and the density/distribution class for each of the following invasive species:

	Canopy Cover (New Way)	Density/ Distribut. Class
bluebuttons (KNAARV):	**0.0**	**0**
Canada thistle (CIRARV):	**0.5**	**1**
cheatgrass (BROTEC):	**0.0**	**0**
common burdock (ARCMIN):	**0.0**	**0**
common cuprina (CRUVUL):	**0.0**	**0**
common hound's-tongue (CYNOFF):	**0.0**	**0**
common tansy (TANVUL):	**0.0**	**0**
dalmatian toadflax (LINDAL):	**0.0**	**0**
diffuse knapweed (CENDIF):	**0.0**	**0**
Dyer's woad (ISATIN):	**0.0**	**0**
field bindweed (CONARV):	**0.0**	**0**
field sow thistle (SONARV):	**0.0**	**0**
Japanese brome (BROJAP):	**0.0**	**0**
leafy spurge (EUPESU):	**0.0**	**0**
musk thistle (CARNUT):	**0.0**	**0**
orange hawkweed (HIEAUR):	**0.0**	**0**
oxeye daisy (CHRLEU):	**0.0**	**0**
perennial pepperweed (LEPLAT):	**0.0**	**0**
purple loosestrife (LYTSAL):	**0.0**	**0**
Russian knapweed (CENREP):	**0.0**	**0**
Russian olive (ELAANG):	**0.0**	**0**
saltcedar (tamarisk) (TAMARI):	**0.0**	**0**
Scotch thistle (ONOACA):	**0.0**	**0**
spotted knapweed (CENMAC):	**0.0**	**0**
St. John's wort (HYPPER):	**0.0**	**0**
sulphur cinquefoil (POTREC):	**0.0**	**0**
tall buttercup (RANACR):	**0.0**	**0**
teasel (DIPFUL):	**0.0**	**0**
whitetop (CARDRA):	**0.0**	**0**
yellow iris (IRIPSE):	**0.0**	**0**
yellow starthistle (CENSOL):	**0.0**	**0**
yellow toadflax (LINVUL):	**0.0**	**0**
Others:	**0.0**	**0**
Others:	**0.0**	**0**

Record ID No: **2024101**

D8. Plant Group by Canopy Cover (%)

Layer	Trees	Shrubs	Graminoids	Forbs
3 (>6.0 ft):	**0.0**	**0.0**	**0.0**	**0.0**
2 (>1.5 - 6.0 ft):	**0.5**	**0.0**	**0.5**	**0.5**
1 (0 - 1.5 ft):	**3.0**	**3.0**	**80.0**	**10.0**

D12c. Cumulative totals for all invasive species:

Canopy Cover (New Way)	Density/ Distribution Class
0.5	**1**

D9. Total canopy cover (%) by lifeform:

Trees: **3.0** Shrubs: **3.0**

Graminoids: **80.0** Forbs: **10.0**

D10. Total canopy cover (%) by woody species: **10.0**

D11. Total canopy cover (%) by all plant lifeforms: **80.0**

D13a. Are undesirable herbaceous species present? Yes; No; NC): **NC**

If ***Yes,* D13b.** Record the combined canopy cover (%) of all undesirable herbaceous species observed: ______

D14. Transect trend: Improving, Degrading, Static, or Status Unknown? **Improving**

D15. Explain trend description and give other comments:

The vegetation transect was a belt transect across the face of the 2001-2002 reclaimed site. The transect was 1 m wide and 95 m long.

Number of tree seedlings in belt transect: PINCON (lodgepole pine) = 49; ABILAS (subalpine fir) = 33; PSEMEN (Douglas fir) = 4.

The 2001-2002 revegetation of the reclaimed site seems to be doing well. There still is some bare ground (approx. 20 percent) on the site. However, the slope seems to be stable with very little to no erosion. The slope has numerous springs located throughout. The springs are not directly associated with the rock lined ditch from the acid mine drainage farther upslope. The rocks of the channel associated with the ditch are colored orange.

The surrounding hillsides are dominated by the Pinus contorta/Vaccinium scoparium (lodgepole pine/whortleberry) community type which is a late successional stage of the Abies lasiocarpa/Vaccinium scoparium (subalpine fir/whortleberry) habitat type. The wetter sites are occupied by either the Abies lasiocarpa/Calamagrostis canadensis (subalpine fir/bluejoint reedgrass) habitat type, or the Abies lasiocarpa/Ledum glandulosum (subalpine fir/Labrador-tea) habitat type.

PHYSICAL SITE DATA

E1a. Is there exposed soil surface (bare ground)? (Yes; No; NC): **Yes** If ***No*** or ***NC,*** go to item **E2.**

E1b. Percent (%) of the polygon which is exposed soil surface (bare ground): **20.0**

E1c. Of this, how much is due to natural processes: **0.0** Human-caused disturbance: **97.5** (must approx. 100%)

E1d. Within ***each*** category (natural & human-caused), how much resulted from the listed processes?

NATURAL PROCESSES *(must approx. 100%)*

0.0	Erosional	**0.0**	Type Dependent
0.0	Depositional	**0.0**	Saline/Alkaline
0.0	Wildlife Use	**0.0**	Other

HUMAN-CAUSED PROCESSES *(must approx. 100%)*

0.0	Grazing	**0.0**	Construction
0.0	Timber Harvest	**97.5**	Mining
0.0	Cultivation	**0.0**	Recreation
0.0	Other		

Explain "Other": ______

E2. Non-vegetated ground cover. (***Note*:** Bare ground and vascular plant cover recorded above.)

Rocks (>2.5 in.): **30.0** Moss: **0.5** Litter/Duff: **0.5** Wood: **20.0** Human Imperv. Surf.: **0.0** Other: **0.0**

E3. Detailed description of ends of the transects:

The transect start just east of the small parking lot and continue east across the face of the reclamation site to the edge of the conifer forest on the east side of the site. The entire transect lies within the 2001-2002 reclaimed site.

PHOTOGRAPH DATA

Record ID No: **2024101**

F1. Identification of photos:

Photographer: **Paul Hansen and Gant Massey**

Photo numbers: **2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356**

F2. Description of views:

Looking along the belt transect from the west end of the transect. The view is towards the east.

ADDITIONAL DATA

G1. Vegetative use by animals (0-25%; 26-50%; 51-75%; 76-100%): **2 - 26-50%**

G2a. Break down the transect area into the land uses listed (must total to approx. 100%):

No land use apparent:	**0.0**
Turf grass (lawn):	**0.0**
Tame pasture (grazing):	**0.0**
Native pasture (grazing):	**0.0**
Recreation (ATV paths, campsites, etc.):	**0.0**
Development (buildings, corrals, paved lots, etc.):	**0.0**
Tilled cropping:	**0.0**
Perennial forage (e.g., alfalfa hayland):	**0.0**
Roads:	**0.0**
Logging:	**0.0**
Mining:	**97.5**
Railroads:	**0.0**
Other:	**0.0**

Description of Other Usage Noted:

G2b. Break down the area adjacent to the transect into the land uses listed (must total to approx. 100%):

No land use apparent:	**0.0**
Turf grass (lawn):	**0.0**
Tame pasture (grazing):	**0.0**
Native pasture (grazing):	**0.0**
Recreation (ATV paths, campsites, etc.):	**0.0**
Development (buildings, corrals, paved lots, etc.):	**0.0**
Tilled cropping:	**0.0**
Perennial forage (e.g., alfalfa hayland):	**0.0**
Roads:	**0.0**
Logging:	**0.0**
Mining:	**97.5**
Railroads:	**0.0**
Other:	**0.0**

Description of Other Usage Noted:

G3. Adjacent uplands (Agriculture; Grassland; Shrubland; Forest; or Other): **Forest**

G4a. Were Category 2 (T & E) plant species observed? (Yes; No): **No** If **Yes, G4b.** Species:

G4c. Location(s):

WILDLIFE DATA

Threatened and Endangered Species Data

H1a. Were T & E animal species observed? (Yes; No; NC): **No**

If ***Yes,* H1b.** What species? Peregrine Falcon: ______ Bald Eagle: ______ Bull Trout: ______

Peregrine Falcon Nest: ______ Bald Eagle Nest: ______

Other T & E species observed: Species ______ Number ______ Species ______ Number ______

H1c. Location in transect where T & E animals or nests were sighted:

ESG VEGETATION TRANSECT FORM

Record ID No: **2024102**

ADMINISTRATIVE DATA

A1. Field data collected by: **Ecological Solutions Group LLC (ESG)**

A2. Funding Agency/Organization: **EPA/CH2MHILL**

A3a. BLM State Office: ______ **A3b.** BLM Field Office/Field Station: ______

A4. USFWS Refuge: ______

A5. Reservation: ______

A6. NPS Park/NHS: ______

A7. USFS National Forest: **Beaverhead-Deerlodge National Forest**

A8. Other Location: **Bullion Mine Site Complex**

A9. Year: **2010** **A10.** Date field data collected: **9/1/2010** **A11.** Observers: **Paul Hansen and Gant Massey**

LOCATION DATA

B1. State/Province: **MT** **B2.** County/Municipal District: **Jefferson**

B3. Area name: **Bullion Mine 2001-2002 Reclamation Site**

B4. Transect number: **4**

B5. Location: 1/4 1/4 Sec: ______ 1/4 Sec: **NW** Sec: **13**

Township (NS): **7N** Range (EW): **6W** **B6.** Elev. (ft): **7,239** ; (m): **2,206**

Aspect (Degree): **330** Slope (%): **15**

B7. Transect latitude/longitude coordinates: GPS Projection: **WGS 84**

		Deg	Min	Sec	N/S	Decimal		Deg	Min	Sec	E/W	Decimal	Accuracy +/- ft	Accuracy +/- m	Observer Initial & WPT
Start:	Lat:	**46**	**21**	**23.4**	**N**	**46.356500**	Lon:	**112**	**17**	**46.0**	**W**	**-112.296111**	**8**	**2.4**	**P006**
End:	Lat:	**46**	**21**	**24.8**	**N**	**46.356889**	Lon:	**112**	**17**	**42.8**	**W**	**-112.295222**	**8**	**2.4**	**P009**
Other:	Lat:				**N**		Lon:				**W**				

B8. Other Point Comments: ______

B9. Quad map(s): **Basin, Montana**

TRANSECT INFORMATION

C1. Belt transect dimensions: length (ft): **269.00** ; (m): **81.99** width (ft): **3.00** ; (m): **0.91**

C2. Belt transect size (acres): **0.02** ; (hect): **0.01**

C3. Number of acres each transect represents (acres): **0.44** ; (hect): **0.18**

VEGETATION DATA

Trees

D1a. Are trees present? (Yes; No): **Yes** **D1b.** Tree species by canopy cover (%) and percent age group (%)

SPECIES	COV (%)	SDLG/DEC		SPLG/DEC		POLE/DEC		MAT/DEC		DEAD
ABILAS	**3.0**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
PINCVL	**3.0**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
PSEMEN	**0.5**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Record ID No: **2024102**

Trees

SPECIES	**D2.** Regen. Category	**D3.** Age Group Dist. Category	**D4a.** Sdlg/Splg Browse Utilization	**D4b.** Browse Architecture Type	**D4c.** Browse Intensity
ABILAS	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**
PINCVL	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**
PSEMEN	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**

Shrubs

D5a. Are shrubs present? (Yes; No): **Yes**

D5b. Does the polygon have potential for preferred woody species ? (Yes; No; NC): **Yes**

D5c. Shrub species canopy cover (%), age/size groups (%), and utilization

SPECIES	COV (%)	SDLG-SPLG/UTIL		MATURE/UTIL		DEC-DEAD/UTIL		**D5d.** Shrub Growth Form (N,F,U,C)	**D5e.** Browse Architecture Type	**D5f.** Browse Intensity
ROSWOO	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**
SALBEB	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**
SALBOO	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**
SALDRU	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**
SPIBET	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**

Record ID No: **2024102**

D5g. Tree ***AND*** shrub removal by other than browse: None (0-5%); Light (6-25%); Moderate (26-50%); Heavy (>50%); NA; NC: **Heavy (>50%)**

D5h. Basis of Call: **The site was reclaimed and any trees or shrubs present were removed prior to the reclaiming of the site.**

D6. Graminoids Graminoids present? (Yes; No): **Yes**

SPECIES	COV (%)	SPECIES	COV (%)	SPECIES	COV (%)	SPECIES	COV (%)
DACGLO	30.0	BROINE	0.5				
DESCES	30.0	CALCAN	0.5				
CARMIC	10.0	CARPRA	0.5				
FESIDA	10.0	JUNBAL	0.5				
AGRSCA	0.5						

D7. Forbs Forbs present? (Yes; No): **Yes**

SPECIES	COV (%)	SPECIES	COV (%)
LOTCOR	20.0		
ACHMVL	10.0		
EQUHYE	3.0		
ANTNEG	0.5		
ASTRAG	0.5		
EPIANG	0.5		
EPICIL	0.5		
LUPARG	0.5		
PYROLA	0.5		
RUMEXX	0.5		
TRIREP	0.5		

Weed Data

D12a. Are invasive species present? (Yes; No; NC): **No**

If ***Yes*, D12b.** Enter the canopy cover and the density/distribution class for each of the following invasive species:

	Canopy Cover (New Way)	Density/ Distribut. Class
bluebuttons (KNAARV):	0.0	0
Canada thistle (CIRARV):	0.0	0
cheatgrass (BROTEC):	0.0	0
common burdock (ARCMIN):	0.0	0
common cuprina (CRUVUL):	0.0	0
common hound's-tongue (CYNOFF):	0.0	0
common tansy (TANVUL):	0.0	0
dalmatian toadflax (LINDAL):	0.0	0
diffuse knapweed (CENDIF):	0.0	0
Dyer's woad (ISATIN):	0.0	0
field bindweed (CONARV):	0.0	0
field sow thistle (SONARV):	0.0	0
Japanese brome (BROJAP):	0.0	0
leafy spurge (EUPESU):	0.0	0
musk thistle (CARNUT):	0.0	0
orange hawkweed (HIEAUR):	0.0	0
oxeye daisy (CHRLEU):	0.0	0
perennial pepperweed (LEPLAT):	0.0	0
purple loosestrife (LYTSAL):	0.0	0
Russian knapweed (CENREP):	0.0	0
Russian olive (ELAANG):	0.0	0
saltcedar (tamarisk) (TAMARI):	0.0	0
Scotch thistle (ONOACA):	0.0	0
spotted knapweed (CENMAC):	0.0	0
St. John's wort (HYPPER):	0.0	0
sulphur cinquefoil (POTREC):	0.0	0
tall buttercup (RANACR):	0.0	0
teasel (DIPFUL):	0.0	0
whitetop (CARDRA):	0.0	0
yellow iris (IRIPSE):	0.0	0
yellow starthistle (CENSOL):	0.0	0
yellow toadflax (LINVUL):	0.0	0
Others:	0.0	0
Others:	0.0	0

Record ID No: **2024102**

D8. Plant Group by Canopy Cover (%)

Layer	Trees	Shrubs	Graminoids	Forbs
3 (>6.0 ft):	**0.0**	**0.0**	**0.0**	**0.0**
2 (>1.5 - 6.0 ft):	**0.5**	**0.0**	**0.5**	**3.0**
1 (0 - 1.5 ft):	**10.0**	**3.0**	**80.0**	**30.0**

D9. Total canopy cover (%) by lifeform:

Trees: **10.0** Shrubs: **3.0**

Graminoids: **80.0** Forbs: **30.0**

D10. Total canopy cover (%) by woody species: **10.0**

D11. Total canopy cover (%) by all plant lifeforms: **80.0**

D12c. Cumulative totals for all invasive species:

Canopy Cover (New Way)	Density/ Distribution Class
0.0	**0**

D13a. Are undesirable herbaceous species present? Yes; No; NC): **NC**

If ***Yes,* D13b.** Record the combined canopy cover (%) of all undesirable herbaceous species observed: ________

D14. Transect trend: Improving, Degrading, Static, or Status Unknown? **Improving**

D15. Explain trend description and give other comments:

The vegetation transect was a belt transect across the face of the 2001-2002 reclaimed site. The transect was 1 m wide and 82 m long.

Number of tree seedlings in belt transect: PINCON (lodgepole pine) = 27; ABILAS (subalpine fir) = 142; PSEMEN (Douglas fir) = 13.

The 2001-2002 revegetation of the reclaimed site seems to be doing well. There still is some bare ground (approx. 20 percent) on the site. However, the slope seems to be stable with very little to no erosion. The slope has numerous springs located throughout. The springs are not directly associated with the rock lined ditch from the acid mine drainage farther upslope. The rocks of the channel associated with the ditch are colored orange.

The surrounding hillsides are dominated by the Pinus contorta/Vaccinium scoparium (lodgepole pine/whortleberry) community type which is a late successional stage of the Abies lasiocarpa/Vaccinium scoparium (subalpine fir/whortleberry) habitat type. The wetter sites are occupied by either the Abies lasiocarpa/Calamagrostis canadensis (subalpine fir/bluejoint reedgrass) habitat type, or the Abies lasiocarpa/Ledum glandulosum (subalpine fir/Labrador-tea) habitat type.

PHYSICAL SITE DATA

E1a. Is there exposed soil surface (bare ground)? (Yes; No; NC): **Yes** If ***No*** or ***NC,*** go to item **E2.**

E1b. Percent (%) of the polygon which is exposed soil surface (bare ground): **20.0**

E1c. Of this, how much is due to natural processes: **0.0** Human-caused disturbance: **97.5** (must approx. 100%)

E1d. Within ***each*** category (natural & human-caused), how much resulted from the listed processes?

NATURAL PROCESSES *(must approx. 100%)*

0.0	Erosional	**0.0**	Type Dependent
0.0	Depositional	**0.0**	Saline/Alkaline
0.0	Wildlife Use	**0.0**	Other

HUMAN-CAUSED PROCESSES *(must approx. 100%)*

0.0	Grazing	**0.0**	Construction
0.0	Timber Harvest	**97.5**	Mining
0.0	Cultivation	**0.0**	Recreation
0.0	Other		

Explain "Other": ________

E2. Non-vegetated ground cover. (***Note*****:** Bare ground and vascular plant cover recorded above.)

Rocks (>2.5 in.): **10.0** Moss: **0.5** Litter/Duff: **0.5** Wood: **10.0** Human Imperv. Surf.: **0.0** Other: **0.0**

E3. Detailed description of ends of the transects:

The transect start just east of the small parking lot and continue east across the face of the reclamation site to the edge of the conifer forest on the east side of the site. The entire transect lies within the 2001-2002 reclaimed site.

Record ID No: **2024102**

PHOTOGRAPH DATA

F1. Identification of photos:

Photographer: **Paul Hansen and Gant Massey**

Photo numbers: **2360, 2361, 2362, 2363, 2364, 2365, 2366**

F2. Description of views:

Looking along the belt transect from the west end of the transect. The view is towards the east.

ADDITIONAL DATA

G1. Vegetative use by animals (0-25%; 26-50%; 51-75%; 76-100%): **2 - 26-50%**

G2a. Break down the transect area into the land uses listed (must total to approx. 100%):

No land use apparent:	0.0
Turf grass (lawn):	0.0
Tame pasture (grazing):	0.0
Native pasture (grazing):	0.0
Recreation (ATV paths, campsites, etc.):	0.0
Development (buildings, corrals, paved lots, etc.):	0.0
Tilled cropping:	0.0
Perennial forage (e.g., alfalfa hayland):	0.0
Roads:	0.0
Logging:	0.0
Mining:	97.5
Railroads:	0.0
Other:	0.0

Description of Other Usage Noted:

G2b. Break down the area adjacent to the transect into the land uses listed (must total to approx. 100%):

No land use apparent:	0.0
Turf grass (lawn):	0.0
Tame pasture (grazing):	0.0
Native pasture (grazing):	0.0
Recreation (ATV paths, campsites, etc.):	0.0
Development (buildings, corrals, paved lots, etc.):	0.0
Tilled cropping:	0.0
Perennial forage (e.g., alfalfa hayland):	0.0
Roads:	0.0
Logging:	0.0
Mining:	97.5
Railroads:	0.0
Other:	0.0

Description of Other Usage Noted:

G3. Adjacent uplands (Agriculture; Grassland; Shrubland; Forest; or Other): **Forest**

G4a. Were Category 2 (T & E) plant species observed? (Yes; No): **No** If **Yes, G4b.** Species:

G4c. Location(s):

WILDLIFE DATA

Threatened and Endangered Species Data

H1a. Were T & E animal species observed? (Yes; No; NC): **No**

If ***Yes,*** **H1b.** What species?

Peregrine Falcon: ______ Bald Eagle: ______ Bull Trout: ______

Peregrine Falcon Nest: ______ Bald Eagle Nest: ______

Other T & E species observed: Species ______ Number ______ Species ______ Number ______

H1c. Location in transect where T & E animals or nests were sighted:

ESG VEGETATION TRANSECT FORM

Record ID No: **2024103**

ADMINISTRATIVE DATA

A1. Field data collected by: **Ecological Solutions Group LLC (ESG)**

A2. Funding Agency/Organization: **EPA/CH2MHILL**

A3a. BLM State Office: ______ **A3b.** BLM Field Office/Field Station: ______

A4. USFWS Refuge: ______

A5. Reservation: ______

A6. NPS Park/NHS: ______

A7. USFS National Forest: **Beaverhead-Deerlodge National Forest**

A8. Other Location: **Bullion Mine Site Complex**

A9. Year: **2010** **A10.** Date field data collected: **9/1/2010** **A11.** Observers: **Paul Hansen and Gant Massey**

LOCATION DATA

B1. State/Province: **MT** **B2.** County/Municipal District: **Jefferson**

B3. Area name: **Bullion Mine 2001-2002 Reclamation Site**

B4. Transect number: **5**

B5. Location: 1/4 1/4 Sec: ______ 1/4 Sec: **NW** Sec: **13**

Township (NS): **7N** Range (EW): **6W** **B6.** Elev. (ft): **7,198** ; (m): **2,194**

Aspect (Degree): **330** Slope (%): **17**

B7. Transect latitude/longitude coordinates: GPS Projection: **WGS 84**

		Deg	Min	Sec	N/S	Decimal		Deg	Min	Sec	E/W	Decimal	Accuracy +/- ft	Accuracy +/- m	Observer Initial & WPT
Start:	Lat:	**46**	**21**	**24.5**	**N**	**46.356806**	Lon:	**112**	**17**	**44.8**	**W**	**-112.295778**	**8**	**2.4**	**P007**
End:	Lat:	**46**	**21**	**25.2**	**N**	**46.357000**	Lon:	**112**	**17**	**42.9**	**W**	**-112.295250**	**8**	**2.4**	**P008**
Other:	Lat:				**N**		Lon:				**W**				

B8. Other Point Comments: ______

B9. Quad map(s): **Basin, Montana**

TRANSECT INFORMATION

C1. Belt transect dimensions: length (ft): **144.00** ; (m): **43.89** width (ft): **3.00** ; (m): **0.91**

C2. Belt transect size (acres): **0.01** ; (hect): **0.00**

C3. Number of acres each transect represents (acres): **0.44** ; (hect): **0.18**

VEGETATION DATA

Trees

D1a. Are trees present? (Yes; No): **Yes** **D1b.** Tree species by canopy cover (%) and percent age group (%)

SPECIES	COV (%)	SDLG/DEC		SPLG/DEC		POLE/DEC		MAT/DEC		DEAD
ABILAS	**3.0**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
PINCVL	**3.0**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
PSEMEN	**0.5**	**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Trees

SPECIES	**D2.** Regen. Category	**D3.** Age Group Dist. Category	**D4a.** Sdlg/Splg Browse Utilization	**D4b.** Browse Architecture Type	**D4c.** Browse Intensity
ABILAS	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**
PINCVL	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**
PSEMEN	**5**	**1**	**None**	**Uninter.**	**Lt-Mod.**

Shrubs

D5a. Are shrubs present? (Yes; No): **Yes**

D5b. Does the polygon have potential for preferred woody species ? (Yes; No; NC): **Yes**

D5c. Shrub species canopy cover (%), age/size groups (%), and utilization

SPECIES	COV (%)	SDLG-SPLG/UTIL		MATURE/UTIL		DEC-DEAD/UTIL		**D5d.** Shrub Growth Form (N,F,U,C)	**D5e.** Browse Architecture Type	**D5f.** Browse Intensity
ROSWOO	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**
SALDRU	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**
SHECAN	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**
SPIBET	**0.5**	**97.5**	**Moderate**	**0.0**	**NA**	**0.0**	**NA**	**C**	**Arrested**	**Lt-Mod.**

Record ID No: **2024103**

D5g. Tree ***AND*** shrub removal by other than browse: None (0-5%); Light (6-25%); Moderate (26-50%); Heavy (>50%); NA; NC: **Heavy (>50%)**

D5h. Basis of Call: **The site was reclaimed and any trees or shrubs present were removed prior to the reclaiming of the site.**

D6. Graminoids Graminoids present? (Yes; No): **Yes**

SPECIES	COV (%)	SPECIES	COV (%)	SPECIES	COV (%)	SPECIES	COV (%)
DESCES	**30.0**	**FESSCA**	**0.5**				
DACGLO	**20.0**						
FESIDA	**10.0**						
AGRSCA	**3.0**						
AGRCAN	**0.5**						

D7. Forbs Forbs present? (Yes; No): **Yes**

SPECIES	COV (%)	SPECIES	COV (%)
ACHMVL	**20.0**		
LOTCOR	**10.0**		
ANTMIC	**0.5**		
ASTRAG	**0.5**		
EPICIL	**0.5**		
FRAVIR	**0.5**		
LUPARG	**0.5**		
PYROLA	**0.5**		
TRIREP	**0.5**		

Weed Data

D12a. Are invasive species present? (Yes; No; NC): **No**

If ***Yes,*** **D12b.** Enter the canopy cover and the density/distribution class for each of the following invasive species:

	Canopy Cover (New Way)	Density/ Distribut. Class
bluebuttons (KNAARV):	**0.0**	**0**
Canada thistle (CIRARV):	**0.0**	**0**
cheatgrass (BROTEC):	**0.0**	**0**
common burdock (ARCMIN):	**0.0**	**0**
common cuprina (CRUVUL):	**0.0**	**0**
common hound's-tongue (CYNOFF):	**0.0**	**0**
common tansy (TANVUL):	**0.0**	**0**
dalmatian toadflax (LINDAL):	**0.0**	**0**
diffuse knapweed (CENDIF):	**0.0**	**0**
Dyer's woad (ISATIN):	**0.0**	**0**
field bindweed (CONARV):	**0.0**	**0**
field sow thistle (SONARV):	**0.0**	**0**
Japanese brome (BROJAP):	**0.0**	**0**
leafy spurge (EUPESU):	**0.0**	**0**
musk thistle (CARNUT):	**0.0**	**0**
orange hawkweed (HIEAUR):	**0.0**	**0**
oxeye daisy (CHRLEU):	**0.0**	**0**
perennial pepperweed (LEPLAT):	**0.0**	**0**
purple loosestrife (LYTSAL):	**0.0**	**0**
Russian knapweed (CENREP):	**0.0**	**0**
Russian olive (ELAANG):	**0.0**	**0**
saltcedar (tamarisk) (TAMARI):	**0.0**	**0**
Scotch thistle (ONOACA):	**0.0**	**0**
spotted knapweed (CENMAC):	**0.0**	**0**
St. John's wort (HYPPER):	**0.0**	**0**
sulphur cinquefoil (POTREC):	**0.0**	**0**
tall buttercup (RANACR):	**0.0**	**0**
teasel (DIPFUL):	**0.0**	**0**
whitetop (CARDRA):	**0.0**	**0**
yellow iris (IRIPSE):	**0.0**	**0**
yellow starthistle (CENSOL):	**0.0**	**0**
yellow toadflax (LINVUL):	**0.0**	**0**
Others:	**0.0**	**0**
Others:	**0.0**	**0**

Record ID No: **2024103**

D8. Plant Group by Canopy Cover (%)

Layer	Trees	Shrubs	Graminoids	Forbs
3 (>6.0 ft):	**0.0**	**0.0**	**0.0**	**0.0**
2 (>1.5 - 6.0 ft):	**0.5**	**0.0**	**0.5**	**0.5**
1 (0 - 1.5 ft):	**3.0**	**3.0**	**60.0**	**30.0**

D9. Total canopy cover (%) by lifeform:

Trees: **3.0** Shrubs: **3.0**

Graminoids: **60.0** Forbs: **30.0**

D10. Total canopy cover (%) by woody species: **10.0**

D11. Total canopy cover (%) by all plant lifeforms: **80.0**

D12c. Cumulative totals for all invasive species:

Canopy Cover (New Way)	Density/ Distribution Class
0.0	**0**

D13a. Are undesirable herbaceous species present?
Yes; No; NC): **NC**

If ***Yes,* D13b.** Record the combined canopy cover (%) of all undesirable herbaceous species observed: ______

D14. Transect trend: Improving, Degrading, Static, or Status Unknown? **Improving**

D15. Explain trend description and give other comments:

The vegetation transect was a belt transect across the face of the 2001-2002 reclaimed site. The transect was 1 m wide and 44 m long.

Number of tree seedlings in belt transect: PINCON (lodgepole pine) = 31; ABILAS (subalpine fir) = 38; PSEMEN (Douglas fir) = 1.

The 2001-2002 revegetation of the reclaimed site seems to be doing well. There still is some bare ground (approx. 20 percent) on the site. However, the slope seems to be stable with very little to no erosion. The slope has numerous springs located throughout. The springs are not directly associated with the rock lined ditch from the acid mine drainage farther upslope. The rocks of the channel associated with the ditch are colored orange.

The surrounding hillsides are dominated by the Pinus contorta/Vaccinium scoparium (lodgepole pine/whortleberry) community type which is a late successional stage of the Abies lasiocarpa/Vaccinium scoparium (subalpine fir/whortleberry) habitat type. The wetter sites are occupied by either the Abies lasiocarpa/Calamagrostis canadensis (subalpine fir/bluejoint reedgrass) habitat type, or the Abies lasiocarpa/Ledum glandulosum (subalpine fir/Labrador-tea) habitat type.

PHYSICAL SITE DATA

E1a. Is there exposed soil surface (bare ground)? (Yes; No; NC): **Yes** If ***No*** or ***NC,*** go to item **E2.**

E1b. Percent (%) of the polygon which is exposed soil surface (bare ground): **20.0**

E1c. Of this, how much is due to natural processes: **0.0** Human-caused disturbance: **97.5** (must approx. 100%)

E1d. Within ***each*** category (natural & human-caused), how much resulted from the listed processes?

NATURAL PROCESSES *(must approx. 100%)*

0.0	Erosional	**0.0**	Type Dependent
0.0	Depositional	**0.0**	Saline/Alkaline
0.0	Wildlife Use	**0.0**	Other

HUMAN-CAUSED PROCESSES *(must approx. 100%)*

0.0	Grazing	**0.0**	Construction
0.0	Timber Harvest	**97.5**	Mining
0.0	Cultivation	**0.0**	Recreation
0.0	Other		

Explain "Other": ______

E2. Non-vegetated ground cover. **(*Note*:** Bare ground and vascular plant cover recorded above.)

Rocks (>2.5 in.): **20.0** Moss: **0.5** Litter/Duff: **0.5** Wood: **20.0** Human Imperv. Surf.: **0.0** Other: **0.0**

E3. Detailed description of ends of the transects:

The transect start just east of the small parking lot and continue east across the face of the reclamation site to the edge of the conifer forest on the east side of the site. The entire transect lies within the 2001-2002 reclaimed site.

Record ID No: **2024103**

PHOTOGRAPH DATA

F1. Identification of photos:

Photographer: **Paul Hansen and Gant Massey**

Photo numbers: **2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379**

F2. Description of views:

Looking along the belt transect from the west end of the transect. The view is towards the east.

ADDITIONAL DATA

G1. Vegetative use by animals (0-25%; 26-50%; 51-75%; 76-100%): **2 - 26-50%**

G2a. Break down the transect area into the land uses listed (must total to approx. 100%):

Land use	
No land use apparent:	**0.0**
Turf grass (lawn):	**0.0**
Tame pasture (grazing):	**0.0**
Native pasture (grazing):	**0.0**
Recreation (ATV paths, campsites, etc.):	**0.0**
Development (buildings, corrals, paved lots, etc.):	**0.0**
Tilled cropping:	**0.0**
Perennial forage (e.g., alfalfa hayland):	**0.0**
Roads:	**0.0**
Logging:	**0.0**
Mining:	**97.5**
Railroads:	**0.0**
Other:	**0.0**

Description of Other Usage Noted:

G2b. Break down the area adjacent to the transect into the land uses listed (must total to approx. 100%):

Land use	
No land use apparent:	**0.0**
Turf grass (lawn):	**0.0**
Tame pasture (grazing):	**0.0**
Native pasture (grazing):	**0.0**
Recreation (ATV paths, campsites, etc.):	**0.0**
Development (buildings, corrals, paved lots, etc.):	**0.0**
Tilled cropping:	**0.0**
Perennial forage (e.g., alfalfa hayland):	**0.0**
Roads:	**0.0**
Logging:	**0.0**
Mining:	**97.5**
Railroads:	**0.0**
Other:	**0.0**

Description of Other Usage Noted:

G3. Adjacent uplands (Agriculture; Grassland; Shrubland; Forest; or Other): **Forest**

G4a. Were Category 2 (T & E) plant species observed? (Yes; No): **No** If **Yes, G4b.** Species:

G4c. Location(s):

WILDLIFE DATA

Threatened and Endangered Species Data

H1a. Were T & E animal species observed? (Yes; No; NC): **No**

If ***Yes,* H1b.** What species? Peregrine Falcon: ____ Bald Eagle: ____ Bull Trout: ____

Peregrine Falcon Nest: ____ Bald Eagle Nest: ____

Other T & E species observed: Species ____ Number ____ Species ____ Number ____

H1c. Location in transect where T & E animals or nests were sighted:

APPENDIX B

BULLION MINE SITE VEGETATION TRANSECT DATA SET SUMMARY

Each Summary Data Set in Appendix B contains the following tables:

- Table 1a. Transect Location Information—General
- Table 1b. Transect Location Information—Latitude and Longitude
- Table 2. Transect Administrative Information
- Table 3. Invasive Plant Species (Weeds) and Acres (by Individual Species)
- Table 4. Tree Species and Acres (by Individual Species)
- Table 5. Shrub Species and Acres (by Individual Species)
- Table 6. Graminoid Species and Acres (by Individual Species)
- Table 7. Forb Species and Acres (by Individual Species)
- Table 8. Ferns and Allies by Species and Acres (by Individual Species)
- Table 9a. Species Dominance (Prominence Values) Sorted by Prominence Value
- Table 9b. Species Dominance (Prominence Values) Sorted by Species Latin Name
- Table 10. Summary Information by Lifeform

ESG VEGETATION TRANSECT DATA SET SUMMARY

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

Agency/Organization: **EPA/CH2MHILL** State/Province: **MT**

Note: The following data is from the Vegetation Transect data base.

DATA SUMMARIES AND ANALYSES INCLUDED

Ecological Solutions Group LLC

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 1a. Transect Location Information—General

This table gives for each transect the area name. For more information, refer to the Vegetation Transect User Manual, accessible on the web at: www.ecologicalsolutionsgroup.com. Inventory form items from which the summarized data are obtained from are referenced in the table column headings. The order is by year (descending) and by area name (ascending).

Transect Record ID	**Year** (A9)	**Area Name** (B4)	**Number of Acres Transect Represents** (C3)
2024099	2010	Bullion Mine 2001-2002 Reclamation Site	0.44
2024100	2010	Bullion Mine 2001-2002 Reclamation Site	0.44
2024101	2010	Bullion Mine 2001-2002 Reclamation Site	0.44
2024102	2010	Bullion Mine 2001-2002 Reclamation Site	0.44
2024103	2010	Bullion Mine 2001-2002 Reclamation Site	0.44

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 1b. Transect Location Information—Latitude and Longitude

This table gives the latitude and longitude for each transect. For more information, refer to the Vegetation Transect User Manual, accessible on the web at: www.ecologicalsolutionsgroup.com.

Transect Record ID		Transect Latitude Coordinates: Deg	Min	Sec	N/S	Decimal	Transect Longitude Coordinates: Deg	Min	Sec	E/W	Decimal	GPS Projection
2024099	Start Point:	46	21	21.1	N	46.355861	112	17	43.8	W	-112.295500	WGS 84
	End Point:	46	21	22.0	N	46.356111	112	17	41.7	W	-112.294917	
2024100	Start Point:	46	21	21.9	N	46.356083	112	17	45.2	W	-112.295889	WGS 84
	End Point:	46	21	23.1	N	46.356417	112	17	41.7	W	-112.294917	
2024101	Start Point:	46	21	22.6	N	46.356278	112	17	45.9	W	-112.296083	WGS 84
	End Point:	46	21	23.7	N	46.356583	112	17	42.0	W	-112.295000	
2024102	Start Point:	46	21	23.4	N	46.356500	112	17	46.0	W	-112.296111	WGS 84
	End Point:	46	21	24.8	N	46.356889	112	17	42.8	W	-112.295222	
2024103	Start Point:	46	21	24.5	N	46.356806	112	17	44.8	W	-112.295778	WGS 84
	End Point:	46	21	25.2	N	46.357000	112	17	42.9	W	-112.295250	

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 2. Transect Administrative Information

This table gives for each transect the state or province, data collection date, vegetation type, and the transect number. For more information on how these data were determined, and their ecological significance, refer to the Vegetation Transect User Manual, accessible on the web at: www.ecologicalsolutionsgroup.com. Transect form items from which the summarized statistics derive are referenced in the table column headings.

Transect Record ID	**State or Province** (B1)	**Date Collected** (A10)	**Transect Number** (B4)	**Total Veg. Cover (%)** (D11)	**Bare Ground (%)** (E1b)
2024099	MT	9/1/2010	1	80	20.0
2024100	MT	9/1/2010	2	80	20.0
2024101	MT	9/1/2010	3	80	20.0
2024102	MT	9/1/2010	4	80	20.0
2024103	MT	9/1/2010	5	80	20.0

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 3. Invasive Plant Species (Weeds) and Acres (by Individual Species)

This table summarizes invasive plant species (weeds) found on transects in this summary set. These are species that are cause for special concern or management focus due to their agressive and/or invasive nature. The list below may not include all species officially designated in any jurisdiction as “noxious weeds.” Instead, this is a list of species of major managerial concern.

Those species below that show values greater than zero were recorded on at least one transect in the set being summarized. The total area covered by each listed species (acres) and the percent of the area covered by that species across all transects is shown. For more information on how these data were determined, and on their ecological significance, refer to Item D13 in the Vegetation Transect User Manual, accessible on the web at: www.ecologicalsolutionsgroup.com.

Total Size of Summary Set (Acres): **2.20**

Total Area (Acres) of Weeds: **0.01**

Percent of Total Acres: **0.45**

Invasive Species (by Common Name)	Acres of Canopy Cover	Percent of Total Area Covered	Range of Individual Transect Percent Area Covered Min		Max
bluebuttons:	—	—	—	to	—
Canada thistle:	0.01	0.45%	0.0%	to	0.5%
cheatgrass:	—	—	—	to	—
common burdock:	—	—	—	to	—
common cuprina:	—	—	—	to	—
common hound’s-tongue:	—	—	—	to	—
common tansy:	—	—	—	to	—
Dalmatian toadflax:	—	—	—	to	—
diffuse knapweed:	—	—	—	to	—
Dyer’s woad:	—	—	—	to	—
field bindweed:	—	—	—	to	—
field sow thistle:	—	—	—	to	—
Japanese brome:	—	—	—	to	—
leafy spurge:	—	—	—	to	—
musk thistle:	—	—	—	to	—
orange hawkweed:	—	—	—	to	—
oxeye daisy:	—	—	—	to	—
perennial pepperweed:	—	—	—	to	—
purple loosestrife:	—	—	—	to	—
Russian knapweed:	—	—	—	to	—
Russian olive:	—	—	—	to	—
saltcedar (tamarisk):	—	—	—	to	—
Scotch thistle:	—	—	—	to	—
spotted knapweed:	—	—	—	to	—
St. John’s wort:	—	—	—	to	—
sulphur cinquefoil:	—	—	—	to	—
tall buttercup:	—	—	—	to	—
teasel:	—	—	—	to	—
whitetop:	—	—	—	to	—
yellow iris:	—	—	—	to	—
yellow starthistle:	—	—	—	to	—
yellow toadflax:	—	—	—	to	—
Others:					
	—	—	—	to	—
	—	—	—	to	—

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 4. Tree Species and Acres (by Individual Species)

This list is taken from the individual vegetation transect data for each record in the summary set. This table lists all tree species recorded on any transect, the total acres occupied by each species, the average and range of percent canopy cover for each species, and the constancy (percent of the number of transects in which the species was recorded). For more information on how these data were determined, and on their ecological significance, refer to the Vegetation Transect User Manual, item D2, accessible on the web at: www.ecologicalsolutionsgroup.com.

Total Size of Summary Set (Acres): **2.20**

Acres of Land Covered by Trees: **0.09**

Total Number of Tree Species: **3**
Number of Native Species: **3**
Number of Introduced Species: **0**
Number of Taxa with Elements of Both: **0**

Species	Acres by Species	Percent Canopy Cover Average	Range			Constancy	Species Status
Pinus contorta var. *latifolia* (lodgepole pine)	0.06	2.5%	0.5%	to	3.0%	100%	Native
Abies lasiocarpa (subalpine fir)	0.03	1.5%	0.5%	to	3.0%	100%	Native
Pseudotsuga menziesii (Douglas fir)	0.01	0.5%	0.0%	to	0.5%	60%	Native

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 5. Shrub Species and Acres (by Individual Species)

This list is taken from the individual vegetation transect data for each record in the summary set. This table lists all shrub species recorded on any transect, the total acres occupied by each species, the average and range of percent canopy cover for each species, and the constancy (percent of the number of transects in which the species was recorded). For more information on how these data were determined, and on their ecological significance, refer to the Vegetation Transect User Manual, item D6, accessible on the web at: www.ecologicalsolutionsgroup.com.

Total Size of Summary Set (Acres): **2.20**

Acres of Land Covered by Shrubs: **0.04**

Number of Shrub Species: **8**

Number of Native Species: **8**

Number of Introduced Species: **0**

Number of Taxa with Elements of Both: **0**

Species	Acres by Species	Percent Canopy Cover Average	Range			Constancy	Species Status
Spiraea betulifolia (shiny-leaf spiraea)	0.01	0.5%	0.5%	to	0.5%	100%	Native
Salix bebbiana (Bebb willow)	0.01	0.5%	0.0%	to	0.5%	80%	Native
Rosa woodsii (Woods rose)	0.01	0.5%	0.0%	to	0.5%	60%	Native
Salix drummondiana (Drummond willow)	0.00	0.5%	0.0%	to	0.5%	40%	Native
Shepherdia canadensis (russet buffaloberry)	0.00	0.5%	0.0%	to	0.5%	40%	Native
Alnus incana (mountain alder)	0.00	0.5%	0.0%	to	0.5%	20%	Native
Rubus idaeus (red raspberry)	0.00	0.5%	0.0%	to	0.5%	20%	Native
Salix boothii (Booth willow)	0.00	0.5%	0.0%	to	0.5%	20%	Native

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 6. Graminoid Species and Acres (by Individual Species)

This list is taken from the individual vegetation transect data for each record in the summary set. This table lists all graminoid species recorded on any transect, the total acres occupied by each species, the average and range of percent canopy cover for each species, and the constancy (percent of the number of transects in which the species was recorded). For more information on how these data were determined, and on their ecological significance, refer to the Vegetation Transect User Manual, item D7, accessible on the web at: www.ecologicalsolutionsgroup.com.

Total Size of Summary Set (Acres): **2.20**

Acres of Land Covered by Graminoids: **1.86**

Total Number of Graminoid Species: **16**
Number of Native Species: **13**
Number of Introduced Species: **2**
Number of Taxa with Elements of Both: **1**

Species	Acres by Species	Percent Canopy Cover Average	Range			Constancy	Species Status
Deschampsia cespitosa (tufted hairgrass)	0.70	32.0%	30.0%	to	40.0%	100%	Native
Dactylis glomerata (orchard-grass)	0.57	26.0%	20.0%	to	40.0%	100%	Introduced
Festuca idahoensis (Idaho fescue)	0.35	16.0%	10.0%	to	20.0%	100%	Native
Carex microptera (small-winged sedge)	0.11	6.5%	0.0%	to	10.0%	80%	Native
Agrostis scabra (tickle-grass)	0.03	1.8%	0.0%	to	3.0%	80%	Native
Festuca scabrella (rough fescue)	0.02	1.1%	0.0%	to	3.0%	80%	Native
Agropyron caninum (bearded wheatgrass)	0.02	1.3%	0.0%	to	3.0%	60%	Native
Calamagrostis stricta (narrow-spiked reedgrass)	0.02	1.8%	0.0%	to	3.0%	40%	Native
Phleum pratense (common timothy)	0.01	3.0%	0.0%	to	3.0%	20%	Introduced
Carex praegracilis (clustered field sedge)	0.01	0.5%	0.0%	to	0.5%	60%	Native
Juncus balticus (Baltic rush)	0.00	0.5%	0.0%	to	0.5%	40%	Native
Bromus inermis (smooth brome)	0.00	0.5%	0.0%	to	0.5%	20%	Both
Calamagrostis canadensis (bluejoint reedgrass)	0.00	0.5%	0.0%	to	0.5%	20%	Native
Hordeum jubatum (foxtail barley)	0.00	0.5%	0.0%	to	0.5%	20%	Native
Sitanion hystrix (bottlebrush squirreltail)	0.00	0.5%	0.0%	to	0.5%	20%	Native
Stipa viridula (green needlegrass)	0.00	0.5%	0.0%	to	0.5%	20%	Native

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 7. Forb Species and Acres (by Individual Species)

This list is taken from the individual vegetation transect data for each record in the summary set. This table lists all forb species recorded on any transect, the total acres occupied by each species, the average and range of percent canopy cover for each species, and the constancy (percent of the number of transects in which the species was recorded). For more information on how these data were determined, and on their ecological significance, refer to the Vegetation Transect User Manual, item D8, accessible on the web at: www.ecologicalsolutionsgroup.com.

Total Size of Summary Set (Acres): **2.20**

Acres of Land Covered by Forbs: **0.59**

Total Number of Forb Species: **15**
Number of Native Species: **9**
Number of Introduced Species: **4**
Number of Taxa with Elements of Both: **2**

Species	Acres by Species	Percent Canopy Cover Average	Range			Constancy	Species Status
Achillea millefolium var. *lanulosa* (common yarrow)	0.31	14.0%	10.0%	to	20.0%	100%	Native
Lotus corniculatus (birds-foot trefoil)	0.20	9.2%	3.0%	to	20.0%	100%	Introduced
Epilobium ciliatum (common willow-herb)	0.01	0.5%	0.5%	to	0.5%	100%	Native
Lupinus argenteus (silvery lupine)	0.01	0.5%	0.5%	to	0.5%	100%	Native
Astragalus spp. (milk-vetch)	0.01	0.5%	0.0%	to	0.5%	80%	Both
Fragaria virginiana (Virginia strawberry)	0.01	0.5%	0.0%	to	0.5%	80%	Native
Cirsium arvense (Canada thistle)	0.01	0.5%	0.0%	to	0.5%	60%	Introduced
Rumex spp. (dock; sorrel)	0.01	0.5%	0.0%	to	0.5%	60%	Both
Trifolium repens (white clover)	0.01	0.5%	0.0%	to	0.5%	60%	Introduced
Antennaria neglecta (field pussy-toes)	0.00	0.5%	0.0%	to	0.5%	40%	Native
Epilobium angustifolium (fireweed)	0.00	0.5%	0.0%	to	0.5%	40%	Native
Geum canadense (white avens)	0.00	0.5%	0.0%	to	0.5%	40%	Native
Pyrola spp. (wintergreen)	0.00	0.5%	0.0%	to	0.5%	40%	Native
Antennaria microphylla (rosy pussy-toes)	0.00	0.5%	0.0%	to	0.5%	20%	Native
Verbascum thapsus (common mullein)	0.00	0.5%	0.0%	to	0.5%	20%	Introduced

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 8. Ferns and Allies by Species and Acres (by Individual Species)

This list is taken from the individual vegetation transect data for each record in the summary set. This table lists all ferns and allies recorded on any transect, the total acres occupied by each species, the average and range of percent canopy cover for each species, and the constancy (percent of the number of transects in which the species was recorded). For more information on how these data were determined, and on their ecological significance, refer to the Vegetation Transect User Manual, item D8, accessible on the web at: www.ecologicalsolutionsgroup.com.

Total Size of Summary Set (Acres): **2.20**

Acres of Land Covered by Ferns and Allies: **0.06**

Total Number of Fern and Allies Species: **1**
Number of Native Species: **1**
Number of Introduced Species: **0**
Number of Taxa with Elements of Both: **0**

Species	Acres by Species	Percent Canopy Cover Average	Range			Constancy	Species Status
Equisetum hyemale (common scouring-rush)	0.06	4.5%	0.0%	to	10.0%	60%	Native

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 9a. Species Dominance (Prominence Values) Sorted by Prominence Score

This list is taken from the individual vegetation transect data for each record in the summary set. It is informative to look at which species predominated the area. Prominence is the product of constancy (percent of occurrence on transects in the set) and average cover on those transects in the summary set having it present.

Total Size of Summary Set (Acres): **2.20**

Total Number of Species: **43**
Number of Native Species: **34**
Number of Introduced Species: **6**
Number of Taxa with Elements of Both: **3**

Species	Prominence Value	Species Status
Deschampsia cespitosa (tufted hairgrass)	32.00	Native
Dactylis glomerata (orchard-grass)	26.00	Introduced
Festuca idahoensis (Idaho fescue)	16.00	Native
Achillea millefolium var. *lanulosa* (common yarrow)	14.00	Native
Lotus corniculatus (birds-foot trefoil)	9.20	Introduced
Carex microptera (small-winged sedge)	5.20	Native
Equisetum hyemale (common scouring-rush)	2.70	Native
Pinus contorta var. *latifolia* (lodgepole pine)	2.50	Native
Abies lasiocarpa (subalpine fir)	1.50	Native
Agrostis scabra (tickle-grass)	1.40	Native
Festuca scabrella (rough fescue)	0.90	Native
Agropyron caninum (bearded wheatgrass)	0.80	Native
Calamagrostis stricta (narrow-spiked reedgrass)	0.70	Native
Phleum pratense (common timothy)	0.60	Introduced
Epilobium ciliatum (common willow-herb)	0.50	Native
Lupinus argenteus (silvery lupine)	0.50	Native
Spiraea betulifolia (shiny-leaf spiraea)	0.50	Native
Astragalus spp. (milk-vetch)	0.40	Both
Fragaria virginiana (Virginia strawberry)	0.40	Native
Salix bebbiana (Bebb willow)	0.40	Native
Carex praegracilis (clustered field sedge)	0.30	Native
Cirsium arvense (Canada thistle)	0.30	Introduced
Pseudotsuga menziesii (Douglas fir)	0.30	Native
Rosa woodsii (Woods rose)	0.30	Native
Rumex spp. (dock; sorrel)	0.30	Both
Trifolium repens (white clover)	0.30	Introduced
Antennaria neglecta (field pussy-toes)	0.20	Native
Epilobium angustifolium (fireweed)	0.20	Native
Geum canadense (white avens)	0.20	Native
Juncus balticus (Baltic rush)	0.20	Native
Pyrola spp. (wintergreen)	0.20	Native
Salix drummondiana (Drummond willow)	0.20	Native
Shepherdia canadensis (russet buffaloberry)	0.20	Native
Alnus incana (mountain alder)	0.10	Native
Antennaria microphylla (rosy pussy-toes)	0.10	Native
Bromus inermis (smooth brome)	0.10	Both
Calamagrostis canadensis (bluejoint reedgrass)	0.10	Native
Hordeum jubatum (foxtail barley)	0.10	Native
Rubus idaeus (red raspberry)	0.10	Native
Salix boothii (Booth willow)	0.10	Native
Sitanion hystrix (bottlebrush squirreltail)	0.10	Native
Stipa viridula (green needlegrass)	0.10	Native

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 9a. Species Dominance (Prominence Values) Sorted by Prominence Score

This list is taken from the individual vegetation transect data for each record in the summary set. It is informative to look at which species predominated the area. Prominence is the product of constancy (percent of occurrence on transects in the set) and average cover on those transects in the summary set having it present.

Total Size of Summary Set (Acres): **2.20**

Total Number of Species: **43**
Number of Native Species: **34**
Number of Introduced Species: **6**
Number of Taxa with Elements of Both: **3**

Species	Prominence Value	Species Status
Verbascum thapsus (common mullein)	0.10	Introduced

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 9b. Species Dominance (Prominence Values) Sorted by Species Latin Name

This list is taken from the individual vegetation transect data for each record in the summary set. It is informative to look at which species predominated the area. Prominence is the product of constancy (percent of occurrence on transects in the set) and average cover on those transects in the summary set having it present.

Total Size of Summary Set (Acres): **2.20**

Total Number of Species: **43**
Number of Native Species: **34**
Number of Introduced Species: **6**
Number of Taxa with Elements of Both: **3**

Species	Prominence Value	Species Status
Abies lasiocarpa (subalpine fir)	1.50	Native
Achillea millefolium var. *lanulosa* (common yarrow)	14.00	Native
Agropyron caninum (bearded wheatgrass)	0.80	Native
Agrostis scabra (tickle-grass)	1.40	Native
Alnus incana (mountain alder)	0.10	Native
Antennaria microphylla (rosy pussy-toes)	0.10	Native
Antennaria neglecta (field pussy-toes)	0.20	Native
Astragalus spp. (milk-vetch)	0.40	Both
Bromus inermis (smooth brome)	0.10	Both
Calamagrostis canadensis (bluejoint reedgrass)	0.10	Native
Calamagrostis stricta (narrow-spiked reedgrass)	0.70	Native
Carex microptera (small-winged sedge)	5.20	Native
Carex praegracilis (clustered field sedge)	0.30	Native
Cirsium arvense (Canada thistle)	0.30	Introduced
Dactylis glomerata (orchard-grass)	26.00	Introduced
Deschampsia cespitosa (tufted hairgrass)	32.00	Native
Epilobium angustifolium (fireweed)	0.20	Native
Epilobium ciliatum (common willow-herb)	0.50	Native
Equisetum hyemale (common scouring-rush)	2.70	Native
Festuca idahoensis (Idaho fescue)	16.00	Native
Festuca scabrella (rough fescue)	0.90	Native
Fragaria virginiana (Virginia strawberry)	0.40	Native
Geum canadense (white avens)	0.20	Native
Hordeum jubatum (foxtail barley)	0.10	Native
Juncus balticus (Baltic rush)	0.20	Native
Lotus corniculatus (birds-foot trefoil)	9.20	Introduced
Lupinus argenteus (silvery lupine)	0.50	Native
Phleum pratense (common timothy)	0.60	Introduced
Pinus contorta var. *latifolia* (lodgepole pine)	2.50	Native
Pseudotsuga menziesii (Douglas fir)	0.30	Native
Pyrola spp. (wintergreen)	0.20	Native
Rosa woodsii (Woods rose)	0.30	Native
Rubus idaeus (red raspberry)	0.10	Native
Rumex spp. (dock; sorrel)	0.30	Both
Salix bebbiana (Bebb willow)	0.40	Native
Salix boothii (Booth willow)	0.10	Native
Salix drummondiana (Drummond willow)	0.20	Native
Shepherdia canadensis (russet buffaloberry)	0.20	Native
Sitanion hystrix (bottlebrush squirreltail)	0.10	Native
Spiraea betulifolia (shiny-leaf spiraea)	0.50	Native
Stipa viridula (green needlegrass)	0.10	Native
Trifolium repens (white clover)	0.30	Introduced

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Transects: **5**

TABLE 9b. Species Dominance (Prominence Values) Sorted by Species Latin Name

This list is taken from the individual vegetation transect data for each record in the summary set. It is informative to look at which species predominated the area. Prominence is the product of constancy (percent of occurrence on transects in the set) and average cover on those transects in the summary set having it present.

Total Size of Summary Set (Acres): **2.20**

Total Number of Species: **43**
Number of Native Species: **34**
Number of Introduced Species: **6**
Number of Taxa with Elements of Both: **3**

Species	Prominence Value	Species Status
Verbascum thapsus (common mullein)	0.10	Introduced

Summary Name: **Bullion Mine Vegetation Belt Transect Data** Number of Polygons: **5**

TABLE 10. Summary Information by Lifeform

The following tables provide information on the number and percent of unique species by lifeform, average number of unique species per polygon, average canopy cover per polygon, and acres of various lifeforms based upon whether the species is native, introduced, or contains elements of both.

Native = native to pre-Columbian North America
Introduced = introduced by post-Columbian human immigrants
Both = species contains native and introduced elements (***NOTE:*** Those plant specimens only identified to genus and the genus includes both native and introduced species, were identified as "Both.")

Table 10a. Total number of unique species by lifeform and by native, introduced, or both for the 5 polygons

LifeForm	Total	Native	Introduced	Both
Trees	3	3	0	0
Shrubs	8	8	0	0
Graminoids	16	13	2	1
Forbs	15	9	4	2
Ferns and Allies	1	1	0	0
Total	***43 (100.0%)***	***34 (79.1%)***	***6 (14.0%)***	***3 (7.0%)***

Table 10b. Percent of unique species by lifeform and by native, introduced, or both

LifeForm	Total	Native	Introduced	Both
Trees	7.0%	8.8%	0.0%	0.0%
Shrubs	18.6%	23.5%	0.0%	0.0%
Graminoids	37.2%	38.2%	33.3%	33.3%
Forbs	34.9%	26.5%	66.7%	66.7%
Ferns and Allies	2.3%	2.9%	0.0%	0.0%
Total	***100.0%***	***100.0%***	***100.0%***	***100.0%***

Table 10c. Average number of unique species per polygon by lifeform and by native, introduced, or both

LifeForm	Total	Native	Introduced	Both
Trees	2.60	2.60	0.00	0.00
Shrubs	3.80	3.80	0.00	0.00
Graminoids	8.60	7.20	1.20	0.20
Forbs	9.40	5.60	2.40	1.40
Ferns and Allies	0.60	0.60	0.00	0.00
Total	***25.00***	***19.80***	***3.60***	***1.60***

TABLE 10. Summary Information by Lifeform

The following tables provide information on the number and percent of unique species by lifeform, average number of unique species per polygon, average canopy cover per polygon, and acres of various lifeforms based upon whether the species is native, introduced, or contains elements of both.

Native = native to pre-Columbian North America
Introduced = introduced by post-Columbian human immigrants
Both = species contains native and introduced elements (***NOTE:*** Those plant specimens only identified to genus and the genus includes both native and introduced species, were identified as "Both.")

Table 10d. Average canopy cover by lifeform per polygon by native, introduced, or both (total average canopy cover can be greater than 100% due to overlap by the various lifeforms)

LifeForm	Total	Native	Introduced	Both
Trees	4.3%	4.3%	0.0%	0.0%
Shrubs	1.9%	1.9%	0.0%	0.0%
Graminoids	84.6%	57.9%	26.6%	0.1%
Forbs	26.9%	16.3%	9.9%	0.7%
Ferns and Allies	2.7%	2.7%	0.0%	0.0%
Average Canopy Coverage:	***120.4%***	***83.1%***	***36.5%***	***0.8%***

Table 10e. Acres of canopy cover by lifeform by native, introduced, or both (total acres can be greater than 100% of the area due to overlap by the various lifeforms) TOTAL ACRES OF DATA SET = 2.20

LifeForm	Total	Native	Introduced	Both
Trees	0.09	0.09	0.00	0.00
Shrubs	0.04	0.04	0.00	0.00
Graminoids	1.86	1.27	0.59	0.00
Forbs	0.59	0.36	0.22	0.02
Ferns and Allies	0.06	0.06	0.00	0.00
Acres of Canopy Cover:	***2.65***	***1.83***	***0.80***	***0.02***

TABLE 11. Crosswalk of Scientific Names Used in This Report With USDA PLANTS Database
The following table represents a crosswalk of scientific names used in this report with USDA PLANTS database.

The scientific names used in this report are from the following taxonomic treatments:
Flora of the Great Plains (Barkley, editor 1986);
Vascular Plants of the Pacific Northwest (Hitchcock and others 1969);
Vascular Plants of Montana (Dorn 1984); and
The Vascular Plants of South Dakota, Second Edition (Theodore Van Bruggen 1985).

Scientific Names Used in This Report	Corresponding Scientific Name in USDA PLANTS Database
Abies lasiocarpa (subalpine fir)	*Abies lasiocarpa* (subalpine fir)
Achillea millefolium var. *lanulosa* (common yarrow)	*Achillea millefolium* var. *occidentalis* (western yarrow)
Agropyron caninum (bearded wheatgrass)	*Elymus caninus* (bearded wheatgrass)
Agrostis scabra (tickle-grass)	*Agrostis scabra* (rough bentgrass)
Alnus incana (mountain alder)	*Alnus incana* (gray alder)
Antennaria microphylla (rosy pussy-toes)	*Antennaria microphylla* (littleleaf pussytoes)
Antennaria neglecta (field pussy-toes)	*Antennaria neglecta* (field pussytoes)
Astragalus spp. (milk-vetch)	*Astragalus* (milkvetch)
Bromus inermis (smooth brome)	*Bromus inermis* (smooth brome)
Calamagrostis canadensis (bluejoint reedgrass)	*Calamagrostis canadensis* (bluejoint)
Calamagrostis stricta (narrow-spiked reedgrass)	*Calamagrostis stricta* (slimstem reedgrass)
Carex microptera (small-winged sedge)	*Carex microptera* (smallwing sedge)
Carex praegracilis (clustered field sedge)	*Carex praegracilis* (clustered field sedge)
Cirsium arvense (Canada thistle)	*Cirsium arvense* (Canada thistle)
Dactylis glomerata (orchard-grass)	*Dactylis glomerata* (orchardgrass)
Deschampsia cespitosa (tufted hairgrass)	*Deschampsia cespitosa* (tufted hairgrass)
Epilobium angustifolium (fireweed)	*Chamerion angustifolium* subsp. *angustifolium* (fireweed)
Epilobium ciliatum (common willow-herb)	*Epilobium ciliatum* (fringed willowherb)
Equisetum hyemale (common scouring-rush)	*Equisetum hyemale* (scouringrush horsetail)
Festuca idahoensis (Idaho fescue)	*Festuca idahoensis* (Idaho fescue)
Festuca scabrella (rough fescue)	*Festuca altaica* (Altai fescue)
Fragaria virginiana (Virginia strawberry)	*Fragaria virginiana* (Virginia strawberry)
Geum canadense (white avens)	*Geum canadense* (white avens)
Hordeum jubatum (foxtail barley)	*Hordeum jubatum* (foxtail barley)
Juncus balticus (Baltic rush)	*Juncus arcticus* subsp. *littoralis* (mountain rush)
Lotus corniculatus (birds-foot trefoil)	*Lotus corniculatus* (bird's-foot trefoil)
Lupinus argenteus (silvery lupine)	*Lupinus argenteus* (silvery lupine)
Phleum pratense (common timothy)	*Phleum pratense* (timothy)
Pinus contorta var. *latifolia* (lodgepole pine)	*Pinus contorta* var. *latifolia* (lodgepole pine)
Pseudotsuga menziesii (Douglas fir)	*Pseudotsuga menziesii* (Douglas-fir)
Pyrola spp. (wintergreen)	*Pyrola* (wintergreen)
Rosa woodsii (Woods rose)	*Rosa woodsii* (Woods' rose)
Rubus idaeus (red raspberry)	*Rubus idaeus* (American red raspberry)
Rumex spp. (dock; sorrel)	*Rumex* (dock)
Salix bebbiana (Bebb willow)	*Salix bebbiana* (Bebb willow)
Salix boothii (Booth willow)	*Salix boothii* (Booth's willow)
Salix drummondiana (Drummond willow)	*Salix drummondiana* (Drummond's willow)
Shepherdia canadensis (russet buffaloberry)	*Shepherdia canadensis* (russet buffaloberry)
Sitanion hystrix (bottlebrush squirreltail)	*Elymus elymoides* subsp. *elymoides* (squirreltail)
Spiraea betulifolia (shiny-leaf spiraea)	*Spiraea betulifolia* (white spirea)
Stipa viridula (green needlegrass)	*Nassella viridula* (green needlegrass)
Trifolium repens (white clover)	*Trifolium repens* (white clover)
Verbascum thapsus (common mullein)	*Verbascum thapsus* (common mullein)

APPENDIX C

LOTIC WETLAND HEALTH ASSESSMENT DATA

Appendix C contains the following parts:

- Jill Creek (Impacted/Reconstructed Reach, Unimpacted Reach)
- Uncle Sam Gulch Creek

U.S. LOTIC WETLAND HEALTH ASSESSMENT FOR STREAMS AND SMALL RIVERS (Survey)

Record ID No: 2024096

Unique Location ID: ____

ADMINISTRATIVE DATA

A1. Field data collected by: **Ecological Solutions Group LLC (ESG)**

A2. Funding Agency/Organization: **EPA/CH2MHILL**

A3a. BLM State Office: ____

A3b. BLM Field Office/Field Station: ____

A3c. BLM Office Code: ____ **A3d.** Is the polygon in an active BLM grazing allotment? (Yes; No; NA): ____

If ***Yes,*** **A3e:** Allotment Number: ____ **A3f:** Allotment Number: ____

Allotment ID: ____ Allotment ID: ____

Allotment Name: ____ Allotment Name: ____

Management Status: ____ Management Status: ____

A4. USFWS Refuge: ____

A5. Reservation: ____

A6. NPS Park/NHS: ____

A7. USFS National Forest: **Beaverhead-Deerlodge National Forest**

A8. Other Location: **Bullion Mine Site Complex**

A9. Year: **2010** **A10.** Date Field data collected: **9/1/2010** **A11.** Observers: **Paul Hansen**

A12a. At least some part of this polygon has been inventoried more than once (resampled)? (Yes; No): **No**

If ***No,*** go to item **A13a.** If ***Yes,*** **A12b.** This polygon coincides exactly with another inventoried polygon? (Yes; No): ____

A12c. Is this the latest inventory for this polygon? (Yes; No): ____

A12d. ID No.(s) of other inventories of this polygon: ____, ____, ____, ____, ____

A12e. Other years: ____

A12f. This polygon shares common area with other inventoried polygon(s)? (Yes; No): ____ **A12g.** Other years: ____

A12h. ID No.(s) of other records sharing area with this polygon: ____, ____, ____, ____, ____

A13a. Has a change in management occurred? (Yes; No): **No** If ***Yes,*** **A13b.** Year that changed occurred: ____

A13c. Type of management change applied:

LOCATION DATA

B1. State/Province: **MT** **B2.** County/Municipal District: **Jefferson**

B3. Allotment/Range Unit: ____

B4a. Area name: **Jill Creek - Pristine Reach (Upstream)**

B4b. Tributary to: **Jack Creek**

B4c. Group name: ____ **B4d.** Group number: ____ **B5.** Polygon number: **1**

B6. Location: 1/4 1/4 Sec: ____ 1/4 Sec: **SE** Sec: **13**

Township (NS): **7N** Range (EW): **6W** **B7.** Elev. (ft): **7,180** ; (m): **2,188**

B8a. Hydrologic unit code (HUC): **10020006** **B8b.** Sub-basin name (4th level HUC): **Boulder**

B8c. Sub-basin (sq mi): **771.40** ; (sq m): **1,997,916,743.20** **B8d.** Sub-basin (ac): **493,696.00** ; (hect): **199,792.35**

B8e. Sub-basin perimeter (mi): ____ ; (m): ____

B9a. Polygon latitude/longitude coordinates: GPS Projection: **WGS 84**

	Lat Deg	Min	Sec	N/S	Decimal	Lon Deg	Min	Sec	E/W	Decimal	Accuracy +/- ft	Accuracy +/- m	Observer Initial & WPT
Upper	46	21	25.8	N	46.357167	112	17	40.3	W	-112.294528	10	3.0	P010
Lower	46	21	25.9	N	46.357194	112	17	44.1	W	-112.295583	10	3.0	P011
Other				N					W				

B9b. Other Point Comments: ____

B10. Quad map(s): **Basin, Montana**

SELECTED SUMMARY DATA Record ID No: **2024096** Unique Location ID: ____

C1. Wetland type: **Perennial Stream** **C2.** Polygon size (ac): **0.19** ; (hect): **0.08**

C3a. Is the entire polygon an upland? (Yes; No): **No** If ***No,*** **C3b.** Does the polygon consist entirely of functional wetland types? (Yes; No): **Yes** **C3c.** Functional wetland (ac): **0.19** ; (hect): **0.08** **C3d**. Percent of total polygon: **100%**

C4. Does the polygon contain a defined streambank or channel? (Yes; No; NC): **Yes**

C5. Channel length (mi): **0.04** ; (km): **0.06** **C6.** Number of river miles the polygon represents: (mi) **0.04** ; (km): **0.06**

C7a. Average riparian zone width (ft): **40.0** ; (m): **12.2**

C7b. Riparian zone width range (ft): **35.0** to **50.0** ; (m): **10.7** to **15.2**

C8. Habitat Types and Community Types

Classification Type Name	Phase	Pct of Poly	Successional Stage or Comments
PICEAX/CALCAN CT		**97.5**	**Late successional stage of the ABILAS/CALCAN (subalpine fir/bluejoint reedgrass) habitat type**

WATER QUALITY DATA

D1. Waterbody number: ____

D2. Is the waterbody a 303(d) listed impaired stream? (Yes; No) ____ Year of listing: ____

D3. Waterbody TMDL priority: ____

D4. TMDL development status: ____

D5. Probable cause(s):

D6. Probable impaired uses:

D7. Probable source(s):

PHOTOGRAPH DATA Unique Location ID: ____

E1a. Identification of photos (taken at the ***Upstream*** end of polygon): Roll #: ________ Photographer: **Paul Hansen**

Photo nos.: (Upstream): **2387, 2388, 2389** (DwnStream): **2390, 2391, 2392** (others): ________

E1b. Location of "other" photos: ________

E1c. Descript. of views Upstream: **Upstream views.**

(Down-stream): **Downstream views.**

(others): ________

E2a. Identification of photos (taken at ***Downstream*** end of polygon): Roll #: ________ Photographer: **Paul Hansen**

Photo nos.: (Upstream): **2393, 2394, 2395** (DwnStream): **2396, 2397, 2398** (others): ________

E2b. Location of "other" photos: ________

E1c. Descript. of views Upstream: **Upstream views.**

(Down-stream): **Looking downstream into the reconstructed section of the stream reach**

(others): ________

LOTIC WETLAND HEALTH ASSESSMENT SCORE SHEET

Data Record ID: **2024096**

Unique Location ID: _____

	Actual Score	Possible Score	Comment
1. Vegetative Cover of Floodplain and Streambanks	6	6	
2a. Total Canopy Cover of Invasive Plant Species (Weeds)	3	3	
2b. Density Distribution Pattern of Invasive Plant Species (Weeds)	3	3	**No weeds observed.**

Are invasive species present? (Yes; No; NC): **No**

List Invasive Plant Species present, including Percent Canopy Cover and Density Distribution Class:

Species	Can.Cov.	Dens.Dist.	Species	Can.Cov.	Dens.Dist.	Species	Can.Cov	Dens.Dist.
bluebuttons:	0.0	0	Japanese brome:	0.0	0	St. John's wort:	0.0	0
Canada thistle:	0.0	0	leafy spurge:	0.0	0	sulphur cinquefoil:	0.0	0
cheatgrass:	0.0	0	musk thistle:	0.0	0	tall buttercup:	0.0	0
common burdock:	0.0	0	orange hawkweed:	0.0	0	teasel:	0.0	0
common cuprina:	0.0	0	oxeye daisy:	0.0	0	whitetop:	0.0	0
common hound's-tongue:	0.0	0	perennial pepperweed:	0.0	0	yellow iris:	0.0	0
common tansy:	0.0	0	purple loosestrife:	0.0	0	yellow starthistle:	0.0	0
dalmatian toadflax:	0.0	0	Russian knapweed:	0.0	0	yellow toadflax:	0.0	0
diffuse knapweed:	0.0	0	Russian olive:	0.0	0	Others: _____	0.0	0
Dyer's woad:	0.0	0	saltcedar (tamarisk):	0.0	0	Others: _____	0.0	0
field bindweed:	0.0	0	Scotch thistle:	0.0	0			
field sow thistle:	0.0	0	spotted knapweed:	0.0	0			

	Actual Score	Possible Score	Comment
3. Disturbance-increaser Undesirable Herbaceous Species	3	3	
4. Preferred Tree and Shrub Species Establishment and/or Regeneration	4	6	
5a. Browse Util. of Preferred Trees and Shrubs	2	3	
5b. Woody Veg. Removal other than Browsing	3	3	
6. Standing Decadent and Dead Woody Material	2	3	**Pine bark beetle killed lodgepole pine.**
Vegetation Subtotal:	26	30	
7. Streambank Root Mass Protection	6	6	
8. Human-Caused Bare Ground	6	6	
9. Streambank Structurally Altered by Human Activity	6	6	
10. Human Physical Alteration to the Rest of the Polygon	3	3	
11. Stream Channel Incisement (Vertical Stability)	9	9	
Soil / Hydrology Subtotal:	30	30	
Overall Polygon Total:	56	60	

RATING CALCULATION

(Actual Score/Possible Score) X 100 = Rating Percent				Descriptive Category
Vegetation Rating:	26 / 30	x 100 =	87%	**Proper Functioning Condition (Healthy)**
Soil / Hydrology:	30 / 30	x 100 =	100%	**Proper Functioning Condition (Healthy)**
OVERALL:	56 / 60	x 100 =	93%	**Proper Functioning Condition (Healthy)**

Rating Percent Range	*Descriptive Category*
80-100	*Proper Functioning Condition (Healthy)*
60-79	*Functional At Risk (Healthy, but with Problems)*
<60	*Nonfunctional (Unhealthy)*

12. Polygon trend (Is the polygon: Improving, Degrading, Static, or Status Unknown?): **Static**

Unique Location ID: ____ Data Record ID: **2024096**

13. Comments and Observations:

The polygon contains the upper reach of Jill Creek, upstream of mine activity. The reach is relatively pristine.

The shrubs Menziesia ferruginea (fool's huckleberry), Ledum groenlandicum (bog Labrador-tea), and Alnus incana (mountain alder) are heavily browsed by wildlife.

ADDITIONAL MANAGEMENT CONCERNS

The following items do not contribute to a site's score. Rather they help to quantify inherent physical site characteristics or assess the direction of change on a site. These data can be useful for planning future site management.

14a. Streambank rock volume: **3 - More than 40% of volume is rocks at least 2.5 inches**

14b. Streambank rock size: **3 - At least 50% of rocks present are boulders and large cobbles (> 5 inch)**

15. Vegetation use by animals: **3 - 0-25%**

16. Susceptibility of parent material to erosion: **3 - Not susceptible to erosion--well armored**

17. Percent of streambank accessible to livestock: **97.5**

18. Break down the polygon area into the land uses listed (must total to approx. 100%):

Land use	%
No land use apparent:	**97.5**
Turf grass (lawn):	**0.0**
Tame pasture (grazing):	**0.0**
Native pasture (grazing):	**0.0**
Recreation (ATV paths, campsites, etc.):	**0.0**
Development (buildings, corrals, paved lots, etc.):	**0.0**
Tilled cropping:	**0.0**
Perennial forage (e.g., alfalfa hayland):	**0.0**
Roads:	**0.0**
Logging:	**0.0**
Mining:	**0.0**
Railroads:	**0.0**
Other:	**0.0**

Description of Other Usage Noted:

19. Break down the area adjacent to the polygon into the land uses listed (must total to approx. 100%):

Land use	%
No land use apparent:	**50.0**
Turf grass (lawn):	**0.0**
Tame pasture (grazing):	**0.0**
Native pasture (grazing):	**0.0**
Recreation (ATV paths, campsites, etc.):	**0.0**
Development (buildings, corrals, paved lots, etc.):	**0.0**
Tilled cropping:	**0.0**
Perennial forage (e.g., alfalfa hayland):	**0.0**
Roads:	**0.0**
Logging:	**0.0**
Mining:	**50.0**
Railroads:	**0.0**
Other:	**0.0**

Description of Other Usage Noted:

U.S. LOTIC WETLAND HEALTH ASSESSMENT FOR STREAMS AND SMALL RIVERS (Survey)

Record ID No: **2024097**

Unique Location ID: _____

ADMINISTRATIVE DATA

A1. Field data collected by: **Ecological Solutions Group LLC (ESG)**

A2. Funding Agency/Organization: **EPA/CH2MHILL**

A3a. BLM State Office: ______

A3b. BLM Field Office/Field Station: ______

A3c. BLM Office Code: ______ **A3d.** Is the polygon in an active BLM grazing allotment? (Yes; No; NA): ______

If ***Yes,* A3e:** Allotment Number: ______ **A3f:** Allotment Number: ______

Allotment ID: ______ Allotment ID: ______

Allotment Name: ______ Allotment Name: ______

Management Status: ______ Management Status: ______

A4. USFWS Refuge: ______

A5. Reservation: ______

A6. NPS Park/NHS: ______

A7. USFS National Forest: **Beaverhead-Deerlodge National Forest**

A8. Other Location: **Bullion Mine Site Complex**

A9. Year: **2010** **A10.** Date Field data collected: **9/1/2010** **A11.** Observers: **Paul Hansen**

A12a. At least some part of this polygon has been inventoried more than once (resampled)? (Yes; No): **No**

If ***No,*** go to item **A13a.** If ***Yes,* A12b.** This polygon coincides exactly with another inventoried polygon? (Yes; No): ______

A12c. Is this the latest inventory for this polygon? (Yes; No): ______

A12d. ID No.(s) of other inventories of this polygon: ______, ______, ______, ______, ______

A12e. Other years: ______

A12f. This polygon shares common area with other inventoried polygon(s)? (Yes; No): ______ **A12g.** Other years: ______

A12h. ID No.(s) of other records sharing area with this polygon: ______, ______, ______, ______, ______

A13a. Has a change in management occurred? (Yes; No): **No** If ***Yes,* A13b.** Year that changed occurred: ______

A13c. Type of management change applied:

LOCATION DATA

B1. State/Province: **MT** **B2.** County/Municipal District: **Jefferson**

B3. Allotment/Range Unit: ______

B4a. Area name: **Jill Creek - Reconstructed Reach (Downstream)**

B4b. Tributary to: **Jack Creek**

B4c. Group name: ______ **B4d.** Group number: ______ **B5.** Polygon number: **2**

B6. Location: 1/4 1/4 Sec: ______ 1/4 Sec: **SE** Sec: **13**

Township (NS): **7N** Range (EW): **6W** **B7.** Elev. (ft): **7,164** ; (m): **2,184**

B8a. Hydrologic unit code (HUC): **10020006** **B8b.** Sub-basin name (4th level HUC): **Boulder**

B8c. Sub-basin (sq mi): ______; (sq m): ______ **B8d.** Sub-basin (ac): ______; (hect): ______

B8e. Sub-basin perimeter (mi): ______ ; (m): ______

B9a. Polygon latitude/longitude coordinates: GPS Projection: **WGS 84**

		Deg	Min	Sec	N/S	Decimal		Deg	Min	Sec	E/W	Decimal	Accuracy +/- ft	Accuracy +/- m	Observer Initial & WPT
Upper:	Lat:	**46**	**21**	**25.9**	**N**	**46.357194**	Lon:	**112**	**17**	**44.1**	**W**	**-112.295583**	**10**	**3.0**	**P012**
Lower:	Lat:	**46**	**21**	**27.6**	**N**	**46.357667**	Lon:	**112**	**17**	**49.6**	**W**	**-112.297111**	**10**	**3.0**	**P013**
Other:	Lat:				**N**		Lon:				**W**				

B9b. Other Point Comments: ______

B10. Quad map(s): **Basin, Montana**

SELECTED SUMMARY DATA Record ID No: **2024097** Unique Location ID: ____

C1. Wetland type: **Perennial Stream** **C2.** Polygon size (ac): **0.97** ; (hect): **0.39**

C3a. Is the entire polygon an upland? (Yes; No): **No** If ***No,*** **C3b.** Does the polygon consist entirely of functional wetland types? (Yes; No): **Yes** **C3c.** Functional wetland (ac): **0.97** ; (hect): **0.39** **C3d**. Percent of total polygon: **100%**

C4. Does the polygon contain a defined streambank or channel? (Yes; No; NC): **Yes**

C5. Channel length (mi): **0.08** ; (km): **0.13** **C6.** Number of river miles the polygon represents: (mi) **0.08** ; (km): **0.13**

C7a. Average riparian zone width (ft): **100.0** ; (m): **30.5**

C7b. Riparian zone width range (ft): **50.0** to **150.0** ; (m): **15.2** to **45.7**

C8. Habitat Types and Community Types

Classification Type Name	Phase	Pct of Poly	Successional Stage or Comments
UNCLASSIFIED WETLAND TYPE 1		**97.5**	**Reconstructed stream channel**

WATER QUALITY DATA

D1. Waterbody number: ____

D2. Is the waterbody a 303(d) listed impaired stream? (Yes; No) ____ Year of listing: ____

D3. Waterbody TMDL priority: ____

D4. TMDL development status: ____

D5. Probable cause(s):

D6. Probable impaired uses:

D7. Probable source(s):

PHOTOGRAPH DATA

Unique Location ID: ____

E1a. Identification of photos (taken at the ***Upstream*** end of polygon): Roll #: ________ Photographer: **Paul Hansen**

Photo nos.: (Upstream): **2393, 2394, 2395** (DwnStream): **2396, 2397, 2398** (others): **2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424,**

E1b. Location of "other" photos: **Photos of the floodplain from the upstream end to the lower end of the polygon. Photos 2400-2467.**

E1c. Descript. of views Upstream: **Upstream views.**

(Down-stream): **Downstream views.**

(others): **Photos of the floodplain from the upstream end to the lower end of the polygon.**

E2a. Identification of photos (taken at ***Downstream*** end of polygon): Roll #: ________ Photographer: **Paul Hansen**

Photo nos.: (Upstream): **2470, 2471, 2472** (DwnStream): **2473, 2474, 2475** (others): ________

E2b. Location of "other" photos:

E1c. Descript. of views Upstream: **Upstream views.**

(Down-stream): **Looking downstream, outside of the reconstructed reach.**

(others):

LOTIC WETLAND HEALTH ASSESSMENT SCORE SHEET

Data Record ID: 2024097

Unique Location ID: ______

	Actual Score	Possible Score	Comment
1. Vegetative Cover of Floodplain and Streambanks	4	6	
2a. Total Canopy Cover of Invasive Plant Species (Weeds)	2	3	
2b. Density Distribution Pattern of Invasive Plant Species (Weeds)	2	3	

Are invasive species present? (Yes; No; NC): **Yes**

List Invasive Plant Species present, including Percent Canopy Cover and Density Distribution Class:

Species	Can.Cov.	Dens.Dist.	Species	Can.Cov.	Dens.Dist.	Species	Can.Cov	Dens.Dist.
bluebuttons:	0.0	0	Japanese brome:	0.0	0	St. John's wort:	0.0	0
Canada thistle:	0.5	1	leafy spurge:	0.0	0	sulphur cinquefoil:	0.0	0
cheatgrass:	0.0	0	musk thistle:	0.0	0	tall buttercup:	0.0	0
common burdock:	0.0	0	orange hawkweed:	0.0	0	teasel:	0.0	0
common cuprina:	0.0	0	oxeye daisy:	0.0	0	whitetop:	0.0	0
common hound's-tongue:	0.0	0	perennial pepperweed:	0.0	0	yellow iris:	0.0	0
common tansy:	0.0	0	purple loosestrife:	0.0	0	yellow starthistle:	0.0	0
dalmatian toadflax:	0.0	0	Russian knapweed:	0.0	0	yellow toadflax:	0.0	0
diffuse knapweed:	0.0	0	Russian olive:	0.0	0	Others:	0.0	0
Dyer's woad:	0.0	0	saltcedar (tamarisk):	0.0	0	Others:	0.0	0
field bindweed:	0.0	0	Scotch thistle:	0.0	0			
field sow thistle:	0.0	0	spotted knapweed:	0.0	0			

	Actual Score	Possible Score	Comment
3. Disturbance-increaser Undesirable Herbaceous Species	0	3	
4. Preferred Tree and Shrub Species Establishment and/or Regeneration	2	6	
5a. Browse Util. of Preferred Trees and Shrubs	1	3	
5b. Woody Veg. Removal other than Browsing	0	3	**Cleared for channel reconstruction.**
6. Standing Decadent and Dead Woody Material	1	3	**Pine bark beetle killed lodgepole pine.**
Vegetation Subtotal:	12	30	
7. Streambank Root Mass Protection	0	6	**The floodplain was cleared of vegetation when they installed the log revetments and coir fabric.**
8. Human-Caused Bare Ground	2	6	
9. Streambank Structurally Altered by Human Activity	0	6	**Streambank was altered when they attempted to stabilize the streambank with rocks, log revetments, and coir.**
10. Human Physical Alteration to the Rest of the Polygon	0	3	**Rest of polygon was altered when the streambank work was done.**
11. Stream Channel Incisement (Vertical Stability)	6	9	
Soil / Hydrology Subtotal:	8	30	
Overall Polygon Total:	20	60	

RATING CALCULATION

(Actual Score/Possible Score) X 100 = Rating Percent				Descriptive Category
Vegetation Rating:	12 / 30	x 100 =	40%	**Nonfunctional (Unhealthy)**
Soil / Hydrology:	8 / 30	x 100 =	27%	**Nonfunctional (Unhealthy)**
OVERALL:	20 / 60	x 100 =	33%	**Nonfunctional (Unhealthy)**

Rating Percent Range	*Descriptive Category*
80-100	*Proper Functioning Condition (Healthy)*
60-79	*Functional At Risk (Healthy, but with Problems)*
<60	*Nonfunctional (Unhealthy)*

12. Polygon trend (Is the polygon: Improving, Degrading, Static, or Status Unknown?): **Static**

Unique Location ID: ____ Data Record ID: **2024097**

13. Comments and Observations:

The stream channel was reconstructed in 2001-2002. The engineering project used log revetments, boulders, and coir fabric along the streambanks.

ADDITIONAL MANAGEMENT CONCERNS

The following items do not contribute to a site's score. Rather they help to quantify inherent physical site characteristics or assess the direction of change on a site. These data can be useful for planning future site management.

14a. Streambank rock volume: **3 - More than 40% of volume is rocks at least 2.5 inches**

14b. Streambank rock size: **3 - At least 50% of rocks present are boulders and large cobbles (> 5 inch)**

15. Vegetation use by animals: **3 - 0-25%**

16. Susceptibility of parent material to erosion: **3 - Not susceptible to erosion--well armored**

17. Percent of streambank accessible to livestock: **97.5**

18. Break down the polygon area into the land uses listed (must total to approx. 100%):

Land use	%
No land use apparent:	**0.0**
Turf grass (lawn):	**0.0**
Tame pasture (grazing):	**0.0**
Native pasture (grazing):	**0.0**
Recreation (ATV paths, campsites, etc.):	**0.0**
Development (buildings, corrals, paved lots, etc.):	**0.0**
Tilled cropping:	**0.0**
Perennial forage (e.g., alfalfa hayland):	**0.0**
Roads:	**0.0**
Logging:	**0.0**
Mining:	**97.5**
Railroads:	**0.0**
Other:	**0.0**

Description of Other Usage Noted:

19. Break down the area adjacent to the polygon into the land uses listed (must total to approx. 100%):

Land use	%
No land use apparent:	**0.0**
Turf grass (lawn):	**0.0**
Tame pasture (grazing):	**0.0**
Native pasture (grazing):	**0.0**
Recreation (ATV paths, campsites, etc.):	**0.0**
Development (buildings, corrals, paved lots, etc.):	**0.0**
Tilled cropping:	**0.0**
Perennial forage (e.g., alfalfa hayland):	**0.0**
Roads:	**0.0**
Logging:	**0.0**
Mining:	**97.5**
Railroads:	**0.0**
Other:	**0.0**

Description of Other Usage Noted:

U.S. LOTIC WETLAND HEALTH ASSESSMENT FOR STREAMS AND SMALL RIVERS (Survey)

Record ID No: 2024098

Unique Location ID: ____

ADMINISTRATIVE DATA

A1. Field data collected by: **Ecological Solutions Group LLC (ESG)**

A2. Funding Agency/Organization: **EPA/CH2MHILL**

A3a. BLM State Office: ____

A3b. BLM Field Office/Field Station: ____

A3c. BLM Office Code: ____ **A3d.** Is the polygon in an active BLM grazing allotment? (Yes; No; NA): ____

If ***Yes,* A3e:** Allotment Number: ____ **A3f:** Allotment Number: ____

Allotment ID: ____ Allotment ID: ____

Allotment Name: ____ Allotment Name: ____

Management Status: ____ Management Status: ____

A4. USFWS Refuge: ____

A5. Reservation: ____

A6. NPS Park/NHS: ____

A7. USFS National Forest: **Beaverhead-Deerlodge National Forest**

A8. Other Location: **Crystal Mine Site Complex**

A9. Year: **2010** **A10.** Date Field data collected: **9/3/2010** **A11.** Observers: **Paul Hansen**

A12a. At least some part of this polygon has been inventoried more than once (resampled)? (Yes; No): **No**

If ***No,*** go to item **A13a.** If ***Yes,* A12b.** This polygon coincides exactly with another inventoried polygon? (Yes; No): ____

A12c. Is this the latest inventory for this polygon? (Yes; No): ____

A12d. ID No.(s) of other inventories of this polygon: ____, ____, ____, ____, ____

A12e. Other years: ____

A12f. This polygon shares common area with other inventoried polygon(s)? (Yes; No): ____ **A12g.** Other years: ____

A12h. ID No.(s) of other records sharing area with this polygon: ____, ____, ____, ____, ____

A13a. Has a change in management occurred? (Yes; No): **No** If ***Yes,* A13b.** Year that changed occurred: ____

A13c. Type of management change applied:

LOCATION DATA

B1. State/Province: **MT** **B2.** County/Municipal District: **Jefferson**

B3. Allotment/Range Unit: ____

B4a. Area name: **Uncle Sam Gulch Creek**

B4b. Tributary to: **Cataract Creek**

B4c. Group name: ____ **B4d.** Group number: ____ **B5.** Polygon number: **1**

B6. Location: 1/4 1/4 Sec: ____ 1/4 Sec: **NW** Sec: **20**

Township (NS): **7N** Range (EW): **5W** **B7.** Elev. (ft): **7,798** ; (m): **2,377**

B8a. Hydrologic unit code (HUC): **10020006** **B8b.** Sub-basin name (4th level HUC): **Boulder**

B8c. Sub-basin (sq mi): ____; (sq m): ____ **B8d.** Sub-basin (ac): ____; (hect): ____

B8e. Sub-basin perimeter (mi): ____ ; (m): ____

B9a. Polygon latitude/longitude coordinates: GPS Projection: **WGS 84**

	Deg	Min	Sec	N/S	Decimal		Deg	Min	Sec	E/W	Decimal	Accuracy +/- ft	Accuracy +/- m	Observer Initial & WPT
Upper: Lat:	46	21	0.8	N	46.350222	Lon:	112	15	42.8	W	-112.261889	7	2.1	P085
Lower: Lat:	46	20	47.1	N	46.346417	Lon:	112	15	41.1	W	-112.261417	14	4.3	P086
Other: Lat:	46	20	50.4	N	46.347333	Lon:	112	15	46.7	W	-112.262972	7	2.1	P087

B9b. Other Point Comments: **At the lower end near the cabins at a pin called Control Point #40.**

B10. Quad map(s): **Basin, Montana**

SELECTED SUMMARY DATA Record ID No: **2024098** Unique Location ID: ____

C1. Wetland type: **Perennial Stream** **C2.** Polygon size (ac): **0.68** ; (hect): **0.28**

C3a. Is the entire polygon an upland? (Yes; No): **No** If ***No,*** **C3b.** Does the polygon consist entirely of functional wetland types? (Yes; No): **Yes** **C3c.** Functional wetland (ac): **0.68** ; (hect): **0.28** **C3d**. Percent of total polygon: **100%**

C4. Does the polygon contain a defined streambank or channel? (Yes; No; NC): **Yes**

C5. Channel length (mi): **0.28** ; (km): **0.45** **C6.** Number of river miles the polygon represents: (mi) **0.26** ; (km): **0.42**

C7a. Average riparian zone width (ft): **20.0** ; (m): **6.1**

C7b. Riparian zone width range (ft): **15.0** to **50.0** ; (m): **4.6** to **15.2**

C8. Habitat Types and Community Types

Classification Type Name	Phase	Pct of Poly	Successional Stage or Comments
UNCLASSIFIED WETLAND TYPE 1		**97.5**	**Denuded floodplain due to toxic mine tailings. Scattered live spruce are present.**

WATER QUALITY DATA

D1. Waterbody number: ____

D2. Is the waterbody a 303(d) listed impaired stream? (Yes; No) ____ Year of listing: ____

D3. Waterbody TMDL priority: ____

D4. TMDL development status: ____

D5. Probable cause(s):

D6. Probable impaired uses:

D7. Probable source(s):

PHOTOGRAPH DATA

Unique Location ID: ____

E1a. Identification of photos (taken at the ***Upstream*** end of polygon): Roll #: ________ Photographer: **Paul Hansen**

Photo nos.: (Upstream): **2636, 2637, 2638** (DwnStream): **2639, 2640, 2641** (others): **2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2673, 2674, 2675, 2676, 2677, 2678, 2679, 0680,**

E1b. Location of "other" photos: **Photos of the floodplain from the upstream end to the lower end of the polygon.**

E1c. Descript. of views Upstream: **Upstream views.**

(Downstream): **Downstream views.**

(others): **Photos of the floodplain from the upstream end to the lower end of the polygon.**

E2a. Identification of photos (taken at ***Downstream*** end of polygon): Roll #: ________ Photographer: **Paul Hansen**

Photo nos.: (Upstream): **2882, 2883, 2884, 2885** (DwnStream): **2886, 2887, 2888, 2889** (others): ________

E2b. Location of "other" photos:

E1c. Descript. of views Upstream: **Upstream views.**

(Downstream): **Downstream views.**

(others):

LOTIC WETLAND HEALTH ASSESSMENT SCORE SHEET

Data Record ID: **2024098**

Unique Location ID: ______

	Actual Score	Possible Score	Comment
1. Vegetative Cover of Floodplain and Streambanks	0	6	
2a. Total Canopy Cover of Invasive Plant Species (Weeds)	3	3	**Most of the floodplain is too toxic for plant growth.**
2b. Density Distribution Pattern of Invasive Plant Species (Weeds)	3	3	**Most of the floodplain is too toxic for plant growth.**

Are invasive species present? (Yes; No; NC): **No**

List Invasive Plant Species present, including Percent Canopy Cover and Density Distribution Class:

Species	Can.Cov.	Dens.Dist.	Species	Can.Cov.	Dens.Dist.	Species	Can.Cov	Dens.Dist.
bluebuttons:	0.0	0	Japanese brome:	0.0	0	St. John's wort:	0.0	0
Canada thistle:	0.0	0	leafy spurge:	0.0	0	sulphur cinquefoil:	0.0	0
cheatgrass:	0.0	0	musk thistle:	0.0	0	tall buttercup:	0.0	0
common burdock:	0.0	0	orange hawkweed:	0.0	0	teasel:	0.0	0
common cuprina:	0.0	0	oxeye daisy:	0.0	0	whitetop:	0.0	0
common hound's-tongue:	0.0	0	perennial pepperweed:	0.0	0	yellow iris:	0.0	0
common tansy:	0.0	0	purple loosestrife:	0.0	0	yellow starthistle:	0.0	0
dalmatian toadflax:	0.0	0	Russian knapweed:	0.0	0	yellow toadflax:	0.0	0
diffuse knapweed:	0.0	0	Russian olive:	0.0	0	Others: ______	0.0	0
Dyer's woad:	0.0	0	saltcedar (tamarisk):	0.0	0	Others: ______	0.0	0
field bindweed:	0.0	0	Scotch thistle:	0.0	0			
field sow thistle:	0.0	0	spotted knapweed:	0.0	0			

	Actual Score	Possible Score	Comment
3. Disturbance-increaser Undesirable Herbaceous Species	2	3	**Tufted hairgrass which is an indicator of mine tailing.**
4. Preferred Tree and Shrub Species Establishment and/or Regeneration	2	6	
5a. Browse Util. of Preferred Trees and Shrubs	3	3	
5b. Woody Veg. Removal other than Browsing	0	3	
6. Standing Decadent and Dead Woody Material	1	3	**Pine bark beetle killed lodgepole pine (approx. 50%); others killed by contamination (approx. 50%).**
Vegetation Subtotal:	14	30	
7. Streambank Root Mass Protection	0	6	**Most of the floodplain is too toxic for plant growth.**
8. Human-Caused Bare Ground	0	6	**Mine tailings throughout the floodplain.**
9. Streambank Structurally Altered by Human Activity	0	6	**Mine tailings dumped throughout the floodplain.**
10. Human Physical Alteration to the Rest of the Polygon	0	3	**Mine tailings dumped throughout the floodplain.**
11. Stream Channel Incisement (Vertical Stability)	3	9	**Channel is incised down to the large boulders and bedrock in most of the reach.**
Soil / Hydrology Subtotal:	3	30	
Overall Polygon Total:	17	60	

RATING CALCULATION

(Actual Score/Possible Score) X 100 = Rating Percent

	Actual		Possible			Rating Percent	Descriptive Category
Vegetation Rating:	14	/	30	x	100 =	47%	**Nonfunctional (Unhealthy)**
Soil / Hydrology:	3	/	30	x	100 =	10%	**Nonfunctional (Unhealthy)**
OVERALL:	17	/	60	x	100 =	28%	**Nonfunctional (Unhealthy)**

Rating Percent Range	*Descriptive Category*
80-100	*Proper Functioning Condition (Healthy)*
60-79	*Functional At Risk (Healthy, but with Problems)*
<60	*Nonfunctional (Unhealthy)*

12. Polygon trend (Is the polygon: Improving, Degrading, Static, or Status Unknown?): **Degrading**

Unique Location ID: ____ Data Record ID: **2024098**

13. Comments and Observations:

Lots of dead/dying Pinus contorta (lodgepole pine) in the floodplain. Picea spp. (spruce) is present in the floodplain and reproducing.

Upper end of the floodplain contains Carex aquatilis (water sedge) and Ledum groenlandicum (bog Labrador-tea). The portions of the middle and lower section that are vegetated contains limited amounts of Agrostis stolonifera (redtop), Deschampsia cespitosa (tufted hairgrass), Calamagrostis canadensis (bluejoint reedgrass), Senecio triangularis (arrowleaf groundsel), Veratrum viride (green false hellebore), Salix boothii (Booth willow), Salix geyeriana (Geyers willow), Equisetum arevense (field horsetail), Alnus incana (mountain alder), and Menziesia ferruginea (fool's huckleberry).

Some sections of the streambed have very old log drop structures to reduce downcutting.

The lower end of the reach has very large sediment dumps resulting in a braided channel.

Elk and moose pellets were observed along the stream.

The streambank rock volume (question 14a) and streambank rock size (question 14b) would both be "3" if not for all the mine tailings in the floodplain.

While walking out of the lower reach of Uncle Sam Gulch Creek, I saw 12 ATV's on the lower Crystal Mine Road heading uphill.

ADDITIONAL MANAGEMENT CONCERNS

The following items do not contribute to a site's score. Rather they help to quantify inherent physical site characteristics or assess the direction of change on a site. These data can be useful for planning future site management.

14a. Streambank rock volume: **2 - 20% to 40% of volume is rocks at least 2.5 inches**

14b. Streambank rock size: **2 - 50% of rocks present are small cobbles and larger (> 2.5 inches)**

15. Vegetation use by animals: **3 - 0-25%**

16. Susceptibility of parent material to erosion: **3 - Not susceptible to erosion--well armored**

17. Percent of streambank accessible to livestock: **40.0**

18. Break down the polygon area into the land uses listed (must total to approx. 100%):

Land use	%
No land use apparent:	**0.0**
Turf grass (lawn):	**0.0**
Tame pasture (grazing):	**0.0**
Native pasture (grazing):	**0.0**
Recreation (ATV paths, campsites, etc.):	**0.0**
Development (buildings, corrals, paved lots, etc.):	**0.0**
Tilled cropping:	**0.0**
Perennial forage (e.g., alfalfa hayland):	**0.0**
Roads:	**0.0**
Logging:	**0.0**
Mining:	**97.5**
Railroads:	**0.0**
Other:	**0.0**

Description of Other Usage Noted:

19. Break down the area adjacent to the polygon into the land uses listed (must total to approx. 100%):

Land use	%
No land use apparent:	**0.0**
Turf grass (lawn):	**0.0**
Tame pasture (grazing):	**0.0**
Native pasture (grazing):	**0.0**
Recreation (ATV paths, campsites, etc.):	**0.0**
Development (buildings, corrals, paved lots, etc.):	**0.0**
Tilled cropping:	**0.0**
Perennial forage (e.g., alfalfa hayland):	**0.0**
Roads:	**0.0**
Logging:	**0.0**
Mining:	**97.5**
Railroads:	**0.0**
Other:	**0.0**

Description of Other Usage Noted:

APPENDIX D

LOTIC WETLAND HEALTH ASSESSMENT (SURVEY) POLYGON DATA SET SUMMARY

Each Summary Data Set in Appendix D contains the following tables:

- Table 1a. Polygon Location Information—General
- Table 1b. Polygon Location Information—Latitude and Longitude
- Table 2. Polygon Administrative Information
- Table 3a. Proper Functioning Condition (Health or PFC) Lotic Summary
- Table 3b. Comparison to Previous Health or PFC Sampling
- Table 4a. Vegetation Characteristics
- Table 4b. Soil/Hydrology Characteristics
- Table 5. Riparian Zone and Polygon Dimensions
- Table 6. Invasive Plant Species (Weeds) and Acres (by Individual Species)
- Table 7. Habitat Types and Community Types

ESG LOTIC WETLAND HEALTH ASSESSMENT (SURVEY) POLYGON DATA SET SUMMARY

Summary Name: **Bullion and Crystal Streams - TOTAL** Number of Polygons: **3**

Agency/Organization: **EPA/CH2MHILL** State/Province: **MT**

Notice: The following data is from the Lotic Wetland Health Assessment for Streams and Small Rivers (Survey). It does not include data from any inventory form (lotic or lentic) or any other health assessment, such as the Lentic Wetland Health Assessment (Survey) or the Lotic Health Assessment for Large River Systems (survey).

DATA SUMMARIES AND ANALYSES INCLUDED

Ecological Solutions Group LLC

Summary Name: **Bullion and Crystal Streams - TOTAL** Number of Polygons: **3**

TABLE 1a. Polygon Location Information

This table gives for each polygon the area name and the waterbody it drains into. For more information on how these data were determined, and their ecological significance, refer to the Lotic Wetland Health Assessment (Survey) User Manual, accessible on the web at: www.ecologicalsolutionsgroup.com. Inventory form items from which the summarized data are obtained from are referenced in the table column headings. The order is by year (descending) and by area name (ascending).

Polygon Record ID	**Year** (A9)	**Area Name** (B4a)	**Tributary to** (B4b)
2024096	2010	Jill Creek - Pristine Reach (Upstream)	Jack Creek
2024097	2010	Jill Creek - Reconstructed Reach (Downstream)	Jack Creek
2024098	2010	Uncle Sam Gulch Creek	Cataract Creek

Summary Name: **Bullion and Crystal Streams - TOTAL** Number of Polygons: **3**

TABLE 1b. Polygon Location Information—Latitude and Longitude

This table gives the latitude and longitude for each polygon. For more information, refer to the Lotic Wetland Health Assessment (Survey) User Manual, accessible on the web at: www.ecologicalsolutionsgroup.com.

Polygon Record ID		Polygon Latitude Coordinates: Deg	Min	Sec	N/S	Decimal	Polygon Longitude Coordinates: Deg	Min	Sec	E/W	Decimal	GPS Projection
2024096	Upper End:	46	21	25.8	N	46.357167	112	17	40.3	W	-112.294528	WGS 84
	Lower End:	46	21	25.9	N	46.357194	112	17	44.1	W	-112.295583	
2024097	Upper End:	46	21	25.9	N	46.357194	112	17	44.1	W	-112.295583	WGS 84
	Lower End:	46	21	27.6	N	46.357667	112	17	49.6	W	-112.297111	
2024098	Upper End:	46	21	0.8	N	46.350222	112	15	42.8	W	-112.261889	WGS 84
	Lower End:	46	20	47.1	N	46.346417	112	15	41.1	W	-112.261417	

Summary Name: **Bullion and Crystal Streams - TOTAL** Number of Polygons: **3**

TABLE 2. Polygon Administrative Information

This table gives for each polygon the state or province, data collection date, wetland type (including non-riparian), and polygon number. For more information on how these data were determined, and their ecological significance, refer to the Lotic Wetland Health Assessment (Survey) User Manual, accessible on the web at: www.ecologicalsolutionsgroup.com. Inventory form items from which the summarized statistics derive are referenced in the table column headings.

Polygon Record ID	**State or Province**	**Date Collected** (A10)	**Wetland Type** (C1)	**Polygon Number** (B5)
2024096	MT	9/1/2010	Perennial Stream	1
2024097	MT	9/1/2010	Perennial Stream	2
2024098	MT	9/3/2010	Perennial Stream	1

Summary Name: **Bullion and Crystal Streams - TOTAL** Number of Polygons: **3**

TABLE 3a. Proper Functioning Condition (Health or PFC) Lotic Summary
This table presents each polygon's health score, rating category, and trend, along with it's channel length (miles) and size (acres), and percentage of the total river miles and acres represented by each polygon in the group. Also given is an overall average score and average health category (weighted by polygon size) for the set. NA = not applicable. ***NOTE:*** Upland (non-riparian) polygons are also presented, but do not have any values and are not included in the aggregate polygon information.

Agregate Polygon Information

Total River Miles in Summary Set: **0.40**

Total Riparian Acres: **1.84**

Total Size of Summary Set (Acres): **1.84**

Summary Set Weighted Average Vegetation Score: **47%**

Summary Set Weighted Average Soil/Hydrology Score: **28%**

Summary Set Weighted Average Final Score: **38%**

Summary Set Weighted Average Final Category: **Nonfunctional (Unhealthy)**

Overall Score Range: **93%** to **28%**

Rating Percent Range	Descriptive Category
80-100	Proper Functioning Condition (Healthy) PFC
60-79	Functional At Risk (Healthy, but with Problems) FAR
<60	Nonfunctional (Unhealthy) NF

Individual Polygon Information

Polygon Record ID	Overall Score	Overall Rating	Vegetation Score	Vegetation Rating	Soil/Hydrology Score	Soil/Hydrology Rating	River Miles	Percent of Total	Acres	Percent of Total	Trend
2024096	93%	PFC	87%	PFC	100%	PFC	0.04	10%	0.19	10.3%	Static
2024097	33%	NF	40%	NF	27%	NF	0.08	20%	0.97	52.7%	Static
2024098	28%	NF	47%	NF	10%	NF	0.28	70%	0.68	37.0%	Degrading

Summary Name: **Bullion and Crystal Streams - TOTAL** Number of Polygons: **3**

TABLE 3b. Comparison to Previous Sampling
This table compares each polygon to any previous Proper Functioning Condition (Health or PFC) sampling which may have been done on the same site. The table shows the most recent sampled polygon first along with any previous sampling in descending order based upon year.

NOTE: Upland (non-riparian) polygons are also presented, but are delineated in the overall score with a NA (not applicable).

Rating Percent Range	Descriptive Category
80-100	Proper Functioning Condition (Healthy) PFC
60-79	Functional At Risk (Healthy, but with Problems) FAR
<60	Nonfunctional (Unhealthy) NF

Comparison Health Score Information

Polygon Record ID	Year	Overall Score	Polygon Record ID	Year	Overall Score	Polygon Record ID	Year	Overall Score	Polygon Record ID	Year	Overall Score
2024096	2010	93%	–	–	–	–	–	–	–	–	–
2024097	2010	33%	–	–	–	–	–	–	–	–	–
2024098	2010	28%	–	–	–	–	–	–	–	–	–

Summary Name: **Bullion and Crystal Streams - TOTAL** Number of Polygons: **3**

TABLE 4a. Vegetation Characteristics

This table gives the vegetation characteristics used in determining a score for each polygon. They include the vegetative cover floodplain and streambanks, total canopy cover of invasive plant species (weeds), density distribution pattern of invasive plant species (weeds), disturbance-increaser undesirable herbaceous species, preferred tree and shrub species establishment and/or regeneration, browse utilization of preferred trees and shrubs, woody vegetation removal other than browsing, and standing decadent and dead woody material. Near the top of the table, this information is summarized across all polygons in the summary set using weighted averages. For more information on how these data were determined, and on the ecological significance, refer to the Lotic Wetland Inventory User Manual or the Lotic Health Survey User Manual, found on the web at: www.ecologicalsolutionsgroup.com.

Polygon Record ID	Vegetation Cover (6 pts)	Weed Cover (3 or 6 pts)	Weed Distribution (3 or 0 pts)	Disturbance Species (3 pts)	Preferred Woody Establishment (6 pts)	Preferred Woody Browse (3 pts)	Live Woody Removal (3 pts)	Standing Dec./Dead Woody Veg. (3 pts)
Summary:	**2.7**	**2.5**	**2.5**	**1.0**	**2.2**	**1.8**	**0.3**	**1.1**
2024096	6	3	3	3	4	2	3	2
2024097	4	2	2	0	2	1	0	1
2024098	0	3	3	2	2	3	0	1

Summary Name: **Bullion and Crystal Streams - TOTAL** Number of Polygons: **3**

TABLE 4b. Soil/Hydrology Characteristics

This table gives the soil/hydrology characteristics used in determining a score for each polygon. They include streambank root mass protection, human-caused bare ground, streambank structurally altered by human activity, human physical alteration to the rest of the polygon, and stream channel incisement (vertical stability). Near the top of the table, this information is summarized across all polygons in the summary set using weighted averages. For more information on how these data were determined, and on the ecological significance, refer to the Lotic Wetland Inventory User Manual or the Lotic Health Survey User Manual, found on the web at: www.ecologicalsolutionsgroup.com.

Polygon Record ID		Streambank Root Mass (6 pts)	Human-Caused Bare Ground (6 pts)	Streambank Altered by Human Activity (6 pts)	Human Alteration to Rest of Polygon (3 pts)	Channel Incisement (9 pts)
	Summary:	**0.6**	**1.7**	**0.6**	**0.3**	**5.2**
2024096		6	6	6	3	9
2024097		0	2	0	0	6
2024098		0	0	0	0	3

Summary Name: **Bullion and Crystal Streams - TOTAL** Number of Polygons: **3**

TABLE 5. Riparian Zone and Polygon Dimensions

This table presents size (acres), length (river miles), average acres per river mile, average riparian-wetland zone width, and minimum and maximum riparian-wetland zone widths for each polygon. Near the top of the table this information is summarized across all polygons using weighted averages. For more information on how these data were determined, and on their ecological significance, refer to the Lotic Wetland Health Assessment (Survey) User Manual, accessible on the web at: www.ecologicalsolutionsgroup.com. Item numbers for locating each parameter in the User Manual are included in the column. **NOTE:** Non-riparian polygons are also presented, but do not have any values and are not included in the aggregate polygon information.

Polygon Record ID	Wetland Type (C1)	Acres (C2)	River Miles (C5)	Avg. Ac./Riv. Mi. (C2 and C5)	Avg. Rip. Zone Width (feet) (C7a)	Minimum & Maximum Rip. Zone Widths (feet) (C7b)		
	Summary:	**1.84**	**0.40**	**4.60**	**38.0**	**15.0**	to	**150.0**
2024096	Perennial Stream	0.19	0.04	4.75	40	35.0	to	50.0
2024097	Perennial Stream	0.97	0.08	12.13	100	50.0	to	150.0
2024098	Perennial Stream	0.68	0.28	2.43	20	15.0	to	50.0

Summary Name: **Bullion and Crystal Streams - TOTAL** Number of Polygons: **3**

TABLE 6. Invasive Plant Species (Weeds) and Acres (by Individual Species)

This table summarizes invasive plant species (weeds) found on polygons in this summary set. These are species that are cause for special concern or management focus due to their agressive and/or invasive nature. The list below may not include all species officially designated in any jurisdiction as "noxious weeds." Instead, this is a list of species of major managerial concern.

Those species below that show values greater than zero were recorded on at least one polygon in the set being summarized. The total area covered by each listed species (acres) and the percent of the area covered by that species across all polygons is shown. For more information on how these data were determined, and on their ecological significance, refer to Invasive Plant Species in the appropriate Lotic/Lentic Wetland Health Assessment User Manual, accessible on the web at: www.ecologicalsolutionsgroup.com.

Total Channel or Shoreline Length (Miles): **0.40**

Total Size of Summary Set (Acres): **1.84**

Total Riparian/Wetland Acres: **1.84**

Total Area (Acres) of Weeds: **0.00**

Percent of Total Acres: **0.00**

Invasive Species (by Common Name)	Acres of Canopy Cover	Percent of Total Area Covered	Range of Individual Polygon Percent Area Covered Min		Max
bluebuttons:	—	—	—	to	—
Canada thistle:	0.00	0.00%	0.0%	to	0.5%
cheatgrass:	—	—	—	to	—
common burdock:	—	—	—	to	—
common cuprina:	—	—	—	to	—
common hound's-tongue:	—	—	—	to	—
common tansy:	—	—	—	to	—
Dalmatian toadflax:	—	—	—	to	—
diffuse knapweed:	—	—	—	to	—
Dyer's woad:	—	—	—	to	—
field bindweed:	—	—	—	to	—
field sow thistle:	—	—	—	to	—
Japanese brome:	—	—	—	to	—
leafy spurge:	—	—	—	to	—
musk thistle:	—	—	—	to	—
orange hawkweed:	—	—	—	to	—
oxeye daisy:	—	—	—	to	—
perennial pepperweed:	—	—	—	to	—
purple loosestrife:	—	—	—	to	—
Russian knapweed:	—	—	—	to	—
Russian olive:	—	—	—	to	—
saltcedar (tamarisk):	—	—	—	to	—
Scotch thistle:	—	—	—	to	—
spotted knapweed:	—	—	—	to	—
St. John's wort:	—	—	—	to	—
sulphur cinquefoil:	—	—	—	to	—
tall buttercup:	—	—	—	to	—
teasel:	—	—	—	to	—
whitetop:	—	—	—	to	—
yellow iris:	—	—	—	to	—
yellow starthistle:	—	—	—	to	—
yellow toadflax:	—	—	—	to	—
Others:					
	—	—	—	to	—
	—	—	—	to	—

Summary Name: **Bullion and Crystal Streams - TOTAL** Number of Polygons: **3**

Table 7. Habitat Types and Community Types
This table presents a list of all habitat types and community types recorded on all polygons of the summary set. Included is the total area (in acres) occupied by each type over the entire summary set, and the percent of the total area that is represented by each type. For more information on how these data were determined, and their ecological significance, refer to the Lotic/Lentic Wetland Health Assessment (Survey) User Manual, item D15, accessible on the web at: www.ecologicalsolutionsgroup.com. **NOTE:** Non-riparian polygons are are not included in the aggregate polygon information.

Total Channel or Shoreline Length (Miles): **0.40** Number of Types: **2**

Total Size of Summary Set (Acres): **1.84** Total Riparian/Wetland Acres: **1.84**

Habitat Type (HT) or Community Type (CT)	Phase	Area of Type (Acres)	Percent of Area
(UNCLASSIFIED WETLAND TYPE 1: Land exhibiting apparent wetland indicators, but can not be keyed to habitat type or community type.)		1.61	87.43%
Picea/Calamagrostis canadensis CT (spruce/bluejoint reedgrass CT)		0.19	10.07%

APPENDIX E

LOTIC WETLAND HEALTH ASSESSMENT FOR STREAMS AND SMALL RIVERS (SURVEY)

Appendix E contains the following parts:

- Blank Field Form
- User Manual

U.S. LOTIC WETLAND HEALTH ASSESSMENT FOR STREAMS AND SMALL RIVERS (Survey)

Record ID No: ____________

Unique Location ID: _____

ADMINISTRATIVE DATA

A1. Field data collected by: ____________________

A2. Funding Agency/Organization: ____________________

A3a. BLM State Office: ____________

A3b. BLM Field Office/Field Station: ____________________

A3c. BLM Office Code: ________ **A3d.** Is the polygon in an active BLM grazing allotment? (Yes; No; NA): ________

If ***Yes,* A3e:** Allotment Number: ______ **A3f:** Allotment Number: ______

Allotment ID: ____________ Allotment ID: ____________

Allotment Name: ____________ Allotment Name: ____________

Management Status: _____ Management Status: _____

A4. USFWS Refuge: ____________________

A5. Reservation: ____________________

A6. NPS Park/NHS: ____________________

A7. USFS National Forest: ____________________

A8. Other Location: ____________________

A9. Year: _____ **A10.** Date field data collected: ________ **A11.** Observers: ____________

A12a. At least some part of this polygon has been inventoried more than once (resampled)? (Yes; No): ________

If ***No,*** go to item **A13a.** If ***Yes,* A12b.** This polygon coincides exactly with another inventoried polygon? (Yes; No): _____

A12c. Is this the latest inventory for this polygon? (Yes; No): ______

A12d. ID No.(s) of other inventories of this polygon: ______, ______, ______, ______, ______

A12e. Other years: ____________________

A12f. This polygon shares common area with other inventoried polygon(s)? (Yes; No): _____ **A12g.** Other years: ________

A12h. ID No.(s) of other records sharing area with this polygon: ______, ______, ______, ______, ______

A13a. Has a change in management occurred? (Yes; No): _____ If ***Yes,* A13b.** Year that changed occurred: ________

A13c. Type of management change applied:

____

____

____

LOCATION DATA

B1. State/Province: ________ **B2.** County/Municipal District: ____________________

B3. Allotment/Range Unit: ____________________

B4a. Area name: ____________________

B4b. Tributary to: ____________________

B4c. Group name: ____________ **B4d.** Group number: _____ **B5.** Polygon number: ____________

B6. Location: 1/4 1/4 Sec: ____________ 1/4 Sec: ____________ Sec: ____________

Township (NS): ____________ Range (EW): ____________ **B7.** Elev. (ft): _____ ; (m): _____

B8a. Hydrologic unit code (HUC): ____________ **B8b.** Sub-basin name (4th level HUC): ____________

B8c. Sub-basin (sq mi): ________; (sq m): ____________ **B8d.** Sub-basin (ac): ________ ; (hect): ________

B8e. Sub-basin perimeter (mi): ________ ; (m): ____________

B9a. Polygon latitude/longitude coordinates: GPS Projection: ____________

		Deg	Min	Sec	N/S	Decimal		Deg	Min	Sec	E/W	Decimal	Accuracy +/- ft	Accuracy +/- m	Observer Initial & WPT
Upper:	Lat:						Lon:								
Lower:	Lat:						Lon:								
Other:	Lat:						Lon:								

B9b. Other Point Comments: ____________________

B10. Quad map(s): ____________________ ____________________

Unique Location ID: ____ Record ID No: ____________

SELECTED SUMMARY DATA

C1. Wetland type: ____________ **C2.** Polygon size (ac): ________ ; (hect): ______

C3a. Is the entire polygon an upland? (Yes; No): ______ If ***No,*** **C3b.** Does the polygon consist entirely of functional wetland types? (Yes; No): _____ **C3c.** Functional wetland (ac): ______ ; (hect): ______ **C3d.** Percent of total polygon: ______

C4. Does the polygon contain a defined streambank or channel? (Yes; No; NC): ______

C5. Channel length (mi): ______ ; (km): ______ **C6.** Number of river miles the polygon represents: ______ ; (km): ______

C7a. Average riparian zone width (ft): ______ ; (m): ______

C7b. Riparian zone width range (ft): ______ to ______ ; (m): ______ to ______

C8. Habitat Types and Community Types

Classification Type Name	Phase	Pct of Poly	Successional Stage or Comments

WATER QUALITY DATA

D1. Waterbody number: ____________

D2. Is the waterbody a 303(d) listed impaired stream? (Yes; No) _____ Year of listing: ______

D3. Waterbody TMDL priority: ____________

D4. TMDL development status: ____________

D5. Probable cause(s):

D6. Probable impaired uses:

D7. Probable source(s):

PHOTOGRAPH DATA

Unique Location ID: _____

E1a. Identification of photos (taken at the ***Upstream*** end of polygon): Roll #: __________ Photographer: __________

Photo nos.: (Upstream): __________ (DwnStream): __________ (others): __________

E1b. Location of "other" photos:

E1c. Descript. of views Upstream:

(Down-stream):

(others):

E2a. Identification of photos (taken at ***Downstream*** end of polygon): Roll #: __________ Photographer: __________

Photo nos.: (Upstream): __________ (DwnStream): __________ (others): __________

E2b. Location of "other" photos:

E1c. Descript. of views Upstream:

(Down-stream):

(others):

LOTIC WETLAND HEALTH ASSESSMENT SCORE SHEET

Data Record ID: ________

Unique Location ID: _____

	Actual Score	Possible Score	Comment
1. Vegetative Cover of Floodplain and Streambanks	_____	_____	_____
2a. Total Canopy Cover of Invasive Plant Species (Weeds)	_____	_____	_____
2b. Density Distribution Pattern of Invasive Plant Species (Weeds)	_____	_____	_____

Are invasive species present? (Yes; No; NC): ________

List Invasive Plant Species present, including Percent Canopy Cover and Density Distribution Class:

	Can.Cov.	Dens.Dist.		Can.Cov.	Dens.Dist.		Can.Cov	Dens.Dist.
bluebuttons:	____	____	Japanese brome:	____	____	St. John's wort:	____	____
Canada thistle:	____	____	leafy spurge:	____	____	sulphur cinquefoil:	____	____
cheatgrass:	____	____	musk thistle:	____	____	tall buttercup:	____	____
common burdock:	____	____	orange hawkweed:	____	____	teasel:	____	____
common cuprina:	____	____	oxeye daisy:	____	____	whitetop:	____	____
common hound's-tongue:	____	____	perennial pepperweed:	____	____	yellow iris:	____	____
common tansy:	____	____	purple loosestrife:	____	____	yellow starthistle:	____	____
dalmatian toadflax:	____	____	Russian knapweed:	____	____	yellow toadflax:	____	____
diffuse knapweed:	____	____	Russian olive:	____	____	Others: ________	____	____
Dyer's woad:	____	____	saltcedar (tamarisk):	____	____	Others: ________	____	____
field bindweed:	____	____	Scotch thistle:	____	____			
field sow thistle:	____	____	spotted knapweed:	____	____			

	Actual Score	Possible Score	Comment
3. Disturbance-increaser Undesirable Herbaceous Species	_____	_____	_____
4. Preferred Tree and Shrub Species Establishment and/or Regeneration	_____	_____	_____
5a. Browse Util. of Preferred Trees and Shrubs	_____	_____	_____
5b. Woody Veg. Removal other than Browsing	_____	_____	_____
6. Standing Decadent and Dead Woody Material	_____	_____	_____
Vegetation Subtotal:	_____	_____	
7. Streambank Root Mass Protection	_____	_____	_____
8. Human-Caused Bare Ground	_____	_____	_____
9. Streambank Structurally Altered by Human Activity	_____	_____	_____
10. Human Physical Alteration to the Rest of the Polygon	_____	_____	_____
11. Stream Channel Incisement (Vertical Stability)	_____	_____	_____
Soil / Hydrology Subtotal:	_____	_____	
Overall Polygon Total:	_____	_____	

RATING CALCULATION

(Actual Score/Possible Score) X 100 = Rating Percent — Descriptive Category

Vegetation Rating: _____ **/** _____ x **100 =** _____ ____________

Soil / Hydrology: _____ **/** _____ x **100 =** _____ ____________

OVERALL: _____ **/** _____ x **100 =** _____ ____________

Rating Percent Range	*Descriptive Category*
80-100	*Proper Functioning Condition (Healthy)*
60-79	*Functional At Risk (Healthy, but with Problems)*
<60	*Nonfunctional (Unhealthy)*

12. Polygon trend (Is the polygon: Improving, Degrading, Static, or Status Unknown?): ____________

Unique Location ID: _____ Data Record ID: ____________

13. Comments and Observations:

ADDITIONAL MANAGEMENT CONCERNS

The following items do not contribute to a site's score. Rather they help to quantify inherent physical site characteristics or assess the direction of change on a site. These data can be useful for planning future site management.

14a. Streambank rock volume: ____________

14b. Streambank rock size: ____________

15. Vegetation use by animals: ____________

16. Susceptibility of parent material to erosion: ____________

17. Percent of streambank accessible to livestock: ____________

18. Break down the polygon area into the land uses listed (must total to approx. 100%):

No land use apparent: ________
Turf grass (lawn): ________
Tame pasture (grazing): ________
Native pasture (grazing): ________
Recreation (ATV paths, campsites, etc.): ________
Development (buildings, corrals, paved lots, etc.): ________
Tilled cropping: ________
Perennial forage (e.g., alfalfa hayland): ________
Roads: ________
Logging: ________
Mining: ________
Railroads: ________
Other: ________

Description of Other Usage Noted:

19. Break down the area adjacent to the polygon into the land uses listed (must total to approx. 100%):

No land use apparent: ________
Turf grass (lawn): ________
Tame pasture (grazing): ________
Native pasture (grazing): ________
Recreation (ATV paths, campsites, etc.): ________
Development (buildings, corrals, paved lots, etc.): ________
Tilled cropping: ________
Perennial forage (e.g., alfalfa hayland): ________
Roads: ________
Logging: ________
Mining: ________
Railroads: ________
Other: ________

Description of Other Usage Noted:

U. S. LOTIC WETLAND HEALTH ASSESSMENT FOR STREAMS AND SMALL RIVERS (Survey) USER MANUAL (Current as of 1/18/2010)

The user manual is intended to accompany the *U. S. Lotic Wetland Health Assessment For Streams and Small Rivers (Survey) Form* for the rapid evaluation of lotic (riparian) wetlands. Use this form generally on streams less than 15 m (50 ft) wide. The *U. S. Lotic Health Assessment for Large River Systems* is available for assessing health on larger rivers. The threshold width is somewhat arbitrary, but generally taken as the size that becomes too deep and/or wide for humans or cattle to easily wade across. In addition, other forms are available for both inventory and survey of lentic (still water) wetlands.

ACKNOWLEDGEMENTS

Development of these assessment tools has been a collaborative and reiterative process. Many people from many agencies and organizations have contributed greatly their time, effort, funding, and moral support for the creation of these documents, as well as to the general idea of devising a way for people to look critically at wetlands and riparian areas in a systematic and consistent way. Some individuals and the agencies/organizations they represent who have been instrumental in enabling this work are Dan Hinckley, Tim Bozorth, and Jim Roscoe of the USDI Bureau of Land Management in Montana; Karen Rice and Karl Gebhardt of the USDI Bureau of Land Management in Idaho; Bill Haglan of the USDI Fish and Wildlife Service in Montana; Barry Adams and Gerry Ehlert of Alberta Sustainable Resource Development; Lorne Fitch of Alberta Environmental Protection; and Greg Hale and Norine Ambrose of the Alberta Cows and Fish Program.

BACKGROUND INFORMATION

Introduction

Public and private land managers are being asked to improve or maintain lotic (riparian) habitat and stream water quality on lands throughout western North America. Three questions that are generally asked about a wetland site are: 1) What is the potential of the site (e.g., climax or potential natural community)? 2) What plant communities currently occupy the site? and 3) What is the overall health (condition) of the site? For a lotic (flowing water) site, the first two questions can be answered by using the Lotic Wetland Inventory Form along with a document such as *Classification and Management of Montana's Riparian and Wetland Sites* (Hansen and others 1995), *Classification and Management of USDI Bureau of Land Management's Riparian and Wetland Sites in Eastern and Southern Idaho* (Hansen and Hall 2002), *Classification and management of upland, riparian, and wetland sites of USDI Bureau of Land Management's Miles City Field Office, eastern Montana USA* (Hansen and others 2008), or a similar publication written for the region in which you are working.

The health assessment survey is a method for rapidly addressing the third question above: What is the site's overall health (condition)? It provides a site rating useful for setting management priorities and stratifying riparian sites for remedial action or more rigorous analytical attention. It is intended to serve as a first approximation, or "coarse filter," by which to identify lotic wetlands in need of closer attention so that managers can more efficiently concentrate effort. We use the term "riparian health" to mean the ability of a riparian reach (including the riparian area and its channel) to perform certain functions. These functions include sediment trapping, bank building and maintenance, water storage, aquifer recharge, flow energy dissipation, maintenance of biotic diversity, and primary production. Excellent sources of practical ideas and tips on good management of these streamside wetland sites are found in *Caring for the Green Zone* (Adams and Fitch 1995), *Riparian Areas: A User's Guide to Health* (Fitch and Ambrose 2003), and *Riparian Health Assessment for Streams and Small Rivers* (Fitch and others 2001).

Flowing Water (Lotic) Wetlands vs. Still Water (Lentic) Wetlands

Cowardin and others (1979) point out that no single, correct definition for wetlands exists, primarily due to the nearly unlimited variation in hydrology, soil, and vegetative types. Wetlands are lands transitional between aquatic (water) and terrestrial (upland) ecosystems. Windell and others (1986) state that "wetlands are part of a continuous landscape that grades from wet to dry. In many cases, it is not easy to determine precisely where they begin and where they end."

In the semi-arid and arid portions of western North America, a useful distinction has been made between wetland types based on association with different aquatic ecosystems. Several authors have used ***lotic*** and ***lentic*** to separate wetlands associated with running water from those associated with still water. The following definitions represent a synthesis and refinement of terminology from Shaw and Fredine (1956), Stewart and Kantrud (1972), Boldt and others (1978), Cowardin and others

(1979), American Fisheries Society (1980), Johnson and Carothers (1980), Cooperrider and others (1986), Windell and others (1986), Environmental Laboratory (1987), Kovalchik (1987), Federal Interagency Committee for Wetland Delineation (1989), Mitsch and Gosselink (1993), and Kent (1994).

Lotic wetlands are associated with rivers, streams, and drainage ways. They contain a defined channel and floodplain. The channel is an open conduit, which periodically or continuously carries flowing water. Beaver ponds, seeps, springs, and wet meadows on the floodplain of, or associated with, a river or stream are part of the lotic wetland.

Lentic wetlands are associated with still water systems. These wetlands occur in basins and lack a defined channel and floodplain. Included are permanent (i.e., perennial) or intermittent bodies of water such as lakes, reservoirs, potholes, marshes, ponds, and stockponds. Other examples include fens, bogs, wet meadows, and seeps not associated with a defined channel.

Functional vs. Jurisdictional Wetland Criteria

Defining wetlands has become more difficult as greater economic stakes have increased the potential for conflict between politics and science. A universally accepted wetland definition satisfactory to all users has not yet been developed because the definition depends on the objectives and the field of interest. However, scientists generally agree that wetlands are characterized by one or more of the following features: 1) ***wetland hydrology,*** the driving force creating all wetlands, 2) ***hydric soils,*** an indicator of the absence of oxygen, and 3) ***hydrophytic vegetation,*** an indicator of wetland site conditions. The problem is how to define and obtain consensus on thresholds for these three criteria and various combinations of them.

Wetlands are not easily identified and delineated for jurisdictional purposes. Functional definitions have generally been difficult to apply to the regulation of wetland dredging or filling. Although the intent of legislation is to protect wetland functions, the current delineation of jurisdictional wetland still relies upon structural features or attributes.

The prevailing view among many wetland scientists is that ***functional wetlands need*** to meet only one of the three criteria as outlined by Cowardin and others (1979) (e.g., hydric soils, hydrophytic plants, and wetland hydrology). On the other hand, ***jurisdictional wetlands need to*** meet all three criteria, except in limited situations. Even though functional wetlands may not meet jurisdictional wetland requirements, they certainly perform wetland functions resulting from the greater amount of water that accumulates on or near the soil surface relative to the adjacent uplands. Examples include some woody draws occupied by the *Fraxinus pennsylvanica*/*Prunus virginiana* (green ash/common chokecherry) habitat type and some floodplain sites occupied by the *Artemisia cana*/*Agropyron smithii* (silver sagebrush/western wheatgrass) habitat type or the *Pinus ponderosa*/*Cornus stolonifera* (ponderosa pine/red-osier dogwood) habitat type. Currently, many of these sites fail to meet jurisdictional wetland criteria. Nevertheless, these sites do provide important wetland functions and may warrant special managerial consideration. The current interpretation, at least in the western United States, is that not all functional wetlands are jurisdictional wetlands, but all jurisdictional wetlands are functional wetlands.

Lotic (Riparian) Health

As noted above, the health of a lotic site (a wetland, or riparian area, adjacent to flowing water) may be defined as the ability of that system to perform certain wetland functions. These functions include sediment trapping, bank building and maintenance, water storage, aquifer recharge, flow energy dissipation, maintenance of biotic diversity, and primary biotic production. A site's health rating may also reflect management considerations. For example, although *Cirsium arvense* (Canada thistle) or *Euphorbia esula* (leafy spurge) may help to trap sediment and provide soil-binding properties, other functions (i.e., productivity and wildlife habitat) will be impaired; and their presence should be a management concern.

No single factor or characteristic of a wetland site can provide a complete picture of either site health or the direction of trend. The lotic health assessment is based on consideration of physical, hydrologic, and vegetation factors. It relies heavily on vegetative characteristics as integrators of factors operating on the landscape. Because they are more visible than soil or hydrologic characteristics, plants may provide early indications of riparian health as well as successional trend. These are reflected not only in the types of plants present, but also by the effectiveness with which the vegetation carries out its wetland functions of stabilizing the soil, trapping sediments, and providing wildlife habitat. Furthermore, the utilization of certain types of vegetation by animals may indicate the current condition of the wetland and may indicate trend toward or away from potential natural community (PNC).

In addition to vegetation factors, an analysis of site health and its susceptibility to degradation must also consider physical factors (soils and hydrology) for both ecologic and management reasons. Changes in soil or hydrologic conditions obviously affect the function of a wetland ecosystem. Moreover, degradation in physical factors is often (but not always) more difficult to remedy than vegetative degradation. For example, extensive incisement (down-cutting) of a stream channel may lower the water table and thus change site potential from a *Salix lutea/Carex rostrata* (yellow willow/beaked sedge) habitat type to a *Bromus inermis* (smooth brome) community type or even to an upland (non-riparian) type. Sites experiencing significant hydrologic, edaphic (soil), or climatic changes will likely also have new plant community potential.

This health assessment method attempts to balance the need for a simple, quick index of health against the reality of an infinite variety of wetland situations. Although this approach will not always work perfectly, we believe in most cases it will yield a usefully accurate rating of riparian health. Some more rigorous methods to determine status of a stream's channel morphology are Dunne and Leopold (1978), Pfankuch (1975), and Rosgen (1996). These relate their ratings to degree of channel degradation, but do not integrate other riparian functions into the rating. Other methods are available for determining condition from perspectives that also include vegetation, most notably the USDI Bureau of Land Management (BLM) proper functioning condition (PFC) methodology (1998).

This rapid assessment procedure has been tested in Montana, Idaho, North Dakota, South Dakota, and other surrounding states and western Canada since 1992. Some potential uses for this rating are: 1) for stratifying streams or stream reaches by degree of ecologic dysfunction, 2) for identifying ecologic problems, and 3) when repeated over time, for monitoring to detect functional change. A less direct, but also important, value of an environmental assessment of this kind is its educational potential. By getting land managers to focus on individual riparian functions and ecologic processes, they may come to better understand how the parts work together and are affected by human activities.

This method is not designed for an in-depth and comprehensive analysis of ecologic processes. Such analysis may be warranted on a site and can be done after this evaluation has identified areas of concern. Nor does this approach yield an absolute rating to be used in comparison with streams in other areas or of other types. Comparisons using this rating with streams of different types (Rosgen 1996), different orders (size class), or from outside the immediate locality should be avoided. Appropriate comparisons using this rating can be made between segments of one stream, between neighboring streams of similar size and type, and between subsequent assessments of the same site.

A single evaluation provides a rating at only one point in time. Due to the range of variation possible on a riparian site, a single evaluation cannot define absolute status of site health or reliably indicate trend (whether the site is improving, degrading, or stable). To monitor trend, health assessments should be repeated in subsequent years during the same time of year. Evaluation should be conducted when most plants can be identified in the field and when hydrologic conditions are most nearly normal (e.g., not during peak spring runoff or immediately after a major storm). Management regime should influence assessment timing. For example, in assessing trend on rotational grazing systems, one should avoid comparing a rating after a season of use one year to a rating another year after a season of rest.

There are some visible changes to riparian area health which we have no simple way to measure. An obvious and commonly encountered example is excess entrained sediment. This may indicate serious degradation, but we leave it out of the assessment due to difficulty in knowing how much is normal. Instead, we address on-site causes of sediment production: bare ground, banks with poor root mass protection, and human-caused structural damage to the banks. Another potentially serious degrading factor for which we have no simple measurement yet is dewatering of the system by irrigation diversion/pumping and by upper drainage retention dams.

Pre-Assessment Preparation

The lotic wetland health assessment process incorporates data on a wide range of biological and physical categories. The basic unit of delineation upon which an assessment is made is referred to as a ***polygon.*** Polygons are delineated on topographic maps by marking the upper and lower ends before evaluators go to the field. (The widths of most riparian zones are unknown before the inventory and cannot be pre-marked.) On the topographic maps, most polygons are usually drawn as a single line following the stream or river and are numbered sequentially proceeding downstream. It is important to clearly mark and number the polygons on the map. Polygons are numbered pre-field (in the office) with consecutive integers (1, 2, 3 . . .). In cases where field inspection shows the need to change the delineation or to subdivide the pre-drawn polygons, additional polygons should be numbered using alpha-numerics (e.g., 1a, 1b, 2a, 2b, etc.). Combinations of delineated polygons will be field identified as the hyphenated tags of both combined parts (e.g., 1-2, 2-3, etc.).

If aerial photos are available, pre-field polygon delineations may be based on vegetation differences, geologic features, or other observable characteristics. On larger systems with wide riparian areas, aerial photos may allow the pre-field drawing of multiple polygons away from the river. In these cases, where polygons can be drawn as enclosed units (instead of just as a line), a minimum mapping unit of 5 to 10 ac (2 to 4 ha) should be used. The size of the minimum mapping unit should be based on factors such as management capabilities and the costs and capabilities of data collection.

Upper and lower polygon boundaries are placed at distinct locations such as fences, stream confluences, or stream meanders that can be recognized in the field. Polygons should not cross fences between areas with different management. In most cases, polygons are delineated 0.4 km to 1.2 km (0.25-0.75 mi) long. On smaller streams, polygons include the land on both sides of the stream. On large rivers, or if property ownership or access differs, polygons may include only one side of a stream.

Once in the field, evaluators will verify (ground truth) the office-delineated polygon boundaries. If the pre-assigned numbers are used, be sure the inventoried polygons correspond exactly as drawn originally. Evaluators are allowed to move polygon boundaries, create new polygons, or consolidate polygons if the vegetation, geography, location of fences, or width of the wetland zone warrant. If polygon boundaries are changed, the changes must be clearly marked on the field copies of the topographic maps. The original polygon numbers should be retained on the map for cross-reference.

Selection of a Reach to Evaluate

If time is available, or the length of stream in question is short, the entire stream can be assessed. If not, then one or more reaches may represent the whole. The evaluator may choose either a ***critical*** reach (an especially sensitive spot) or one ***representing*** (typical of) the larger area. It may be wise to assess both critical and representative reaches. To determine what is actually representative, evaluators must become familiar with the entire length of the designated stream and adjacent riparian area. This will require walking the entire length.

Identification of plant communities by vegetation type (such as Hansen and others 1995, Hansen and others 2008, Hansen and Hall 2002, etc.) will be useful both in site selection and, later, in determining appropriate management. These communities may be in a mosaic difficult to map. An area may have a mix of herbaceous communities, shrubs, and forest. These communities have diverse resource values and may respond differently to a management action, but it is seldom practical to manage such communities separately. Community composition can be described as percentages of component types. Management actions can then be keyed to the higher priority types present.

We recommend the length of reach be at least one channel meander cycle, although two is preferable. Streambank problems will be overestimated if the reach is located mostly on an outside curve and underestimated if it is mostly on an inside curve. A complete meander cycle has equal inside and outside curvature (Figure 1).

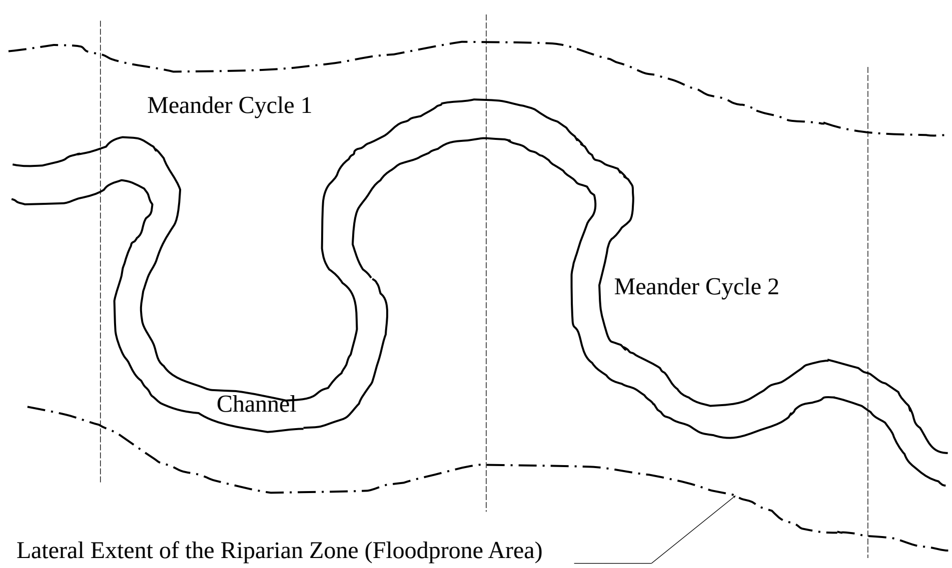


Figure 1. A schematic example of meander cycle delineation showing two cycles

Scale should be considered in determining reach length. Whereas a 180 m (600 ft) reach length may include two meander cycles on smaller streams, such a length would be inadequate on a river 30 m (100 ft) wide. If the reach to be assessed must be shorter than a full meander cycle, the evaluator should look beyond the delineated reach to include a full meander cycle when rating channel morphology and streambank factors. If it is impractical to assess a full meander cycle, we recommend a 180 m (600 ft) minimum length.

In addition to reach length, riparian zone width must be considered. The outer boundaries of riparian polygons are at the wetland vegetative type outer edges. These boundaries are sometimes clearly defined by abrupt changes in the geography and/or vegetation, but proper determination often depends on experienced interpretation of more subtle differences. The area to be assessed includes any terraces dominated by facultative wetland and wetter plant species (Reed 1988), the active floodplain, streambanks, and areas in the channel with emergent vegetation (Figure 2). Reference to Reed's list of plants found in wetlands should not be necessary to determine the area for evaluation. The evaluator should simply focus on that area which is obviously more lush, dense, or greener by virtue of proximity to the stream.

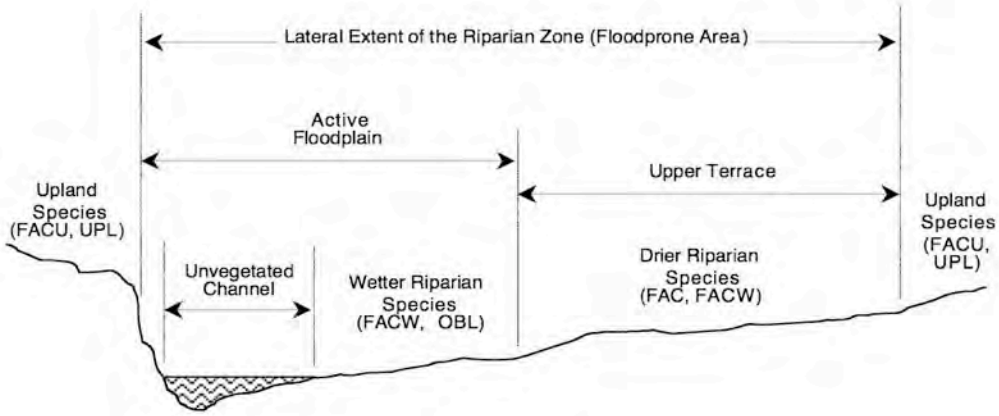


Figure 2. A schematic example of a typical riparian zone cross section showing near-channel landform features. *Note:* FAC (facultative), OBL (obligate), UPL (upland), etc. refer to categories of frequency a species is found in wetlands (Reed 1988).

The location of the inner (or streamside) polygon boundary must be known (at least approximately), even on polygons that span the stream. On most streams the area of the channel bottom is excluded from the polygon. (***Note:*** *The whole channel width extends from right bankfull stage to left bankfull stage; however we need to include the lower banks in all polygons, therefore consider for exclusion ONLY the relatively flat and lowest area of the channel—the "bottom."*) This allows data to be collected on the riparian area while excluding the aquatic zone, or open water, of the stream. The aquatic zone is the area covered by water and lacking persistent emergent vegetation. Persistent emergent vegetation consists of perennial wetland species that normally remain standing at least until the beginning of next growing season, e.g., *Typha* species (cattails), *Scirpus* species (bulrushes), *Carex* species, and other perennial graminoids.

In many systems, large portions of the channel bottom may become exposed due to seasonal irrigation use, hydroelectric generation, and natural seasonal changes such as are found in many prairie ecosystems. In these cases, especially the prairie streams, the channel bottom may have varying amounts of herbaceous vegetation, and the channel area is ***included*** in the polygon as area to be inventoried. Typically these are the "pooled channel" stream type that has scour pools scattered along the length, interspersed with reaches of grass, bulrush, or sedge-covered channel bottom. If over half (>50%) the channel bottom area has a canopy cover of persistent vegetation cover (perennial species), then it qualifies for inclusion within the inventoried polygon area. If you are in doubt whether to include the channel bottom in the polygon, then leave it out, but be sure to indicate this in the comment section. This is important so that future assessments of the polygon will be looking at the same area of land.

Assessments should not cross fences between areas with different management. If the stream to be rated crosses more than one management unit, at least one reach should be assessed in each unit. Fences exert a strong influence on livestock movement and grazing patterns; therefore, assessed reaches should be located at least 75 m (250 ft) from any fence. The evaluation should include the riparian zone on both sides of the stream if both are under the same management. Along a large stream, the same operator may not manage both sides. The channel may be so large that livestock (or evaluators) cannot easily cross. In such cases it may not be feasible to evaluate both sides at once.

DATA FORM ITEMS

Record ID No. This is the unique identifier allocated to each polygon. This number will be assigned in the office when the form is entered into the database.

Administrative Data

A1. Agency or organization collecting the data.

A2. Funding Agency/Organization.

A3a. BLM (Bureau of Land Management) State Office.

A3b. BLM Field Office/Field Station.

A3c. BLM Office Code (recorded in the office).

A3d. Is the polygon in an active BLM grazing allotment (recorded in the office)?

A3e, f. For BLM polygons, the BLM Office Code, whether the polygon is in an active BLM grazing allotment, and the Allotment Number is supplied by the BLM. These items are entered into the computer in the office; the computer then references a master list of Allotment ID's to complete the remaining Allotment information. Because some polygons incorporate more than one Allotment, space is provided to enter two sets of Allotment information. The master Allotment list is periodically updated by the BLM National Applied Resource Sciences Center to make needed corrections.

A4. USDI Fish and Wildlife Service Refuge name.

A5. Indian Reservation name.

A6. USDI National Park Service Park/National Historical Site name.

A7. USFS (Forest Service) National Forest name.

A8. Other location.

A9. Year the field work was done.

A10. Date of field work by day, month, and year.

A11. Names of all field data observers.

Note: Information for items **A12a-h** is found in the office; field evaluators need not complete these items.

A12. The several parts of these items identify various ways in which a data record may represent a resampling of a polygon that may have been inventoried again at some other time. The data in this record may have been collected on an area that coincides precisely with an area inventoried at another time and recorded as another record in the database. It may also represent the resampling of only a part of an area previously sampled. This would include the case where this polygon overlaps, but does not precisely and entirely coincide with one inventoried at another time. One other case is where more than one polygon inventoried one year coincides with a single polygon inventoried another year. All of these cases are represented in the database, and all have some value for monitoring purposes, in that they give some information on how the status on a site changes over time. ***This is done in the office with access to the database; field evaluators need not complete these items.***

A12a. Has any part of the area within this polygon been inventoried previously, or subsequently, as represented by any other data record in the database? Such other records would logically carry different dates.

A12b. Does the areal extent of this polygon exactly coincide with that of any other inventory represented in the database? In many cases, subsequent inventories only partially overlap spatially. The purpose of this question is to identify those records that can be compared as representing exactly the same ground area.

A12c. Does this record represent the latest data recorded for this site (polygon)?

A12d. If A12b is answered “Yes,” then enter the record ID number(s) of any other previous or subsequent re-inventories (resampling) of this exact polygon for purposes of cross-reference.

A12e. Enter the years of any records recorded in item A12d as representing other inventories of this exact polygon.

A12f. Even though this polygon is not a re-inventory of the exact same area as any other polygon, does it share at least some common area with one or more polygons inventoried at another time?

A12g. Enter the years of any other inventories of polygons sharing common ground area with this one.

A12h. If A12f is answered “Yes,” then enter the record ID number(s) of any other polygon(s) sharing common ground area with this one.

A13a. Has a management change been implemented on this polygon?

A13b. If A13a is answered “Yes,” in what year was the management change implemented?

A13c. If A13a is answered “Yes,” describe the management change implemented.

Location Data
B1. State in which the field work was done (recorded in the office).

B2. County or municipal district in which the field work was done (recorded in the office).

B3. This field for allotment or range unit is intended for entities other than the BLM to use for grouping polygons by management unit. The BLM management units are grouped using the grazing allotment information in A3 above.

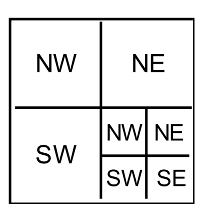
B4a. For lentic polygons the area is usually listed as a lake name, or other local designation that identifies the area where the inventory is conducted. If possible, use a name that is shown on the 7.5 minute topographic map.

B4b. Record the stream (if there is one) with which the inventoried lentic wetland is associated. Such association may be by inlet or outlet surface flow, or by general ground water (sub surface) connection.

B4c, d. Polygons are grouped together for management purposes. For example, all polygons around Henry’s Lake in the Idaho Falls Field Office could be identified as Group Name: Idaho Falls Field Office; Group Number: 1 (recorded in the office).

B5. Polygon number is a sequential identifier of the portion of the area assessed. This is referenced to the map delineations. Sequences normally progress clockwise.

B6. The Township, Range, Section, 1/4 section, and 1/4–1/4 section is the location of the midpoint of the polygon area. When reading this information as a legal description, the order is presented from smallest to largest unit. Below is a schematic showing the quarter sections, with the SE quarter divided into quarter-quarters.



B7. Elevation (feet or meters) of the polygon midpoint. Elevation is interpolated from the topographic map(s).

B8a-e. The US Geological Survey has divided the nation into successively smaller hydrologic units based on drainage basins. These units in the United States are subdivided into fourth levels, uniquely identified by a two-digit number for each level. This results in a eight-digit identifier for a drainage at the fourth level. Some regions have units defined to the fifth and sixth level (finer scales). (Data is entered in the office.)

B9a. Record the latitude and longitude of the polygon, along with the GPS projection and accuracy. Record the degrees, minutes, and seconds. ***Note: All of North America is latitude = North, and longitude = West.***

B9b. Record any comments pertaining to the location of the polygon.

B10. Record the name(s) of the 7.5 minute quadrangle map(s) locating the polygon using precisely the name listed on the map sheet. Provision is made for listing two maps in case the polygon crosses between two maps.

Selected Summary Data

C1. Wetland type is a categorical description of predominant polygon character. Select from the following list of categories that may occur within a lotic system the one that best characterizes the majority of the polygon. Evaluators will ***select only one category*** as representative of the entire polygon. If significant amounts of other categories are present, indicate this in the last item, "Comments and Observations," or consider dividing the original polygon into two or more polygons.

Category Description

Perennial Stream. A stream or stretch of stream that flows continuously for most of most years. Perennial streams are generally fed in part by springs or discharge from groundwater. Perennial streams are distinguished from larger rivers by size. Streams wider than 15 m (50 ft) are considered rivers for the purpose of this inventory (see below).

Intermittent Stream. A stream or stretch of stream which flows only at certain periods of the year when it receives water from springs, discharge from groundwater, or melting snow in mountainous areas. These streams generally flow continuously at least one month most years.

Ephemeral Stream. A stream or stretch of stream that flows in normal water years only in direct response to precipitation. In normal years, it receives no water from springs and no extended supply from melting snow or other surface source. Ephemeral streams are not in contact with groundwater and normally do not flow continuously for as long as one month. Not all ephemeral streams support riparian plant communities.

Subterranean Stream. A stream that flows underground for part of the stream reach. This occurs on systems composed of coarse textured, porous substrates. Surface flow may disappear and re-emerge farther downstream.

Pooled Channel Stream. An intermittent stream that has significant channel pools after surface flow ceases. Pools are generally at meander curves and are usually considerably deeper than the rest of the channel bottom. Water sources for the pools may be springs or contact with subsurface groundwater. This stream type is typical of fine textured sedimentary plains in semi-arid regions where headwater drainages lack the extended runoff of deep mountain snowpack. This stream type may not be apparent early in the season when flow is continuous.

River. Rivers are generally larger than streams. They flow year around, in years of normal precipitation and when significant amounts of water are not being diverted out of them. Those watercourses called rivers on topographic quads and/or those having bankfull channel widths greater than 15 m (50 ft) will be classified as rivers for the purpose of this inventory.

Beaver Dams. A system that is predominantly characterized by beaver dams that change the character of the system from a regular flowing channel to a "stepped" system of ponds where water is spread wide and flow velocity is apparent only at each dam outlet before it enters the next pond. Water is still flowing through the riparian system.

Wet Meadow. This type of wetland may occur in either running water (lotic) or in still water (lentic) systems. A lotic wet meadow has a defined channel or flowing surface water nearby, but is typically much wider than the riparian zone associated with the classes described above. This is often the result of the influence of lateral groundwater not associated with the stream flow. Lotic and lentic wet meadows may occur in proximity (e.g., when enough groundwater emerges to begin to flow from a mountain meadow, the system goes from lentic to lotic). Such communities are typically dominated by herbaceous hydrophytic vegetation that requires saturated soils near the surface, but tolerates no standing water for most of the year. This type of wetland typically occurs as the filled-in basin of old beaver ponds, lakes, and potholes.

Spring/Seep. Groundwater discharge areas. In general, springs have more flow than seeps. This wetland type may occur in a running water (lotic) or still water (lentic) system.

Irrigation Canal. Includes all types of canals and ditches associated with irrigation systems.
Other. Describe the water source (e.g., irrigation return flow, industrial discharge, etc.).
Upland. This designation is for those areas which are included in the inventoried polygon, but which do not support functional wetland vegetation communities. Such areas may be undisturbed inclusions of naturally occurring high ground or such disturbed high ground as roadways and other elevated sites of human activity.

C2. The size (acres/hectares) of polygons large enough to be drawn as enclosed units on 1:20,000 or 1:50,000 scale maps is determined in the office using a planimeter, dot grid, or GIS. For polygons too small to be accurately drawn as enclosed units on the maps, and which are represented by line segments on the map along the drainage bottom, polygon size is calculated using polygon length and average polygon width (items C5 and C7a).

C3a-d. Evaluators may be asked to survey some areas that have not been determined to be wetlands for the purpose of making such a determination. Other polygons include areas supporting non-wetland vegetation types. A "Yes" answer here indicates that no part of the polygon keys to a riparian habitat type or community type (HT/CT). Areas classified in item C8 as any vegetation type described in a riparian and/or wetland classification document for the region in which you are working are counted as functional wetlands. Areas listed as UNCLASSIFIED WETLAND TYPE are also counted as functional wetlands. Other areas are counted as non-wetlands, or uplands. The functional wetland fraction of the polygon area is listed in item C3c in acres and as a percentage of the entire polygon area in item C3d.

C4. Some riparian areas do not contain an unvegetated, defined stream channel. In some cases, these polygons are in ephemeral systems which may flow infrequently, but which do support riparian plant communities. In other cases, these polygons may be associated with larger river systems that have wide floodplains where polygons may be delineated in areas not adjacent to the channel.

C5. Channel length—the length of channel contained within or adjacent to the polygon—is measured by scaling from the map. This data is considered accurate to the nearest 0.16 km (0.1 mi).

C6. In some cases, the polygon record is used to characterize, or represent, a larger portion of a stream system. The length represented by the polygon is given here. For example, a 0.8 km (0.5 mi) polygon may be used to represent 6.4 km (4 mi) of a stream. In the case, 0.8 km (0.5 mi) is the channel length of the polygon (item C5), and 6.4 km (4 mi) is entered in item C6.

C7a. Record average width of the polygon, which on smaller streams corresponds to the width of the riparian zone. To determine this width, subtract the width of the non-vegetated stream channel (item F9) from the distance between the two opposite riparian/upland boundaries. In the case of very wide systems where the polygon inventoried does not extend across the full width of the riparian zone (e.g., area with riparian vegetation communities lies outside the polygon), record the average width of the polygon inventoried and make note of the situation in the narrative comments.

C7b. Record the range of width (ft/m), narrowest to widest, of the riparian zone in the polygon.

C8. List the riparian habitat type(s) and/or community type(s) found in the polygon using a manual for identifying types in the region in which you are working, such as *Classification and Management of Montana's Riparian and Wetland Sites* (Hansen and others 1995), *Classification and Management of USDI Bureau of Land Management's Riparian and Wetland Sites in Eastern and Southern Idaho* (Hansen and Hall 2002), *Classification and management of upland, riparian, and wetland sites of USDI Bureau of Land Management's Miles City Field Office, eastern Montana USA* (Hansen and others 2008), or a similar publication written for the region in which you are working. If the habitat type cannot be determined for a portion of the polygon, then list the appropriate community type(s) of that portion. If neither the habitat type nor community type can be determined for any portion of the polygon (or in areas where the habitat and community types have not been named and described), list the area in question as "unclassified wetland type" and give the dominant species present. Indicate with the appropriate abbreviation if these are habitat types (HT), community types (CT), or dominance types (DT), for example, PSEMEN/CORSTO HT. For each type listed, estimate the percent of the polygon represented. If known, record the successional stage (i.e., early seral, mid-seral, late seral, and climax), or give other comments about the type. As a minimum, list all types which cover 5% or more of the polygon. The total must approximate 100%. Slight deviations due to use of class codes or to omission of types covering less than 5% of the polygon are allowed. ***Note:*** For any area classified as an "unclassified wetland type," it is important to list any species present which can indicate the wetness or dryness of the site.

NOTE: Open water in the polygon that does not have emergent vegetation, but that is less than 2 m (6.6 ft) deep is counted here as a "type" called "Open Water."

Water Quality Data
Note: This data will be entered in the office.

D1-D2. For Montana, this information can be obtained from the current state 303(d) list of impaired waters maintained by Montana Department of Environmental Quality. In other states, contact the appropriate agency.

D3. Enter High, Medium, or Low for TMDL development priority. Obtain from current federal/state 303(d) list of impaired waters.

D4. Enter TMDL development status: EPA approved, de-listed due to reassessment, incomplete at present. Obtain from state environmental health agency.

D5-D7. Enter probable causes, probable impaired uses, and probable sources. Information can be obtained from current state 303(d) list of impaired waters.

Photograph Data
Note: Take at least one photo upstream and one downstream at each end of every polygon. This applies even to situations where the polygon is at one end of an inventoried reach and one of the photos is taken into a non-inventoried area, as well as situations in which another polygon is adjacent to the one being inventoried.

E1a-c. Identify the film roll/digital card number, photo (frame) number, photographer, camera used, and the description of each photograph taken at the ***upstream*** end of the polygon. List them in the order of upstream (out of polygon) views first, then downstream (into polygon) views, and then each other shot taken to show other features of interest.

E2a-c. Identify the film roll/digital card number, photo (frame) number, photographer, camera used, and the description of each photograph taken at the ***downstream*** end of the polygon. List them in the order of downstream (out of polygon) views first, then upstream (into polygon) views, and then each other shot taken to show other features of interest.

FACTORS FOR ASSESSING LOTIC WETLAND HEALTH (SURVEY)

Some factors on the evaluation will not apply on all sites. For example, sites without potential for woody species are not rated on factors concerning trees and shrubs. Vegetative site potential can be determined by using a key to site type (e.g., Hansen and others 1995, 2008; Hansen and Hall 2002; Thompson and Hansen 2001, 2002, 2003, or another appropriate publication). On severely disturbed sites, vegetation potential can be difficult to determine. On such sites, clues to potential may be sought on nearby sites with similar landscape position.

Most of the factors rated in this evaluation are based on ocular estimations. Such estimation may be difficult on large, brushy sites where visibility is limited, but extreme precision is not necessary. While the rating categories are broad, evaluators do need to calibrate their eye with practice. It is important to remember that a health rating is not an absolute value. The factor breakout groupings and point weighting in the evaluation are somewhat subjective and are not grounded in quantitative science so much as in the collective experience of an array of riparian scientists, range professionals, and land managers.

The evaluator must keep in mind that this assessment form is designed to account for most sites and conditions in the applicable region. However, rarely will all the questions seem exactly to fit the circumstances on a given site. Therefore, try to answer each question with a literal reading. If necessary, explain anomalies in the comment section. Each factor below will be rated according to conditions observed on the site. The evaluator will estimate the scoring category and enter that value on the score sheet.

1. Vegetative Cover of Floodplain and Streambanks. Vegetation cover helps to stabilize banks, control nutrient cycling, reduce water velocity, provide fish cover and food, trap sediments, reduce erosion, and reduce the rate of evaporation (Platts and others 1987). On most streams the area of the channel bottom is excluded from the polygon. (***Note:*** *The whole channel width extends from right bankfull stage to left bankfull stage; however we need to include the lower banks in all polygons, therefore consider for exclusion ONLY the relatively flat and lowest area of the channel—the "bottom."*) This allows data to be collected on the riparian area while excluding the aquatic zone, or open water, of the stream. The aquatic zone is the area covered by water and lacking persistent emergent vegetation. Persistent emergent vegetation consists of perennial wetland species that normally remain standing at least until the beginning of next growing season, e.g., *Typha* species (cattails), *Scirpus* species (bulrushes), *Carex* species, and other perennial graminoids.

In many systems, large portions of the channel bottom may become exposed due to seasonal irrigation use, hydroelectric generation, and natural seasonal changes such as are found in many prairie ecosystems. In these cases, especially the prairie streams, the channel bottom may have varying amounts of herbaceous vegetation, and the channel area is ***included*** in the polygon as area to be inventoried. Typically these are the "pooled channel" stream type that has scour pools scattered along the length, interspersed with reaches of grass, bulrush, or sedge-covered channel bottom. If over half (>50%) the channel bottom area has a canopy cover of persistent vegetation cover (perennial species), taken over the entire length of the polygon as a whole, then it qualifies for inclusion within the inventoried polygon area. If you are in doubt whether to include the channel bottom in the polygon, then leave it out, but be sure to indicate this in the comment section. This is important so that future assessments of the polygon will be looking at the same area of land.

The evaluator is to estimate the fraction of the polygon covered by plant growth. Vegetation cover is ocularly estimated using the canopy cover method (Daubenmire 1959).

Scoring:
6 = More than 95% of the polygon area is covered by live plant growth.
4 = 85% to 95% of the polygon area is covered by live plant growth.
2 = 75% to 85% of the polygon area is covered by live plant growth.
0 = Less than 75% of the polygon area is covered by live plant growth.

2. Invasive Plant Species (Weeds). Invasive plants (weeds) are alien species whose introduction does or is likely to cause economic or *environmental* harm. Whether the disturbance that allowed their establishment is natural or human-caused, weed presence indicates a degrading ecosystem. While some of these species may contribute to some riparian functions, their negative impacts reduce overall site health. This item assesses the degree and extent to which the site is infested by invasive plants. The severity of the problem is a function of the density/distribution (pattern of occurrence), as well as canopy cover (abundance) of the weeds. In determining the health score, all invasive species are considered collectively, not individually. A weed list should be used that is standard for the locality and that indicates which species are being considered. Space is provided on the form for recording weed species counted. Include both woody and herbaceous invasive species.

The site's health rating on this item combines two factors: weed density/distribution class and total canopy cover. A perfect score of 6 out of 6 points can only be achieved if the site is weed free. A score of 4 out of the 6 points means the weed problem is just beginning (i.e., very few weeds and small total canopy cover [less than 1%]). A moderate weed problem gets 2 out of 6 points. It has a moderately dense weed plant distribution (a class between 4 and 7) and moderate total weed canopy cover (between 1% and 15%). A site scores 0 points if the density/distribution is in class 8 or higher, or if the total weed canopy cover is 15% or more.

2a. Total Canopy Cover of Invasive Plant Species (Weeds). The evaluator must evaluate the total percentage of the polygon area that is covered by the combined canopy of all plants of all species of invasive plants. Determine which rating applies in the scoring scale below.

Scoring:
3 = No invasive plant species (weeds) on the site.
2 = Invasive plants present with total canopy cover less than 1% of the polygon area.
1 = Invasive plants present with total canopy cover between 1% and 15% of the polygon area.
0 = Invasive plants present with total canopy cover more than 15% of the polygon area.

2b. Density/Distribution Pattern of Invasive Plant Species (Weeds). The observer must pick a category of pattern and extent of invasive plant distribution from the chart below (Figure 3) that best fits what is observed on the polygon, while realizing that the real situation may be only roughly approximated at best by any of these diagrams. Choose the category that most closely matches the view of the polygon.

Scoring:
3 = No invasive plant species (weeds) on the site.
2 = Invasive plants present with density/distribution in categories 1, 2, or 3.
1 = Invasive plants present with density/distribution in categories 4, 5, 6, or 7.
0 = Invasive plants present with density/distribution in categories 8, or higher.

CLASS	DESCRIPTION OF ABUNDANCE	DISTRIBUTION PATTERN
0	No invasive plants on the polygon	
1	Rare occurrence	
2	A few sporadically occurring individual plants	
3	A single patch	
4	A single patch plus a few sporadically occurring plants	
5	Several sporadically occurring plants	
6	A single patch plus several sporadically occurring plants	
7	A few patches	
8	A few patches plus several sporadically occurring plants	
9	Several well spaced patches	
10	Continuous uniform occurrence of well spaced plants	
11	Continuous occurrence of plants with a few gaps in the distribution	
12	Continuous dense occurrence of plants	
13	Continuous occurrence of plants associated with a wetter or drier zone within the polygon.	

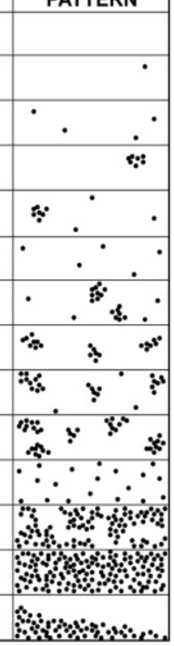


Figure 3. Weed density distribution class guidelines

NOTE: Prior to the 2001 season, the health score for weed infestation was assessed from a single numerical value that does not represent weed canopy cover, but instead represents the fraction of the polygon area on which weeds had a well established population of individuals (i.e., the area infested).

3. Disturbance-Increaser Undesirable Herbaceous Species. A large cover of disturbance-increaser undesirable herbaceous species, native or exotic, indicates displacement from the potential natural community (PNC) and a reduction in riparian health. These species generally are less productive, have shallow roots, and poorly perform most riparian functions. They usually result from some disturbance, which removes more desirable species. Invasive species considered in the previous item are not reconsidered here. As in the previous item, the evaluator should state the list of species considered. A partial list of undesirable herbaceous species appropriate for use in follows. A list should be used that is standard for the locality and that indicates which species are being considered. The evaluator should list any additional species included.

Amaranthus spp. (pigweed)	*Antennaria* spp. (pussy-toes)	*Brassicaceae* (mustards)
Fragaria spp. (strawberries)	*Kochia scoparia* (kochia; fire-weed)	*Medicago lupulina* (black medic)
Plantago spp. (plantains)	*Poa pratensis* (Kentucky bluegrass)	*Potentilla anserina* (silverweed)
Salsola iberica (Russian thistle; tumbleweed)	*Taraxacum* spp. (dandelion)	*Trifolium* spp. (clovers)
______________________________	______________________________	______________________________

Scoring:
3 = Less than 5% of the site covered by disturbance-increaser undesirable herbaceous species.
2 = 5% to 25% of the site covered by disturbance-increaser undesirable herbaceous species.
1 = 25% to 50% of the site covered by disturbance-increaser undesirable herbaceous species.
0 = More than 50% of the site covered by disturbance-increaser undesirable herbaceous species.

4. Preferred Tree and Shrub Establishment and/or Regeneration. (*Skip this item if the site lacks potential for trees or shrubs; for example, the site is a herbaceous wet meadow or marsh.*) Not all riparian areas can support trees and/or shrubs. However, on those sites where such species do belong, they play important roles. The root systems of woody species are excellent bank stabilizers, while their spreading canopies provide protection to soil, water, wildlife, and livestock. Young age classes of woody species are important for the continued presence of woody communities not only at a given point in time but into the future. Woody species potential can be determined by using a key to site type (Hansen and others 1995, 2008; Hansen and Hall 2002; Thompson and Hansen 2001, 2002, 2003, etc.). On severely disturbed sites, the evaluator should seek clues to potential by observing nearby sites with similar landscape position. (***Note:*** Vegetation potential is commonly underestimated on sites with a long history of disturbance.)

The following species are excluded from the evaluation:

- *Artemisia cana* (silver sagebrush), including subsp. *cana* and *viscidula*;
- *Artemisia frigida* (fringed sagewort);
- *Crataegus* species (hawthorn);
- *Elaeagnus angustifolia* (Russian olive);
- *Gutierrezia sarothrae* (broom snakeweed);
- *Rosa* species (rose);
- *Sarcobatus vermiculatus* (greasewood);
- *Symphoricarpos* spp. (snowberry);
- *Tamarix* species (salt cedar); and
- non-native species.

These are species that may reflect long-term disturbance on a site, that are generally less palatable to browsers, and that tend to increase under long-term moderate-to-intense grazing pressure; ***AND*** for which there is rarely any problem in maintaining presence on site. Examples of the latter include *Artemisia cana* (silver sagebrush) and *Sarcobatus vermiculatus* (greasewood). Both are considered climax species in many riparian situations and rarely have any problem maintaining a presence on a site. Only under extreme long-term grazing pressures will these species be eliminated from a site. On the other hand, *Elaeagnus angustifolia* (Russian olive) and *Tamarix* species (salt cedar) are especially aggressive, undesirable exotic plants.

The main reason for excluding these plants is that they are far more abundant on many sites than are species of greater concern (i.e., *Salix* species [willows], *Cornus stolonifera* [red-osier dogwood], *Amelanchier alnifolia* [Saskatoon serviceberry], and many other taller native riparian species), and they may mask the ecological significance of a small amount of a species of greater concern. ***FOR EXAMPLE:*** A polygon may have *Symphoricarpos occidentalis* (western snowberry) with 30% canopy cover showing young plants for replacement of older ones, while also having a trace of *Salix exigua* (sandbar willow) present, but represented only by older mature individuals. We feel that the failure of the willow to regenerate (even though there is only a small amount) is very important in the health evaluation, but by including the snowberry and willow together on this polygon, the condition of the willow would be hidden (overwhelmed by the larger amount of snowberry).

For shrubs in general, seedlings and saplings can be distinguished from mature plants as follows. For those species having a mature height generally over 6.0 ft (1.8 m), seedlings and saplings are those individuals less than 6.0 ft (1.8 m) tall. For species normally not exceeding 6.0 ft (1.8 m), seedlings and saplings are those individuals less than 1.5 ft (0.45 m) tall or which lack reproductive structures and the relative stature to suggest maturity. (***Note:*** Evaluators should take care not to confuse short stature resulting from intense browsing with that due to young plants.)

Scoring: *(If the site has no potential for trees or shrubs [except for the species listed above to be excluded], replace both Actual Score and Possible Score with NA. If the evaluator is not fairly certain potential exists for preferred trees or shrubs, then enter NC and explain in the comment field below.)*
6 = More than 15% of the total canopy cover of preferred trees/shrubs is seedlings and/or saplings.
4 = 5% to 15% of the total canopy cover of preferred trees/shrubs is seedlings and/or saplings.
2 = Less than 5% of the total canopy cover of preferred tree/shrubs is seedlings and/or saplings.
0 = Preferred tree/shrub seedlings and saplings absent.

5a. Browse Utilization of Available Preferred Trees and Shrubs. (*Skip this item if the site lacks trees or shrubs; for example, the site is a herbaceous wet meadow or cattail marsh, or all woody plants have already been removed.*) Livestock and/or wildlife browse many riparian woody species. Excessive browsing can eliminate these important plants from the community and result in their replacement by undesirable invaders. With excessive browsing, the plant loses vigor, is prevented from flowering, or is killed. Utilization in small amounts is normal and not a health concern, but concern increases with greater browse intensity.

The following species are excluded from the evaluation:

- *Artemisia cana* (silver sagebrush), including subsp. *cana* and *viscidula*;
- *Artemisia frigida* (fringed sagewort);
- *Crataegus* species (hawthorn);
- *Elaeagnus angustifolia* (Russian olive);
- *Gutierrezia sarothrae* (broom snakeweed);
- *Rosa* species (rose);
- *Sarcobatus vermiculatus* (greasewood);
- *Symphoricarpos* spp. (snowberry);
- *Tamarix* species (salt cedar); and
- non-native species.

These are species that may reflect long-term disturbance on a site, that are generally less palatable to browsers, and that tend to increase under long-term moderate-to-intense grazing pressure; ***AND*** for which there is rarely any problem in maintaining presence on site. Examples of the latter include *Artemisia cana* (silver sagebrush) and *Sarcobatus vermiculatus* (greasewood). Both are considered climax species in many riparian situations and rarely have any problem maintaining a presence on a site. Only under extreme long-term grazing pressures will these species be eliminated from a site. On the other hand, *Elaeagnus angustifolia* (Russian olive) and *Tamarix* species (salt cedar) are especially aggressive, undesirable exotic plants.

The main reason for excluding these plants is that they are far more abundant on many sites than are species of greater concern (i.e., *Salix* species [willows], *Cornus stolonifera* [red-osier dogwood], *Amelanchier alnifolia* [Saskatoon serviceberry], and many other taller native riparian species), and they may mask the ecological significance of a small amount of a species of greater concern. ***FOR EXAMPLE:*** A polygon may have *Symphoricarpos occidentalis* (western snowberry) with 30% canopy cover showing young plants for replacement of older ones, while also having a trace of *Salix exigua* (sandbar willow) present, but represented only by older mature individuals. We feel that the failure of the willow to regenerate (even though there is only a small amount) is very important in the health evaluation, but by including the snowberry and willow together on this polygon, the condition of the willow would be hidden (overwhelmed by the larger amount of snowberry).

Consider as available all tree and shrub plants to which animals may gain access and that they can reach. For tree species, this means mostly just seedling and sapling age classes. When estimating degree of utilization, count browsed second year and older leaders on representative plants of woody species normally browsed by ungulates. Do not count current year's use, because this would not accurately reflect actual use when more browsing can occur later in the season. Browsing of second year or older material affects the overall health of the plant and continual high use will affect the ability of the plant to maintain itself on the site. Determine percentage by comparing the number of leaders browsed or utilized with the total number of leaders available (those within animal reach) on a representative sample (at least three plants) of each tree and shrub species present. Do not count utilization on dead plants, unless it is clear that death resulted from over-grazing. ***Note:*** If a shrub is entirely mushroom/umbrella shaped by long term intense browse or rubbing, count utilization of it as heavy.

Scoring: (*Consider all shrubs within animal reach and seedlings and saplings of tree species. If the site has no woody vegetation [except for the species listed above to be excluded], replace both Actual Score and Possible Score with NA.*)
3 = None (0% to 5% of available second year and older leaders of preferred species are browsed).
2 = Light (5% to 25% of available second year and older leaders of preferred species are browsed).
1 = Moderate (25% to 50% of available second year and older leaders of preferred species are browsed).
0 = Heavy (More than 50% of available second year and older leaders of preferred species are browsed).

5b. Live Woody Vegetation Removal by Other Than Browsing. Excessive cutting or removing parts of plants or whole plants by agents other than browsing animals (e.g., human clearing, cutting, beaver activity, etc.) can result in many of the same negative effects to the community that are caused by excessive browsing. However, other effects from this kind of removal are direct and immediate, including reduction of physical community structure and wildlife habitat values. ***Do not include natural phenomena such as natural fire, insect infestation, etc. in this evaluation.***

Removal of woody vegetation may occur at once (timber harvest), or it may be cumulative over time (annual firewood cutting or beaver activity). This question is not so much to assess long term incremental harvest, as it is to assess the extent that the stand is lacking vegetation that would otherwise be there today. Give credit for re-growth. Consider how much the removal of a tree many years ago may have now been mitigated with young replacements.

Three non-native species or genera are excluded from consideration here because these are aggressive, invasive exotic plants that should be removed. They are *Elaeagnus angustifolia* (Russian olive), *Rhamnus cathartica* (common buckthorn), and *Tamarix* species (salt cedar).

Determine the extent to which woody vegetation (trees and shrubs) is lacking due to being physically removed (i.e., cut, mowed, trimmed, logged, cut by beaver, or otherwise removed from their growing position). The timeframe is less important than the ecological effect. Time to recover from this kind of damage can vary widely with site characteristics. The objective is to measure the extent of any damage remaining ***today*** to the vegetation structure resulting from woody removal. We expect that the woody community will recover over time (re-grow), just as an eroding bank will heal with re-growing plant roots. This question simply asks "How much woody material is still missing from what should be here?" The amount of time since removal doesn't really matter, if re-growth has been allowed to progress. If 20 years after logging, the site has a stand of sapling spruce trees, then it should get partial re-growth credit, but not full credit, since the trees still lack much of their potential habitat and ecological value. (***NOTE:*** In general, the more recent the removal, the more entirely it should be fully counted; and conversely, the older the removal, the more likely it will have been mitigated by re-growth.)

This question is really looking at volume (three dimensions) and not canopy cover (two dimensions). For example, if an old growth spruce tree is removed, a number of new seedlings/saplings may become established and could soon achieve the same canopy cover as the old tree had. However, the value of the old tree to wildlife and overall habitat values is far greater than that of the seedling/saplings. It will take a very long time before the seedlings/saplings can grow to replace all the lost habitat values that were provided by the tall old tree. On the other hand, shrubs, such as willows, grow faster and may replace the volume of removed plants in a much shorter time. Answer this question by estimating the percent of woody material that is missing from the site due to having been removed by human action. Select a range category from the choices given that best represents the percent of missing woody material.

Scoring: (*If the site has no trees or shrubs* ***AND*** *no cut plants or stumps of any trees or shrubs [except for the species listed above to be excluded], replace both Actual Score and Possible Score with NA.*)
3 = None (0% to 5% of live woody vegetation expected on the site is lacking due to cutting).
2 = Light (5% to 25% of live woody vegetation expected on the site is lacking due to cutting).
1 = Moderate (25% to 50% of live woody vegetation expected on the site is lacking due to cutting).
0 = Heavy (More than 50% of live woody vegetation expected on the site is lacking due to cutting).

6. Standing Decadent and Dead Woody Material. (*Skip this item if the site lacks trees or shrubs; for example, the site is a herbaceous wet meadow or cattail marsh.*) The amount of decadent and dead woody material on a site can be an indicator of the overall health of a riparian area. Large amounts of decadent and dead woody material may indicate a reduced flow of water through the stream (dewatering) due to either human or natural causes. Dewatering of a site, if severe enough, may change the site vegetation potential from riparian species to upland species. In addition, decadent and dead woody material may indicate severe stress from over browsing. Finally, large amounts of decadent and dead woody material may indicate climatic impacts, disease and insect damage. For instance, severe winters may cause extreme die back of trees and shrubs, and cyclic insect infestations may kill individuals in a stand. In all these cases, a high percentage of dead and decadent woody material reflects degraded vegetative health, which can lead to reduced streambank integrity, channel incisement, and excessive lateral cutting, besides reducing production and other wildlife values.

The most common usage of the term ***decadent*** may be for over mature trees past their prime and which may be dying, but we use the term in a broader sense. We count decadent plants, both trees and shrubs, as those with 30% or more dead wood in the upper canopy. In this item, scores are based on the percentage of total woody canopy cover which is decadent or dead, not on how much of the total polygon canopy cover consists of dead and decadent woody material. Only decadent and dead standing material is included, not that which is lying on the ground. The observer is to ignore (not count) decadence in poplars or cottonwoods which are decadent ***due to old age*** (rough and furrowed bark extends substantially up into the crowns of the trees) (species: *Populus deltoides* [plains cottonwood], *P. angustifolia* [narrowleaf cottonwood], and *P. balsamifera* [balsam poplar]), because cottonwoods/poplars are early seral species and naturally die off in the absence of disturbance to yield the site to later seral species. The observer is to consider (count) decadence in these species if apparently caused by de-watering, browse stress, climatic influences, or parasitic infestation (insects/disease). The observer should comment on conflicting or confounding indicators, and/or if the cause of decadence is simply unknown (*but not due to old age*).

Scoring: (*If site lacks potential for woody species, replace both Actual and Potential Scores with NA.*)
3 = Less than 5% of the total canopy cover of woody species is decadent and/or dead.
2 = 5% to 25% of the total canopy cover of woody species is decadent and/or dead.
1 = 25% to 50% of the total canopy cover of woody species is decadent and/or dead.
0 = More than 50% of the total canopy cover of woody species is decadent and/or dead.

7. Streambank Root Mass Protection. Vegetation along streambanks performs the primary physical functions of stabilizing the soil with a binding root mass and of filtering sediments from overland flow. Few studies have documented depth and extent of root systems of plant species found in wetlands. Despite this lack of documented evidence, some generalizations can be made. All tree and shrub species are considered to have deep, binding root masses. Among wetland herbaceous species, the first rule is that annual plants lack deep, binding roots. Perennial species offer a wide range of root mass qualities. Some rhizomatous species such as the deep rooted *Carex* species (sedges) are excellent bank stabilizers. Others, such as *Poa pratensis* (Kentucky bluegrass), have only shallow roots and are poor bank stabilizers. Still others, such as *Juncus balticus* (Baltic rush), are intermediate in their ability to stabilize banks. The size and nature of the stream will determine which herbaceous species can be effective. The evaluator should try to determine if the types of root systems present in the polygon are in fact contributing to the stability of the streambanks.

In situations where you are assessing a high, cut bank (usually on an outside bend), the top may be upland, but the bottom is riparian. Do not assess the area that is non-riparian. In cases of tall, nearly vertical cut banks, assess the bottom portion that comes in contact with floodwaters. Omit from consideration those areas where the bank is comprised of bedrock, since these neither provide binding root mass, nor erode at a perceptible rate.

Note: Rip-rap does not substitute for, act as, or preclude the need for deep, binding root mass.

Since the kind and amount of deep, binding roots needed to anchor a bank is dependent on size of the stream, use the following table as a general guide to determine width of a band along the banks to assess for deep, binding roots. This is a "rule of thumb" for guidance that requires only estimated measurements.

Stream Size (Bankfull Channel Width)	Width of Band to Assess for Deep, Binding Roots
Rivers (Larger Than 30 m [>100 ft])	15 m (50 ft)
Large Streams (Approx. 5-30 m [16-100 ft])	5 m (16 ft)
Small Streams (Up To Approx. 5 m [16 ft])	2 m (6 ft)

Scoring:
6 = More than 85% of the streambank has a deep, binding root mass.
4 = 65% to 85% of the streambank has a deep, binding root mass.
2 = 35% to 65% of the streambank has a deep, binding root mass.
0 = Less than 35% of the streambank has a deep, binding root mass.

8. Human-Caused Bare Ground. Bare ground is soil not covered by plants, litter or duff, downed wood, or rocks larger than 6 cm (2.5 in). Hardened, impervious surfaces (e.g., asphalt, concrete, etc.) are not bare ground—these do not erode nor allow weeds sites to invade. Bare ground caused by human activity indicates a deterioration of riparian health. Sediment deposits and other natural bare ground are excluded as normal or probably beyond immediate management control. Human land uses causing bare ground include livestock grazing, recreation, roads, and industrial activities. The evaluator should consider the causes of all bare ground observed and estimate the fraction that is human-caused.

Stream channels that go dry during the growing season can create problems for polygon delineation. Some stream channels remain unvegetated after the water is gone. On most streams the area of the channel bottom is excluded from the polygon. (***Note:*** *The whole channel width extends from right bankfull stage to left bankfull stage; however we need to include the lower banks in all polygons, therefore consider for exclusion ONLY the relatively flat and lowest area of the channel—the "bottom."*) This allows data to be collected on the riparian area while excluding the aquatic zone, or open water, of the stream. The aquatic zone is the area covered by water and lacking persistent emergent vegetation. Persistent emergent vegetation consists of perennial wetland species that normally remain standing at least until the beginning of next growing season, e.g., *Typha* species (cattails), *Scirpus* species (bulrushes), *Carex* species, and other perennial graminoids.

In many systems, large portions of the channel bottom may become exposed due to seasonal irrigation use, hydroelectric generation, and natural seasonal changes such as are found in many prairie ecosystems. In these cases, especially the prairie streams, the channel bottom may have varying amounts of herbaceous vegetation, and the channel area is ***included*** in the polygon as area to be inventoried. Typically, these are the "pooled channel" stream type that has scour pools scattered along the length, interspersed with reaches of grass, bulrush, or sedge-covered channel bottom. If over half (>50%) the channel bottom area has a canopy cover of persistent vegetation cover (perennial species), taken over the entire length of the polygon as a whole, then it qualifies for inclusion within the inventoried polygon area. If you are in doubt whether to include the channel bottom in the polygon, then leave it out, but be sure to indicate this in the comment section. This is important so that future assessments of the polygon will be looking at the same area of land.

Scoring:
6 = Less than 1% of the polygon is human-caused bare ground.
4 = 1% to 5% of the polygon is human-caused bare ground.
2 = 5% to 15% of the polygon is human-caused bare ground.
0 = More than 15% of the polygon is human-caused bare ground.

9. Streambank Structurally Altered by Human Activity. Altered streambanks are those having impaired structural integrity (strength or stability) usually due to human causes. These banks are more susceptible to cracking and/or slumping. Count as streambank alteration such damage as livestock or wildlife hoof shear and concentrated trampling, vehicle or ATV tracks, and any other areas of human-caused disruption of bank integrity, including rip-rap or use of fill. The basic criterion is any disturbance to bank structure that increases erosion potential or bank profile shape change. One large exception is lateral bank cutting caused by stream flow, even if thought to result from upstream human manipulation of the flow. The intent of this item is to assess only direct, on-site mechanical or structural damage to the banks. Each bank is considered separately, so total bank length for this item is approximately twice the reach length of stream channel in the polygon (more if the stream is braided). ***NOTE:*** Constructed streambanks (especially those with rip-rap) may be stabilized at the immediate location, but are likely to disrupt normal flow dynamics and cause erosion of banks downstream. The width of the bank to be considered is proportional to stream size. The table below gives a conceptual guideline for how wide a band along the bank to assess.

Stream Size (Bankfull Channel Width)	**Width of Band to Assess for Bank Alteration**
Rivers (Larger Than 30 m [>100 ft])	4 m (13 ft)
Large Streams (Approx. 5-30 m [16-100 ft])	2 m (6 ft)
Small Streams (Up To Approx. 5 m [16 ft])	1 m (3 ft)

Scoring:
6 = Less than 5% of the bank is structurally altered by human activity.
4 = 5% to 15% of the bank is structurally altered by human activity.
2 = 15% to 35% of the bank is structurally altered by human activity.
0 = More than 35% of the bank is structurally altered by human activity.

10. Human Physical Alteration to the Rest of the Polygon. Within the remainder of the polygon area, outside the stream bank area that was addressed in the previous question, estimate the amount of area that has been physically altered by human causes. The purpose of this question is to evaluate physical change to the soil, hydrology, etc. as it affects the ability of the natural system to function normally. Changes in soil structure will alter infiltration of water, increase soil compaction, and change the amount of sediment contributed to the water body. Every human activity in or around a natural site can alter that site. This question seeks to assess the accumulated effects of all human-caused change. Count such things as:

- **Soil Compaction.** This kind of alteration includes livestock-caused hummocking and pugging, recreational trails that obviously have compacted the soil, vehicle and machine tracks and ruts in soft soil, etc.
- **Plowing/Tilling.** This is disruption of the soil surface for cultivation purposes. It does not include the alteration of drainage or topographic pattern, which are included in the **Topographic Change** category.
- **Hydrologic Change.** Include in this category any area that is physically affected by removal or addition of water for human purpose. The physical effects to look for are erosion due to reduced or increased water, bared soil surface that had water cover removed, or flooded area that normally supports a drier vegetation type.
- **Human Impervious Surface.** This includes roofs, hardened surfaces like walkways and roads, boat launches, etc.
- **Topographic Change.** This is the deliberate alteration of terrain and/or drainage pattern for human purposes. It may be for aesthetic (landscaping) or other reasons, including such structures as water diversions ditches and canals.

Scoring:
3 = Less than 5% of the polygon is altered by human causes.
2 = 5% to 15% of the polygon is altered by human causes.
1 = 15% to 25% of the polygon is altered by human causes.
0 = More than 25% of the polygon is altered by human causes.

11. Stream Channel Incisement (Vertical Stability). An incised stream channel has experienced vertical downcutting of its bed. Incisement can lower the water table enough to change vegetation site potential. It can also increase stream energy by reducing sinuosity, reduce water retention/storage, and increase erosion. A stream becomes critically incised when downcutting lowers the channel bed so that the two-year flood event cannot overflow the banks. Some typical downcutting indicators are:

a) Headcuts;
b) Exposed cultural features (pipelines, bridge footings, culverts, etc.);
c) Lack of sediment deposits;
d) Exposed bedrock; and
e) A low, vertical scarp at the bank toe on the inside of a channel bend.

A severe disturbance can initiate downcutting, transforming the system from one having a high water table, appropriate floodplain, and high productivity to one of degraded water table, narrow (or no) active floodplain, and low productivity. These stages of incisement can be categorized in terms of Schumm's stages of incised channel evolution (Schumm and others 1984). The following indicators, taken together, collectively will enable the observer to assess severity of channel incisement:

Channel bed downcutting—Look for headcuts, lack of bed load sediment and exposed bedrock, a low vertical scarp at tow of bank along straight reaches and inside curves, hanging culverts and exposed cultural features.

Limited access to floodplain by flood flows of 1 to 3 year frequency—Look for a lack of sediment deposits and debris deposits on lower floodplain elevations.

Widening of the incised channel—Look for lateral cutting and sloughing of the high banks. This is one of the early steps in the healing process on a severely incised channel. Initially, the downward bed erosion forms a narrow, deep channel that often resembles a gully. Flood waters in such a channel normally cannot deposit, but can only erode and transport, sediment; therefore the narrow incisement must be widened to provide lateral space for a new floodplain to form. This lateral cutting also supplies the sediment that may be deposited at the bottom to begin the formation of a new floodplain.

New floodplain formation within the incised channel—Look for small depositional bars and low, flat areas near the channel. These will increase in width and length, as the healing process proceeds. Look especially for perennial vegetation becoming established on these depositional features, as it is the vegetation that secures the newly gained floodplain increments. The relative width of the active floodplain (the lowest level, the one that is most frequently flooded) determines to what extent an incisement has healed. Remember that floodplain width is inversely proportional to stream gradient, so that higher gradient (B stream type) channels typically have narrow floodplains (typically less than one bankfull channel width), and C and E stream type have wide to very wide floodplains (typically greater than one bankfull channel width).

A top rating is given to un-incised channels from which the normal 1-2 year high flow can access a well formed floodplain. These can be meandering meadow streams (E stream type) and wide valley bottom streams (C stream type) which access floodplains much wider than the stream channel, or they may be mountain and foothill streams in V-shaped valleys which have narrow floodplains limited by topography or bedrock. These latter types are usually armoured (well-rocked) systems with highly stable beds and streambanks that are not susceptible to downcutting (typically mountain and foothill streams of A and B stream types). The lowest rating goes to entrenched channels (F or G stream types) where even medium high flows which occur at 5-10 year intervals cannot over-top the high banks. Intermediate stages may be either improving or degrading, and may reflect slightly incised channels that are not yet downcut so badly that some flood stages still cannot access the floodplain, or they may be old incisements that are now healing and rebuilding a new floodplain in the bottom of the ravine.

Because a channel can be incised in any of several stages, the observer is to examine the channel in the polygon for indicators of the degree of channel bed grade stability and stage of incisement, as illustrated in Figure 4. Figure 4 adapts the Schumm channel evolution model to show a generalized schematic of stages through which a channel progresses from destabilization and downcutting to healing and reestablishment of a new floodplain. Actual sites will often have characteristics that are difficult to match with the generalized drawings in Figure 4. However, make a “best fit” call for category of incisement based on available evidence. If the indicators are confusing and inconclusive, choose the higher (less incised) indicated category. Explain your call in the comment field, and be sure to provide photo documentation of evidence on severely incised channels.

The following table defines the categories of incisement severity in terms of the Schumm’s model of channel evolution stages, as adapted by Rosgen (2006). Note that with destabilizing disturbance and subsequent change to remove the disturbance, a channel may progress through predictable stages of incisement and healing, returning ultimately to a functional and stable system again.

Health Assessment Scoring	Incisement Class	Schumm's Channel Evolution Stages	Rosgen Types Included	Description of Incisement Situation
9	None	A	A, B, C, E	Channel is vertically stable and not incised; 1-2 year high flows can begin to access a floodplain appropriate to stream type. Active downcutting is not evident. Any old incisement is characterized by a broad floodplain in which perennial riparian vegetation well established. This category includes a variety of stream types in all land forms and substrates. The floodplain may be narrow or wide, depending on the type of stream, but the key factor is vertical stability. The system may have once incised, and later become healed and is now stable again, with a new floodplain appropriate to its stream type. In this case, the erosion of the old gully side walls will have ceased, and stabilized. A mature, or nearly mature, vegetation community will occupy much of the new valley bottom.
6	Slight	B/D	C, F, G	This category contains both degrading and healing stages. In either case, the extent of incisement is minimal. In Stage B, the channel is just beginning to degrade, and a 2 year flood event may still access some floodplain, partially or in spots. Downcutting is likely progressing. In Stage D, the system is healing. Downcutting should have ceased at this stage. A new floodplain should be well established with perennial vegetation, although it may not be as wide as the stream type needs. This is indicated by ongoing lateral erosion of high side walls of the original incisement, as the system continues to widen itself at its new grade level.
3	Moderate	B/D	C, F, G	This category also contains both degrading and healing stages. In both cases, the extent of incisement is significant. In Stage B, the channel has downcut to a level that floods of the 1-5 year magnitude cannot reach a floodplain. Downcutting is likely still progressing, but the channel may already look like a gully. In Stage D, the system has only just begun to heal. A small floodplain along the new curves in the gully is forming, and perennial vegetation is starting to colonize new sediment features. The high side walls of the gully are actively eroding as the system widens, and much of the fallen materials is being incorporated along the bottom.
0	Severe	C	F, G	The worst case category, where there is no floodplain in the bottom of a deep entrenchment, and small-to-moderate floods cannot reach the original floodplain level. Downcutting may still be in progress. High side wall banks may have begun to collapse and erode into the bottom, but high flows typically just wash this material directly through the system, with none of it being trapped to build new floodplain. At this stage, the system has lost practically all of its riparian function and habitat value.

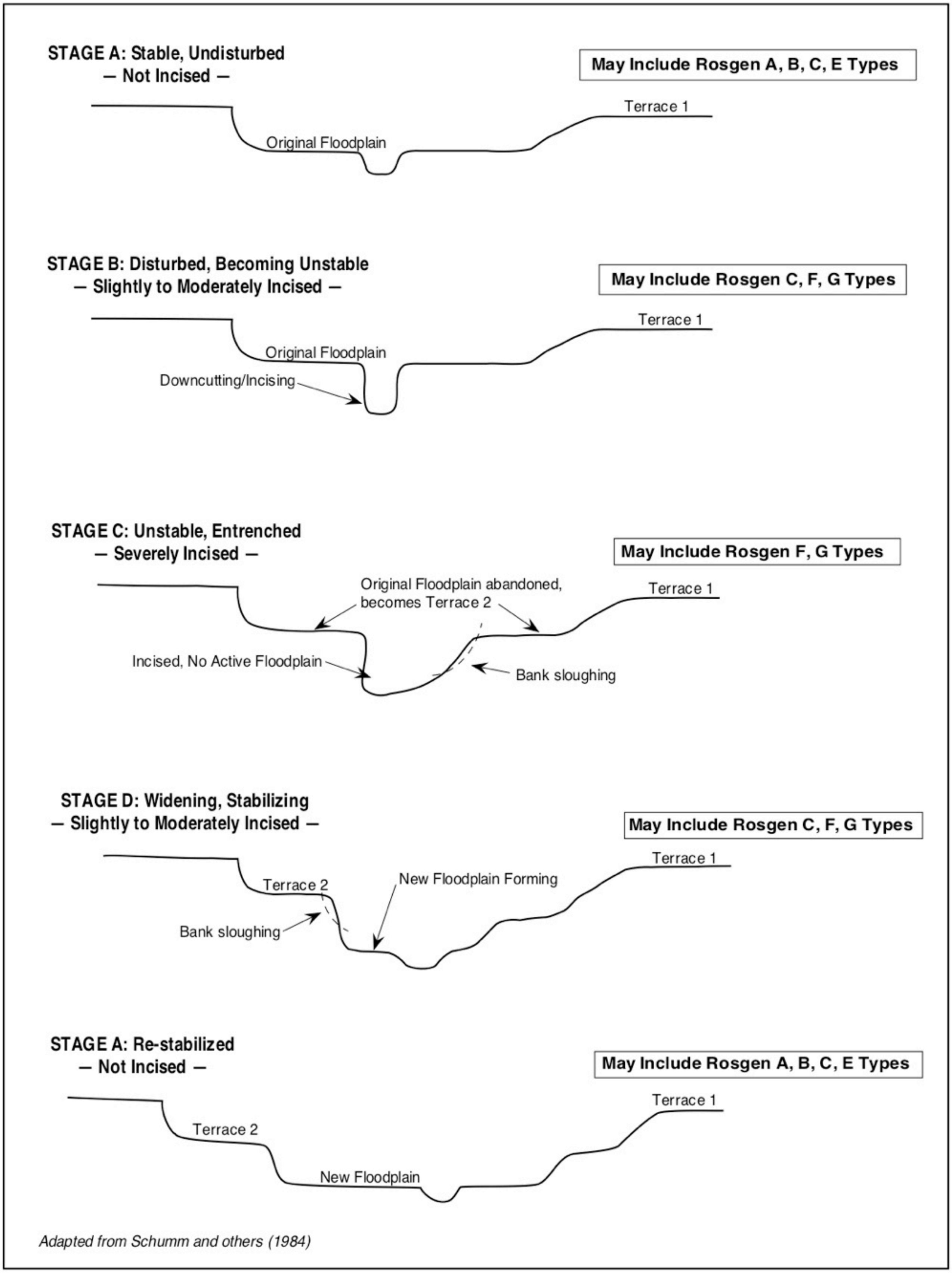


Figure 4. Schumm's stages of stream channel evolution (Rosgen 2006), going from initial destabilization and incisement, through ultimate healing and re-stabilization with a new floodplain

12. Trend. Select the ***one category*** (Improving, Degrading, Static, or Status Unknown) which best indicates the current trend of the vegetative community on the polygon to the extent possible. Trend refers, in the sense used here, not specifically to successional pathway change, but in a more general sense of apparent community health. By definition, trend implies change over time. Accordingly, a trend analysis would require comparison of repeated observations over time. However, some insights into trend can be observed in a single visit. For example, the evaluator may notice healing (revegetating) of a degraded shoreline and recent establishment of woody seedlings and saplings. This would indicate changing conditions that suggest an improving trend. If such indicators are not apparent, enter the category "status unknown."

13. Comments and Observations. Comments and Observations. Add any necessary commentary to explain or amplify the data recorded. Do not leave this space blank. Describe any unique characteristics of the site and other observations relating to the vegetation or to the physical conditions of the site. Each item in the health rating has a small space provided for specific information to enlighten the score given. This larger space is the place for more general commentary to help the reader understand the larger context of the data. Such things as landscape setting and local land use history are appropriate here.

Calculating the Lotic Health Score

To arrive at the overall site health rating, the scores are totaled for all the factors, and that total is divided by the possible perfect score total. A sample score sheet is shown below.

A sample score sheet of a site with no apparent potential for trees or shrubs

Vegetation Factors	**Actual Pts**	**Possible Pts**
1. Vegetative Cover of Floodplain and Streambanks	6	6
2a. Total Canopy Cover of Invasive Plant Species (Weeds)	0	3
2b. Density/Distribution Pattern of Invasive Plant Species (Weeds)	1	3
3. Disturbance-Increaser Undesirable Herbaceous Species	2	3
4. Preferred Tree and Shrub Establishment and/or Regeneration	NA	NA
5a. Browse Utilization of the Preferred Trees and Shrubs	NA	NA
5b. Live Woody Vegetation Removal by Other Than Browsing	NA	NA
6. Standing Decadent and Dead Woody Material	NA	NA
Vegetative Score:	**9**	**15**
Soil/Hydrology Factors		
7. Streambank Root Mass Protection	4	6
8. Human-Caused Bare Ground	2	6
9. Streambank Structurally Altered by Human Activity	6	6
10. Human Physical Alteration to the Rest of the Polygon	2	3
11. Stream Channel Incisement (Vertical Stability)	9	9
Soil/Hydrology Score:	**23**	**30**
TOTAL SCORE:	**32**	**45**

Health Rating Formula: Health Rating = (Total Actual Score) / (Total Possible Score) X 100%

Health Rating = (32) / (45) X 100% = 71%

Health Category: 80 to 100% = Proper Functioning Condition (Healthy)
60 to less than 80% = Functional At Risk (Healthy, but with Problems)
Less than 60% = Nonfunctional (Unhealthy)

The manager should realize that a less than perfect score is not necessarily cause for concern. An area rated at 80% is still considered to be functioning properly. At the same time, ratings of individual factors can be useful in detecting strengths or weaknesses of a site. A low score on any factor may warrant management focus. In the example reach above, low scores for invasive plants and bare ground (items 2 and 8) indicate factors that management might improve in a subsequent assessment.

ADDITIONAL MANAGEMENT CONCERNS

The following items do not contribute to a site's health assessment rating. Rather, they may help to quantify inherent physical site characteristics that reveal structural weaknesses or sensitivities or to assess the direction of change on a site. These data can be useful for planning future site management.

14. Streambank Rock Volume and Size. The composition of streambank materials influences the susceptibility of the streambanks to erosion caused by trampling, water flow or other disturbance. In general, larger rocks provide better protection against disturbance than smaller materials. Thus, streambanks composed primarily of silts and clays—characteristic of the majority of streams in the Great Plains—require more vegetative protection to compensate for the smaller particle sizes.

14a. Streambank Rock Volume. Rate the streambank rock volume as the highest appropriate of the following categories:

Scoring:
3 = More than 40% of streambank volume is rocks at least 6.4 cm (2.5 in).
2 = 20% to 40% of streambank volume is rock at least 6.4 cm (2.5 in).
1 = 10% to 20% of streambank volume is rock at least 6.4 cm (2.5 in).
0 = Less than 10% of streambank volume is rocks at least 6.4 cm (2.5 in).

14b. Streambank Rock Size. Rate the streambank rock size for the polygon as the highest appropriate of the following categories:

Scoring:
3 = At least 50% of rocks present are boulders and large cobbles (>13 cm [5 in]).
2 = 50% of rocks present are small cobbles and larger (>6.4 cm [2.5 in]).
1 = At least 50% of rocks present are coarse gravels and larger (>1.5 cm [0.6 in]).
0 = Less than 50% of rocks present are coarse gravels and larger (>1.5 cm [0.6 in]).

15. Vegetation Use by Animals. Record the rating category, which best describes the vegetation use by animals (Platts and others, 1987).

Code	Category Description
0% to 25%	Vegetation use is light or none. Almost all plant biomass at the current development stage remains. Vegetative cover is close to that which would occur without use. Unvegetated areas (such as bedrock) are not a result of land uses.
26% to 50%	Vegetation use is moderate. At least half the potential plant biomass remains. Average stubble height is more than half its potential at the present stage of development.
51% to 75%	Vegetation use is high. Less than half the potential plant biomass remains. Plant stubble height is usually more than 5 cm (2 in) (on many ranges).
76% to 100%	Vegetation use is very high. Only short stubble remains (usually less than 5 cm [2 in] on many ranges). Almost all plant biomass has been removed. Only the root systems and parts of the stems remain.

16. Susceptibility of Parent Material to Erosion. The soils derived from shale or having a large clay content are highly susceptible to compaction and trampling when wet. There is evidence that trampling by hooves and subsequent loss of herbaceous vegetation when soils are wet are major contributions to site degradation. In contrast, those sites having soils derived from sandstone or any of the hard metamorphosed rock found in the Rocky Mountains commonly have a fine sandy loam to loam texture and are more resistant to damage when wet. Intermediate of these soils are those having textures of clay loam to loam. Texturing the soil by the ribboning technique or by feel will be required for this determination. Rate the polygon soil according to one of these categories based on indicators as described above.

Scoring:
3 = Not susceptible to erosion (well armored).
2 = Slightly susceptible to erosion (moderately armored).
1 = Moderately susceptible to erosion.
0 = Extremely susceptible to erosion.

17. Percent of Streambank Accessible to Livestock. Record the percent of streambank length accessible to large hooved animals (livestock and wildlife). In general, only consider topography (steep banks, deep water, etc.) and dense vegetation as restricting access. Fences, unless part of an exclosure, do not necessarily restrict livestock access even though they may appear to be doing so at the time.

18. Break Down the Polygon Area into the Land Uses Listed. Name any “Others” Observed.

19. Break Down the Area Adjacent to the Polygon into the Land Uses Listed. Name any “Others” Observed.

LITERATURE CITED

Adams, Barry and Lorne Fitch. 1995. Caring for the green zone, riparian areas and grazing management. Alberta Riparian Habitat Management Project. Lethbridge, Alberta, Canada. 37 p.

Alberta Natural Heritage Information Centre. 1999. Natural regions and subregions of Alberta. Internet website: http://www.gov.ab.ca/env/parks/anhic/abnatreg.html. Edmonton, Alberta, Canada. T5K 2J6.

American Fisheries Society, Western Division. 1980. Position paper on management and protection of western riparian stream ecosystems. American Fisheries Society, Bethesda, Maryland, USA. 24 p.

Boldt, Charles D., Daniel W. Uresk, and Keith E. Severson. 1978. Riparian woodlands in jeopardy on Northern High Plains. In: Strategies for protection and management of floodplain wetlands and other riparian ecosystems (R. R. Johnson and J. F. McCormick, Technical Coordinators). USDA Forest Service General Technical Report WO-12. Washington, DC, USA. pp. 184-189.

Cooperrider, Allen Y., Raymond J. Boyd, and Hanson R. Stuart. 1986. Inventory and monitoring of wildlife habitat. USDI Bureau of Land Management, Denver Service Center, Denver, Colorado, USA. 858 p.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deep water habitats of the United States. USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC, USA. Publication Number FWS/OBS-79/31. 107 p.

Cows and Fish. 2001. Invasive Weed and Disturbance-caused Herbaceous Species List For Use in Riparian Health Assessment and Inventory in Alberta --draft. Alberta Riparian Habitat Management Program. Lethbridge, Alberta, Canada.

Federal Interagency Committee for Wetland Delineation. 1989. Federal manual for identifying and delineating jurisdictional wetlands. US Army Corps of Engineers, US Environmental Protection Agency, USDI Fish and Wildlife Service, and USDA Soil Conservation Service Cooperative Technical Publication, Washington, DC, USA. 76 p.

Fitch, L., B.W. Adams and G. Hale, Eds. 2001. Riparian Health Assessment for Streams and Small Rivers - Field Workbook. Lethbridge, Alberta: Cows and Fish Program. (adapted from Riparian and Wetland Research Program, School of Forestry. 2001. Lotic health assessments: Riparian Health Assessment for Streams and Small Rivers [Survey] User Guide. University of Montana, Missoula, Montana, USA. January 2001.) 75 p.

Fitch, L. and N. Ambrose. 2003. Riparian areas: A user's guide to health. Lethbridge, Alberta: Cows and Fish Program. ISBN No. 0-7785-2305-5. 46 p.

Hansen, Paul L. and James B. Hall. 2002. Classification and management of USDI Bureau of Land Management's riparian and wetland sites in eastern and southern Idaho. Bitterroot Restoration, Inc., Corvallis, Montana, USA. 304 p.

Hansen, Paul L., Robert D. Pfister, Keith Boggs, Bradley J. Cook, John Joy, and Dan K, Hinckley. 1995. Classification and management of Montana's riparian and wetland sites. Miscellaneous Publication No 54. Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Missoula, Montana, USA. 646 p.

Hansen, Paul L., William H. Thompson, J. Gant Massey, and Max Thompson. 2008. Classification and management of upland, riparian, and wetland sites of USDI Bureau of Land Management's Miles City Field Office, eastern Montana USA. Prepared for the USDI Bureau of Land Management Miles City Field Office, Miles City, Montana, USA. 640 p. plus 91 p. of Appendix B (Indicator Species).

Huel, Denis. 1998. Streambank stewardship, your guide to caring for riparian areas in Saskatchewan. ISBN No. 1-896793-20-7. Saskatchewan Wetland Conservation Corporation. Regina, Saskatchewan, Canada. 43 p.

Huel, Denis. 2000. Managing Saskatchewan Wetlands—a landowner's guide. ISBN No. 1-896793-26-6. Saskatchewan Wetland Conservation Corporation. Regina, Saskatchewan, Canada. 68 p.

Johnson, R. R., and S. W. Carothers. 1980. Riparian habitats and recreation: interrelationships and impacts in the Rocky Mountain region. Produced under agreement 53-82 FT-0-125 of the Eisenhower Consortium for Western Environmental Forestry Research, Fort Collins, Colorado, USA. 109 p.

Kent, Donald M. 1994. Applied wetlands science and technology. Donald M. Kent, editor. CRC Press, Inc., Lewis Publishers, Boca Raton, Florida, USA. 436 p.

Kovalchik, Bernard L. 1987. Riparian zone associations: Deschutes, Ochoco, Fremont, and Winema National Forests. USDA Forest Service Region 6 Ecology Technical Paper 279-87. Pacific Northwest Region, Portland, Oregon, USA. 171 p.

Mitsch, William J., and James G. Gosselink. 1993. Wetlands. Second Edition. Van Nostrand Reinhold, Publishers, New York, New York, USA. 722 p.

Padgett, Wayne G., Andrew P. Youngblood, and Alma H. Winward. 1989. Riparian community type classification of Utah and southeastern Idaho. USDA Forest Service Region 4 Ecology 89-01. Intermountain Research Station, Ogden, Utah, USA. 191 p.

Platts, W. S., C. Armour, G. D. Booth, M. Bryant, J. L. Bufford, P. Cuplin, S. Jensen, G. W. Lienkaemper, G. W. Minshall, S. B. Monsen, R. L. Nelson, J. R. Sedell, and J. S. Tuhy. 1987. Methods for evaluating riparian habitats with applications to management. USDA Forest Service General Technical Report INT-221. Intermountain Research Station, Ogden, Utah, USA. 187 p.

Reed, Porter B., Jr. 1988. National list of plant species that occur in wetlands: Northwest (Region 9). US Fish and Wildlife Service Biological Report 88 (26.9). USDI Fish and Wildlife Service, Research and Development, Washington, DC, USA. 89 p.

Rosgen, D. L. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, Colorado, USA. 246 p.

Rosgen, Dave. 2006. Watershed assessment of river stability and sediment supply (WARSSS). Wildland Hydrology. Pagosa Springs, Colorado, USA. 628 p.

Shaw, S. P., and C. G. Fredine. 1956. Wetlands of the United States: Their extent and their value for waterfowl and other wildlife. USDI Fish and Wildlife Service, Circular 39. Washington, DC, USA. 67 p.

Stewart, R. E., and H. A. Kantrud. 1972. Classification of natural ponds and lakes in the glaciated prairie region. USDI Fish and Wildlife Service, Research Publication 92. 57 p.

Thompson, William H. and Paul L. Hansen. 2001. Classification and management of riparian and wetland sites of the Saskatchewan prairie ecozone and parts of adjacent subregions. Saskatchewan Wetland Conservation Corporation. Regina, Saskatchewan, Canada. 298 p.

Thompson, William H. and Paul L. Hansen. 2002. Classification and management of riparian and wetland sites of the Alberta Grassland Natural Region and adjacent subregions. Bitterroot Restoration, Inc. Prepared for the Alberta Riparian Habitat Management Program-Cows and Fish, Lethbridge, Alberta, Canada. 416 p.

Thompson, William H. and Paul L. Hansen. 2003. Classification and management of riparian and wetland sites of Alberta's Parkland Natural Region and Dry Mixedwood Natural Subregion. Bitterroot Restoration, Inc. Prepared for the Alberta Riparian Habitat Management Program-Cows and Fish, Lethbridge, Alberta, Canada. 340 p.

USDA Forest Service. 1989. Ecosystem classification handbook: ECODATA. USDA Forest Service, Northern Region, Missoula, Montana, USA.

Windell, John T., Beatrice E. Willard, David J. Cooper, Susan Q. Foster, Christopher F. Knud-Hansen, Lauranne P. Rink, and George N. Kiladis. 1986. An ecological characterization of Rocky Mountain montane and subalpine wetlands. USDI Fish and Wildlife Service Biological Report 86(11). National Ecology Center, Division of Wildlife and Contaminant Research, Fish and Wildlife Service, US Department of the Interior, Washington, DC, USA. 298 p.

LOTIC WETLAND SURVEY HEALTH ASSESSMENT
FIELD SCORE SHEET

1. Vegetative Cover of Floodplain and Streambanks. **Score:_____**/ 6

6 = More than 95% of the reach soil surface is covered by live plant growth.
4 = 85% to 95% of the reach soil surface is covered by live plant growth.
2 = 75% to 85% of the reach soil surface is covered by live plant growth.
0 = Less than 75% of the reach soil surface is covered by live plant growth.

2a. Total Canopy Cover of Invasive Plant Species (Weeds). **Score:_____**/ 3

3 = No invasive plant species (weeds) on the site.
2 = Invasive plants present with total canopy cover less than 1% of the polygon area.
1 = Invasive plants present with total canopy cover between 1 and 15% of the polygon area.
0 = Invasive plants present with total canopy cover more than 15% of the polygon area.

2b. Density/Distribution Pattern of Invasive Plant Species (Weeds). **Score:_____**/ 3

3 = No invasive plant species (weeds) on the site.
2 = Invasive plants present with density/distribution in categories 1, 2, or 3.
1 = Invasive plants present with density/distribution in categories 4, 5, 6, or 7.
0 = Invasive plants present with density/distribution in categories 8, or higher.

3. Disturbance-Increaser Undesirable Herbaceous Species. **Score:_____**/ 3

3 = Less than 5% of the site covered by disturbance-increaser undesirable herbaceous species.
2 = 5% to 25% of the site covered by disturbance-increaser undesirable herbaceous species.
1 = 25% to 50% of the site covered by disturbance-increaser undesirable herbaceous species.
0 = More than 50% of the site covered by disturbance-increaser undesirable herbaceous species.

4. Preferred Tree and Shrub Establishment and/or Regeneration. **Score:_____**/ 6

(*If the site has no woody vegetation [except for the species listed to be excluded], replace both Actual Score and Possible Score with NA.*)

6 = More than 15% of the total canopy cover of preferred trees/shrubs is seedlings and saplings.
4 = 5% to 15% of the total canopy cover of preferred trees/shrubs is seedlings and saplings.
2 = Less than 5% of the total canopy cover of preferred tree/shrubs is seedlings and saplings.
0 = Preferred tree/shrub seedlings or saplings absent.

5a. Browse Utilization of Preferred Trees and Shrubs. **Score:_____**/ 3

(*If the site has no woody vegetation [except for the species listed to be excluded], replace both Actual Score and Possible Score with NA.*)

3 = None (0% to 5% of available second year and older leaders of preferred species are browsed).
2 = Light (5% to 25% of available second year and older leaders of preferred species are browsed).
1 = Moderate (25% to 50% of available second year and older leaders of preferred species are browsed).
0 = Heavy (More than 50% of available second year and older leaders of preferred species are browsed).

5b. Live Woody Vegetation Removal by Other Than Browsing **Score:_____**/ 3

(*If the site has no trees or shrubs **AND** no cut plants or stumps of any trees or shrubs [except for the species listed to be excluded], replace both Actual Score and Possible Score with NA.*)

3 = None (0% to 5% of live woody vegetation expected on the site is lacking due to cutting).
2 = Light (5% to 25% of live woody vegetation expected on the site is lacking due to cutting).
1 = Moderate (25% to 50% of live woody vegetation expected on the site is lacking due to cutting).
0 = Heavy (More than 50% of live woody vegetation expected on the site is lacking due to cutting).

6. Standing Decadent and Dead Woody Material. **Score:_____**/ 3

(*If the site has no woody vegetation [except for the species listed to be excluded], replace both Actual Score and Possible Score with NA.*)

3 = Less than 5% of the total canopy cover of woody species is decadent and/or dead.
2 = 5% to 25% of the total canopy cover of woody species is decadent and/or dead.

1 = 25% to 50% of the total canopy cover of woody species is decadent and/or dead.
0 = More than 50% of the total canopy cover of woody species is decadent and/or dead.

7. Streambank Root Mass Protection. **Score:**_____/ 6
6 = More than 85% of the streambank has a deep, binding root mass.
4 = 65% to 85% of the streambank has a deep, binding root mass.
2 = 35% to 65% of the streambank has a deep, binding root mass.
0 = Less than 35% of the streambank has a deep, binding root mass.

8. Human-Caused Bare Ground. **Score:**_____/ 6
6 = Less than 1% of the polygon is human-caused bare ground.
4 = 1% to 5% of the polygon is human-caused bare ground.
2 = 5% to 15% of the polygon is human-caused bare ground.
0 = More than 15% of the polygon is human-caused bare ground.

9. Streambank Structurally Altered by Human Activity. **Score:**_____/ 6
6 = Less than 5% of the bank is structurally altered by human activity.
4 = 5% to 15% of the bank is structurally altered by human activity.
2 = 15% to 35% of the bank is structurally altered by human activity.
0 = More than 35% of the bank is structurally altered by human activity.

10. Human Physical Alteration to the Rest of the Polygon. **Score:**_____/ 3
3 = Less than 5% of the polygon is altered by human causes.
2 = 5% to 15% of the polygon is altered by human causes.
1 = 15% to 25% of the polygon is altered by human causes.
0 = More than 25% of the polygon is altered by human causes.

11. Stream Channel Incisement (Vertical Stability). **Score:**_____/ 9
9 = Not incised
6 = Slightly incised
3 = Moderately incised
0 = Severely incised

12. Polygon Trend. Select one: Improving, Degrading, Static, or Status Unknown **Trend:**______________________

13. Comments and Observations.
____
____
____
____
____
____
____

Overall Polygon Health Rating Calculation. The sum of scores assessed for all items is calculated as the “Total Actual Score,” and the sum of all possible item scores is calculated as the “Total Possible Score.” These “Totals” are entered into the Health Rating Formula shown to derive a percentage “Health Rating” for the polygon. The percentage “Rating” is then categorized into a “Health Category” as defined below.

Health Rating Formula: Health Rating = (Total Actual Score) / (Total Possible Score) X 100%

Health Category: 80 to 100% = Proper Functioning Condition (Healthy)
60 to less than 80% = Functional At Risk (Healthy, but with Problems)
Less than 60% = Nonfunctional (Unhealthy)

ADDITIONAL MANAGEMENT CONCERNS

14. Streambank Rock Volume and Size.

14a. Streambank Rock Volume. Rate the streambank rock volume as the highest appropriate category: **Score:**_____/ 3

- **3** = More than 40% of streambank volume is rocks at least 6.4 cm (2.5 in).
- **2** = 20% to 40% of streambank volume is rocks at least 6.4 cm (2.5 in).
- **1** = 10% to 20% of streambank volume is rocks at least 6.4 cm (2.5 in).
- **0** = Less than 10% of streambank volume is rocks at least 6.4 cm (2.5 in).

14b. Streambank Rock Size. Rate the streambank rock size for the polygon as the highest appropriate category: **Score:**_____/ 3

- **3** = At least 50% of rocks present are boulders and large cobbles (>13 cm [5 in]).
- **2** = 50% of rocks present are small cobbles and larger (>6.4 cm [2.5 in]).
- **1** = At least 50% of rocks present are coarse gravels and larger (>1.5 cm [0.6 in]).
- **0** = Less than 50% of rocks present are coarse gravels and larger (>1.5 cm [0.6 in]).

15. Vegetative Use by Animals. Use the categories below to score the amount of utilization. **Score:**_____/ 3

- **3** = 0% to 25% available forage taken.
- **2** = 26% to 50% available forage taken.
- **1** = 51% to 75% available forage taken.
- **0** = 76% to 100% available forage taken.

16. Susceptibility of Parent Material to Erosion. **Score:**_____/ 3

- **3** = Not susceptible to erosion (well armored).
- **2** = Slightly susceptible to erosion (moderately armored).
- **1** = Moderately susceptible to erosion.
- **0** = Extremely susceptible to erosion.

17. Percent of Streambank Accessible to Livestock. **Percent:**_________

18. Break Down the Polygon Area into the Land Uses Listed (must total to approx. 100%):

No land use apparent:__________
Turf grass (lawn): __________
Tame pasture (grazing): __________
Native pasture (grazing): __________
Recreation (ATV paths, campsites, etc.): __________
Development (buildings, corrals, paved lots, etc.): __________
Tilled cropping: __________
Perennial forage (e.g., alfalfa hayland): __________
Roads: __________
Logging: __________
Mining: __________
Railroads: __________
Other: __________

Description of Other Usage Noted:____

19. Break Down the Area Adjacent to the Polygon Into the Land Uses Listed (must total to approx. 100%):

No land use apparent:__________
Turf grass (lawn): __________
Tame pasture (grazing): __________
Native pasture (grazing): __________
Recreation (ATV paths, campsites, etc.): __________
Development (buildings, corrals, paved lots, etc.): __________
Tilled cropping: __________
Perennial forage (e.g., alfalfa hayland): __________
Roads: __________
Logging: __________
Mining: __________
Railroads: __________
Other: __________

Description of Other Usage Noted:____

APPENDIX F

DEVELOPMENT OF METHODOLOGIES TO EVALUATE THE HEALTH OF RIPARIAN AND WETLAND SYSTEMS (REPRINT OF 2000 PUBLICATION)

DEVELOPMENT OF METHODOLOGIES TO EVALUATE THE HEALTH OF RIPARIAN AND WETLAND SYSTEMS

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DEVELOPMENT OF METHODOLOGIES TO EVALUATE THE HEALTH OF RIPARIAN AND WETLAND AREAS

Paul L. Hansen[1], William H. Thompson[1], Robert C. Ehrhart[1],
Dan K. Hinckley[2], Bill Haglan[3], and Karen Rice[4]

ABSTRACT

Since 1988, we have been developing various assessments to address a wide range of riparian and wetland questions. Throughout this process, we have worked with various USDI Bureau of Land Management and USDI Fish and Wildlife Service personnel. Out of this collaborative effort, the following assessments for riparian and wetland areas have been developed: 1) lotic inventory, 2) lotic health evaluation (derived from the lotic inventory), 3) lotic health assessment (stand-alone), 4) river health assessment (stand-alone), 5) lentic inventory, 6) lentic health evaluation (derived from the lentic inventory), and 7) lentic health assessment (stand-alone). Each of the assessments also includes a discussion on the codes or instructions used with each form.

BACKGROUND

In 1986, work began at The University of Montana on developing a statewide riparian and wetland vegetation-based ecological site classification for Montana. This resulted in the document *Classification and Management of Montana's Riparian and Wetland Sites* (Hansen and others 1995). While developing this statewide classification, The University of Montana was asked by the USDI Bureau of Land Management (BLM) in the spring of 1988 to develop and conduct a large scale inventory and assessment for the Upper Missouri National Wild and Scenic River corridor in central Montana. The major goal of the work was to develop a sampling protocol that would allow the BLM to address some basic questions about the location, extent, and health of the various plant communities along 253 km (157 mi) of the Missouri River and its tributaries. In addition, some basic soil and physical site information was collected.

Since 1988, The University of Montana has continually worked with Dan Hinckley of the BLM Montana State Office, and later Karen Rice of the BLM Upper Snake River District in eastern Idaho to develop various assessment protocols to address a wide range of management questions. In addition, Bill Haglan of the USDI Fish and Wildlife Service at Charles M. Russell National Wildlife Refuge in central Montana provided invaluable field input and critical review. Out of this collaborative effort, we have developed the following assessments for riparian and wetland areas: 1) lotic inventory, 2) lotic health evaluation (derived from the lotic inventory), 3) lotic health assessment (stand-alone), 4) river health assessment (stand-alone), 5) lentic inventory, 6) lentic health evaluation (derived from the lentic inventory), and 7) lentic health assessment (stand-alone). Each of the forms also includes a discussion on the codes or instructions used with each form. In addition, we utilize the Pfankuch channel

[1]Riparian and Wetland Research Program, School of Forestry, The University of Montana, Missoula, Montana, USA.
[2]Montana State Office, USDI Bureau of Land Management, Billings, Montana, USA
[3]Charles M. Russell National Wildlife Refuge, USDI Fish and Wildlife Service, Lewistown, Montana, USA
[4]Upper Snake River District, USDI Bureau of Land Management, Idaho Falls, Idaho, USA

assessment (Pfankuch 1975), the BLM's lotic proper functioning condition (PFC) checklist (USDI Bureau of Land Management 1998), and the BLM's lentic proper functioning condition (PFC) checklist (Prichard and others 1994).

INTRODUCTION

Public and private land managers in the United States are being asked to improve or maintain riparian and wetland habitat and water quality. Those who live and work on the land can usually tell which sites support diverse, vigorous plant and animal communities, which sites have lost their capacity to retain spring season waters long into the summer dry season, and which sites are biologically depauperate. While it may be easy for an astute observer to see that a site has been degraded by human use, it is often difficult to quantify such changes. Presented here are methods for rapidly assessing riparian and wetland health. These methods provide an indexed site rating useful for setting management priorities and stratifying segments for remedial or more rigorous analytical attention. These methods are intended to serve as a first approximation, or "coarse filter," by which to identify segments in need of closer attention so that the manager can more efficiently concentrate effort.

Three questions that are generally asked about a riparian or wetland site are: 1) What is the potential of the site (e.g., climax or potential natural community)? 2) What plant communities currently occupy the site? and 3) What is the overall health (condition) of the site? For riparian and wetland sites in Montana, the first two questions can be answered using the *Classification and Management of Montana's Riparian and Wetland Sites* (Hansen and others 1995). Other regions of North America may have similar publications to aid in addressing these two questions. The assessments outlined in this paper address the third question: what is the site's overall health (condition)? These methods provide an indexed site rating useful for setting management priorities and stratifying riparian and wetland sites for remedial or more rigorous analytical attention.

We use the term "health" to mean the ability of a riparian or wetland area to perform certain functions such as adequate vegetation, landform, or woody debris present to dissipate stream and wave energy associated with high water levels, thereby reducing erosion and improving water quality; filter sediment, capture streambed load, and aid floodplain development; improve flood-water retention and ground-water recharge; develop root masses that stabilize streambanks and shorelines against stream cutting and wave action; develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and others uses; and support greater biodiversity.

In some cases management steps may have already been taken to remedy a functionally degraded riparian or wetland areas. In many such cases, however, it is unclear how the results of those changes can be assessed. How, for example, can we stratify sites on a large management unit among those functioning well, those functioning with slight impairment, those having lost much of their functional capacity, and those so severely impaired that restoration would be too costly and difficult?

Flowing Water (Lotic) Wetlands vs. Still Water (Lentic) Wetlands

Cowardin and others (1979) point out that no single, correct definition for wetlands exists, primarily due to the nearly unlimited variation in hydrology, soil, and vegetative types. Wetlands are lands transitional between aquatic (water) and terrestrial (upland) ecosystems. Windell and others (1986) state that "wetlands are part of a continuous landscape that grades from wet to dry. In many cases, it is not easy to determine precisely where they begin and where they end."

In the semi-arid and arid interior western North America, a useful distinction has been made between wetland types based on association with different aquatic ecosystems. Several authors have used lotic and lentic to separate wetlands associated with flowing water (lotic) from those associated with still water (lentic). The following definitions represent a synthesis and refinement of terminology from Shaw and Fredine (1956), Stewart and Kantrud (1972), Boldt and others (1978), Cowardin and others (1979), American Fisheries Society (1980), Johnson and Carothers (1980), Cooperrider and others (1986), Windell and others (1986), Environmental Laboratory (1987), Kovalchik (1987), Federal Interagency Committee for Wetland Delineation (1989), Mitsch and Gosselink (1993), and Kent (1994).

Lotic wetlands are associated with rivers, streams, and drainageways. Such wetlands, also referred to as riparian wetlands, contain a defined channel and floodplain. The channel is an open conduit that periodically or continuously carries flowing water and dissolved and suspended material. Beaver ponds, seeps, springs, and wet meadows on the floodplain of, or associated with, a river or stream are part of the lotic wetland.

Lentic wetlands are associated with still water systems. These wetlands occur in basins and lack a defined channel and floodplain. Included are permanent (i.e., perennial) or intermittent bodies of water such as lakes, reservoirs, potholes, marshes, ponds, and stockponds. Other examples include fens, bogs, wet meadows, and seeps not associated with a defined channel.

Functional vs. Jurisdictional Wetland Criteria

Defining wetlands has become more difficult as greater economic stakes have increased the potential for conflict between politics and science. A universally accepted wetland definition satisfactory to all users has not yet been developed because the definition depends on the objectives and the field of interest. However, scientists generally agree that wetlands are characterized by one or more of the following features: 1) wetland hydrology, the driving force creating all wetlands, 2) hydric soils, an indicator of the absence of oxygen, and 3) hydrophytic vegetation, an indicator reflecting wetland site conditions. The problem is how to define and obtain consensus on thresholds for these three criteria and various combinations of the three criteria.

In the United States jurisdictional wetlands are those wet areas that are protected by law through Section 404 of the Clean Water Act and the Swampbuster Provision of the Food Security Act (Mitsch and Gosselink 1993). The US Army Corps of Engineers (Federal Register 1982) and the Environmental Protection Agency (Federal Register 1980) jointly define wetlands for purposes of Section 404 of the Clean Water Act as:

> *Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.*

Currently, jurisdictional wetlands in the United States are those that meet the criteria defined in the 1987 Corps of Engineers Wetlands Delineation Manual (Environmental Laboratory 1987) and part 513 of the National Food Security Act Manual, Third Edition (Conservation Planning Division 1994). These are not inclusive of all wetlands included in the classification of Cowardin and others (1979).

Wetlands are not easily identified and delineated for jurisdictional purposes. Functional definitions have generally been difficult to apply to the regulation of wetland dredging or filling. Although the intent of legislation is to protect wetland functions, delineation of jurisdictional wetlands has relied largely on structural features or attributes. The hydrogeomorphic (HGM) approach being developed by the US Army Corps of Engineers is intended to focus more specifically on wetland functions.

The prevailing view among many wetland scientists is that functional wetlands need to meet only one of the three criteria as outlined by Cowardin and others (1979) (e.g., hydric soils, hydrophytic plants, and wetland hydrology). On the other hand, jurisdictional wetlands need to meet all three criteria, except in limited situations. Even though functional wetlands may not meet jurisdictional wetland requirements, they certainly perform wetland functions resulting from the greater amount of water that accumulates on or near the soil surface relative to the adjacent uplands. Examples include some woody draws occupied by the *Fraxinus pennsylvanica*/*Prunus virginiana* (green ash/common chokecherry) habitat type and some floodplain sites occupied by the *Artemisia cana*/*Agropyron smithii* (silver sagebrush/western wheatgrass) habitat type or the *Pinus ponderosa*/*Cornus stolonifera* (ponderosa pine/red-osier dogwood) habitat type. Currently, many of these sites fail to meet jurisdictional wetland criteria. Nevertheless, these sites do provide important wetland functions and may warrant special managerial consideration. The current interpretation, at least in the western United States, is that not all functional wetlands are jurisdictional wetlands, but all jurisdictional wetlands are functional wetlands.

METHODS

Since 1988, we have been continually developing various assessment protocols to address the health of riparian and wetland sites. The first assessment that was developed was the lotic inventory. At the beginning of the process, we evaluated a wide range of inventory procedures. Most were developed for upland sites and not always applicable. Therefore, in many instances, we had to develop new procedures for use in a riparian or wetland site. Through a series of workshops with a large number of natural resource professionals, a lotic inventory assessment began to take shape. We utilized the Delphi approach or expert opinion approach for developing the assessment. The Delphi approach is designed to bring together the experts in the field of study and develop a consensus on a topic.

In the beginning, the protocols evolved at a rapid rate as the field personnel provided invaluable feedback. As the years have progressed, the assessment and the codes and instructions for the form has evolved to where today it contains over 800 data base fields comprising detailed information on vegetation, physical site, and hydrology data.

As work progressed on the lotic inventory assessment, the public and many natural resource professionals began asking questions about the "health" of a riparian or wetland zone. In early 1992, we began the process of developing a methodology that would address the health issue. Once again, through a series of workshops with natural resource professionals, a lotic health assessment was developed.

To-date the collaborative effort has resulted in the development of the following assessments for riparian and wetland areas: 1) lotic inventory, 2) lotic health evaluation (derived from the lotic inventory), 3) lotic health assessment (stand-alone), 4) river health assessment (stand-alone), 5) lentic inventory, 6) lentic health evaluation (derived from the lentic inventory), and 7) lentic health assessment (stand-alone). Each of the assessments also includes a discussion on the codes or instructions used with each form.

RESULTS AND DISCUSSION

The health of a site may be defined as the ability of that system to perform certain wetland functions. A site's health rating may also reflect management considerations. For example, although noxious weeds such as *Centaurea maculosa* (spotted knapweed) or *Euphorbia esula* (leafy spurge) may help to trap sediment and provide soil-binding properties, other functions (i.e., productivity and wildlife habitat) will be impaired; and their presence should be a management concern.

No single factor or characteristic of a wetland site can provide a complete picture of either site health or the direction of trend. For example, the lotic assessment is based on consideration of channel and riparian vegetation factors. It relies extensively on vegetative characteristics as integrators of factors operating on the landscape. Because they are more visible than soil or hydrologic characteristics, plants may provide early indications of riparian health as well as successional trend. These are reflected not only in the types of plants present, but also by the effectiveness with which the vegetation carries out its wetland functions of stabilizing the soil, trapping sediments, and providing wildlife habitat. Furthermore, the utilization of certain types of vegetation by animals may indicate the current condition of the wetland and may indicate trend toward or away from potential natural community (PNC).

In addition to vegetation factors, an analysis of site health and its susceptibility to degradation must consider physical factors (soils and hydrology) for both ecologic and management reasons. Changes in soil or hydrologic conditions obviously affect functioning of a wetland ecosystem. Moreover, changes in physical characteristics are often (but not always) more difficult to remedy than vegetative changes. For example, extensive incisement (down-cutting) of a stream channel may lower the water table and thus change site potential from a *Fraxinus pennsylvanica/Prunus virginiana* (green ash/common chokecherry) habitat type to an *Artemisia cana/Agropyron smithii* (silver sagebrush/western wheatgrass) habitat type or even to an upland (non-riparian) type. Sites experiencing significant hydrologic, edaphic (soil), or climatic changes will likely also have a change in plant community potential.

The assessments attempt to balance the need for a simple, quick index of health against the reality of an infinite range of wetland situations. Although this approach will not always work perfectly, we believe that in most cases it will yield a usefully accurate index of riparian health. Some more rigorous methods to determine status of a stream's channel morphology are Dunne and Leopold (1978), Pfankuch (1975), and Rosgen (1996). These relate their ratings to degree of channel degradation, but do not integrate other riparian functions into the rating. Other methods are available for determining condition from perspectives that also include vegetation, most notably the USDI Bureau of Land Management (BLM) proper functioning condition (PFC) methodology (1998).

Potential Uses

The rapid lotic health (stand-alone) assessment procedure has been tested in Montana, surrounding states, and western Canada since 1992. Currently, over 5,000 people have been trained using the assessment. Some potential uses for this health rating include: 1) stratifying streams or wetlands by degree of ecologic dysfunction, 2) identifying ecologic problems, and 3) when repeated over time, monitoring to detect functional change. A less direct, but also important, value of an environmental assessment of this kind is its educational potential. By getting land managers to focus on individual riparian functions and ecologic processes, they may come to a better understand how the parts work together and are affected by human activities.

Once land managers have determined health of the stream reach in question, they next need to determine the appropriate course of action, if any. If the stream reach rated Proper Functioning Condition (Healthy), then no action may be needed. If the stream reach rated Functional At Risk (Healthy, but with problems) or Nonfunctional (Unhealthy), the manager needs to determine what remedy is appropriate. The form is divided into two categories: vegetation and physical site factors. The land manager should review the assessment to see which category rated low. This will indicate the prime area of focus. *Classification and Management of Montana's Riparian and Wetland Sites* (Hansen and others 1995) offers assistance in this area. Suppose, for example, a stream reach was rated at 54%, and a review of the health assessment form revealed major problems in these areas: 1) altered streambanks, 2) lateral cutting of the streambank, 3) cover of undesirable herbaceous species, 4) utilization of trees and shrubs, and 5) tree and shrub regeneration. (These are determined by comparing the actual value against the possible value for each factor.) This tells the manager that the banks are eroding because high use is impacting the banks and reducing woody species cover. If potential for the site is woody species (determined from the habitat types or community types recorded on the lotic inventory form), and there are low values for both utilization and regeneration of woody species, the manager may accelerate the restoration process by planting woody species to help stabilize the streambanks. The appropriate woody species and methods for planting them can be found in *Classification and Management of Montana's Riparian and Wetland Sites* (Hansen and others 1995) or another appropriate publication. If livestock are causing the problem, changes in grazing regime are needed before planting to prevent new plants from being browsed. Management change can include measures designed to discourage livestock from spending long periods along the streambanks.

Types of Assessments

Through the years we have developed a variety of assessments for both lotic (flowing water) systems and lentic (still water) systems. The following is a brief description of the assessment protocols.

Lotic Inventory—A comprehensive inventory of a stream segment and its associated riparian area, including detailed vegetation data, physical site data, some wildlife data, trend commentary, and photographs. The inventory form contains over 800 data base fields. The vegetation data collected includes species identification and canopy cover estimations, as well as age class breakdowns for each tree and shrub species. Physical site data includes channel morphology and condition, substrate composition, disturbance degree and kind, amount and cause of bare ground, and commentary. Wildlife data includes details of beaver activity and observations of fishery, amphibian, and reptile data. Currently, this approach has been used on over 4,828 km (3,000 mi) of streams and rivers in western North America.

Lotic Health Evaluation (derived from the Lotic Inventory)—An evaluation of riparian functional health derived from data collected in the RWRP Lotic Inventory form. An array of vegetation (biotic) and physical site (abiotic) items are weighted and rated for calculation of a health evaluation index score. The items include information on hydric soils, hydrophytic vegetation, and wetland hydrology.

Lotic Health Assessment (Stand-Alone)—A rapid assessment of lotic site functional health based on a similar set of factors as the Lotic Health Evaluation, but derived from on-site estimation instead of from the detailed Lotic Inventory form. This assessment has been taught to over 5,000 land owners/managers in Montana, Idaho, North Dakota, Colorado, Utah, and the four western Canadian Provinces of Alberta, Saskatchewan, Manitoba, and British Columbia.

River Health Assessment (Stand-Alone)—A rapid assessment of river functional health based on a set of factors similar to the Lotic Health Assessment, but with some differences to take into account differences of a river system vs. a stream system.

Lentic Inventory—A comprehensive inventory of a lentic site and its associated functional wetland area, including detailed vegetation data, physical site data, some wildlife data, trend commentary, and photographs. The inventory form contains over 800 data base fields. The vegetation data collected includes species identification and canopy cover estimations, as well as age class breakdowns for each tree and shrub species. Physical site data includes shoreline morphology and condition, substrate composition, disturbance degree and kind, amount and cause of bare ground, and commentary. Wildlife data includes observations of fishery, amphibian, and reptile data.

Lentic Health Evaluation (derived from the Lentic Inventory)—An evaluation of wetland functional health derived from data collected in the Lentic Inventory form. An array of vegetation and physical site items are weighted and rated for calculation of a health evaluation index score. The items include information on hydric soils, hydrophytic vegetation, and wetland hydrology.

Lentic Health Assessment (Stand-Alone)—A rapid assessment of lentic site functional health based on a similar set of factors as the Lentic Health Evaluation, but derived from on-site estimation instead of from the detailed site inventory.

Table 1 compares the various assessments in terms of type of data collected (vegetation vs. physical data), level of effort required, and potential miles/day.

Table 1. Type of data collected (vegetation vs. physical data), level of effort required, and potential miles/day

Assessment	Detailed Veg. Data	Detailed Physical Data	Level of Effort Required	Potential Km/Day by Evaluator
Lotic Wetlands				
Lotic Inventory	Yes	Yes	High	Low
Lotic Health Evaluation (derived from lotic inventory form)	No	No	High	Low
Lotic Health Assessment (stand-alone)	No	No	Moderate	Moderate
River Health Assessment (stand-alone)	No	No	Moderate	Moderate
Lentic Wetlands				
Lentic Inventory	Yes	Yes	High	Low
Lentic Health Evaluation (derived from lentic inventory form)	No	No	High	Low
Lentic Health Assessment (stand-alone)	No	No	Moderate	Moderate

The current assessment protocols can be obtained at the web site www.rwrp.umt.edu. The forms and their codes and instructions are available for downloading using the free program from Adobe(R) called Acrobat(R). The files are PDF (Portable Document Format) files.

Limitations

These assessments are not designed for an in-depth and comprehensive analysis of ecologic processes. Such analysis may be warranted on a site and can be done after this evaluation has identified areas of concern.

These assessments attempt to balance the need for a simple, quick index of health against the reality of an infinite range of situations. There are some visible changes to site health for which we have no simple way to measure. An obvious and commonly encountered example is excess entrained sediment. This may indicate serious degradation, but we leave it out of the assessment due to difficulty in knowing how much is normal. Instead, we address on-site causes of sediment production: bare ground, banks with poor root mass protection, and human-caused structural damage to the banks. Another potentially serious degrading factor for which we have no simple measurement yet is dewatering of the system by irrigation diversion/pumping and by upper drainage retention dams. Although these approaches will not always work perfectly, we believe that in most cases they will yield a usefully accurate index of riparian or wetland health.

No single factor or characteristic of a riparian site can provide a complete picture of either site health or the direction in which it might be heading. Because of inherent dynamics of such systems, riparian sites often contain a mix of indicators. Moreover, characteristics that in traditional evaluations of ecological sites have been considered negative may not be so in riparian sites. For example, bare soil, which often reflects overgrazing or erosion on upland sites, may be only a reflection of normal riparian activity, such as recent sediment deposits resulting from spring runoff or a high water event. The ratings in the evaluation form have been weighted to take such situations into consideration. Thus, only human-caused bare ground is rated negatively, although naturally occurring bare ground can be considered an indicator of susceptibility to impacts such as erosion and weed invasion.

A single evaluation provides a rating at only one point in time. Due to the range of variation possible on a riparian or wetland site, a single evaluation cannot define absolute status of site health or reliably indicate trend (whether the site is improving, degrading, or stable). To measure trend, health assessments should be repeated in subsequent years during the same time of year. Evaluation should be conducted when most plants can be identified in the field and when hydrologic conditions are most nearly normal (e.g., not during peak spring runoff or immediately after a major storm).

Each assessment has its strengths and weaknesses. Our overall goal has been to provide land managers with a variety of "tools" to choose from in their "toolbox" (e.g., different tools for different needs). Which tool is the best for the job? This can only be answered after the specific goals and objectives are determined for the project (e.g., a needs assessment). Once this has been completed, the proper or best tool(s) can then be chosen.

LITERATURE CITED

American Fisheries Society, Western Division. 1980. Position paper on management and protection of western riparian stream ecosystems. American Fisheries Society, Bethesda, MD. 24 p.

Boldt, Charles D., Daniel W. Uresk, and Keith E. Severson. 1978. Riparian woodlands in jeopardy on Northern High Plains. In: Strategies for protection and management of floodplain wetlands and other riparian ecosystems (R. R. Johnson and J. F. McCormick, Technical Coordinators). USDA Forest Service General Technical Report WO-12. Washington, DC. pp. 184-189.

Cooperrider, Allen Y., Raymond J. Boyd, and Hanson R. Stuart. 1986. Inventory and monitoring of wildlife habitat. USDI Bureau of Land Management, Denver Service Center, Denver CO. 858 p.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deep water habitats of the United States. USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC. Publication Number FWS/OBS-79/31. 107 p.

Dunne, T. and L. B. Leopold. 1978. Water in environmental planning. W. H. Freeman & Company, San Francisco, CA. 818 pp.

Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Technical Report Y-87-1. US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. 100 p.

Federal Interagency Committee for Wetland Delineation. 1989. Federal manual for identifying and delineating jurisdictional wetlands. US Army Corps of Engineers, US Environmental Protection Agency, USDI Fish and Wildlife Service, and USDA Soil Conservation Service Cooperative Technical Publication, Washington, DC. 76 p.

Hansen, Paul L., Robert D. Pfister, Keith Boggs, Bradley J. Cook, John Joy, and Dan K, Hinckley. 1995. Classification and management of Montana's riparian and wetland sites. Miscellaneous Publication No 54. Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Missoula, Montana. 646 p.

Johnson, R. R., and S. W. Carothers. 1980. Riparian habitats and recreation: interrelationships and impacts in the Rocky Mountain region. Produced under agreement 53-82 FT-0-125 of the Eisenhower Consortium for Western Environmental Forestry Research, Fort Collins, CO. 109 p.

Kent, Donald M. 1994. Applied wetlands science and technology. Donald M. Kent, editor. CRC Press, Inc., Lewis Publishers, Boca Raton, FL. 436 p.

Kovalchik, Bernard L. 1987. Riparian zone associations: Deschutes, Ochoco, Fremont, and Winema National Forests. USDA Forest Service Region 6 Ecology Technical Paper 279-87. Pacific Northwest Region, Portland, OR. 171 p.

Mitsch, William J., and James G. Gosselink. 1993. Wetlands. Second Edition. Van Nostrand Reinhold, Publishers, New York, NY. 722 p.

Pfankuch, D. J. 1975. Stream reach inventory and channel stability evaluation. USDA Forest Service, RI-75-002. Government Printing Office #696-260/200, Washington, DC. 26 pp.

Prichard, Don, Clay Bridges, Steve Leonard, Russ Krapf, and Warren Hagenbuck. 1994. Riparian area management: Process for assessing proper functioning condition for lentic riparian-wetland areas. Technical Reference 1737-11. USDI Bureau of Land Management. Denver Service Center. 39 p.

Rosgen, D. L. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, CO. 246 pp.

Shaw, S. P., and C. G. Fredine. 1956. Wetlands of the United States: Their extent and their value for waterfowl and other wildlife. USDI Fish and Wildlife Service, Circular 39. Washington, DC. 67 p.

Stewart, R. E., and H. A. Kantrud. 1972. Classification of natural ponds and lakes in the glaciated prairie region. USDI Fish and Wildlife Service, Research Publication 92. 57 p.

USDI Bureau of Land Management. 1998. Riparian area management: A user guide to assessing proper functioning condition and the supporting science for lotic areas, TR 1737-15. Bureau of Land Management National applied Resource Sciences Center, Denver, CO. 125 pp.

Windell, John T., Beatrice E. Willard, David J. Cooper, Susan Q. Foster, Christopher F. Knud-Hansen, Lauranne P. Rink, and George N. Kiladis. 1986. An ecological characterization of Rocky Mountain montane and subalpine wetlands. USDI Fish and Wildlife Service Biological Report 86(11). National Ecology Center, Division of Wildlife and Contaminant Research, Fish and Wildlife Service, US Department of the Interior, Washington, DC. 298 p.

APPENDIX G

THREATENED AND ENDANGERED SPECIES DESCRIPTIONS

Canada Lynx - *Lynx canadensis*

Species of Concern

Global Rank: G5
State Rank: S3

Agency Status
USFWS: LT
USFS: THREATENED
BLM: SPECIAL STATUS
FWP Conservation Tier: 1

- 
- 

Image Copyright and Usage Information

General Description

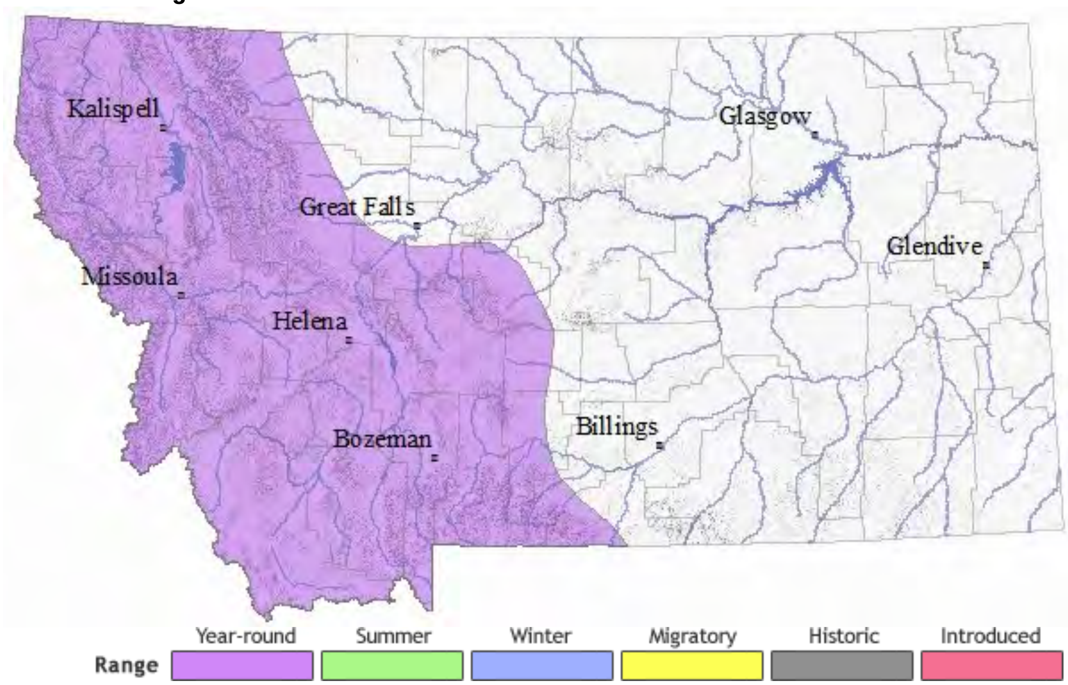
The Canada Lynx is a medium-sized cat (about 10 kilograms for males and 8 kilograms for females) with silver-gray to grayish-brown upperparts and a white belly and throat. Lynx have long legs and a relatively short, compact body. The total length averages approximately 92.5 centimeters for males and 89.5 centimeters for females (Foresman 2001). A facial ruff surrounds the face except directly beneath the snout. The facial ruff is longest on either side of the snout and has black markings on these longest hairs. The ears are 70 to 80 millimeters long and have a long, 30 millimeters black tuft at the end. The backs of the ears are darker than the rest of the body and have a central white spot. The feet are large and round (10 x 10 centimeters) and heavily furred (Foresman 2001). The tail is short and the tip is entirely black.

Diagnostic Characteristics

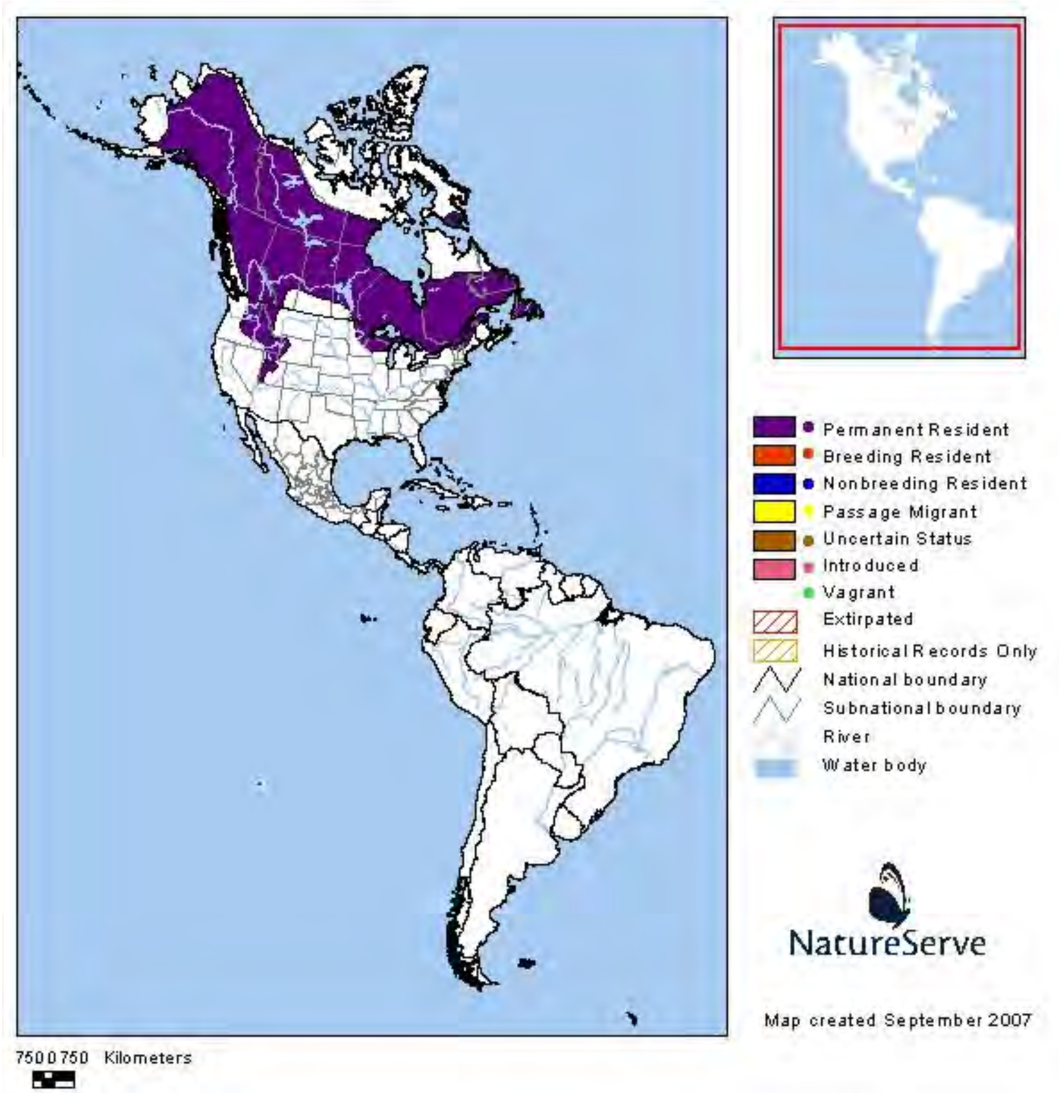
Canada Lynx are most similar to Bobcats, but differ in many respects. At a distance, Canada Lynx appear leggier and are grayer in color, with less distinctive spotting (Foresman 2001). Canada Lynx have much larger feet and longer ear tufts. In addition, the entire tail tip is black in Canada Lynx whereas in Bobcats the underside of the tail tip is white (Foresman 2001) and the back of the hind legs is black on Bobcats and a light beige color on Canada Lynx. Immature Mountain Lions may be superficially similar to Canada Lynx but have a much longer tail and body.

General Distribution

Montana Range



Western Hemisphere Range

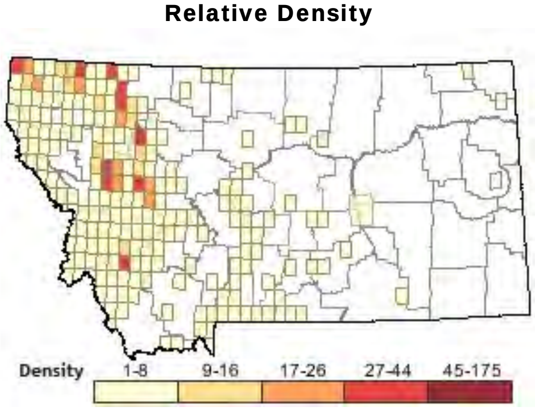


Summary of Observations Submitted for Montana

Number of Observations: 1884

(Click on the following maps and charts to see full sized version) Map Help and Descriptions

Relative Density



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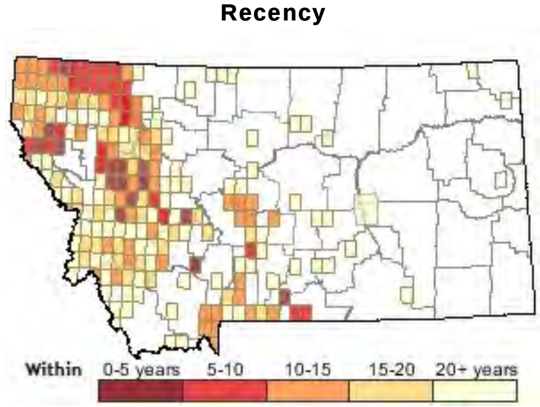

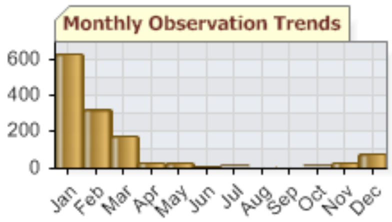

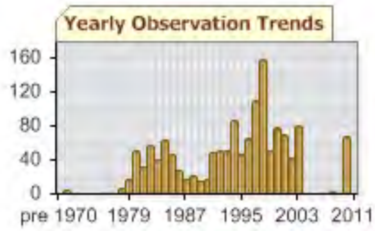

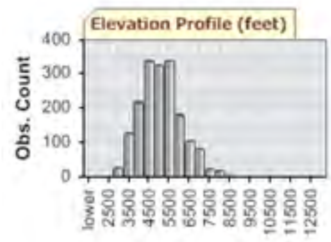

(Records associated with a range of dates are excluded from time charts)

Migration

Canada Lynx are non-migratory, but movements of 90 to 125 miles have been recorded between Montana and Canada (Hash 1990). In other areas, long distance dispersal has been reported to range from 103 to 616 kilometers (Saunders 1963, Nellis and Wetmore 1969, Brainerd 1985, Ward 1985, Brittell et al. 1989).

Habitat

Canada Lynx west of the Continental Divide generally occur in subalpine forests between 1,220 and 2,150 meters in stands composed of pure lodgepole pine but also mixed stands of subalpine fir, lodgepole pine, Douglas-fir, grand fir, western larch and hardwoods (J. Squires pers. comm. 1999 in Ruediger et al. 2000). In extreme northwestern Montana, primary vegetation may include cedar-hemlock habitat types (Ruediger et al. 2000). East of the Continental Divide the subalpine forests inhabited by Canada Lynx occur at higher elevations (1,650 to 2,400 meters) and are composed mostly of subalpine fir. Secondary habitat is intermixed Englemann spruce and Douglas-fir habitat types where lodgepole pine is a major seral species (Ruediger et al. 2000). Throughout their range, shrub-steppe habitats may provide important linkage habitat between the primary habitat types described above (Reudiger et al. 2000). Typical snow conditions are important factors for Canada Lynx, with occurrence primarily in habitats that also receive relatively uniform and moderately deep snowfall amounts (total annual snowfall of 100 to 127 centimeters) (Kelsall et al. 1977). Within these habitat types, disturbances that create early successional stages such as fire, insect infestations, and timber harvest, provide foraging habitat for lynx by creating forage and cover for Snowshoe Hares, although older forests also provide habitats for Snowshoe Hares and Canada Lynx for longer periods of time than disturbance-created habitats (Ruediger et al. 2000).

Canada Lynx avoid large openings but often hunt along edges in areas of dense cover (Ruediger et al. 2000). When inactive or birthing, they occupy dens typically in hollow trees, under stumps, or in thick brush. Den sites tend to be in mature or old-growth stands with a high density of logs (Koehler 1990, Koehler and Brittell 1990). These habitats must be near or adjacent to foraging habitat because the hunting range of the female is reduced during this time (Ruediger et al. 2000).

In the South Fork Flathead, Canada Lynx were mostly located in fire-created, densely stocked young stands of lodgepole pine where Snowshoe Hares were most abundant. No locations in open or semi-open areas were observed (Koehler at al. 1979). In the Garnet Range, most were found in subalpine fir forest (Smith 1984). Denning sites are found in mature and old-growth lodgepole pine, spruce, and subalpine fir forests with a high density of logs (Koehler 1990, Koehler and Brittell 1990). Denning stands need not be large (1 to 3 hectares) but several stands should be interconnected (Koehler and Brittell 1990). Canada Lynx require cover for stalking and security, and usually do not cross openings wider than 100 meters (Koehler and Brittell 1990).

Ecological Systems Associated with this Species

Commonly Associated with these Ecological Systems

Forest and Woodland Systems

Aspen and Mixed Conifer Forest
Aspen Forest and Woodland
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest

Rocky Mountain Lodgepole Pine Forest
Rocky Mountain Mesic Montane Mixed Conifer Forest
Rocky Mountain Montane Douglas-fir Forest and Woodland
Rocky Mountain Ponderosa Pine Woodland and Savanna
Rocky Mountain Poor Site Lodgepole Pine Forest
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland
Rocky Mountain Subalpine Woodland and Parkland

Shrubland, Steppe and Savanna Systems

Rocky Mountain Subalpine Deciduous Shrubland

Wetland and Riparian Systems

Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland
Rocky Mountain Conifer Swamp
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland
Rocky Mountain Subalpine-Montane Riparian Shrubland
Rocky Mountain Subalpine-Montane Riparian Woodland
Rocky Mountain Wooded Vernal Pool

Occasionally Associated with these Ecological Systems

Forest and Woodland Systems

Rocky Mountain Foothill Limber Pine - Juniper Woodland

Grassland Systems

Rocky Mountain Subalpine-Montane Mesic Meadow

Food Habits

The primary winter food for Canada Lynx throughout their range is the Snowshoe Hare (*Lepus americanus*), comprising 35 to 97% of their diet (Koehler and Aubry 1994). Red Squirrels are also an important prey item, particularly when Snowshoe Hare populations are reduced (Ruediger et al. 2000). Summer diets are not as well known but are probably more varied (Mowat et al. 2000). Canada Lynx in Montana probably prey on a wider variety of species throughout the year because of generally lower Snowshoe Hare densities and available alternate prey (Ruediger et al. 2000). Other known prey items include grouse, Northern Flying Squirrel, ground squirrels, Porcupines, Beavers, mice, voles, shrews and occasionally ungulates as prey or carrion (Reudiger et al. 2000).

Ecology

Canada Lynx populations are tied to Snowshoe Hare populations and cycle with them. Snowshoe Hare populations were not thought to cycle in Montana, but recent research suggests that southern Snowshoe Hare populations do cycle, but not at the amplitude of northern populations (Hodges 2000). Southern Snowshoe Hare populations also exist at lower densities than northern populations (Koehler and Aubry 1994). Montana Canada Lynx ecology is subsequently different than those populations further north with average home ranges nearly twice the size of those found in the north (Aubrey et al. 2000). Home ranges are quite variable with increasing home range sizes during periods of low Snowshoe Hare populations (Ruediger et al. 2000). Home ranges of males are larger than that of females. Long distance dispersal movements of up to several hundred kilometers have been recorded and dispersal is common and thought to be essential for population regulation (Schwartz et. al. 2002). Population density usually is less than 10 (locally up to 20) per 100 square kilometers, depending on prey availability. Mean densities range between 2 and 9 per 100 square kilometers (McCord and Cardoza 1982).

Home range sizes in North America are large, varying from 10 to 243 square kilometers (McCord and Cardoza 1982); typical home ranges are 16 to 20 square kilometers (Quinn and Parker 1987, Butts 1992). Home range sizes vary with sex, age, population density, prey density, and method of survey and calculation (McCord and Cardoza 1982, Ward and Krebs 1985, Quinn and Parker 1987, Hatler 1988). Some researchers have reported Canada Lynx maintain single sex territories (especially males) with male territories overlapping female territories (Mech 1980, Stephenson 1986, Koehler 1987). However, others found substantial overlap between territories of both the same and opposite sexed animals (Nellis et al. 1972, Brand et al. 1976, Carbyn and Patriquin 1983, Ward and Krebs 1985). Where Canada Lynx and Bobcat are sympatric, home ranges overlap; however Bobcats are at lower elevation in winter (Smith 1984).

Reproductive Characteristics

Canada Lynx breed through March and April. Gestation lasts 62 to 74 days with litter sizes averaging 3 or 4. Males do not help rear the young. Adult females produce one litter every 1 to 2 years and the young stay with their mother until next mating season or longer. Some females give birth as yearlings, particularly during years with high Snowshoe Hare populations, but their pregnancy rate is lower than that of older females (Brainerd 1985). Prey scarcity suppresses breeding and may result in mortality of nearly all young (Brand and Keith 1979). In Alberta, reproduction fell 38% (ovulation rates, pregnancy rates and litter size) and mortality of kittens reached 95% during cyclic Snowshoe Hare population lows (Brand and Keith 1979).

Management

Canada Lynx are classified as a furbearer in Montana but the trapping season is currently closed in Montana. Any Canada Lynx accidentally trapped must be released uninjured and reported to designated Fish, Wildlife and Parks employees within the trapping district within five days. Any Canada Lynx trapped that cannot be released unharmed must be reported to Fish, Wildlife and Parks for assistance to determine disposition and/or collection of the animal. Canada Lynx were listed as a threatened species under the Endangered Species Act in the contiguous United States in 2000 because of the inadequacy of guidance for conservation of Canada Lynx in the National Forest Land and Resource Management Plans and Bureau of Land Management Land Use Plans (Reudiger et al. 2000). Subsequently, the Canada Lynx Conservation Assessment and Strategy (Reudiger et al. 2000) was produced to provide guidance for conservation measures on federally managed lands to ensure that Canada Lynx populations were not jeopardized by management of critical habitat. Please consult the plan for details of this strategy.

References

Literature Cited Above

Web Search Engines for Articles on "Canada Lynx"

Additional Sources of Information Related to "Mammals"

Citation for data on this website:
Canada Lynx — Lynx canadensis. Montana Field Guide. Retrieved on September 8, 2010, from http://FieldGuide.mt.gov/detail_AMAJH03010.aspx

Home - Other Field Guides
Kingdom - Animals - *Animalia*
Phylum - Vertebrates - *Craniata*
Class - Mammals - *Mammalia*
Order - Carnivores - *Carnivora*
Family - Wolves / Coyotes / Foxes - *Canidae*
Species - Gray Wolf - *Canis lupus*

Gray Wolf - *Canis lupus*

Species of Concern

Global Rank: G4
State Rank: S4

Agency Status
USFWS: LE, XN
USFS: SENSITIVE
BLM: SENSITIVE
FWP Conservation Tier: 1

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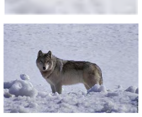
- 
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Image Copyright and Usage Information

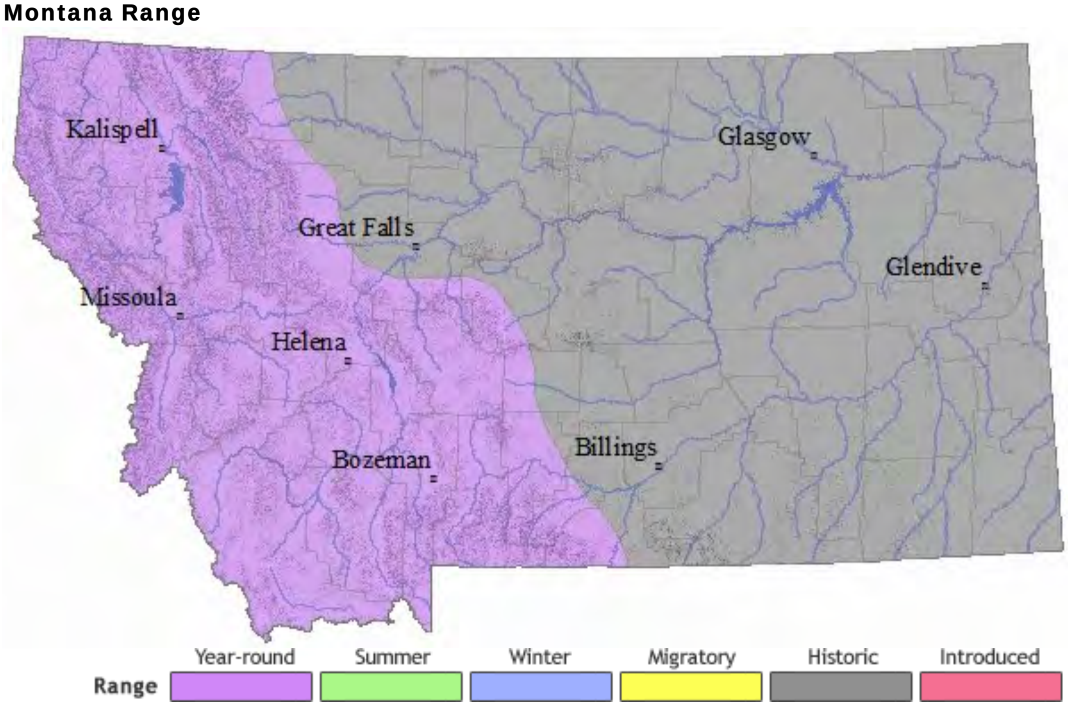
General Description

The Gray Wolf is the largest of the wild dogs. Adult male Gray Wolves in Montana weigh around 47 kilograms

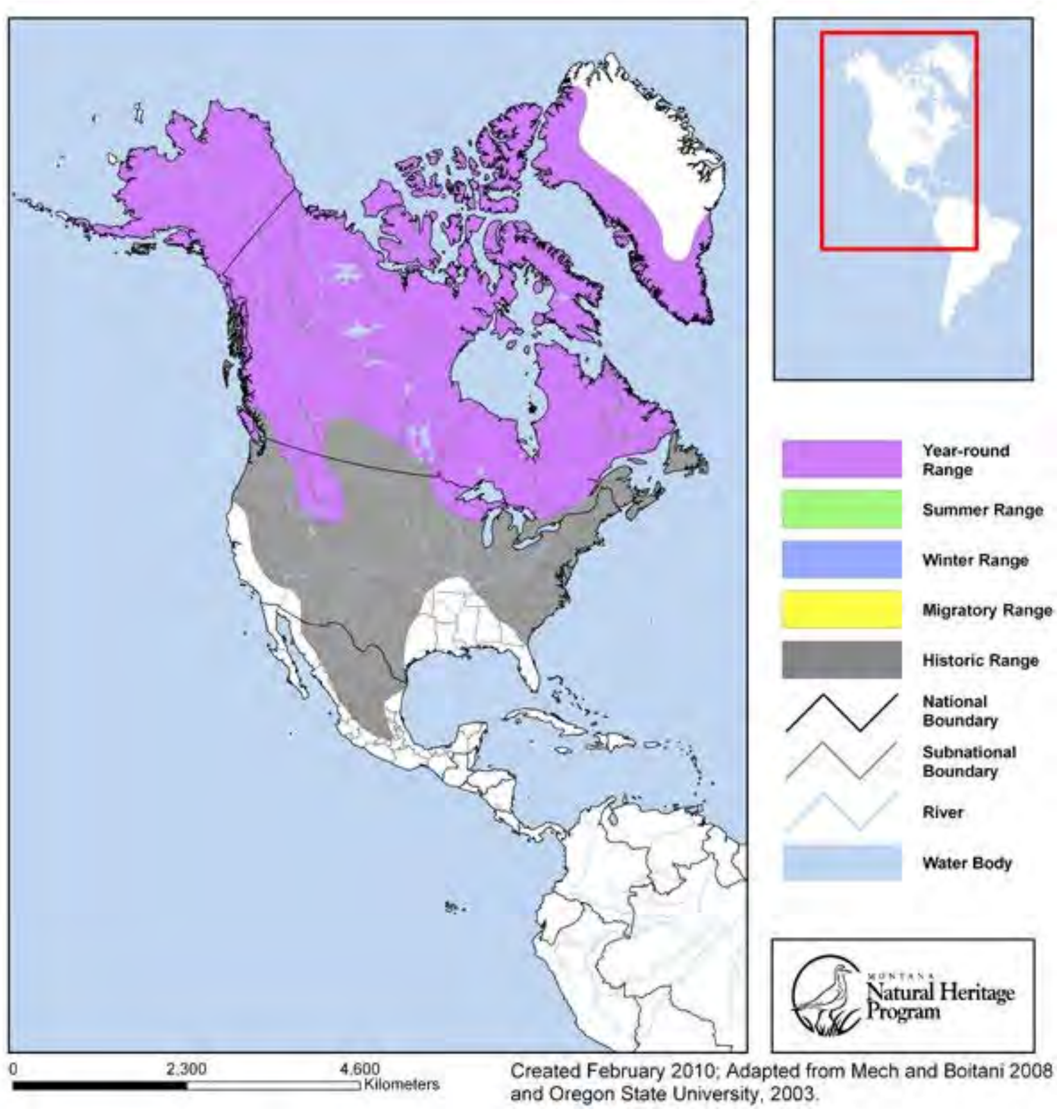
(104 pounds) and females weigh around 36 kilograms (80 pounds). Males average approximately 186 centimeters (73 inches) in length, while 180 centimeters (70 inches) is the average for females, with the tail compromising a little less than one-third of the total length in both sexes (Foresman 2001). About half the Gray Wolves in Montana are black with the other half gray. Both color phases may be found in a pack or in a litter of pups.

General Distribution

Montana Range



Western Hemisphere Range

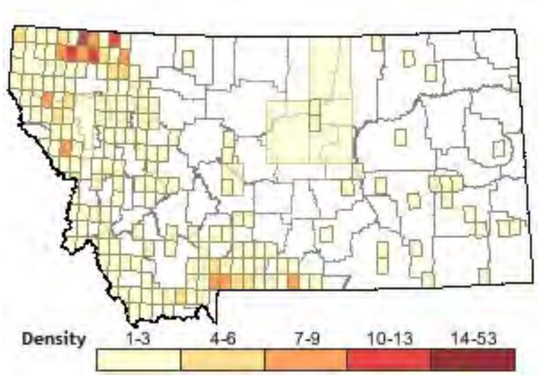


Summary of Observations Submitted for Montana

Number of Observations: 626

(Click on the following maps and charts to see full sized version) Map Help and Descriptions

Relative Density



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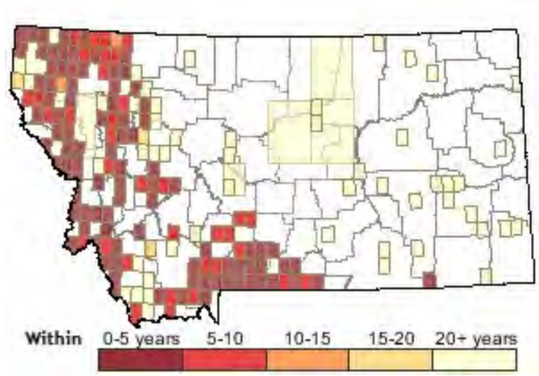

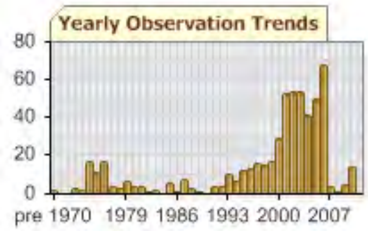

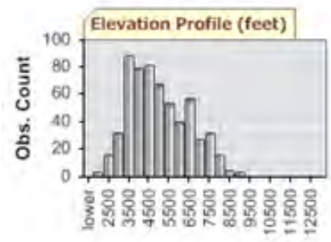

(Records associated with a range of dates are excluded from time charts)

Migration

This species is not migratory but may move seasonally following migrating ungulates within its territory. Gray Wolves also disperse widely. Males in northwestern Montana can move an average of 113 km (70 miles) from their natal territory, and females 77 km (48 miles), before establishing a new territory or joining an existing pack (Boyd and Pletscher 1999). Dispersal peaks twice per year; first in January/February and second, in May/June (Boyd and Pletscher 1999). Some Gray Wolves are known to have dispersed up to 805 km (500 miles). Dispersal has been documented from Canada, Idaho and Wyoming to Montana. Montana Gray Wolves are also known to have dispersed to Canada, Idaho, and Wyoming.

Habitat

The Gray Wolf exhibits no particular habitat preference except for the presence of native ungulates within its territory on a year-round basis. In Minnesota and Wisconsin, Gray Wolves usually occur in areas with few roads and human disturbance (Thiel 1985, Mech et al. 1988, Mech 1989). Gray Wolves establishing new packs in Montana have demonstrated greater tolerance of human presence and disturbance than previously thought characteristic of this species. They have established territories where prey are more abundant at lower elevations than expected, especially in winter (Montana Fish, Wildlife and Parks 2003).

Ecological Systems Associated with this Species

Commonly Associated with these Ecological Systems

Forest and Woodland Systems

- Aspen and Mixed Conifer Forest
- Aspen Forest and Woodland
- Great Plains Ponderosa Pine Woodland and Savanna
- Great Plains Wooded Draw and Ravine
- Mountain Mahogany Woodland and Shrubland
- Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
- Rocky Mountain Foothill Limber Pine - Juniper Woodland
- Rocky Mountain Foothill Woodland-Steppe Transition
- Rocky Mountain Lodgepole Pine Forest
- Rocky Mountain Mesic Montane Mixed Conifer Forest
- Rocky Mountain Montane Douglas-fir Forest and Woodland
- Rocky Mountain Ponderosa Pine Woodland and Savanna
- Rocky Mountain Poor Site Lodgepole Pine Forest
- Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
- Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland
- Rocky Mountain Subalpine Woodland and Parkland

Grassland Systems

- Great Plains Mixedgrass Prairie
- Great Plains Sand Prairie
- Rocky Mountain Lower Montane, Foothill, and Valley Grassland
- Rocky Mountain Subalpine-Montane Mesic Meadow
- Rocky Mountain Subalpine-Upper Montane Grassland

Shrubland, Steppe and Savanna Systems

- Big Sagebrush Shrubland
- Big Sagebrush Steppe

Great Plains Shrubland
Low Sagebrush Shrubland
Mat Saltbush Shrubland
Mixed Salt Desert Scrub
Montane Sagebrush Steppe
Rocky Mountain Lower Montane-Foothill Shrubland
Rocky Mountain Montane-Foothill Deciduous Shrubland
Rocky Mountain Subalpine Deciduous Shrubland

Sparse and Barren Systems

Active and Stabilized Dune
Great Plains Badlands

Wetland and Riparian Systems

Emergent Marsh
Greasewood Flat
Great Plains Closed Depressional Wetland
Great Plains Open Freshwater Depression Wetland
Great Plains Prairie Pothole
Great Plains Riparian
Great Plains Saline Depression Wetland
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland
Rocky Mountain Conifer Swamp
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland
Rocky Mountain Subalpine-Montane Riparian Shrubland
Rocky Mountain Subalpine-Montane Riparian Woodland
Rocky Mountain Wooded Vernal Pool

Occasionally Associated with these Ecological Systems

Alpine Systems

Alpine Bedrock and Scree
Alpine Dwarf-Shrubland
Alpine Fell-Field
Alpine Turf

Sparse and Barren Systems

Great Plains Cliff and Outcrop
Rocky Mountain Cliff, Canyon and Massive Bedrock
Shale Badland
Wyoming Basin Cliff and Canyon

Wetland and Riparian Systems

Alpine-Montane Wet Meadow
Great Plains Floodplain
Rocky Mountain Subalpine-Montane Fen

Food Habits

Gray Wolves are opportunistic carnivores that predominantly prey on large ungulates. Main prey items in Montana include deer, Elk, and Moose (Montana Fish, Wildlife and Parks 2003). Bison are also taken where the ranges of the two species overlap in and around Yellowstone National Park. Domestic livestock such as cattle and sheep are also preyed upon. Gray Wolves may also eat alternative prey, such as rodents, vegetation and carrion. Gray Wolves commonly hunt in packs, but lone animals and pairs are able to kill prey as large as adult Moose (Thurber and Peterson 1993).

Ecology

In most areas, Gray Wolves are territorial throughout the year. Packs generally consist of a socially dominant pair, their offspring of the previous year, and new pups, although other breeding-age adults that may or may not be related to the alpha pair may also be present (Montana Fish, Wildlife and Parks 2003). More than 1 female in the pack can breed and give birth to pups. Pup survival when there are multiple litters is highly variable. Pack size varies and may include as few as 3 and as many as 37 (U.S. Fish and Wildlife Service et al. 2001). In the Glacier National Park area, packs generally include 8 to 12 individuals (Bangs and Fritts 1993). Packs share pup-rearing responsibilities including food provisioning and tending pups at the den or rendezvous sites (Montana Fish, Wildlife and Parks 2003). Pack activity is centered on the den site and nearby rendezvous sites from late April until September (Montana Fish, Wildlife and Parks 2003). Lone Gray Wolves may move through territories of established packs (Thurber and Peterson 1993). Pack territories are dynamic and change from year to year depending on prey availability, Gray Wolf populations, and relationships with neighboring packs.

Summer home ranges are smaller than winter ranges; the annual range may be up to several hundred square kilometers (km). In the Glacier National Park area, territory size averages around 780 square kilometers (301 square miles)(Bangs and Fritts 1993). Gray Wolves may occasionally move several hundred kilometers, especially dispersing young. In Minnesota, most dispersers left when they were 11 to 12 months old; dispersal occurred mainly in February to April and October to November; 35% of known-age Gray Wolves remained in their natal territory for more than 2 years (Gese and Mech 1991). Average territory size in northwestern Montana was 220 square kilometers (185 square miles) but was highly variable (U.S. Fish and Wildlife Service et al. 2002). Average territory size for Yellowstone Gray Wolves was larger, averaging 891 square kilometers (344 square miles) (U.S. Fish and Wildlife Service et al. 2002).

Gray Wolves are generally not instrumental in causing prey declines but their effect varies with other environmental circumstances. In Quebec, winter weather appeared to affect the deer population trend more than did Gray Wolf predation (Potvin et al. 1992). In south-central Alaska, Gray Wolf predation may have limited Caribou recruitment (Bergerud and Ballard 1988), though winter starvation also was proposed as a significant population control. Gray Wolves may take livestock as secondary prey when deer fawns (the primary summer prey) are less vulnerable due to better prenatal nutrition resulting from mild winter (USFWS 1990). In Minnesota, snow-induced changes in deer distribution and mobility resulted in changes in Gray Wolf movement patterns, sociality, and feeding behavior. When snow was shallow, Gray Wolves traveled farther and more often, spent less time with pack members, and used conifer cover less and killed fewer deer (Fuller 1991). Gray Wolves have been implicated in declines in Elk numbers around Yellowstone National Park. This relationship is still being studied in conjunction with other environmental factors.

Reproductive Characteristics

In Montana, Gray Wolves breed in mid- to late February (Boyd et al. 1993), with gestation lasting about 63 days (Montana Fish, Wildlife and Parks 2003). A female can only give birth once a year. Breeding usually occurs between the dominant male and female in the pack and Gray Wolves normally do not breed until they are at least 22 months old (Mech 1970). Occasionally, more than 1 female in a pack may breed, resulting in more than 1 litter per pack (Ballard et al 1987). Young are typically born in late April in an underground burrow that has been abandoned by another mammal or dug by Gray Wolves. In northwestern Montana litter sizes range from 1 to 9 with a mean of 5.3 (Montana Fish, Wildlife and Parks 2003). Pups emerge from the den in about 3 weeks and are weaned in 50 days (also reported as 5 weeks). Young vacate the den when they are about 3 months old (Hoffmeister 1986) and move to a series of rendezvous sites throughout the pack's territory. The pups are large enough to travel with the entire pack by September. Some offspring remain with the pack; others disperse as they mature. Lone Gray Wolves generally do not successfully rear young, but they may if food is abundant (Boyd and Jimenez 1994).

Pup survival is variable and influenced by a number of factors including disease, predation, and nutrition. In Montana, pup mortality was most often attributed to human causes (Pletscher et al. 1997), but canine parvo virus was strongly suspected as a main factor in low pup survival in Yellowstone Gray Wolves in 1999 (Montana Fish, Wildlife and Parks 2003).

Management

Although Gray Wolves dispersing from Canada were occasionally observed, they were essentially extirpated from Montana and the rest of the western United States in the early 1900s primarily due to conflicts with people. As a result, they were listed as Endangered under the Endangered Species Act in 1967 (32 FR 4001). Gray Wolves started recolonizing the area around Glacier National Park in 1979 and the first den documented in Montana in over 50 years was found in Glacier National Park in 1986. In 1995 and 1996 Gray Wolves were reintroduced into Yellowstone National Park and central Idaho. Wolves resulting from these reintroductions and those dispersing naturally from northwestern Montana and Canada have now colonized most of western Montana. Gray wolves reached biological recovery goals for the Northern Rocky Mountains at the end of 2002 and were delisted in May of 2009 (74 FR 15123 15188). They were relisted as Endangered/Experimental Nonessential on August 5, 2010 through federal court order.

Montana Fish, Wildlife and Parks is the lead agency for Gray Wolves, including population monitoring, resolving wolf-livestock conflicts, research, and public outreach. Federal regulations continue to guide Montana FWP management practices. You can access a variety of detailed information on Gray Wolves in Montana from the Montana Fish, Wildlife, and Park's Wolf Program website.

References

Literature Cited Above

Web Search Engines for Articles on "Gray Wolf"

Additional Sources of Information Related to "Mammals"

Login

Citation for data on this website:
Gray Wolf — Canis lupus. Montana Field Guide. Retrieved on September 8, 2010, from http://FieldGuide.mt.gov/detail_AMAJA01030.aspx

mt.gov
Montana's Official State Website

Grizzly Bear - *Ursus arctos*

Other Names: Brown Bear

Species of Concern

Global Rank: G4
State Rank: S2S3

Agency Status
USFWS: LT,XN
USFS: THREATENED
BLM: SENSITIVE
FWP Conservation Tier: 1

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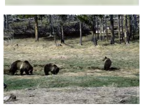
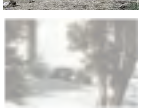
- 
- 
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General Description

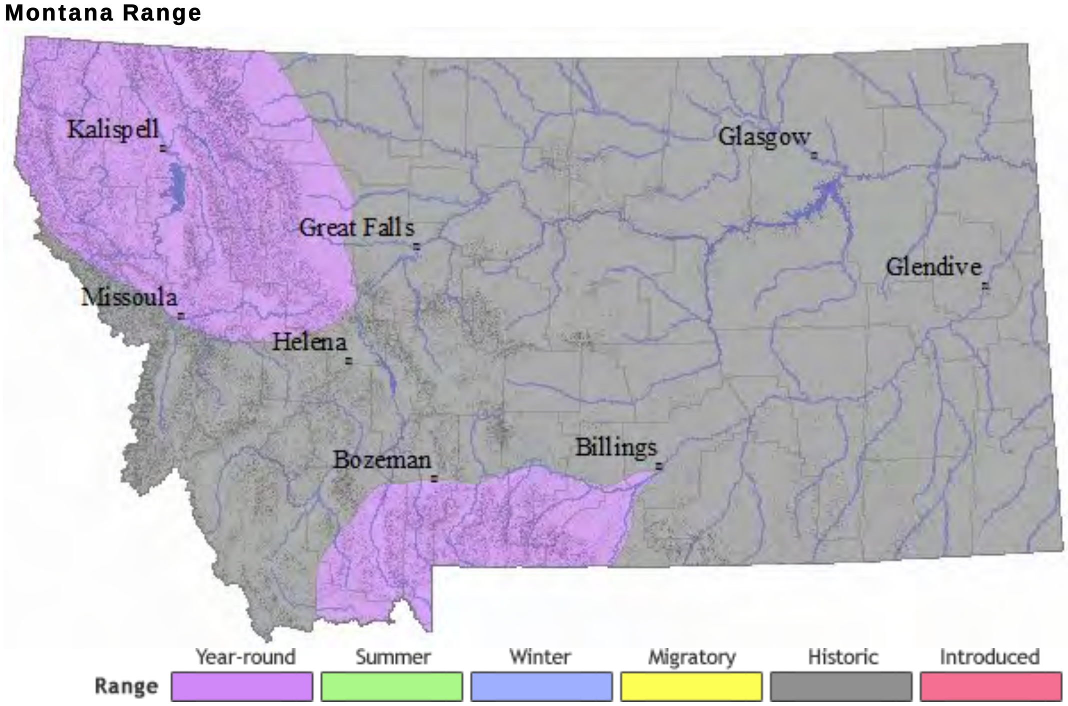
Grizzly Bears have a massive head with a prominent nose, rounded inconspicuous ears, small eyes, short tail and a large, powerful body (Pasitschnaik-Arts 1993). The facial profile is concave and there is a noticeable hump above the shoulders. The claws on the front feet of adults are about 4 inches long and slightly curved. Grizzly Bears range widely in color and size. The most prevalent coloration of Grizzly Bears in Montana is medium to dark brown underfur, brown legs, hump and underparts, with light to medium grizzling on the head and back and a light patch behind the front legs. Other forms, lighter or darker with varying levels of grizzled hair patches, occur in lesser numbers. Although extremely variable depending on the season, adults are around 185 centimeters long (Foresman 2001) and weigh around 200 kilograms in males and 130 kilograms in females (Kasworm and Manley 1988).

Diagnostic Characteristics

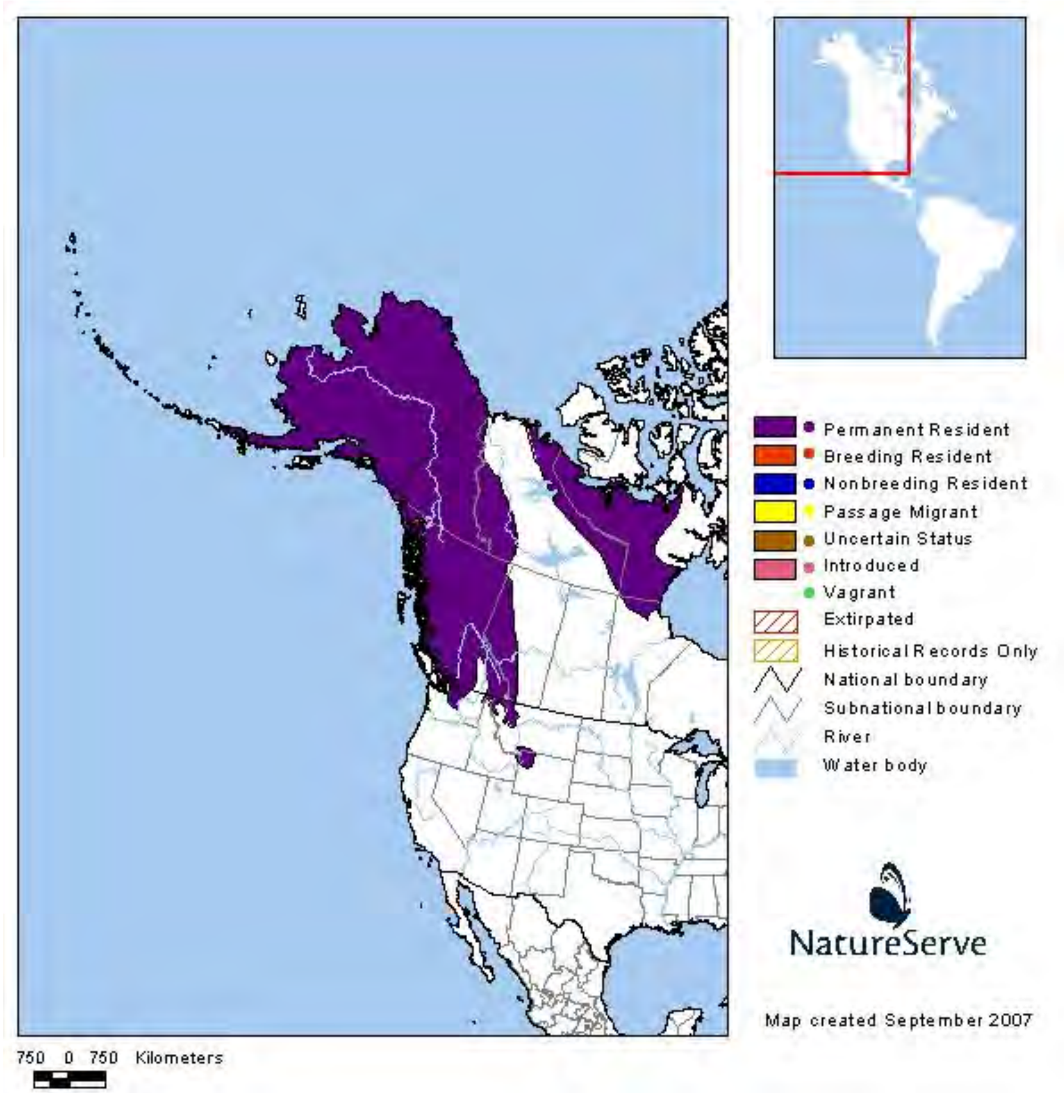
Adult Grizzly Bears differ from American Black Bears (*Ursus americanus*) in being larger and by having a hump above the shoulders, a concave (rather than straight or convex) facial profile, shorter and more rounded ears, a rump lower than the shoulder hump, and longer, less curved claws usually evident in the tracks. Identification can be difficult at times and Montana Fish, Wildlife and Parks has developed an Online Bear ID Test to help people better distinguish between American Black Bears and Grizzly Bears.

General Distribution

Montana Range



Western Hemisphere Range

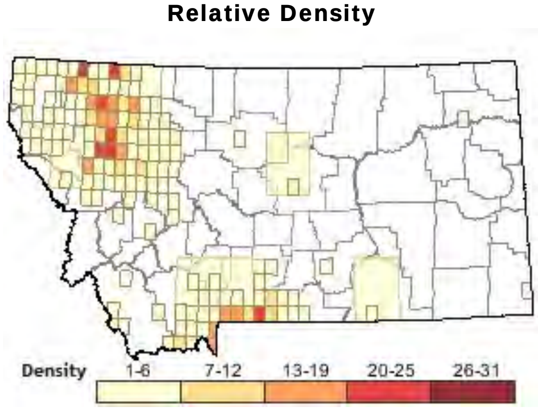


Summary of Observations Submitted for Montana

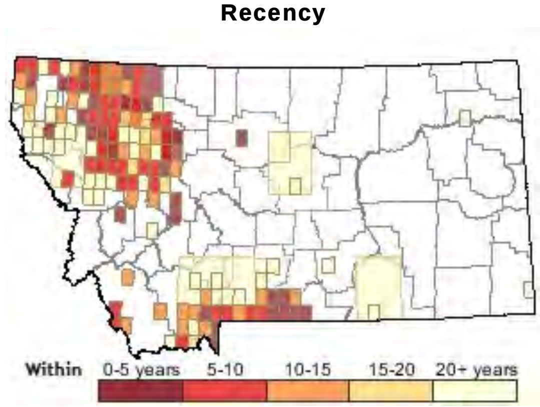
Number of Observations: 1074

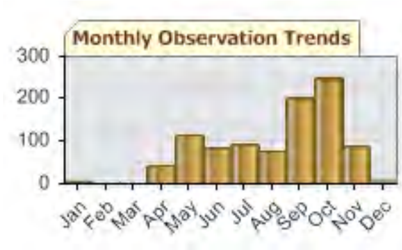
(Click on the following maps and charts to see full sized version) Map Help and Descriptions

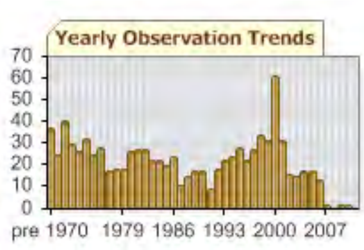
Relative Density

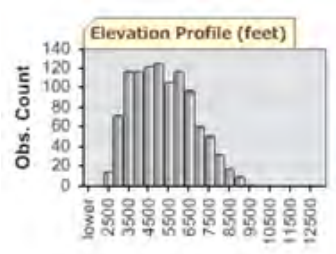


Recency









(Records associated with a range of dates are excluded from time charts)

Migration

No true migration occurs, although Grizzly Bears often exhibit discrete elevational movements from spring to fall, following seasonal food availability (LeFranc et al. 1987). They are generally at lower elevations in spring and higher elevations in mid-summer and winter.

Habitat

In Montana, Grizzly Bears primarily use meadows, seeps, riparian zones, mixed shrub fields, closed timber, open timber, sidehill parks, snow chutes, and alpine slabrock habitats. Habitat use is highly variable between areas, seasons, local populations, and individuals (Servheen 1983, Craighead 1982, Aune 1984). Historically, the Grizzly Bear was primarily a plains species occurring in higher densities throughout most of eastern Montana.

Ecological Systems Associated with this Species

Commonly Associated with these Ecological Systems

Alpine Systems

Alpine Bedrock and Scree
Alpine Dwarf-Shrubland
Alpine Fell-Field
Alpine Turf

Forest and Woodland Systems

Aspen and Mixed Conifer Forest
Aspen Forest and Woodland
Great Plains Wooded Draw and Ravine
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
Rocky Mountain Foothill Limber Pine - Juniper Woodland
Rocky Mountain Foothill Woodland-Steppe Transition
Rocky Mountain Lodgepole Pine Forest
Rocky Mountain Mesic Montane Mixed Conifer Forest
Rocky Mountain Montane Douglas-fir Forest and Woodland
Rocky Mountain Ponderosa Pine Woodland and Savanna
Rocky Mountain Poor Site Lodgepole Pine Forest
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland
Rocky Mountain Subalpine Woodland and Parkland

Grassland Systems

Great Plains Mixedgrass Prairie
Rocky Mountain Lower Montane, Foothill, and Valley Grassland
Rocky Mountain Subalpine-Montane Mesic Meadow
Rocky Mountain Subalpine-Upper Montane Grassland

Shrubland, Steppe and Savanna Systems

Big Sagebrush Shrubland
Big Sagebrush Steppe
Great Plains Shrubland
Montane Sagebrush Steppe
Rocky Mountain Montane-Foothill Deciduous Shrubland
Rocky Mountain Subalpine Deciduous Shrubland

Wetland and Riparian Systems

- Alpine-Montane Wet Meadow
- Emergent Marsh
- Great Plains Floodplain
- Great Plains Riparian
- Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland
- Rocky Mountain Conifer Swamp
- Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland
- Rocky Mountain Subalpine-Montane Fen
- Rocky Mountain Subalpine-Montane Riparian Shrubland
- Rocky Mountain Subalpine-Montane Riparian Woodland
- Rocky Mountain Wooded Vernal Pool

Occasionally Associated with these Ecological Systems

Forest and Woodland Systems

- Mountain Mahogany Woodland and Shrubland

Food Habits

Grizzly Bears are opportunistic and adaptable omnivores. Grizzly Bears have a large vegetative component (more than half) to their diet and have evolved longer claws for digging and larger molar surface area to better exploit vegetative food sources. Grizzly Bears feed on carrion, fish (Yellowstone cutthroat trout are a large seasonal component of the diet for Yellowstone Grizzly Bears), large and small mammals, insects, fruit, grasses, bark, roots, mushrooms, and garbage. They often cache food and guard it. In the Yellowstone region, ungulate remains and rodents were a major portion of early season scats; grasses, sedges and herbs dominated in May and June, with whitebark pine seeds, fish and berries most prevalent in late season scats when Grizzly Bears become hyperphagic (Mattson et al. 1991). Whitebark pine seeds appear to be so important to Grizzly Bears that there is a correlation between Grizzly Bears killed in control actions and the success of the whitebark pine crop. More fatalities have been recorded during poor crop years when Grizzly Bears forage at lower elevations and come into contact with humans more often. Grizzly Bears often feed on insect aggregations (e.g., army cutworm moths, ladybird beetles). In the Yellowstone ecosystem, alpine insect aggregations are an important source of food, especially in the absence of high-quality foraging alternatives in July and August of most years (Mattson et al. 1991). Grizzly Bears have been known to kill and consume American Black Bears (Gunther et al. 2002).

Grizzly Bears are known to feed on a wide variety of plants (36 to 74 species) in Montana. Food habits vary locally, seaonally and individually. Generally, Grizzly Bears feed on graminoids, forbs, rodents and carrion in spring. In summer, they feed on forbs, fruit, horsetails, insects, and roots; in fall, berries and pine nuts predominate (Craighead and Mitchell 1982, Servheen 1983, Aune 1984). Yellow sweet-vetch is an important food with wide distribution (Edge, Marcum, and Olson-Edge 1990).

Ecology

Annual home ranges in the Swan Mountains, Montana, averaged 768 square kilometers for males and 125 square kilometers for females; adult home ranges were larger than those for subadults. Spatial and temporal factors affected home range size (Mace and Waller 1997). Two studies examined Grizzly Bear responses to resource development (Aunie 1984). Cannibalism has been reported (Mattson et al. 1992).

Reproductive Characteristics

Grizzly Bears exhibit a long life span, late sexual maturity and protracted reproductive cycles (Craighead et al. 1976). They are polygamous and several males may fight over an estrus female. In Montana, Grizzly Bears breed in late April through late June or early July (Aune 1984). Implantation of the fertilized egg is delayed until late autumn when the embryo implants into the uterus. Around two months after implantation, 1 to 4 (average 2.8 in Montana) young are born in the winter den. They are helpless at birth and weigh around 500 grams. Growth is rapid and young are nursed for the first 1.5 to 2.5 years (Foresman 2001). The young remain with their mother through the next two winters. Young usually obtain adult size in 4 to 6 years. Females generally breed every 2 to 4 years. Females first breed when they are 4.5 to 5.5 years old and males gain sexual maturity at the age of four and half years. A few live as long as 20 to 25 years.

Management

On July 28th, 1975, the Grizzly Bear was designated as Threatened in lower 48 states under the Endangered Species Act. Currently populations in the Cabinet/Yaak and Northern Continental Divide Recovery areas are listed as Threatened. The Bitterroot Recovery Zone in the Bitterroot Mountains of Montana and Idaho was designated in anticipation of reintroduction of Grizzly Bears where they would be classified as experimental nonessential. This reintroduction never took place, but in 2007 a naturally colonizing Grizzly Bear was killed in the Idaho portion of this recovery area. On March 22, 2007, the U.S. Fish and Wildlife Service announced that the Yellowstone Distinct Population Segment (DPS) of Grizzly Bears is a recovered population no longer meeting the ESA's definition of threatened or endangered (USFWS 2007). On September 21, 2009 the Yellowstone DPS was relisted as Threatened as a result of a ruling by U.S. District Judge Donald Molloy that declines in whitebark pine and inadequate conservation plans threatened the species. The state of Montana has a Grizzly Bear Policy (MCA 12.9.103) that outlines policy guidelines for Montana Fish, Wildlife and Parks to promote the conservation of Grizzly Bears in Montana. Other regionally specific management plans include the Grizzly Bear Management Plan for Southwestern Montana 2002 to 2012 and various tribal, National Forest, and National Park plans and policies. Most of these management plans are centered on three major themes: management of habitat to ensure Grizzly Bears have large expanses of suitable interconnected lands in which to exist (see Habitat and Food sections above), management of Grizzly Bear/human interactions that most often result in death for the bears (and sometimes humans) involved (this is a particularly important concern for female bears because their removal may have significant impacts on the demography of isolated populations), and research to determine the population size and trends to ensure that Grizzly Bear populations are not being jeopardized. Please consult the management plans listed above for specifics on Grizzly Bear management.

References

Literature Cited Above

Web Search Engines for Articles on "Grizzly Bear"

Additional Sources of Information Related to "Mammals"

Login

Citation for data on this website:
Grizzly Bear — Ursus arctos. Montana Field Guide. Retrieved on September 8, 2010, from http://FieldGuide.mt.gov/detail_AMAJB01020.aspx

Ecological Solutions Group LLC
115 West Third Street, Suite 210
Stevensville, Montana USA 59870
www.ecologicalsolutionsgroup.com

Appendix I
Soils XRF Data Validation Report

Reclamation Research Group, LLC
202 South Black Avenue, Suite 4
P.O. Box 6309, Bozeman, MT 59715
Phone: (406) 624-6571
Fax: (406) 551-2036

Technical Memorandum - REVISED

To: Dennis Smith, CH2M Hill/Boise
From: Dennis Neuman
Date: 15 November 2010
Re: Review and data validation of soil data for samples analyzed by a field XRF device. Samples were collected from soil pits developed at selected locations at the Bullion and Crystal Mine sites.

Soil samples were collected from soil pits developed at selected locations at the Bullion and Crystal Mine sites in the Basin Creek watershed during the summer and early fall of 2010. The concentrations of arsenic, cadmium, copper, lead and zinc were determined using a field XRF instrument. Collections and determinations were conducted under the direction of a Sampling and Analysis Plan (CH2M Hill, 2010). The analytical data were subjected to a modified validation process similar to those described in the following documents:

- USEPA CLP National Functional Guidelines for Inorganic Data Review, OSWER 9240.1-51, EPA 540-R-10-011 (1January 2010).
- Clark Fork River Superfund Site Investigations, data management/Data Validation Plan (PTI, 1992 with revision (1993), and addendum (2000).

The XRF instrument QC protocol included initial and continuing calibrations and blanks, and duplicate analysis. The control limits for each QC type were specified as:

- Blank value < LOD (limit of detection)
- Duplicate sample < $\pm$ 35% RPD (relative percent difference)
- Standard (NIST 2702-marine sediment) within 2 standard deviations of the mean value as calculated by 20 determinations of the analytes using the XRF instrument.

Eight separate analytical events took place and eight data packages were received from CH2M Hill. These data packages were identified as:

- XRF result-100807
- XRF result-100810
- XRF result-100811
- XRF result-100812
- XRF result-100813
- XRF result-100814
- XRF result-100815
- XRF result-100816

A summary of the validation of data contained in each data package and results of the validation are described below.

- **XRF result - 100807**

  Most QC samples (calibrations, blanks, duplicates) were found to be within the limits specified in the analytical method. Because some zinc and lead continuing standard calibration values were outside their respective control windows, zinc and lead data for associated samples are judged to be of Screening Quality as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). The associated samples are as follows:

  btp7-0-2
  btp7-0-2d
  btp7-8-10
  btp7-12-14
  btp7-16-18
  btp7-22-25
  btp8-0-2
  btp8-4-6
  btp8-7-9
  btp8-10-12
  btp8-17-19
  btp9-0-2
  btp9-4-6
  btp9-7-9
  btp9-11-13
  btp9-20-23
  btp10-0-2
  btp10-4-6
  btp10-10-12
  btp10-14-16
  btp10-20-23

  The arsenic and copper data were generated while the XRF instrument was in statistical control and these data are considered to be of Enforcement Quality as specified in the document cited above. All cadmium results were reported at the LOD.

- **XRF result – 100810**

  Most QC samples (calibrations, blanks, duplicates) were found to be within the limits specified in the analytical method. Because one zinc continuing standard calibration value was outside its control window, zinc data associated with this standard are judged to be of Screening Quality as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). The associated samples are as follows:

ctp-21-0-2
ctp-22-0-2
ctp-23-0-2
ctp-24-0-2
ctp-25-0-2
ctp-26-0-2
ctp-27-0-2
ctp-28-0-2
ctp-29-0-2
air pipe
75' w adit
75' w aditd

The arsenic, copper, and lead data were generated while the XRF instrument was in statistical control and lead data are considered to be of Enforcement Quality as specified in the document cited above. All cadmium results were reported at the LOD.

- **XRF result – 100811**

All QC samples (calibrations, blanks, duplicates) were found to be within the limits specified in the analytical method. All data were generated while the XRF instrument was in statistical control and are considered to be of Enforcement Quality (highest) as specified in CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). All cadmium results were reported at the LOD.

- **XRF result – 100812**

Most QC samples (calibrations, blanks, duplicates) were found to be within the limits specified in the analytical method. Because the ending zinc standard calibration values was outside its control windows, associated zinc data are judged to be of Screening Quality as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). Associated samples are identified as follows:

ctp-6-.5
ctp-6-1
ctp-6-1.5
ctp-6-2
ctp-7-1
ctp-7-2
ctp-7-2.5
ctp-7-3.5
ctp-8-1
ctp-8-2
ctp-8-3

ctp-8-4
ctp-8-4d
ctp-9-1
ctp-9-1.5
ctp-9-2.5
ctp-9-3
ctp-9-3d

The arsenic, lead, and copper data were generated while the XRF instrument was in statistical control and these data are considered to be of Enforcement Quality as specified in the document cited above. All cadmium results were reported at the LOD.

- **XRF result - 100813**

Most QC samples (calibrations, blanks, duplicates) were found to be within the limits specified in the analytical method. Because the ending zinc standard calibration values was outside its control windows, zinc data for associated samples are judged to be of Screening Quality as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). Associate samples are as follows:

ctp-23-3
ctp-23-4
ctp-24-1
ctp-24-2
ctp-24-2.5
ctp-25-1
ctp-25-2
ctp-25-3
ctp-26-1
ctp-26-2
ctp-26-3
ctp-27-1
ctp-27-2
ctp-27-3
ctp-28-1
ctp-28-2
ctp-28-3
ctp-29-1
ctp-29-2
ctp-29-3
ctp-29-5
ctp-29-5d

The arsenic, lead, and copper data were generated while the XRF instrument was in statistical control and these data are considered to be of Enforcement Quality as specified in the document cited above. All cadmium results were reported at the LOD.

- **XRF result - 100814**

Most QC samples (calibrations, blanks, duplicates) were found to be within the limits specified in the analytical method. Because zinc, copper, and lead continuing standard calibration values was outside their respective control windows, zinc, copper and lead data for associated samples are judged to be of Screening Quality as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). Associated samples are as follows:

Associated samples for copper and lead:

ctp-36-0-2
ctp-36-10-12
ctp-36-28-32
ctp-37-0-2
ctp-37-6-8
ctp-37-6-8
ctp-37-10-13
ctp-37-17-19
ctp-37-17-19d

Associated samples for zinc:

ctp-32-1-3
ctp-32-6-8
ctp-32-10-12
ctp-32-14-16
ctp-32-22-24
ctp-33-1-3
ctp-33-5-7
ctp-33-10-12
ctp-33-14-16
ctp-33-24-26
ctp-34-1-3
ctp-34-4-6
ctp-34-7-9
ctp-34-10-12
ctp-34-22-24
ctp-35-0-2
ctp-35-4-6

ctp-35-10-12
ctp-35-16-18
ctp-35-24-26
ctp-35-24-26d

The arsenic data were generated while the XRF instrument was in statistical control and lead data are considered to be of Enforcement Quality as specified in the document cited above. All cadmium results were reported at the LOD.

- **XRF result – 100815**

  Most QC samples (calibrations, blanks, duplicates) were found to be within the limits specified in the analytical method. Because one copper continuing standard calibration value was outside its control window, copper data in associated samples are judged to be of Screening Quality as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). The associated samples are as follows:

  cbg-2-0-2
  cbg-2-5-7
  cbg-2-8-10
  cbg-2-16-18
  cbg-2-24-26
  cbg-2-24-26d

  The arsenic, lead, and zinc data were generated while the XRF instrument was in statistical control and lead data are considered to be of Enforcement Quality as specified in the document cited above. All cadmium results were reported at the LOD.

- **XRF result – 100816**

  All QC samples (calibrations, blanks, duplicates) were found to be within the limits specified in the analytical method. The arsenic, copper, lead, and zinc data were generated while the XRF instrument was in statistical control and these data are considered to be of Enforcement Quality as specified in the document cited above. All cadmium results were reported at the LOD.

Validation Forms for each data package are appended below.

Field XRF - Data Validation
Data Set for 100807

Site: Basin Creek
Project: Crystal/Bullion Soils
Sample Dates: Summer/Fall 2010
Data Validator: Neuman

Case No.: None **Laboratory:** Field XRF
Analyses: Total As, Cd, Cu, Pb, Zn
Analysis Dates: Summer/Fall 2010
Validation Dates: 9 November 2010

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection Date	Analysis Date	Holding Time Met? (Y/N)	Affected Data Flagged? (Y/N)
Total As, Cd, Cu, Pb, and Zn	Soils	Field xrf per manufacturer	NA	Aug 7, 2010	Aug 7, 2010	NA	N

* cite reference for holding time: CFR SSI XRF LAP (1995)
Were any data flagged because of holding time problems? Y _____ N__X__

2. XRF Quality Control

Were the samples prepared according to the SAP? Y___X___N______
Were initial and continuing calibrations performed at the frequency of 5% (1/20 samples)? Y __X___ N_____

Were initial and continuing calibration results within control windows of 2x standard deviations developed by analyzing NIST 2702? Y ______ N__X__
The control windows are As (32 to 60); Cu (62 to 108); Zn (358 to 405) and Pb (97 to 134 mg/kg)
Were initial and continuing blank determinations made at a frequency of 5% (1/20 samples). Y __X___ N_____
Were blank levels lees than the LOD for each analyte? Y __X___ N_____
Was a field duplicate analysis performed at the frequency of 1 per 20? Y __X___ N_____
Were field duplicate results within control window of __<35%______? Y ______ N__X__
Were any data flagged because of XRF analysis? Y ______ N__X__

3. Field QC Samples

Field duplicates: BTP5-0-2 and BTP5 -0-2

Analyte	Sample Value	Field Duplicate	RPD Value
As	60	57	5.1
Cd	53	43	20.8
Cu	110	110	0
Pb	49	45	8.5
Zn	209	191	9.0

Field duplicates: BTP7-0-2 and BTP7-0-2d

Analyte	Sample Value	Field Duplicate	RPD Value
As	105	126	18.2
Cd	LOD	LOD	--
Cu	42	47	11.2
Pb	94	111	16.6
Zn	89	104	15.5

4. Overall Assessment

Are there analytical limitations of the data that users should be aware of? Y __X___ N_____
If so, explain: Some CCS values for Zn and Pb were outside their respective control windows.

5. Authorization of Data Release from the Laboratory

Data Validator: Name: Dennis R. Neuman______________________ Date: ________________________

Field XRF - Data Validation
Data Set for 100810

Site: Basin Creek
Project: Crystal/Bullion Soils
Sample Dates: Summer/Fall 2010
Data Validator: Neuman

Case No.: None **Laboratory:** Field XRF
Analyses: Total As, Cd, Cu, Pb, Zn
Analysis Dates: August 10, 2010
Validation Dates: 9 November 2010

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection Date	Analysis Date	Holding Time Met? (Y/N)	Affected Data Flagged? (Y/N)
Total As, Cd, Cu, Pb, and Zn	Soils	Field xrf per manufacturer	NA	August 10, 2010	August 10, 2010	NA	N

* cite reference for holding time: CFR SSI XRF LAP (1995)
Were any data flagged because of holding time problems? Y _____ N__X__

2. XRF Quality Control

Were the samples prepared according to the SAP? Y___X___N______
Were initial and continuing calibrations performed at the frequency of 5% (1/20 samples)? Y __X___ N_____

Were initial and continuing calibration results within control windows of 2x standard deviations developed by analyzing NIST 2702? Y ______ N__X__
The control windows are As (32 to 60); Cu (62 to 108); Zn (358 to 405) and Pb (97 to 134 mg/kg)
Were initial and continuing blank determinations made at a frequency of 5% (1/20 samples). Y __X___ N_____
Were blank levels lees than the LOD for each analyte? Y __X___ N_____
Was a field duplicate analysis performed at the frequency of 1 per 20? Y __X___ N_____
Were field duplicate results within control window of <35%_______? Y ______ N__X__
Were any data flagged because of XRF analysis? Y ______ N__X__

3. Field QC Samples

Field duplicates: CTP 20-0-2 and CTP 20-0-2d

Analyte	Sample Value	Field Duplicate	RPD Value
As	371	271	31.2
Cd			
Cu	52	48	8.0
Pb	674	522	25.4
Zn	265	210	23.2

75' adit and 75' adit d

Analyte	Sample Value	Field Duplicate	RPD Value
As	13	16	20.7
Cd	LOD	LOD	--
Cu	LOD	29	--
Pb	31	25	21.4
Zn	623	615	1.3

4. Overall Assessment

Are there analytical limitations of the data that users should be aware of? Y __X___ N_____
If so, explain: One CCS value for Zn was outside control window.

5. Authorization of Data Release from the Laboratory

Data Validator: Name: Dennis R. Neuman ____________________Date: ________________________

Field XRF - Data Validation
Data Set for 100811

Site: Basin Creek
Project: Crystal/Bullion Soils
Sample Dates: Summer/Fall 2010
Data Validator: Neuman

Case No.: None **Laboratory:** Field XRF
Analyses: Total As, Cd, Cu, Pb, Zn
Analysis Dates: August 10, 2010
Validation Dates: 9 November 2010

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection Date	Analysis Date	Holding Time Met? (Y/N)	Affected Data Flagged? (Y/N)
Total As, Cd, Cu, Pb, and Zn	Soils	Field xrf per manufacturer	NA	August 11, 2010	August 11, 2010	NA	N

* cite reference for holding time: CFR SSI XRF LAP (1995)
Were any data flagged because of holding time problems? Y _____ N__X__

2. XRF Quality Control

Were the samples prepared according to the SAP? Y___X___N______
Were initial and continuing calibrations performed at the frequency of 5% (1/20 samples)? Y __X___ N_____

Were initial and continuing calibration results within control windows of 2x standard deviations developed by analyzing NIST 2702? Y __X___ N_____
The control windows are As (32 to 60); Cu (62 to 108); Zn (358 to 405) and Pb (97 to 134 mg/kg)
Were initial and continuing blank determinations made at a frequency of 5% (1/20 samples). Y __X___ N_____
Were blank levels lees than the LOD for each analyte? Y __X___ N_____
Was a field duplicate analysis performed at the frequency of 1 per 20? Y __X___ N_____
Were field duplicate results within control window of __<35%______? Y __X___ N_____
Were any data flagged because of XRF analysis? Y ______ N__X__

3. Field QC Samples

Field duplicates: CTP 14-4-0 and CTP 14-4-0d

Analyte	Sample Value	Field Duplicate	RPD Value
As	512	521	1.7
Cd	LOD	LOD	--
Cu	79	74	6.5
Pb	245	226	8.1
Zn	590	645	8.9

CTP 30-7-0 and CTP 30-7-0d

Analyte	Sample Value	Field Duplicate	RPD Value
As	64	60	6.5
Cd	LOD	LOD	--
Cu	94	83	12.4
Pb	118	116	1.7
Zn	509	527	3.5

4. Overall Assessment

Are there analytical limitations of the data that users should be aware of? Y ______ N__X__
If so, explain: ____

5. Authorization of Data Release from the Laboratory

Data Validator: Name: Dennis R. Neuman ______________________Date: _________________________

Field XRF - Data Validation
Data Set for 100812

Site: Basin Creek
Project: Crystal/Bullion Soils
Sample Dates: Summer/Fall 2010
Data Validator: Neuman

Case No.: None **Laboratory:** Field XRF
Analyses: Total As, Cd, Cu, Pb, Zn
Analysis Dates: August 10, 2010
Validation Dates: 9 November 2010

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection Date	Analysis Date	Holding Time Met? (Y/N)	Affected Data Flagged? (Y/N)
Total As, Cd, Cu, Pb, and Zn	Soils	Field xrf per manufacturer	NA	August 12, 2010	August 12, 2010	NA	N

* cite reference for holding time: CFR SSI XRF LAP (1995)
Were any data flagged because of holding time problems? Y _____ N__X__

2. XRF Quality Control

Were the samples prepared according to the SAP? Y___X___N______
Were initial and continuing calibrations performed at the frequency of 5% (1/20 samples)? Y __X___ N_____

Were initial and continuing calibration results within control windows of 2x standard deviations developed by analyzing NIST 2702? Y _ N__X___
The control windows are As (32 to 60); Cu (62 to 108); Zn (358 to 405) and Pb (97 to 134 mg/kg)
Were initial and continuing blank determinations made at a frequency of 5% (1/20 samples). Y __X___ N_____
Were blank levels lees than the LOD for each analyte? Y __X___ N_____
Was a field duplicate analysis performed at the frequency of 1 per 20? Y __X___ N_____
Were field duplicate results within control window of _<35%_______? Y __X___ N_____
Were any data flagged because of XRF analysis? Y ______ N__X__

3. Field QC Samples

Field duplicates: CTP 8-4 and CTP 8-4d

Analyte	Sample Value	Field Duplicate	RPD Value
As	8780	8949	1.9
Cd	LOD	LOD	--
Cu	198	191	3.6
Pb	478	493	3.1
Zn	504	508	0.8

CTP 9-3 and CTP 9-3d

Analyte	Sample Value	Field Duplicate	RPD Value
As	2381	2351	1.3
Cd	LOD	LOD	--
Cu	271	265	2.2
Pb	1458	1470	0.8
Zn	783	752	4.0

4. Overall Assessment

Are there analytical limitations of the data that users should be aware of? Y __X___ N_____
If so, explain: Ending CCS value for Zn was outside control window.

5. Authorization of Data Release from the Laboratory

Data Validator: Name: Dennis R. Neuman ____________________ Date: ________________________

Field XRF - Data Validation
Data Set for 100813

Site: Basin Creek
Project: Crystal/Bullion Soils
Sample Dates: Summer/Fall 2010
Data Validator: Neuman

Case No.: None **Laboratory:** Field XRF
Analyses: Total As, Cd, Cu, Pb, Zn
Analysis Dates: August 10, 2010
Validation Dates: 9 November 2010

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection Date	Analysis Date	Holding Time Met? (Y/N)	Affected Data Flagged? (Y/N)
Total As, Cd, Cu, Pb, and Zn	Soils	Field xrf per manufacturer	NA	August 13, 2010	August 13, 2010	NA	N

* cite reference for holding time: CFR SSI XRF LAP (1995)
Were any data flagged because of holding time problems? Y _____ N __X__

2. XRF Quality Control

Were the samples prepared according to the SAP? Y___X___N______
Were initial and continuing calibrations performed at the frequency of 5% (1/20 samples)? Y __X___ N_____

Were initial and continuing calibration results within control windows of 2x standard deviations developed by analyzing NIST 2702? Y ______ N__X__
The control windows are As (32 to 60); Cu (62 to 108); Zn (358 to 405) and Pb (97 to 134 mg/kg)
Were initial and continuing blank determinations made at a frequency of 5% (1/20 samples). Y __X___ N_____
Were blank levels lees than the LOD for each analyte? Y __X___ N_____
Was a field duplicate analysis performed at the frequency of 1 per 20? Y __X___ N_____
Were field duplicate results within control window of <35%_______? Y ______ N__X__
Were any data flagged because of XRF analysis? Y ______ N__X__

3. Field QC Samples

Field duplicates: CTP 23-2 and CTP 23-2d

Analyte	Sample Value	Field Duplicate	RPD Value
As	11	9	20
Cd	LOD	LOD	--
Cu	30	45	40
Pb	25	27	7.7
Zn	388	405	4.3

CTP 29-5 and CTP 29-5d

Analyte	Sample Value	Field Duplicate	RPD Value
As	1275	1234	3.3
Cd	LOD	LOD	--
Cu	686	680	0.9
Pb	1911	1878	1.7
Zn	1604	1613	0.6

4. Overall Assessment

Are there analytical limitations of the data that users should be aware of? Y __X___ N_____
If so, explain: Ending CCS value for Zn of 425 mg/kg was outside the control window of 358 to 406 mg/kg.

5. Authorization of Data Release from the Laboratory

Data Validator: Name: Dennis R. Neuman ______________________Date: _________________________

Field XRF - Data Validation
Data Set for 100814

Site: Basin Creek
Project: Crystal/Bullion Soils
Sample Dates: Summer/Fall 2010
Data Validator: Neuman

Case No.: None **Laboratory:** Field XRF
Analyses: Total As, Cd, Cu, Pb, Zn
Analysis Dates: August 10, 2010
Validation Dates: 9 November 2010

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection Date	Analysis Date	Holding Time Met? (Y/N)	Affected Data Flagged? (Y/N)
Total As, Cd, Cu, Pb, and Zn	Soils	Field xrf per manufacturer	NA	August 14 2010	August 14, 2010	NA	N

* cite reference for holding time: CFR SSI XRF LAP (1995)
Were any data flagged because of holding time problems? Y _____ N__X__

2. XRF Quality Control

Were the samples prepared according to the SAP? Y___X___N______
Were initial and continuing calibrations performed at the frequency of 5% (1/20 samples)? Y __X___ N_____

Were initial and continuing calibration results within control windows of 2x standard deviations developed by analyzing NIST 2702? Y ______ N__X__
The control windows are As (32 to 60); Cu (62 to 108); Zn (358 to 405) and Pb (97 to 134 mg/kg)
Were initial and continuing blank determinations made at a frequency of 5% (1/20 samples). Y __X___ N_____
Were blank levels lees than the LOD for each analyte? Y __X___ N_____
Was a field duplicate analysis performed at the frequency of 1 per 20? Y __X___ N_____
Were field duplicate results within control window of _<35%_______? Y __X___ N_____
Were any data flagged because of XRF analysis? Y ______ N__X__

3. Field QC Samples

Field duplicates: CTP 35-24-26 and CTP 35-24-26d

Analyte	Sample Value	Field Duplicate	RPD Value
As	6203	6921	10.9
Cd	LOD	LOD	--
Cu	260	303	15.3
Pb	2189	2535	14.6
Zn	220	253	14.0

CTP 37-17-19 and CTP 37-17-19d

Analyte	Sample Value	Field Duplicate	RPD Value
As	6055	5984	1.2
Cd	LOD	LOD	--
Cu	372	353	5.2
Pb	2326	2351	1.1
Zn	1611	1237	26.3

4. Overall Assessment

Are there analytical limitations of the data that users should be aware of? Y __X___ N_____
If so, explain: Some CCS values for Zn, Cu and Pb were outside their respective control windows.

5. Authorization of Data Release from the Laboratory

Data Validator: Name: Dennis R. Neuman ______________________Date: _________________________

Field XRF - Data Validation
Data Set for 100815

Site: Basin Creek
Project: Crystal/Bullion Soils
Sample Dates: Summer/Fall 2010
Data Validator: Neuman

Case No.: None **Laboratory:** Field XRF
Analyses: Total As, Cd, Cu, Pb, Zn
Analysis Dates: August 10, 2010
Validation Dates: 9 November 2010

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection Date	Analysis Date	Holding Time Met? (Y/N)	Affected Data Flagged? (Y/N)
Total As, Cd, Cu, Pb, and Zn	Soils	Field xrf per manufacturer	NA	August 15 2010	August 15, 2010	NA	N

* cite reference for holding time: CFR SSI XRF LAP (1995)
Were any data flagged because of holding time problems? Y _____ N X

2. XRF Quality Control

Were the samples prepared according to the SAP? Y X N______
Were initial and continuing calibrations performed at the frequency of 5% (1/20 samples)? Y X N_____

Were initial and continuing calibration results within control windows of 2x standard deviations developed by analyzing NIST 2702? Y ______ N X
The control windows are As (32 to 60); Cu (62 to 108); Zn (358 to 405) and Pb (97 to 134 mg/kg)
Were initial and continuing blank determinations made at a frequency of 5% (1/20 samples). Y X N_____
Were blank levels lees than the LOD for each analyte? Y X N_____
Was a field duplicate analysis performed at the frequency of 1 per 20? Y X N_____
Were field duplicate results within control window of <35%_______? Y ______ N X
Were any data flagged because of XRF analysis? Y ______ N X

3. Field QC Samples

Field duplicates: cbg-1-24-26 and cbg-1-24-26d

Analyte	Sample Value	Field Duplicate	RPD Value
As	LOD	LOD	--
Cd	LOD	LOD	--
Cu	LOD	LOD	--
Pb	25	28	11.3
Zn	13	15	14.3

cgb-2-24-26 and cgb-2-24-26d

Analyte	Sample Value	Field Duplicate	RPD Value
As	17	LOD	--
Cd	LOD	LOD	--
Cu	36	48	28.6
Pb	71	111	44.0
Zn	311	304	2.3

4. Overall Assessment

Are there analytical limitations of the data that users should be aware of? Y X N_____
If so, explain: One CCS value for Cu was outside the control window.

5. Authorization of Data Release from the Laboratory

Data Validator: Name: Dennis R. Neuman _______________________Date:

Field XRF - Data Validation
Data Set for 100816

Site: Basin Creek
Project: Crystal/Bullion Soils
Sample Dates: Summer/Fall 2010
Data Validator: Neuman

Case No.: None **Laboratory:** Field XRF
Analyses: Total As, Cd, Cu, Pb, Zn
Analysis Dates: August 10, 2010
Validation Dates: 9 November 2010

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection Date	Analysis Date	Holding Time Met? (Y/N)	Affected Data Flagged? (Y/N)
Total As, Cd, Cu, Pb, and Zn	Soils	Field xrf per manufacturer	NA	August 16 2010	August 16, 2010	NA	N

* cite reference for holding time: CFR SSI XRF LAP (1995)
Were any data flagged because of holding time problems? Y _____ N__X__

2. XRF Quality Control

Were the samples prepared according to the SAP? Y___X___N______
Were initial and continuing calibrations performed at the frequency of 5% (1/20 samples)? Y __X___ N_____

Were initial and continuing calibration results within control windows of 2x standard deviations developed by analyzing NIST 2702? Y __X___ N_____
The control windows are As (32 to 60); Cu (62 to 108); Zn (358 to 405) and Pb (97 to 134 mg/kg)
Were initial and continuing blank determinations made at a frequency of 5% (1/20 samples). Y __X___ N_____
Were blank levels lees than the LOD for each analyte? Y __X___ N_____
Was a field duplicate analysis performed at the frequency of 1 per 20? Y __X___ N_____
Were field duplicate results within control window of _<35%_______? Y __X___ N_____
Were any data flagged because of XRF analysis? Y ______ N__X__

3. Field QC Samples

Field duplicates: bbg 2-20-22 and bbg-2-20-22d

Analyte	Sample Value	Field Duplicate	RPD Value
As	21	30	35.3
Cd	LOD	LOD	--
Cu	37	39	5.3
Pb	38	32	17.1
Zn	65	61	6.3

4. Overall Assessment

Are there analytical limitations of the data that users should be aware of? Y ______ N__X__
If so, explain:

5. Authorization of Data Release from the Laboratory

Data Validator: Name: Dennis R. Neuman Date: ________________________

Appendix J
Soils Data Validation Report

Reclamation Research Group, LLC
202 South Black Avenue, Suite 4
P.O. Box 6309, Bozeman, MT 59715
Phone: (406) 624-6571
Fax: (406) 551-2036

Technical Memorandum
To: Dennis Smith, CH2M Hill/Boise
From: Dennis Neuman
Date: 9 November 2010
Re: Review and data validation of soil data for samples collected from soil pits developed at selected locations at the Bullion and Crystal Mine sites.

Soil samples were collected from soil pits developed at selected locations at the Bullion and Crystal Mine sites in the Basin Creek watershed during the summer and early fall of 2010. Collections and determination of concentrations selected total metals and arsenic, and pH levels were conducted under the direction of a Sampling and Analysis Plan (CH2M Hill, 2010). Samples were and shipped under chain of custody, to the analytical laboratory. Concentrations of total and arsenic was determined using EPA methods 3050 (acid digestion) and 6020 – ICP. Levels of pH in the soil samples were determined using ASA 10-3.2. The analytical data were subjected to a validation process as described in the following documents:

- USEPA CLP National Functional Guidelines for Inorganic Data Review, OSWER 9240.1-51, EPA 540-R-10-011 (1January 2010).
- Clark Fork River Superfund Site Investigations, data management/Data Validation Plan (PTI, 1992 with revision (1993), and addendum (2000).

Three separate sampling events took place and four data packages were received from the analytical laboratory. These data packages were identified as:

- Pace Analytical 10135486
- Pace Analytical 10135942
- Pace Analytical 10135946

A summary of the validation of data contained in each data package and results of the validation are described below.

- **Pace Analytical 10135486 Validation Narrative**

  Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in

acceptable statistical control while data for the Bullion soil samples were analyzed. No field QC samples (blanks, duplicates or reference materials) were submitted. All total metal and arsenic concentrations in the soils were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum).
pH: There are no analytical limitations for which data that users should be aware. Results of the validation process for data package #10135486 are shown below

- **Pace Analytical 10135942 Validation Narrative**

  Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Crystal soil samples were analyzed. Field QC samples (blanks and reference materials) were not submitted. All total metal and arsenic concentrations in the soils were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum).
  pH: There are no analytical limitations for which data that users should be aware. Results of the validation process for data package #10135942 are shown below

- **Pace Analytical 10135946 Validation Narrative**

  Validation Narrative - Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Crystal soil samples were analyzed. No field QC samples (blanks, duplicates or reference materials) were submitted. All total metal and arsenic concentrations in the soils were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum).
  Validation Narrative – pH: There are no analytical limitations for which data that users should be aware. Results of the validation process for data package #10135946 are shown below

Data validation packages for each data set are displayed below.

Pace Analytical Project #10135486 – Bullion Soil Samples

Validation Narrative - Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Bullion soil samples were analyzed. No field QC samples (blanks, duplicates or reference materials) were submitted. All total metal and arsenic concentrations in the soils were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum).

Validation Narrative – pH: There are no analytical limitations for which data that users should be aware. Results of the validation process for data package #10135486 are shown below

Laboratory Data Validation

Checklist for Metals Analysis by ICPMS

Site: Bullion

Case No.: 10135486

Laboratory: Pace Analytical

Project: Springs, adit, creek

Sample Matrix: Water

Analyses: Total As, Cd, Cu. Pb, Zn and pH

Sample Dates: Aug 4, 2010

Analysis Dates: Aug 12,19,2010

Data Validator: Neuman/RRG

Validation Dates: 8 Nov 2010

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection date	Analysis date	Holding time met? (Y/N)	Affected data flagged? (Y/N)
Total As, Cd, Cu, Pb, Zn	Soil	EPA 6010 EPA 3050	6 mo	Aug 4, 2010	Aug 19,2010	Y	N
pH	soil	ASA 10-3.2			Aug 12, 2010	Y	N

* cite reference for holding time

Were any data flagged because of holding time problems? Y ______ N___X__

2. Instrument Calibration

Was instrument successfully calibrated at the correct frequency and with appropriate standards and blanks?
Y ___X__ N______

Was Initial Calibration Verification (ICV) performed? Y ___X__ N______

Was ICV within control window of __90%____ to 110%_? Y ___X__ N______

Were Continuing Calibration Verifications (CCVs) performed at the frequency of __5%_____? Y ___X__ N______

Were CCVs within control window of __90%____ to _110%____? Y ___X__ N______

Describe corrective actions taken because of calibration problems None

Were any data flagged because of calibration problems? Y ______ N___X__

3. Blanks

Was Initial Calibration Blank (ICB) analyzed? Y ___X__ N______

Was ICB within control window of ___<RL______? Y ___X__ N______

Were Continuing Calibration Blanks (CCBs) analyzed at the frequency of __5%______? Y ___X__ N______

Were CCBs within control window of _____<RL_______? Y __X__ N______

Were Preparation Blanks (PB) analyzed at the frequency of ________1/batch___? Y ___X__ N______

Were PBs within control window of ____<RL____? Y ______ N___X__

Describe corrective action taken because of blank problems None

Were any data flagged because of blank problems? Y ______ N___X__

Zn in method blank was elevated, but no Zn data in soil samples were affected.

4. ICP Interference Check Sample

Was ICP Interference Check Sample (ICS) analyzed at the frequency of __1/batch_________? Y ___X__ N______

Were ICS results within the control window of ____yes____________? Y ___X__ N______

Describe corrective actions taken because of ICS results None

Were any data flagged because of ICS problems? Y ______ N__X___

5. Laboratory Control Sample

Was Laboratory Control Sample (LCS) analyzed at the frequency of _1/batch_________? Y ___X__ N______

What was the source of the LCS? _Unknown

Were LCS results within the control window of ______80%______to_120%_______? Y ___X__ N______

Describe corrective actions taken because of LCS results None.

Were any data flagged because of LCS problems? Y ______ N_X___

6. Matrix Spike and Matrix Spike Duplicate

Was Matrix Spike & Matrix Spike Duplicate analyzed at the frequency of 1/batch ? Y X N____

Were results of MSD within the control window of +/- 20 % ? Y

___X__ N ____

Were MSD % recovery within control window of 75% to 125% Y

X________ N______

Were any data flagged because of MSD problems? Y ______ N X

7. Matrix Spike Results

Was Laboratory Matrix Spike Sample (LMS) analyzed at the frequency of 1/batch ? Y X N____

Were results of LMS within the control window of 75% to 125% ? Y ______ N X

Describe corrective actions taken because of LMS results None

Were data flagged because of MS problems? Y ______ N X

8. ICP Serial Dilution

Was ICP Serial Dilution (SD) analyzed at the frequency of 1/batch ? Y X N____

Were results of SD within the control window of _______? Y X N____

Describe corrective actions taken because of SD results None.

Were any data flagged because of SD problems? Y ______ N X

9. Laboratory QC Sample Results – Total Metals

Analyte Total	LCS Recovery (%R)	Matrix Spike Recovery (%R)	Matrix Spike Duplicate (RPD)
As	94	211	1
Cd	94	91	3
Cu	100	7	3
Pb	94	40	2
Zn	95	6	3

10. Checklist for Field Quality Control

Field QC Samples

Field Blanks

Were field blanks submitted as specified in the Sampling & Analysis Plan? Y ________ N X________

Were any data qualified because of field blank problems? Y ________ N __

No field blanks were required or submitted.

Field Replicates

Were field duplicates submitted as specified in the Sampling & Analysis Plan? Y N X

Were any data qualified because of field duplicate results? Y __ N X

Were results for field blanks within the target control limits in the Project QAPP? Y __ N X

No field duplicates were submitted – field duplicate is specified in the QAPP.

. **Field Reference Materials**

Were field Reference Materials or Performance Evaluation Samples specified in the Sampling & Analysis Plan? Y __ N X

Were the results within the manufacturer's control limits? Y __ N _

_ No field reference material were submitted_ - field reference sample is specified in the QAPP.

10. Instrument Calibration - pH

Was instrument successfully calibrated at the correct frequency and with appropriate standards and blanks? Y ___X___ N_____

Was Initial Calibration Verification (ICV) performed? Y ___X___ N_____

Was ICV within control window of __98%___ to 102%_? Y ___X___ N_____

Were Continuing Calibration Verifications (CCVs) performed at the frequency of __5%____? Y ___X___ N_____

Were CCVs within control window of __98%___ to __102%___? Y ___X___ N_____

Describe corrective actions taken because of calibration problems None

Were any data flagged because of calibration problems? Y ______ N___X__

11. Laboratory Duplicate Sample - pH

Was Laboratory Duplicate Sample (LDS) analyzed at the frequency of 1/batch ? Y X N____

Were LDS results within the control window of 20% ? Y X N____

Describe corrective actions taken because of LCS results None.

Were any data flagged because of LDS problems? Y ____ N X

11. Level A/B Screening Checklist

Data are:

Project: Bullion/Crystal springs, adit, creeks

Client: CH2M Hill/EPA

Sample Matrix: Water

1) Unusable ____________

2) Level A X

3) Level B X

I. Level A Screening

Criteria	Yes/No	Comments
1. Sampling date	Yes	
2. Sample team/or leader	Yes	
3. Physical description of sample location	Yes	
4. Sample depth (soils)	Yes	
5. Sample collection technique	Yes	
6. Field preparation technique	Yes	
7. Sample reservation technique	Yes	
8. Sample shipping records	Yes	

II. Level B Screening

Criteria	Yes/No	Comments
1. Field instrumentation methods and standardization complete	Yes	
2. Sample container preparation	Yes	
3. Collection of field replicates (1/20 minimum)	No	
4. Proper and decontaminated sampling equipment	NA	
5. Field custody documentation	Yes	
6. Shipping custody documentation	Yes	
7. Traceable sample designation number	Yes	
8. Field notebook(s), custody records in secure repository	Yes	
9. Completed field forms	Yes	

. 12. **Overall Assessment**

Are there analytical limitations of the data that users should be aware of? Y X
N____

If so, explain:

No field QC samples (blanks, duplicates or standards were submitted for analyses.

13. **Data Validator**

____

Dennis R. Neuman

Reclamation Research Group, LLC

Bozeman, MT

Pace Analytical Project #10135942 – Crystal Soil Samples

Validation Narrative - Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Crystal soil samples were analyzed. Field QC samples (blanks and reference materials) were not submitted. All total metal and arsenic concentrations in the soils were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum).
Validation Narrative – pH: There are no analytical limitations for which data that users should be aware. Results of the validation process for data package #10135942 are shown below

Laboratory Data Validation

Checklist for Metals Analysis by ICPMS

Site: Bullion | Case No.: 10135942 | Laboratory: Pace Analytical

Project: Springs, adit, creek | Sample Matrix: Water | Analyses: Total As, Cd, Cu. Pb, Zn and pH

Sample Dates: Aug 11-13, 2010 | Analysis Dates: Aug 20 and 26, 2010

Data Validator: Neuman/RRG | Validation Dates: 9 Nov 2010

---

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection date	Analysis date	Holding time met? (Y/N)	Affected data flagged? (Y/N)
Total As, Cd, Cu, Pb, Zn	Soil	EPA 6010 EPA 3050	6 mo	Aug 11-13, 2010	Aug 26, 2010	Y	N
pH	soil	ASA 10-3.2			Aug 26, 2010	Y	N

* cite reference for holding time

Were any data flagged because of holding time problems? Y ______ N__X__

2. Instrument Calibration

Was instrument successfully calibrated at the correct frequency and with appropriate standards and blanks?

Y __X__ N______

Was Initial Calibration Verification (ICV) performed? Y __X__ N______

Was ICV within control window of __90%___ to 110%_? Y __X__ N______

Were Continuing Calibration Verifications (CCVs) performed at the frequency of __5%____? Y __X__ N______

Were CCVs within control window of __90%___ to _110%___? Y __X__ N______

Describe corrective actions taken because of calibration problems None

Were any data flagged because of calibration problems? Y ______ N__X__

3. Blanks

Was Initial Calibration Blank (ICB) analyzed? Y __X__ N______

Was ICB within control window of ___<RL______? Y __X__ N______

Were Continuing Calibration Blanks (CCBs) analyzed at the frequency of __5%_____? Y __X__ N______

Were CCBs within control window of ____<RL_______? Y __X__ N______

Were Preparation Blanks (PB) analyzed at the frequency of ______1/batch__? Y __X__ N______

Were PBs within control window of ___<RL____? Y ______ N__X__

Describe corrective action taken because of blank problems None

Were any data flagged because of blank problems? Y ______ N__X__

Zn in method blank was elevated, but no Zn data in soil samples were affected.

4. ICP Interference Check Sample

Was ICP Interference Check Sample (ICS) analyzed at the frequency of _1/batch________? Y __X__ N______

Were ICS results within the control window of ___yes___________? Y __X__ N______

Describe corrective actions taken because of ICS results None

Were any data flagged because of ICS problems? Y ______ N__X__

5. Laboratory Control Sample

Was Laboratory Control Sample (LCS) analyzed at the frequency of _1/batch________? Y __X__ N______

What was the source of the LCS? _Unknown

Were LCS results within the control window of _____80%_____to_120%______? Y __X__ N______

Describe corrective actions taken because of LCS results None.

Were any data flagged because of LCS problems? Y ______ N_X___

6. Matrix Spike and Matrix Spike Duplicate

Was Matrix Spike & Matrix Spike Duplicate analyzed at the frequency of __1/batch________? Y ___X_ N_____

Were results of MSD within the control window of +/- 20 %_________? Y ___X__ N ____

Were MSD % recovery within control window of 75% to 125% Y X________ N______

Were any data flagged because of MSD problems? Y ______ N_X__

7. Matrix Spike Results

Was Laboratory Matrix Spike Sample (LMS) analyzed at the frequency of __1/batch________? Y __X__ N_____

Were results of LMS within the control window of ____75%__to__125%____? Y ______ N___X_

Describe corrective actions taken because of LMS results None

Were data flagged because of MS problems? Y ______ N__X__

8. ICP Serial Dilution

Was ICP Serial Dilution (SD) analyzed at the frequency of __1/batch_____? Y __X__ N_____

Were results of SD within the control window of _______? Y ___X_ N_____

Describe corrective actions taken because of SD results None.

Were any data flagged because of SD problems? Y ______ N___X_

9. Laboratory QC Sample Results – Total Metals

Analyte Total	LCS Recovery (%R)	Matrix Spike Recovery (%R)	Matrix Spike Duplicate (RPD)
As	88 and 86	797	27 and 49
Cd	87 and 86	96	2 and 15
Cu	91 and 92	-64	10 and 3
Pb	90 and 88	-1040	20 and 17
Zn	88 and 86	184	5 and 19

10. Checklist for Field Quality Control

Field QC Samples

Field Blanks

Were field blanks submitted as specified in the Sampling & Analysis Plan? Y ____ N X____

Were any data qualified because of field blank problems? Y ____ N __

No field blanks were required or submitted.

Field Replicates

Were field duplicates submitted as specified in the Sampling & Analysis Plan? Y _X_ N ____

Were any data qualified because of field duplicate results? Y __ N X_

Were results for field blanks within the target control limits in the Project QAPP? Y X____ N __

Pit 14 3' and Pit 14 3'D

Analyte Total	Field Sample	Field Duplicate	RPD
As	2100	2200	4.7
Cd	32.9	35.2	6.8
Cu	226	289	24.5
Pb	1500	1680	11.3
Zn	483	516	6.6
pH	3.4	3.2	6.7

. **Field Reference Materials**

Were field Reference Materials or Performance Evaluation Samples specified in the Sampling & Analysis Plan? Y __ N X_

Were the results within the manufacturer's control limits? Y __ N _

_ No field reference material were submitted_- field reference sample is specified in the QAPP.

10. Instrument Calibration - pH

Was instrument successfully calibrated at the correct frequency and with appropriate standards and blanks? Y ___X___ N______

Was Initial Calibration Verification (ICV) performed? Y ___X___ N______

Was ICV within control window of __98%___ to 102%_? Y ___X___ N______

Were Continuing Calibration Verifications (CCVs) performed at the frequency of __5%____? Y ___X___ N______

Were CCVs within control window of __98%___ to __102%___? Y ___X___ N______

Describe corrective actions taken because of calibration problems None

Were any data flagged because of calibration problems? Y ______ N___X___

11. Laboratory Duplicate Sample - pH

Was Laboratory Duplicate Sample (LDS) analyzed at the frequency of _1/batch________? Y ___X___ N______

Were LDS results within the control window of _____20%____? Y ___X___ N______

Describe corrective actions taken because of LCS results None.

Were any data flagged because of LDS problems? Y ______ N__X___

11. Level A/B Screening Checklist

Data are:

Project: Bullion/Crystal springs, adit, creeks

Client: CH2M Hill/EPA

Sample Matrix: Water

1) Unusable ______________

2) Level A _______X_____

3) Level B _____X_______

I. Level A Screening

Criteria	Yes/No Comments
1. Sampling date	Yes

2. Sample team/or leader	Yes	
3. Physical description of sample location	Yes	
4. Sample depth (soils)	Yes	
5. Sample collection technique	Yes	
6. Field preparation technique	Yes	
7. Sample reservation technique	Yes	
8. Sample shipping records	Yes	

II. Level B Screening

Criteria	Yes/No	Comments
1. Field instrumentation methods and standardization complete	Yes	
2. Sample container preparation	NA	
3. Collection of field replicates (1/20 minimum)	Yes	
4. Proper and decontaminated sampling equipment	NA	
5. Field custody documentation	Yes	
6. Shipping custody documentation	Yes	
7. Traceable sample designation number	Yes	
8. Field notebook(s), custody records in secure repository	Yes	
9. Completed field forms	Yes	

. **12. Overall Assessment**

Are there analytical limitations of the data that users should be aware of? Y __X__

________ N______

If so, explain:

No field QC samples (blanks, duplicates or standards were submitted for analyses.

13. Data Validator

____

Dennis R. Neuman

Reclamation Research Group, LLC

Bozeman, MT

Pace Analytical Project #10135946 – Crystal Soil Samples

Validation Narrative - Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Crystal soil samples were analyzed. Field QC samples (blanks and reference materials) were not submitted. All total metal and arsenic concentrations in the soils were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum).
Validation Narrative – pH: There are no analytical limitations for which data that users should be aware. Results of the validation process for data package #10135946 are shown below

Laboratory Data Validation
Checklist for Metals Analysis by ICPMS

Site: Bullion　　Case No.: 10135946　　Laboratory: Pace Analytical

Project: Springs, adit, creek　　Sample Matrix: Water　　Analyses: Total As, Cd, Cu. Pb, Zn and pH

Sample Dates: Aug 13-16, 2010　　Analysis Dates: Aug 20 and 26, 2010

Data Validator: Neuman/RRG　　Validation Dates: 9 Nov 2010

---

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection date	Analysis date	Holding time met? (Y/N)	Affected data flagged? (Y/N)
Total As, Cd, Cu, Pb, Zn	Soil	EPA 6010 EPA 3050	6 mo	Aug 13-16, 2010	Aug 26, 2010	Y	N
pH	soil	ASA 10-3.2			Aug 20, 2010	Y	N

* cite reference for holding time

Were any data flagged because of holding time problems? Y ______ N__X__

2. Instrument Calibration

Was instrument successfully calibrated at the correct frequency and with appropriate standards and blanks? Y __X__ N______

Was Initial Calibration Verification (ICV) performed? Y __X__ N______

Was ICV within control window of __90%___ to 110%_? Y __X__ N______

Were Continuing Calibration Verifications (CCVs) performed at the frequency of __5%____? Y __X__ N______

Were CCVs within control window of __90%___ to _110%___? Y __X__ N______

Describe corrective actions taken because of calibration problems None

Were any data flagged because of calibration problems? Y ______ N__X__

3. Blanks

Was Initial Calibration Blank (ICB) analyzed? Y __X__ N______

Was ICB within control window of ___<RL______? Y __X__ N______

Were Continuing Calibration Blanks (CCBs) analyzed at the frequency of __5%_____? Y __X__ N______

Were CCBs within control window of ____<RL_______? Y __X__ N______

Were Preparation Blanks (PB) analyzed at the frequency of _______1/batch__? Y __X__ N______

Were PBs within control window of ___<RL____? Y ______ N__X__

Describe corrective action taken because of blank problems None

Were any data flagged because of blank problems? Y ______ N__X__

Zn in method blank was elevated, but no Zn data in soil samples were affected.

4. ICP Interference Check Sample

Was ICP Interference Check Sample (ICS) analyzed at the frequency of _1/batch________? Y __X__ N______

Were ICS results within the control window of ___yes___________? Y __X__ N______

Describe corrective actions taken because of ICS results None

Were any data flagged because of ICS problems? Y ______ N__X__

5. Laboratory Control Sample

Was Laboratory Control Sample (LCS) analyzed at the frequency of _1/batch________? Y __X__ N______

What was the source of the LCS? _Unknown

Were LCS results within the control window of ______80%_____to_120%______? Y __X__ N______

Describe corrective actions taken because of LCS results None.

Were any data flagged because of LCS problems? Y ______ N_X__

6. Matrix Spike and Matrix Spike Duplicate

Was Matrix Spike & Matrix Spike Duplicate analyzed at the frequency of __1/batch________? Y ___X_ N_____

Were results of MSD within the control window of_+/- 20 %_________? Y ___X__ N ____

Were MSD % recovery within control window of 75% to 125% Y X________ N______

Were any data flagged because of MSD problems? Y ______ N_X___

7. Matrix Spike Results

Was Laboratory Matrix Spike Sample (LMS) analyzed at the frequency of __1/batch________? Y __X__ N_____

Were results of LMS within the control window of ____75%__to__125%____? Y ______ N___X_

Describe corrective actions taken because of LMS results None

Were data flagged because of MS problems? Y ______ N__X__

8. ICP Serial Dilution

Was ICP Serial Dilution (SD) analyzed at the frequency of __1/batch_____? Y __X__ N_____

Were results of SD within the control window of _______? Y ____X_ N_____

Describe corrective actions taken because of SD results None.

Were any data flagged because of SD problems? Y ______ N___X_

9. Laboratory QC Sample Results – Total Metals

Analyte Total	LCS Recovery (%R)	Matrix Spike Recovery (%R)	Matrix Spike Duplicate (RPD)
As	87 and 86	94	15 and 4
Cd	88 and 86	85	15 and 4
Cu	97 and 91	241	13 and 2
Pb	90 and 89	164	15 and 2
Zn	90 and 87	92	16 and 4

10. Checklist for Field Quality Control

Field QC Samples

Field Blanks

Were field blanks submitted as specified in the Sampling & Analysis Plan? Y ________ N

X ________

Were any data qualified because of field blank problems? Y ________ N __

No field blanks were required or submitted.

Field Replicates

Were field duplicates submitted as specified in the Sampling & Analysis Plan? Y

N X

Were any data qualified because of field duplicate results? Y __ N X

Were results for field blanks within the target control limits in the Project QAPP? Y __ N X

BBG-2 and BBG-2D

Analyte Total	Field Sample	Field Duplicate	RPD
As	17.5	18.1	3.4
Cd	0.4	0.4	--
Cu	13.9	18.7	29.4
Pb	17.5	17.0	2.9
Zn	63.2	63.1	0.2
pH	6.9	7.1	2.9

CTP 32 and 32D

Analyte Total	Field Sample	Field Duplicate	RPD
As	444	198	62.9
Cd	3.7	2.7	31.3
Cu	102	67.2	41.1
Pb	1410	200	150.3
Zn	416	353	7.8

pH	6.6	6.1	7.9

. Field Reference Materials

Were field Reference Materials or Performance Evaluation Samples specified in the Sampling & Analysis Plan? Y __ N X

Were the results within the manufacturer's control limits? Y __ N _

_ No field reference material were submitted_- field reference sample is specified in the QAPP.

10. Instrument Calibration - pH

Was instrument successfully calibrated at the correct frequency and with appropriate standards and blanks? Y X N_____

Was Initial Calibration Verification (ICV) performed? Y X N_____

Was ICV within control window of 98% to 102%_? Y X N_____

Were Continuing Calibration Verifications (CCVs) performed at the frequency of 5%? Y X N_____

Were CCVs within control window of 98% to 102%? Y X N_____

Describe corrective actions taken because of calibration problems None

Were any data flagged because of calibration problems? Y _____ N X

11. Laboratory Duplicate Sample - pH

Was Laboratory Duplicate Sample (LDS) analyzed at the frequency of 1/batch? Y X N_____

Were LDS results within the control window of 20%? Y X N_____

Describe corrective actions taken because of LCS results None.

Were any data flagged because of LDS problems? Y _____ N X

11. Level A/B Screening Checklist

Data are:

Project: Bullion/Crystal springs, adit, creeks

1) Unusable _____________

Client: CH2M Hill/EPA

Sample Matrix: Water

2) Level A ______X_____

3) Level B ____X_______

I. Level A Screening

Criteria	Yes/No	Comments
1. Sampling date	Yes	
2. Sample team/or leader	Yes	
3. Physical description of sample location	Yes	
4. Sample depth (soils)	Yes	
5. Sample collection technique	Yes	
6. Field preparation technique	Yes	
7. Sample reservation technique	Yes	
8. Sample shipping records	Yes	

II. Level B Screening

Criteria	Yes/No	Comments
1. Field instrumentation methods and standardization complete	Yes	
2. Sample container preparation	NA	
3. Collection of field replicates (1/20 minimum)	No	
4. Proper and decontaminated sampling equipment	NA	
5. Field custody documentation	Yes	
6. Shipping custody documentation	Yes	
7. Traceable sample designation number	Yes	
8. Field notebook(s), custody records in secure repository	Yes	

9. Completed field forms	Yes

. **12. Overall Assessment**

Are there analytical limitations of the data that users should be aware of? Y __X__

________ N______

If so, explain:

No field QC samples (blanks, duplicates or standards were submitted for analyses.

13. Data Validator

____

Dennis R. Neuman

Reclamation Research Group, LLC

Bozeman, MT

Appendix K
Water Data Validation Report

Reclamation Research Group, LLC
202 South Black Avenue, Suite 4
P.O. Box 6309, Bozeman, MT 59715
Phone: (406) 624-6571
Fax: (406) 551-2036

Technical Memorandum - REVISED

To: Dennis Smith, CH2M Hill/Boise
From: Dennis Neuman
Date: 16 November 2010
Re: Review and data validation of water data for samples collected from springs, creeks, adits, monitoring wells, and piezometers at the Bullion and Crystal Mine sites.

Water samples were collected from springs, creeks, adits, monitoring wells, and piezometers at the Bullion and Crystal Mine sites in the Basin Creek watershed during the summer and early fall of 2010. Collections and determination of concentrations selected total and dissolved metals and arsenic, alkalinity, chloride, and sulfate were conducted under the direction of a Sampling and Analysis Plan (CH2M Hill, 2010). Field determinations of pH, specific conductivity, and temperature were made at the time of collection using calibrated meters. Samples were preserved in pre-acidified sample bottles and under chain of custody, shipped to the analytical laboratory. Concentrations of total and dissolved metals and arsenic was determined using EPA method 200.8 – ICP/MS. Alkalinity measurements were conducted using SM 2320-B, and chloride and sulfate levels were determined using EPA 300.0. The analytical data were subjected to a validation process as described in the following documents:

- USEPA CLP National Functional Guidelines for Inorganic Data Review, OSWER 9240.1-51, EPA 540-R-10-011 (1January 2010)
- Clark Fork River Superfund Site Investigations, data management/Data Validation Plan (PTI, 1992 with revision (1993), and addendum (2000).

Four separate sampling events took place and four data packages were received from the analytical laboratory. These data packages were identified as:

- Pace Analytical 10133880
- Pace Analytical 10138195
- Pace Analytical 10138755
- Pace Analytical 10139035
- Pace Analytical 10139661

A summary of the validation of data contained in each data package and results of the validation are described below.

- **Pace Analytical 10133880 Validation Narrative**
  Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Bullion and Crystal springs, adit and creek water samples were analyzed. Elevated manganese concentrations were reported in the laboratory method blank and the field blank. Affected dissolved Mn levels are considered to be estimates for the following samples: Bullion Springs # 12 and 14; Crystal Springs # 1, 2, 4, and 5; USC-TRIB; and CB-40B; JC-4B, Bullion Springs #9, 12D; JC-1; USC-1 and USC -2. Except for the dissolved Mn levels in the identified samples, all other total and dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). The affected Mn data are of Screening Quality as defined in the same document.
  Chloride, Sulfate, and Alkalinity: There are no analytical limitations for which data users should be aware.

- **Pace Analytical 10138195 Validation Narrative**
  Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Crystal springs and creek water samples were analyzed. Elevated dissolved Pb was found in field blank. Samples affected are Crystal Springs #1, 1D, 2, 4, and 5; USC#1, 2, 3, and TRIB. Except for the dissolved Pb levels in the identified samples, all other total and dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). The affected dissolved Pb data are of Screening Quality as defined in the same document.
  Chloride, Sulfate, and Alkalinity: There are no analytical limitations for which data users should be aware.

- **Pace Analytical 10138755 Validation Narrative**
  Metals: Validation Narrative - Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Bullion springs, adit , adit channel, and creek water samples were analyzed. Total Na value in the field blank sample was elevated. Affected samples for total Na are: BS#3,4,8,1,7,5,6,9,10, 13D, 11, 13, 14, 12; Adit, Adit Channel, JC# 1, 2, 3, and 4. Dissolved Al value in the field blank also found to be elevated. Affected samples for dissolved Al are BS# 3, 8, 6, 9, 13D, 13, 12; JC-1, 2, and 4. Except for the total Na and dissolved Al in the identified samples, all other total and dissolved concentrations were judged to be of highest quality (Enforcement

Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). The affected Na and Al data are of Screening Quality as defined in the same document.

Chloride, Sulfate, and Alkalinity: There are no analytical limitations for which data users should be aware.

- **Pace Analytical 10139035 Validation Narrative**
  Metals: Laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Bullion monitoring well and piezometer water samples were analyzed. No field blank and no field duplicate were submitted to the laboratory. With these exceptions, all of the dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum).
  Chloride, Sulfate, and Alkalinity: There are no analytical limitations for which data users should be aware.

- **Pace Analytical Project #101339661 Validation Narrative**
  Metals: Laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Bullion piezometer water samples were analyzed. No field blank and no field duplicate (because of limited sample volume was obtained) were submitted to the laboratory. With these exceptions, the dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum).

Data validation packages for each data set are displayed below.

Data Package 1 – Pace Analytical Project #10133880 – Bullion and Crystal Water Samples

Validation Narrative - Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Bullion, Crystal springs, adit and creek water samples were analyzed. Elevated manganese concentrations were reported in the laboratory method blank and the field blank. Affected dissolved Mn levels are considered to be estimates for the following samples: Bullion Springs # 12 and 14; Crystal Springs # 1, 2, 4, and 5; USC-TRIB; and CB-40B; JC-4B, Bullion Springs #9, 12D; JC-1; USC-1 and USC -2. Except for the dissolved Mn levels in the identified samples, all other total and dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). The affected Mn data are of Screening Quality as defined in the same document.

Validation Narrative – Chloride, Sulfate, and Alkalinity: There are no analytical limitations for which data users should be aware. Results of the validation process for data package #10133880 are shown below

Set 1, Laboratory Data Validation

Checklist for Metals Analysis by ICPMS

Site: Crystal/Bullion Case No.: 10133880 Laboratory: Pace Analytical

Project: Springs, adit, creek Sample Matrix: Water Analyses: Total Al,

Sample Dates: Jul 14-18,2010 Analysis Dates: Jul 27-30,2010 As, Cd, Cu, Fe, Pb, Mg, K, Na, Zn

Data Validator: Neuman/RRG Validation Dates: 2 NOV 2010 Dissolved Al, As, Cd, Cu, Pb, MnZn

---

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection date	Analysis date	Holding time met? (Y/N)	Affected data flagged? (Y/N)
Total and	Water	EPA	6 mo.	Jul 14-	Jul 27-30,2010	Yes	No

dissolved metals		200.8 ICPMS		18,2010			

* cite reference for holding time

Were any data flagged because of holding time problems? Y ______ N__X__

2. Instrument Calibration

Was instrument successfully calibrated at the correct frequency and with appropriate standards and blanks?

Y ___X_ N_____

Was Initial Calibration Verification (ICV) performed? Y ___X_ N_____

Was ICV within control window of __90%___ to 110%_? Y ___X_ N_____

Were Continuing Calibration Verifications (CCVs) performed at the frequency of __5%____? Y ___X_ N_____

Were CCVs within control window of ___90%___ to _110%___? Y ___X_ N_____

Describe corrective actions taken because of calibration problems None

Were any data flagged because of calibration problems? Y ______ N__X__

3. Blanks

Was Initial Calibration Blank (ICB) analyzed? Y ___X_ N_____

Was ICB within control window of ___<RL______? Y ___X_ N_____

Were Continuing Calibration Blanks (CCBs) analyzed at the frequency of __5%_____? Y ___X_ N_____

Were CCBs within control window of _____<RL_______? Y __X__ N_____

Were Preparation Blanks (PB) analyzed at the frequency of _______1/batch__? Y ___X_ N_____

Were PBs within control window of ___<RL____? Y ___X_ N_____

Describe corrective action taken because of blank problems None

Were any data flagged because of blank problems? Y __X__ N_____

Mn was detected in the method blank. Lab qualified associated data B, data are estimates. Dissolved Mn in the following samples is considered to be estimates: Bullion Springs # 12 and 14; Crystal Springs # 1, 2, 4, and 5; USC-TRIB; and CB-40B.

4. ICP Interference Check Sample

Was ICP Interference Check Sample (ICS) analyzed at the frequency of __1/batch________? Y ___X_ N_____

Were ICS results within the control window of ____yes___________? Y ___X_ N_____

Describe corrective actions taken because of ICS results None

Were any data flagged because of ICS problems? Y ______ N__X__

5. Laboratory Control Sample

Was Laboratory Control Sample (LCS) analyzed at the frequency of 1/batch ? Y X N___

What was the source of the LCS? _Unknown

Were LCS results within the control window of 85% to 115% ? Y X N___

Describe corrective actions taken because of LCS results None.

Were any data flagged because of LCS problems? Y ___ N X

6. Matrix Spike and Matrix Spike Duplicate

Was Matrix Spike & Matrix Spike Duplicate analyzed at the frequency of 1/batch ? Y X N___

Were results of MSD within the control window of +/- 20 % ? Y

___X__ N ____

Were MSD % recovery within control window of 70% to 130% Y ___ N X

Were any data flagged because of MSD problems? Y X N___

Affected data were qualified MO by lab

7. Matrix Spike Results

Was Laboratory Matrix Spike Sample (LMS) analyzed at the frequency of 1/batch ? Y X N___

Were results of LMS within the control window of 70% to 130% ? Y ___ N X

Describe corrective actions taken because of LMS results None

Were data flagged because of LMS problems? Y X N___

Affected data were qualified MO by lab

8. ICP Serial Dilution

Was ICP Serial Dilution (SD) analyzed at the frequency of 1/batch ? Y X N___

Were results of SD within the control window of _______? Y X N___

Describe corrective actions taken because of SD results None.

Were any data flagged because of SD problems? Y ___ N X

9. Laboratory QC Sample Results – Total Metals

Analyte Total	LCS Recovery (%R)	Matrix Spike Recovery (%R)	Matrix Spike Duplicate (RPD)
Al	94 and 94	105 and 445	1 and 0.1
As	95 and 98	98 and 127	3 and 4
Cd	96 and 98	96 and 155	3 and 5
Ca	95 and 96	106 and 594	.05 and 3
Cu	97 and 98	93 and 488	4 and 4
Fe	96 and	89 and 164	2 and 2

	102		
Pb	96 and 105	97 and 143	3 and 4
Mg	97 and 98	98 and 230	0.7 and 3
K	99 and 99	101 and 135	2 and 3
Na	96 and 93	103 and 183	5 and 3
Zn	97 and 99	75 and 2370	9 and 5

10. Laboratory QC Sample Results – Dissolved Metals

Analyte Dissolved	LCS Recovery (%R)	Matrix Spike Recovery (%R)	Matrix Spike Duplicate (RPD)
Al	94 and 98	117	3 and1
As	98 and 92	102	9 and 0.4
Cd	100 and 96	108	9 and 2
Cu	98 and 99	221	3 and 1
Fe	102 and 100	105	1 and .04
Pb	106 and 95	105	4 and1
Mn	101 and 103	222	2 and 4
Zn	99 and 103	-120	7 and1

11. Checklist for Field Quality Control

Field QC Samples

Field Blanks

Were field blanks submitted as specified in the Sampling & Analysis Plan? Y ________ N __

Dissolved Mn in field blank is two times the RL. Data for dissolved Mn < 17 ug/L are estimates. These dissolved Mn values are in the following samples:

JC-4B, Bullion Springs #9, 12D, 6, 8. 14, 12, 5; Crystal Springs 1,2, and 4; JC-1, USC TRIB, USC-1 and USC -2.

Were any data qualified because of field blank problems? Y
X______ N __

Field Replicates

Were field duplicates submitted as specified in the Sampling & Analysis Plan? Y
X N _

Were any data qualified because of field duplicate results? Y __ N X

Were results for field blanks within the target control limits in the Project QAPP? Y
X______ N __

Duplicate Results – Total Metals (Bullion Springs 12 and 12D)

Analyte Total	Sample Value	Duplicate Value	%RPD
Al	11.4	8.7	26.9
As	12.7	12.2	4.0
Cd	6.3	6.2	1.6
Ca	31200	30100	3.6
Cu	7.1	7.0	1.4
Fe	ND	ND	--
Pb	0.11	ND	--
Mg	6050	6160	1.8
K	1760	1780	0.6
Na	2710	2850	5.0
Zn	3010	2900	3.7

. **Duplicate Results – Dissolved Metals (Bullion Springs 12 and 12D)**

Analyte Total	Sample Value	Duplicate Value	%RPD
Al	ND	ND	--
As	12.4	12.3	0.8
Cd	5.8	6.3	8.3
Cu	6.7	6.6	1.5
Fe	ND	ND	--
Pb	ND	ND	--
Mn	2.3	0.8	96.8
Zn	3109	2860	8.3

Field Reference Materials

Were field Reference Materials or Performance Evaluation Samples specified in the Sampling & Analysis Plan? Y __ N X

Were the results within the manufacturer's control limits? Y __ N _

12. Level A/B Screening Checklist

Data are:

Project: Bullion/Crystal springs, adit, creeks

Client: CH2M Hill/EPA

Sample Matrix: Water

1) Unusable ______________

2) Level A ______X_____

3) Level B ____X_______

I. Level A Screening

Criteria	Yes/No	Comments
1. Sampling date	Yes	
2. Sample team/or leader	Yes	
3. Physical description of sample location	Yes	
4. Sample depth (soils)	NA	

5. Sample collection technique	Yes	
6. Field preparation technique	Yes	
7. Sample reservation technique	Yes	
8. Sample shipping records	Yes	

II. Level B Screening

Criteria	Yes/No	Comments
1. Field instrumentation methods and standardization complete		
2. Sample container preparation	Yes	
3. Collection of field replicates (1/20 minimum)	Yes	
4. Proper and decontaminated sampling equipment	NA	
5. Field custody documentation	Yes	
6. Shipping custody documentation	Yes	
7. Traceable sample designation number	Yes	
8. Field notebook(s), custodv records in secure repository	Yes	
9. Completed field forms	Yes	

. 13. Overall Assessment

Are there analytical limitations of the data that users should be aware of? Y __X__

N______

If so, explain:

Elevated manganese concentrations were reported in the laboratory method blank and the filed blank. Affected dissolved Mn levels are considered to be estimates for the following samples: Bullion Springs # 12 and 14; Crystal Springs # 1, 2, 4, and 5; USC-TRIB; and CB-40B; JC-4B, Bullion Springs #9, 12D; JC-1; USC-1 and USC -2. Except for the dissolved Mn levels in the identified samples, all other total and dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). Results of the validation process for data package #1099095 are shown below. The affected Mn data are of Screening Quality as defined in the same document.

14. Data Validator

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Dennis R. Neuman
Reclamation Research Group, LLC
Bozeman, MT

Data Package 2 – Pace Analytical Project #10138195 – Crystal Water Samples

Validation Narrative - Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Crystal springs and creek water samples were analyzed. Elevated dissolved Pb was found in field blank. Samples affected are Crystal Springs #1, 1D, 2, 4, and 5; USC#1, 2, 3, and TRIB. Except for the dissolved Pb levels in the identified samples, all other total and dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). The affected dissolved Pb data are of Screening Quality as defined in the same document.

Validation Narrative – Chloride, Sulfate, and Alkalinity: There are no analytical limitations for which data users should be aware. Results of the validation process for data package #10138195 are shown below.

Set 2, Laboratory Data Validation

Checklist for Metals Analysis by ICPMS

Site: Crystal Case No.: 10138195 Laboratory: Pace Analytical

Project: Springs, adit, creek Sample Matrix: Water Analyses: Total Al,

Sample Dates: Sep 13-14, 2010 Analysis Dates: Sep 16,2010 As, Cd, Cu, Pb, Zn; Dissolved

Data Validator: Neuman/RRG Validation Dates: 3 NOV 2010 Al, As, Cd, Cu, Pb, Mn, Fe, Zn

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection date	Analysis date	Holding time met? (Y/N)	Affected data flagged? (Y/N)
Total and dissolved metals	Water	EPA 200.8 ICPMS	6 mo.	Sep 13-14,2010	Sep16,2010	Yes	No

* cite reference for holding time

Were any data flagged because of holding time problems? Y ______ N__X__

2. Instrument Calibration

Was instrument successfully calibrated at the correct frequency and with appropriate standards and blanks?

Y __X__ N_____

Was Initial Calibration Verification (ICV) performed? Y __X__ N_____

Was ICV within control window of __90%__ to 110%_? Y __X__ N_____

Were Continuing Calibration Verifications (CCVs) performed at the frequency of __5%__? Y __X__ N_____

Were CCVs within control window of __90%__ to __110%__? Y __X__ N_____

Describe corrective actions taken because of calibration problems None

Were any data flagged because of calibration problems? Y ______ N__X__

3. Blanks

Was Initial Calibration Blank (ICB) analyzed? Y __X__ N_____

Was ICB within control window of __<RL__? Y __X__ N_____

Were Continuing Calibration Blanks (CCBs) analyzed at the frequency of __5%__? Y __X__ N_____

Were CCBs within control window of __<RL__? Y __X__ N_____

Were Preparation Blanks (PB) analyzed at the frequency of __1/batch__? Y __X__ N_____

Were PBs within control window of __<RL__? Y __X__ N_____

Describe corrective action taken because of blank problems None

Were any data flagged because of blank problems? Y ______ N__X__

4. ICP Interference Check Sample

Was ICP Interference Check Sample (ICS) analyzed at the frequency of __1/batch__? Y __X__ N_____

Were ICS results within the control window of __yes__? Y __X__ N_____

Describe corrective actions taken because of ICS results None

Were any data flagged because of ICS problems? Y ______ N__X__

5. Laboratory Control Sample

Was Laboratory Control Sample (LCS) analyzed at the frequency of __1/batch__? Y __X__ N_____

What was the source of the LCS? _Unknown

Were LCS results within the control window of __85%__to__115%__? Y __X__ N__X__

Zn in one LCS reported at 116%.

Describe corrective actions taken because of LCS results None.

Were any data flagged because of LCS problems? Y ______ N__X__

6. Matrix Spike and Matrix Spike Duplicate

Was Matrix Spike & Matrix Spike Duplicate analyzed at the frequency of 1/batch? Y X N___

Were results of MSD within the control window of +/- 20 %?

Y X N ___

Were MSD % recovery within control window of 70% to 130% Y ___ N X

Al matrix spike of 133%, Cu recovery of 132

Were any data flagged because of MSD problems? Y ___ N X

7. Matrix Spike Results

Was Laboratory Matrix Spike Sample (LMS) analyzed at the frequency of 1/batch? Y X N___

Were results of LMS within the control window of 70% to 130%? Y ___ N X

Describe corrective actions taken because of LMS results None

Were data flagged because of LMS problems? Y ___ N X

8. ICP Serial Dilution

Was ICP Serial Dilution (SD) analyzed at the frequency of 1/batch? Y X N___

Were results of SD within the control window of ___? Y X N___

Describe corrective actions taken because of SD results None.

Were any data flagged because of SD problems? Y ___ N X

9. Laboratory QC Sample Results – Total Metals

Analyte Total	LCS Recovery (%R)	Matrix Spike Recovery (%R)	Matrix Spike Duplicate (RPD)
Al	111	133	5
As	109	109	.06
Cd	104	104	.1
Cu	112	114	.8
Pb	103	101	.2
Zn	116	110	.8

10. Laboratory QC Sample Results – Dissolved Metals

Analyte Dissolved	LCS Recovery (%R)	Matrix Spike Recovery (%R)	Matrix Spike Duplicate (RPD)
Al	109	146	3
As	101	102	3
Cd	102	102	3
Cu	101	101	3
Fe	104	104	5
Pb	107	110	4
Mn	102	103	3
Zn	106	105	4

11. Checklist for Field Quality Control

Field QC Samples

Field Blanks

Were field blanks submitted as specified in the Sampling & Analysis Plan? Y X___ N _

Was FB within control window of ___<RL______? Y ____ N___X

Dissolved Pb in field blank is two times the RL. Data for dissolved Pb < 3.4 ug/L

Are estimates. Samples affected are Crystal Springs #1, 1D, 2, 4, and 5; USC#1, 2, 3, and TRIB

Were any data qualified because of field blank problems? Y X_______ N __

Field Replicates

Were field duplicates submitted as specified in the Sampling & Analysis Plan? Y X N ________

Were any data qualified because of field duplicate results? Y __ N X_

Were results for field blanks within the target control limits in the Project QAPP? Y X_______ N __

Duplicate Results – Total Metals (Bullion Springs 12 and 12D)

Analyte Total	Sample Value	Duplicate Value	%RPD
Al	9.8	9.6	2.1
As	ND	ND	
Cd	ND	ND	
Cu	ND	ND	
Pb	0.16	ND	
Zn	ND	ND	

. Duplicate Results – Dissolved Metals (Bullion Springs 12 and 12D)

Analyte Total	Sample Value	Duplicate Value	%RPD
Al	9.1	8.2	10.4
As	ND	ND	
Cd	ND	ND	
Cu	ND	ND	
Fe	ND	ND	
Pb	ND	ND	
Mn	ND	ND	
Zn	ND	ND	

Field Reference Materials

Were field Reference Materials or Performance Evaluation Samples specified in the Sampling & Analysis Plan? Y __ N X

Were the results within the manufacturer's control limits? Y __ N _

12. Level A/B Screening Checklist

Data are:

Project: Crystal springs and creeks
Client: CH2M Hill/EPA
Sample Matrix: Water

1) Unusable ______________
2) Level A _______X_____
3) Level B _____X_______

I. Level A Screening

Criteria	Yes/No	Comments
1. Sampling date	Yes	
2. Sample team/or leader	Yes	
3. Physical description of sample location	Yes	
4. Sample depth (soils)	NA	
5. Sample collection technique	Yes	
6. Field preparation technique	Yes	
7. Sample reservation technique	Yes	
8. Sample shipping records	Yes	

II. Level B Screening

Criteria	Yes/No	Comments
1. Field instrumentation methods and standardization complete		
2. Sample container preparation	Yes	
3. Collection of field replicates (1/20 minimum)	Yes	
4. Proper and decontaminated sampling equipment	NA	
5. Field custody documentation	Yes	
6. Shipping custody documentation	Yes	
7. Traceable sample designation number	Yes	

8. Field notebook(s), custodv records in secure repository	Yes
9. Completed field forms	Yes

. **13. Overall Assessment**

Are there analytical limitations of the data that users should be aware of? Y __X________ N______

If so, explain:

Dissolved Pb in field blank is two times the RL. Data for dissolved Pb < 3.4 ug/L are estimates. Samples affected are Crystal Springs #1, 1D, 2, 4, and 5; USC#1, 2, 3, and TRIB. Except for the dissolved Pb levels in the identified samples, all other total and dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). The affected Pb data are of Screening Quality as defined in the same document.

14. Data Validator

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Dennis R. Neuman

Reclamation Research Group, LLC

Bozeman, MT

Data Package 3 – Pace Analytical Project #10138755 – Bullion Water Samples

Validation Narrative - Metals: Most laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Bullion springs, adit , adit channel, and creek water samples were analyzed. Total Na value in the field blank sample was elevated. Affected samples for total Na are: BS#3,4,8,1,7,5,6,9,10, 13D, 11, 13, 14, 12; Adit, Adit Channel, JC# 1, 2, 3, and 4. Dissolved Al value in the field blank also found to be elevated. Affected samples for dissolved Al are BS# 3, 8, 6, 9, 13D, 13, 12; JC-1, 2, and 4. Except for the total Na and dissolved Al in the identified samples, all other total and dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). The affected Na and Al data are of Screening Quality as defined in the same document.

Validation Narrative – Chloride, Sulfate, and Alkalinity: There are no analytical limitations for which data users should be aware. Results of the validation process for data package #10138755 are shown below.

Set 3, Laboratory Data Validation

Checklist for Metals Analysis by ICPMS

Site: Bullion　　Case No.: 10138775　　Laboratory: Pace Analytical

Project: Springs, adit, creek　　Sample Matrix: Water　　Analyses: Total Al, Ca. Na, K, Fe

Sample Dates: Sep 20-21, 2010　　Analysis Dates: Oct 1 and 6, 2010　　As, Cd, Cu, Pb, Zn; Dissolved

Data Validator: Neuman/RRG　　Validation Dates: 3 NOV 2010　　Al, As, Cd, Cu, Pb, Mn, Fe, Zn

1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection date	Analysis date	Holding time met? (Y/N)	Affected data flagged? (Y/N)
Total and dissolved metals	Water	EPA 200.8	6 mo.	Sep 20-21, 2010	Oct 1 and 6, 2010	Yes	No

		ICPMS					

* cite reference for holding time

Were any data flagged because of holding time problems? Y ______ N___X_

2. Instrument Calibration

Was instrument successfully calibrated at the correct frequency and with appropriate standards and blanks?

Y ____X_ N______

Was Initial Calibration Verification (ICV) performed? Y ____X_ N______

Was ICV within control window of __90%____ to 110%_? Y ____X_ N______

Were Continuing Calibration Verifications (CCVs) performed at the frequency of __5%_____? Y ____X_ N______

Were CCVs within control window of __90%____ to _110%___? Y ____X_ N______

Describe corrective actions taken because of calibration problems None

Were any data flagged because of calibration problems? Y ______ N___X_

3. Blanks

Was Initial Calibration Blank (ICB) analyzed? Y ____X_ N______

Was ICB within control window of ___<RL______? Y ____X_ N______

Were Continuing Calibration Blanks (CCBs) analyzed at the frequency of __5%______? Y ____X_ N______

Were CCBs within control window of _____<RL_______? Y ___X__ N______

Were Preparation Blanks (PB) analyzed at the frequency of _______1/batch___? Y ____X_ N______

Were PBs within control window of ____<RL____? Y ____X_ N______

Describe corrective action taken because of blank problems None

Were any data flagged because of blank problems? Y ______ N___X_

4. ICP Interference Check Sample

Was ICP Interference Check Sample (ICS) analyzed at the frequency of __1/batch_________? Y ____X_ N______

Were ICS results within the control window of ____yes____________? Y ____X_ N______

Describe corrective actions taken because of ICS results None

Were any data flagged because of ICS problems? Y ______ N__X__

5. Laboratory Control Sample

Was Laboratory Control Sample (LCS) analyzed at the frequency of _1/batch_________? Y ____X_ N______

What was the source of the LCS? _Unknown

Were LCS results within the control window of _______85%______to__115%_______? Y ____X_ N__X__

Zn in one LCS reported at 116%.

Describe corrective actions taken because of LCS results None.

Were any data flagged because of LCS problems? Y ______ N_X__

6. Matrix Spike and Matrix Spike Duplicate

Was Matrix Spike & Matrix Spike Duplicate analyzed at the frequency of __1/batch_______? Y ___X_ N_____

Were results of MSD within the control window of_+/- 20 %_________? Y

___X__ N ____

Were MSD % recovery within control window of 70% to 130% Y ______ N___X_

Al matrix spike of 133%, Cu recovery of 132

Were any data flagged because of MSD problems? Y ______ N___X_

7. Matrix Spike Results

Was Laboratory Matrix Spike Sample (LMS) analyzed at the frequency of __1/batch_______? Y __X__ N_____

Were results of LMS within the control window of ____70%___to___130%____? Y ______ N___X_

Ca recovery of 187 is outside control window. Dissolved Al recovery is outside of window

Describe corrective actions taken because of LMS results None

Were data flagged because of LMS problems? Y ______ N_X__

8. ICP Serial Dilution

Was ICP Serial Dilution (SD) analyzed at the frequency of __1/batch_____? Y ___X_ N_____

Were results of SD within the control window of _______? Y ___X_ N_____

Describe corrective actions taken because of SD results None.

Were any data flagged because of SD problems? Y ______ N___X_

9. Laboratory QC Sample Results – Total Metals

Analyte Total	LCS Recovery (%R)	Matrix Spike Recovery (%R)	Matrix Spike Duplicate (RPD)
Al	105	114	7
As	105	103	3
Cd	105	106	.2
Cu	104	105	2
Pb	102	112	1
Zn	103	74	2
Ca	110	187	.3
Mg	100	115	2

Na	101	113	1
K	104	110	1

10. Laboratory QC Sample Results – Dissolved Metals

Analyte Dissolved	LCS Recovery (%R)	Matrix Spike Recovery (%R)	Matrix Spike Duplicate (RPD)
Al	109	146	3
As	101	102	3
Cd	102	102	3
Cu	101	101	3
Fe	104	104	5
Pb	107	110	4
Mn	102	103	3
Zn	106	105	4

11. Checklist for Field Quality Control

Field QC Samples

Field Blanks

Were field blanks submitted as specified in the Sampling & Analysis Plan? Y X N _

Was FB within control window of <RL? Y ____ N X

Total Na values > 2X RL. Total Na values < 9610 mg/kg are estimated .

Affected samples for total Na are: BS#3,4,8,1,7,5,6,9,10, 13D, 11, 13, 14, 12; Adit, Adit Channel, JC# 1, 2, 3, and 4.

Dissolved Al value > 2x RL. Dissolved Al < 64 mg/kg are estimated . Affected samples for dissolved Al are BS# 3, 8, 6, 9, 13D, 13, 12; JC-1, 2, and 4.

Were any data qualified because of field blank problems? Y X N __

Field Replicates

Were field duplicates submitted as specified in the Sampling & Analysis Plan? Y X

Were any data qualified because of field duplicate results? Y __ N X

Were results for field blanks within the target control limits in the Project QAPP? Y X N __

Duplicate Results – Total Metals (Bullion Springs 12 and 12D)

Analyte Total	Sample Value	Duplicate Value	%RPD
Al	25.4	26.5	4.2
As	14.1	15.4	8.8
Cd	5.4	5.6	3.6
Ca	16600	16700	0.6
Cu	47.8	48.1	0.6
Pb	0.26	0.32	20.7
Mg	3260	3260	0.0
K	1130	1140	0.9
Na	2380	2420	1.7
Zn	697	711	2.0

Duplicate Results – Dissolved Metals (Bullion Springs 12 and 12D)

Analyte Total	Sample Value	Duplicate Value	%RPD
Al	30.1	29.1	3.4
As	13.9	14.9	6.9
Cd	5.4	5.8	7.1
Cu	46.7	50	6.8
Fe	ND	ND	--
Pb	0.42	0.29	36.6
Mn	30.9	32.0	3.5
Zn	691	736	6.3

Field Reference Materials

Were field Reference Materials or Performance Evaluation Samples specified in the Sampling & Analysis Plan? Y __ N X

Were the results within the manufacturer's control limits? Y __ N _

12. Level A/B Screening Checklist

Data are:

Project: Bullion springs and creeks

Client: CH2M Hill/EPA

Sample Matrix: Water

1) Unusable ____________

2) Level A ______X_____

3) Level B ____X_______

I. Level A Screening

Criteria	Yes/No	Comments
1. Sampling date	Yes	
2. Sample team/or leader	Yes	
3. Physical description of sample location	Yes	
4. Sample depth (soils)	NA	
5. Sample collection technique	Yes	
6. Field preparation technique	Yes	
7. Sample reservation technique	Yes	
8. Sample shipping records	Yes	

II. Level B Screening

Criteria	Yes/No	Comments

1. Field instrumentation methods and standardization complete		
2. Sample container preparation	Yes	
3. Collection of field replicates (1/20 minimum)	Yes	
4. Proper and decontaminated sampling equipment	NA	
5. Field custody documentation	Yes	
6. Shipping custody documentation	Yes	
7. Traceable sample designation number	Yes	
8. Field notebook(s), custody records in secure repository	Yes	
9. Completed field forms	Yes	

. 13. Overall Assessment

Are there analytical limitations of the data that users should be aware of? Y __X__

________ N______

If so, explain:

Total Na value in the field blank was > 2X RL. Total Na values < 9610 mg/kg are estimated . Affected samples for total Na are: BS#3,4,8,1,7,5,6,9,10, 13D, 11, 13, 14, 12; Adit, Adit Channel, JC# 1, 2, 3, and 4. Dissolved Al value in the field blank was > 2x RL. Dissolved Al < 64 mg/kg are estimated . Affected samples for dissolved Al are BS# 3, 8, 6, 9, 13D, 13, 12; JC-1, 2, and 4. Except for the total Na and dissolved Al in the identified samples, all other total and dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). The affected Na and Al data are of Screening Quality as defined in the same document.

14. Data Validator

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Dennis R. Neuman

Reclamation Research Group, LLC
Bozeman, MT

Data Package 4 – Pace Analytical Project #10139035 – Bullion Water Samples

Validation Narrative - Metals: Laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Bullion monitoring well and piezometer water samples were analyzed. No field blank and no field duplicate were submitted to the laboratory. With these exceptions,
the dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum).
Validation Narrative – Chloride, Sulfate, and Alkalinity: There are no analytical limitations for which data users should be aware. Results of the validation process for data package #10139035 are shown below.

Set 4, Laboratory Data Validation

Checklist for Metals Analysis by ICPMS

Site: Bullion Case No.: 10139035 Laboratory: Pace Analytical

Project: MW and P Sample Matrix: Water Analyses: Total Al, Ca. Na, K, Fe

Sample Dates: Sep 22, 23, 24, 2010 Analysis Dates: Oct 6, 2010

As, Cd, Cu, Pb, Zn; Dissolved

Data Validator: Neuman/RRG Validation Dates: 4 NOV 2010 Al, As, Cd, Cu, Pb, Mn, Fe, Zn

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1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection date	Analysis date	Holding time met? (Y/N)	Affected data flagged? (Y/N)
Total and dissolved metals	Water	EPA 200.8 ICPMS	6 mo.	Sep 22, 2010	Oct 6, 2010	Yes	No

* cite reference for holding time

Were any data flagged because of holding time problems? Y ______ N__X__

2. Instrument Calibration

Was instrument successfully calibrated at the correct frequency and with appropriate standards and blanks?
Y __X__ N_____

Was Initial Calibration Verification (ICV) performed? Y __X__ N_____

Was ICV within control window of _90%___ to 110%_? Y __X__ N_____

Were Continuing Calibration Verifications (CCVs) performed at the frequency of _5%____? Y __X__ N_____

Were CCVs within control window of __90%___ to _110%___? Y __X__ N_____

Describe corrective actions taken because of calibration problems None

Were any data flagged because of calibration problems? Y ______ N__X__

3. Blanks

Was Initial Calibration Blank (ICB) analyzed? Y __X__ N_____

Was ICB within control window of __<RL______? Y __X__ N_____

Were Continuing Calibration Blanks (CCBs) analyzed at the frequency of _5%_____? Y __X__ N_____

Were CCBs within control window of ____<RL_______? Y __X__ N_____

Were Preparation Blanks (PB) analyzed at the frequency of ______1/batch__? Y __X__ N_____

Were PBs within control window of ___<RL____? Y __X__ N_____

Describe corrective action taken because of blank problems. None

Were any data flagged because of blank problems? Y ______ N__X__

4. ICP Interference Check Sample

Was ICP Interference Check Sample (ICS) analyzed at the frequency of _1/batch________? Y __X__ N_____

Were ICS results within the control window of ___yes___________? Y __X__ N_____

Describe corrective actions taken because of ICS results None

Were any data flagged because of ICS problems? Y ______ N__X__

5. Laboratory Control Sample

Was Laboratory Control Sample (LCS) analyzed at the frequency of _1/batch________? Y __X__ N_____

What was the source of the LCS? _Unknown

Were LCS results within the control window of ______85%_____to_115%_______? Y __X__ N__X__

Zn in one LCS reported at 116%.

Describe corrective actions taken because of LCS results None.

Were any data flagged because of LCS problems? Y ______ N_X___

6. Matrix Spike and Matrix Spike Duplicate

Was Matrix Spike & Matrix Spike Duplicate analyzed at the frequency of __1/batch________? Y ___X_ N_____

Were results of MSD within the control window of +/- 20 %_________? Y

___X__ N ____

Were MSD % recovery within control window of 70% to 130% Y ______ N___X_

Al matrix spike of 133%, Cu recovery of 132

Were any data flagged because of MSD problems? Y ______ N___X_

7. Matrix Spike Results

Was Laboratory Matrix Spike Sample (LMS) analyzed at the frequency of __1/batch________? Y __X__ N_____

Were results of LMS within the control window of ____70%___to___130%____? Y ______ N___X_

Al and Mn and Zn recoveries are outside the control window.

Describe corrective actions taken because of LMS results None

Were data flagged because of LMS problems? Y ______ N_X___

8. ICP Serial Dilution

Was ICP Serial Dilution (SD) analyzed at the frequency of ___1/batch_____? Y ___X_ N_____

Were results of SD within the control window of _______? Y ___X_ N_____

Describe corrective actions taken because of SD results None.

Were any data flagged because of SD problems? Y ______ N___X_

9. Laboratory QC Sample Results – Dissolved Metals

Analyte Dissolved	LCS Recovery (%R)	Matrix Spike Recovery (%R)	Matrix Spike Duplicate (RPD)
Al	113	750	3
As	109	110	3
Cd	106	114	3
Cu	111	187	3
Fe	107	116	5
Pb	115	119	4
Mn	107	1240	3
Zn	112	419	4

11. Checklist for Field Quality Control

Field QC Samples

Field Blanks

Were field blanks submitted as specified in the Sampling & Analysis Plan? Y ____ N X _

No field blank was submitted with the natural samples.

Was FB within control window of ___<RL______? Y ____ N___X

Were any data qualified because of field blank problems? Y

Field Replicates

Were field duplicates submitted as specified in the Sampling & Analysis Plan? NO

No field duplicate sample was submitted

Were any data qualified because of field duplicate results? Y __ N X

Were results for field blanks within the target control limits in the Project QAPP? Y __ N X

Field Reference Materials

Were field Reference Materials or Performance Evaluation Samples specified in the Sampling & Analysis Plan? Y __ N X

Were the results within the manufacturer's control limits? Y __ N _

12. Level A/B Screening Checklist

Data are:

Project: Bullion wells and piezometers

Client: CH2M Hill/EPA

Sample Matrix: Water

1) Unusable ____________

2) Level A ______X_____

3) Level B ____X_______

I. Level A Screening

Criteria	Yes/No Comments
	Yes

1. Sampling date		
2. Sample team/or leader	Yes	
3. Physical description of sample location	Yes	
4. Sample depth (soils)	NA	
5. Sample collection technique	Yes	
6. Field preparation technique	Yes	
7. Sample reservation technique	Yes	
8. Sample shipping records	Yes	

II. Level B Screening

Criteria	Yes/No	Comments
1. Field instrumentation methods and standardization complete		
2. Sample container preparation	Yes	
3. Collection of field replicates (1/20 minimum)	Yes	
4. Proper and decontaminated sampling equipment	NA	
5. Field custody documentation	Yes	
6. Shipping custody documentation	Yes	
7. Traceable sample designation number	Yes	
8. Field notebook(s), custody records in secure repository	Yes	
9. Completed field forms	Yes	

. 13. Overall Assessment

Are there analytical limitations of the data that users should be aware of? Y __X__

________ N______

If so, explain:

No field blank or field duplicate samples were submitted with these natural samples.
All and dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum).

14. Data Validator

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Dennis R. Neuman
Reclamation Research Group, LLC
Bozeman, MT

Data Package 5 – Pace Analytical Project #101339661 – Bullion Water Samples

Validation Narrative - Metals: Laboratory QC samples (calibrations, blanks, internal standards, laboratory control sample, matrix spikes, and duplicates) were found to be within the limits specified in the analytical method. The ICP/MS instrument was in acceptable statistical control while data for the Bullion piezometer water samples were analyzed. No field blank and no field duplicate (because of limited sample volume was obtained) were submitted to the laboratory. With these exceptions, the dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum). Results of the validation process for data package #10139661 are shown below.

Set 5, Laboratory Data Validation

Checklist for Metals Analysis by ICPMS

Site: Bullion piezometers Case No.: 10139661 Laboratory: Pace Analytical

Project: MW and P Sample Matrix: Water Analyses: Dissolved Al, As, Cd, Cu, Fe, Pb, Mn, and Zn

Sample Dates: Oct 1, 2010 Analysis Dates: Oct 15-17, 2010

Data Validator: Neuman/RRG Validation Dates: 16 NOV 2010

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1. Holding Times

Analyte	Matrix	Method	Holding Time*	Collection date	Analysis date	Holding time met? (Y/N)	Affected data flagged? (Y/N)
Dissolved metals	Water	EPA 200.8 ICPMS	6 mo.	Oct 1, 2010	Oct 6, 2010	Yes	No

* cite reference for holding time

Were any data flagged because of holding time problems? Y ______ N___X__

2. Instrument Calibration

Was instrument successfully calibrated at the correct frequency and with appropriate standards and blanks?

	Y __X_ N____
Was Initial Calibration Verification (ICV) performed?	Y __X_ N____
Was ICV within control window of _90%__ to 110%_?	Y __X_ N____
Were Continuing Calibration Verifications (CCVs) performed at the frequency of _5%___?	Y __X_ N____
Were CCVs within control window of _90%__ to _110%__?	Y __X_ N____
Describe corrective actions taken because of calibration problems None	
Were any data flagged because of calibration problems?	Y ____ N__X_

3. Blanks

Was Initial Calibration Blank (ICB) analyzed?	Y __X_ N____
Was ICB within control window of __<RL____?	Y __X_ N____
Were Continuing Calibration Blanks (CCBs) analyzed at the frequency of _5%___?	Y __X_ N____
Were CCBs within control window of ___<RL____?	Y _X_ N____
Were Preparation Blanks (PB) analyzed at the frequency of ___1/batch__?	Y __X_ N____
Were PBs within control window of __<RL__?	Y __X_ N____
Describe corrective action taken because of blank problems. None	
Were any data flagged because of blank problems?	Y ____ N__X_

4. ICP Interference Check Sample

Was ICP Interference Check Sample (ICS) analyzed at the frequency of _1/batch_____?	Y __X_ N____
Were ICS results within the control window of __yes______?	Y __X_ N____
Describe corrective actions taken because of ICS results None	
Were any data flagged because of ICS problems?	Y ____ N_X_

5. Laboratory Control Sample

Was Laboratory Control Sample (LCS) analyzed at the frequency of _1/batch_____?	Y __X_ N____
What was the source of the LCS? _Unknown	
Were LCS results within the control window of ___85%___to_115%____?	Y __X_ N_X_
Zn in one LCS reported at 116%.	
Describe corrective actions taken because of LCS results None.	
Were any data flagged because of LCS problems?	Y ____ N_X_

6. Matrix Spike and Matrix Spike Duplicate

Was Matrix Spike & Matrix Spike Duplicate analyzed at the frequency of _1/batch_____?	Y __X_ N____
Were results of MSD within the control window of_+/- 20 %_____?	Y __X_ N____
Were MSD % recovery within control window of 70% to 130%	Y
X_____	N____
Were any data flagged because of MSD problems?	Y ____ N__X_

7. **Matrix Spike Results**

Was Laboratory Matrix Spike Sample (LMS) analyzed at the frequency of 1/batch ? Y X N____

Were results of LMS within the control window of 70% to 130% ? Y X N____

Al and Mn and Zn recoveries are outside the control window.

Describe corrective actions taken because of LMS results None

Were data flagged because of LMS problems? Y ____ N X

8. **ICP Serial Dilution**

Was ICP Serial Dilution (SD) analyzed at the frequency of 1/batch ? Y X N____

Were results of SD within the control window of _______? Y X N____

Describe corrective actions taken because of SD results None.

Were any data flagged because of SD problems? Y ____ N X

9. **Laboratory QC Sample Results – Dissolved Metals**

Analyte Dissolved	LCS Recovery (%R)	Matrix Spike Recovery (%R)	Matrix Spike Duplicate (RPD)
Al	102	107	4
As	99	105	4
Cd	100	103	3
Cu	102	104	4
Fe	101	103	3
Pb	106	108	4
Mn	102	106	4
Zn	105	103	4

11. **Checklist for Field Quality Control**

Field QC Samples

Field Blanks

Were field blanks submitted as specified in the Sampling & Analysis Plan? Y ____ N X

Was FB within control window of <RL ? Y ____ N X

Were any data qualified because of field blank problems? Y ______ N__X___

There were only 4 sample collected and no field blank was submitted.

Field Replicates

Were field duplicates submitted as specified in the Sampling & Analysis Plan? Y ______ N__X___

No field duplicate sample was submitted

Were any data qualified because of field duplicate results? Y __ N X

Were results for field blanks within the target control limits in the Project QAPP? Y __ N X

Field Reference Materials

Were field Reference Materials or Performance Evaluation Samples specified in the Sampling & Analysis Plan? Y __ N X

Were the results within the manufacturer's control limits? Y ______ N______

12. Level A/B Screening Checklist

Data are:

Project: Bullion wells and piezometers — 1) Unusable ______________

Client: CH2M Hill/EPA — 2) Level A _______X_____

Sample Matrix: Water — 3) Level B _____X_______

I. Level A Screening

Criteria	Yes/No	Comments
1. Sampling date	Yes	
2. Sample team/or leader	Yes	
3. Physical description of sample location	Yes	
4. Sample depth (soils)	NA	
5. Sample collection technique	Yes	
	Yes	

6. Field preparation technique		
7. Sample reservation technique	Yes	
8. Sample shipping records	Yes	

II. Level B Screening

Criteria	Yes/No	Comments
1. Field instrumentation methods and standardization complete		
2. Sample container preparation	Yes	
3. Collection of field replicates (1/20 minimum)	Yes	
4. Proper and decontaminated sampling equipment	NA	
5. Field custody documentation	Yes	
6. Shipping custody documentation	Yes	
7. Traceable sample designation number	Yes	
8. Field notebook(s), custody records in secure repository	Yes	
9. Completed field forms	Yes	

. **13. Overall Assessment**

Are there analytical limitations of the data that users should be aware of? Y __X__

________ N______

If so, explain:

No field blank or field duplicate samples were submitted with these natural samples.

All and dissolved concentrations were judged to be of highest quality (Enforcement Quality) as defined by CFR SSI Data management/Data Validation Plan (PTI 1992, and revision, addendum).

14. Data Validator

Dennis R. Neuman

Reclamation Research Group, LLC

Bozeman, MT

Appendix L
Soils XRF Data vs. Analytical Lab Data – Statistical Comparison

Reclamation Research Group, LLC
202 South Black Avenue, Suite 4
P.O. Box 6309, Bozeman, MT 59715
Phone: (406) 624-6571
Fax: (406) 551-2036

Technical Memorandum

To: Dennis Smith, CH2M Hill/Boise
From: Dennis Neuman
Date: 16 November 2010
Re: Comparisons of concentrations of arsenic, lead, copper, and zinc in soils determined by two different analytical techniques – Bullion and Crystal Mines soils.

Soil samples were collected from soil pits developed at selected locations at the Bullion and Crystal Mine sites in the Basin Creek watershed during the summer and early fall of 2010. The concentrations of arsenic, cadmium, copper, lead and zinc were determined using a field XRF instrument. A subset of these soil samples was sent to Pace Analytical Labs for determinations of levels of the same elements using acid digestion (EPA 3050) and ICP spectroscopy (EPA 6020). Both sets of data were validated using the following protocols.

- USEPA CLP National Functional Guidelines for Inorganic Data Review, OSWER 9240.1-51, EPA 540-R-10-011 (1January 2010).
- Clark Fork River Superfund Site Investigations, data management/Data Validation Plan (PTI, 1992 with revision (1993), and addendum (2000).

The purpose of this memorandum is to compare the concentrations of the five elements in the soils determined by the different methods by; 1) displaying descriptive statistics for each data set; 2) displaying histograms of each data set; 3) calculating the relative percent difference between each pair of elemental concentrations; 4) conducting paired t-tests; 5) using regression analysis to evaluate systematic error; and 6) calculating relative XRF error as a function of ICP concentration.

Arsenic

Descriptive statistics

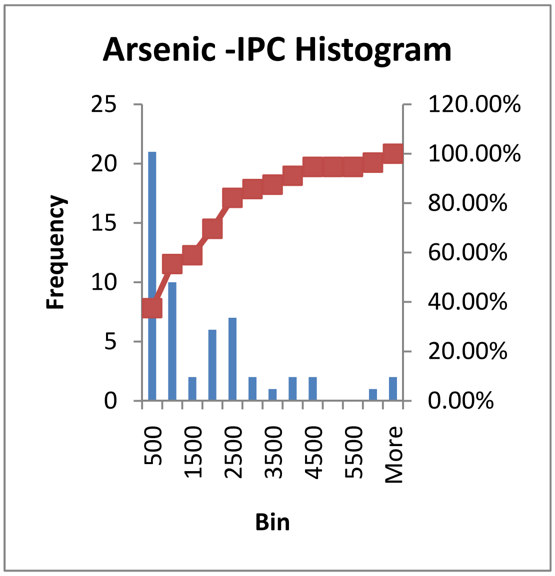
Descriptive statistics for each data set are shown in Table 1. Mean and median values are similar. The range in concentrations spans four orders of magnitude resulting in relative elevated standard deviations.

Table 1. Descriptive statistics for arsenic concentrations determined by field XRF and laboratory ICP. All values in mg/kg.

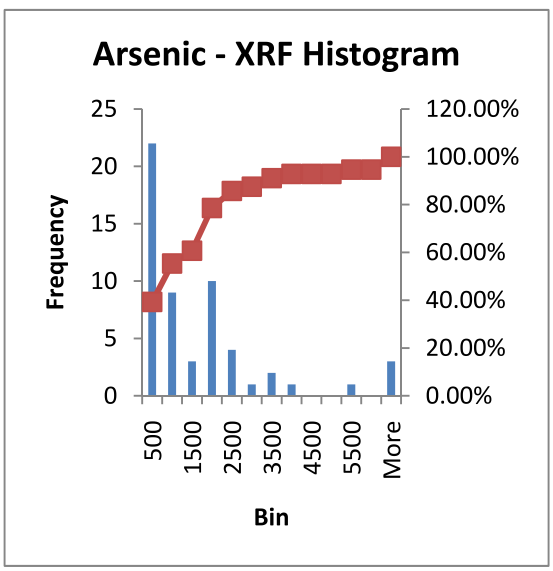
	N	Mean Value	Standard Deviation	Median Value	Minimum Value	Maximum Value	Standard Error	95%C.I.
ICP	54	2,205	5,686	871	5.1	41,094	773	1,552
XRF	54	2,152	5,838	903	10	42,466	794	1,594

Histograms of Data Sets

Histograms of each data set (Figure 1) are similar and indicate that the data are not normally distributed. There are some slight differences with a greater number of samples with arsenic levels between 1500 and 2000 mg/kg (10 samples determined by XRF compared to 6 determined by ICP).



Bin	Frequency	Cumulative %
500	21	37.50%
1000	10	55.36%
1500	2	58.93%
2000	6	69.64%
2500	7	82.14%
3000	2	85.71%
3500	1	87.50%
4000	2	91.07%
4500	2	94.64%
5000	0	94.64%
5500	0	94.64%
6000	1	96.43%
More	2	100.00%



Bin	Frequency	Cumulative %
500	22	39.29%
1000	9	55.36%
1500	3	60.71%
2000	10	78.57%
2500	4	85.71%
3000	1	87.50%
3500	2	91.07%
4000	1	92.86%
4500	0	92.86%
5000	0	92.86%
5500	1	94.64%
6000	0	94.64%
More	3	100.00%

Figure 1. Histograms of Arsenic Data Sets

Paired t tests

The traditional paired t test is not applicable as the data sets are not normally distributed; a nonparametric test, Signed Rank, indicated no significant difference between data sets (P = 0.521).

Table 2. Paired t-tests

Type	Normal distribution	Equal Variance	P Value	Significantly Different
Parametric	No	Yes	0.385	No
Signed Rank	NA	NA	0.521	No

Relative Percent Difference

The relative percent difference between each arsenic concentration determined by the two methods is a measure of inter method precision. Relative percent difference is calculated as:

[ICP value – XRF value/ (ICP value + XRF value)/2] x 100

Visual observation of Figure 2 indicated there are approximately the same number of negative RPD values (XRF concentration is greater than corresponding ICP value) as positive RPD values. The values vary from +75.7 to -120%, with a central value of -8.0%.

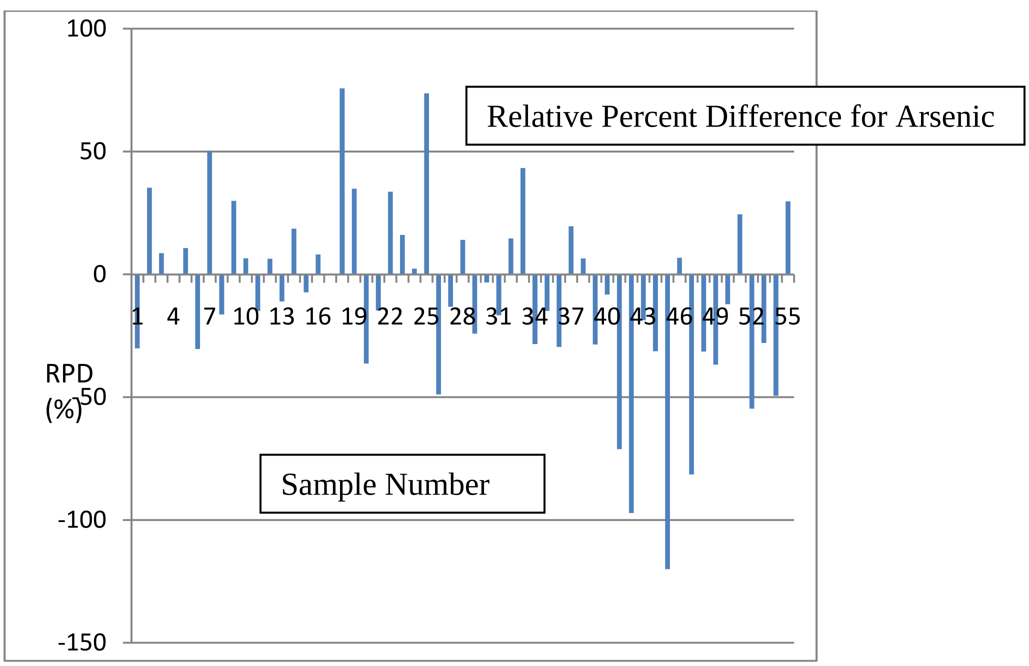


Figure 2. Relative Percent Difference for Arsenic.

Linear Regression Analysis

The universally adopted comparison technique for instrumental methods of analysis and resulting data is the use of regression analysis (Miller and Miller 1984)[1]. Data for the paired samples are plotted so that each point on the graph represents a sample analyzed by each technique. The slope, intercept, and correlation coefficient of the regression line are then calculated. If each laboratory generated the identical result for each sample, the regression line would have a slope equal to one, an intercept equal to zero, and a correlation coefficient of unity. Deviations from these values are indicative of systematic and/or random errors. In practice, it is determined if the slope and intercept values are significantly different from their ideal values, within some confidence limit, usually 95%.

In regression analysis, it is assumed that all errors are associated with data assigned to the y-axis (dependent variable) and that errors in the independent variable (x-axis) are negligible. For these comparative tests the Field XRF data were assigned to the y axis and the ICP laboratory generated data to the x-axis (Figure 3a). Obviously, both techniques are subject to error, but it is assumed that the ICP data are correct, non-biased, and of acceptable quality.

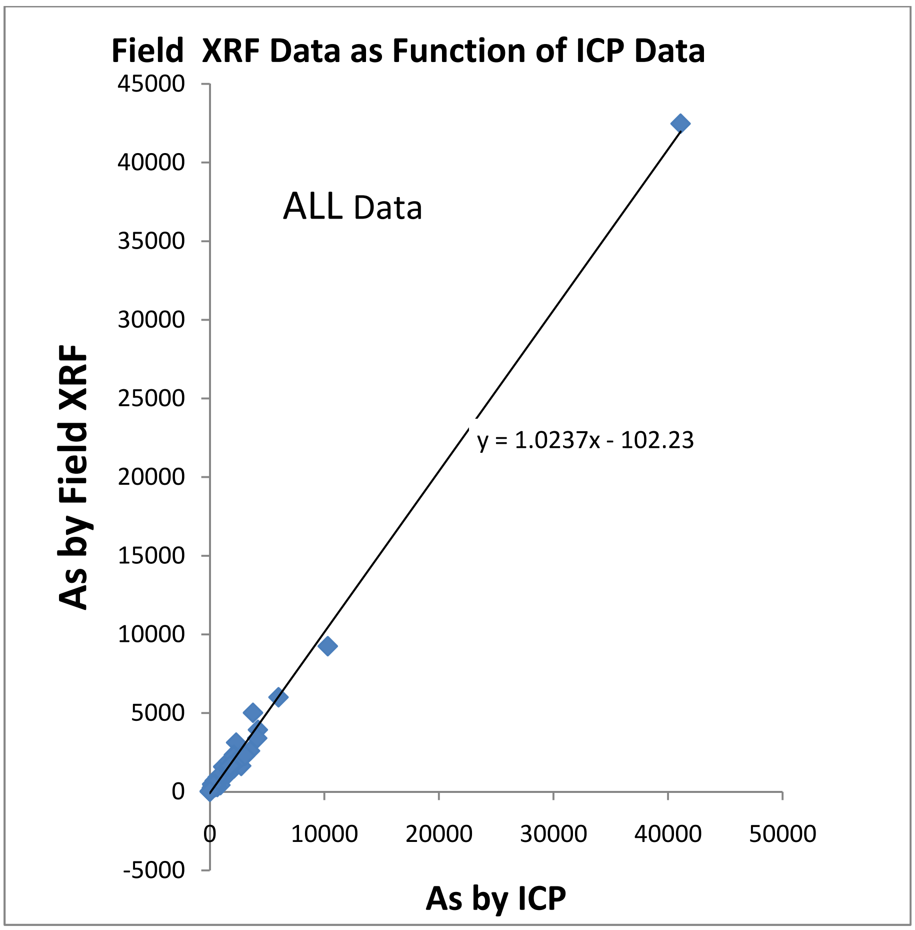


Figure 3a. Regression Graphics and Coefficients for Arsenic

The equation of the regression line in Figure 3a is As-XRF = 1.02 (As-ICP) -102.23. The calculated 95 % confidence limits associated with the slope and intercept are ± 0.02 and ± 122.6, respectively. The ideal coefficients of 1 and zero are with their respective confidence limits, indicating little overall random error. However the intercept can vary from 20.1 to – 224.5 mg/kg and one data point is an order of magnitude greater than the rest of the data points. Removing this data point from the regression analysis yielded the following graphic (Figure 3b).

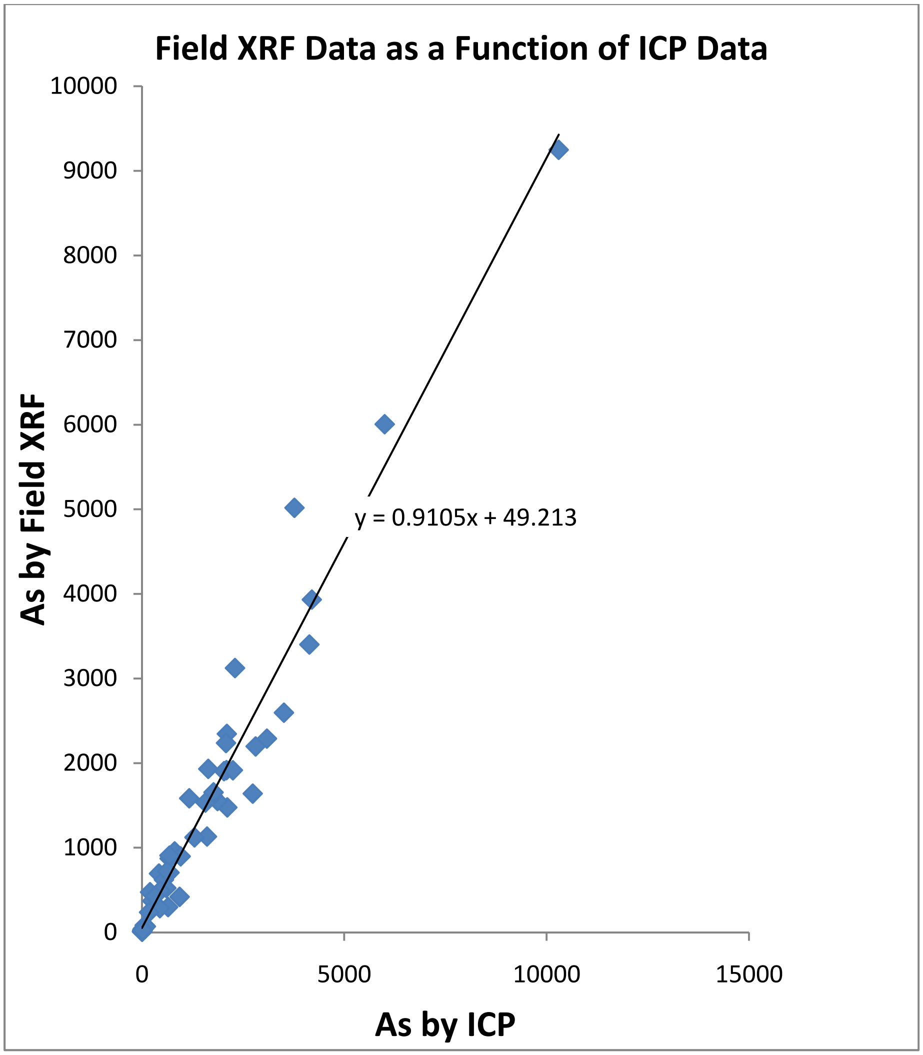


Figure 3b. Regression Graphics and Coefficients for Arsenic

The equation of the regression line is As-XRF = 0.91 (As-ICP) + 49.2. The calculated 95 % confidence limits associated with the slope and intercept are ± 0.056 and ± 128.1, respectively. The ideal coefficient of 1 for the slope is not within the confidence limit, but zero is within the confidence limit for the intercept. However the intercept can vary from 177.1 to – 78.8 mg/kg, This may indicate systematic error in either the XRF or ICP determinations.

[1] Miller, J.C. and J.N. Miller. 1984. Statistics for Analytical Chemistry. Ellis Horwood Ltd., Chichester. Halsted Press, John Wiley and Sons, NY. 202 pp.

XRF Error as a Function of ICP Concentration

The relative XRF error as a function of ICP concentration can be calculated as follows.

[XRF value – ICP value)/ICP value] x 100

These calculations are displayed in Figure 4a.

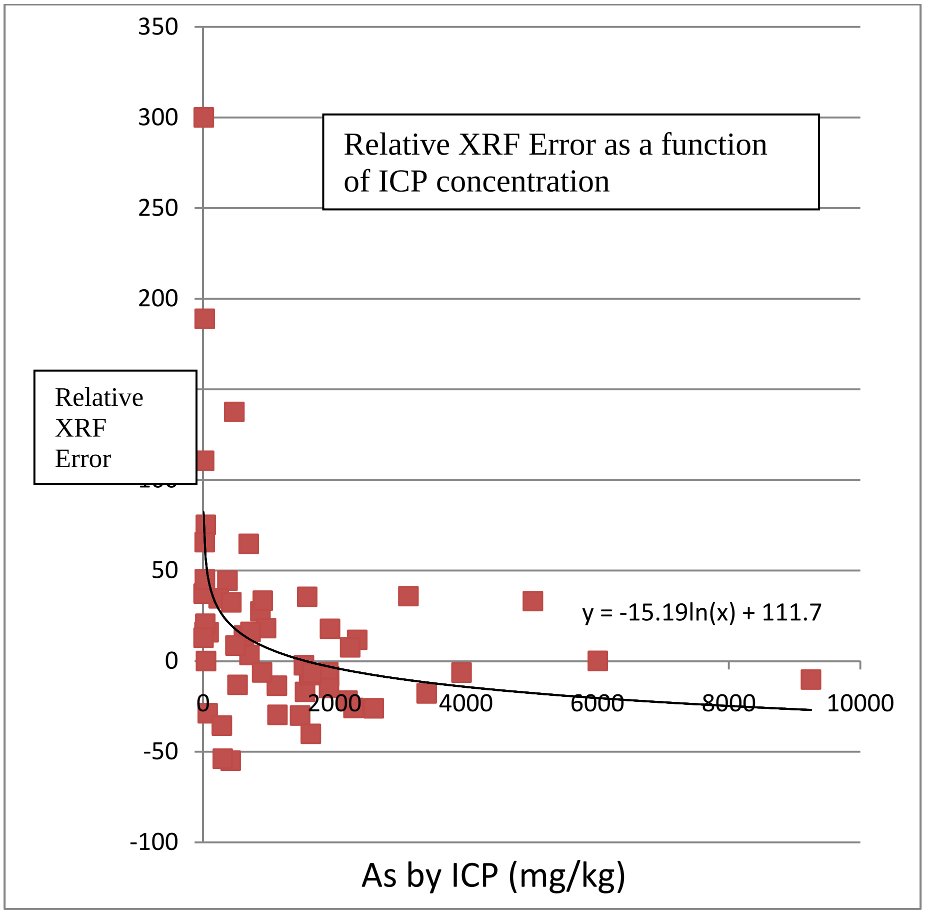


Figure 4a. XRF Error as a Function of ICP Concentration

As expected XRF error is greatest at low concentrations and decreases as concentration increases. The error values were calculated with regard to sign (negative and positive). If absolute error values were graphed, the curve would be quite smooth as displayed in Figure 4b. Using the equation of this relationship an ICP concentration of approximately 400 mg/kg (and greater) results in a relative xrf error of less than 35%.

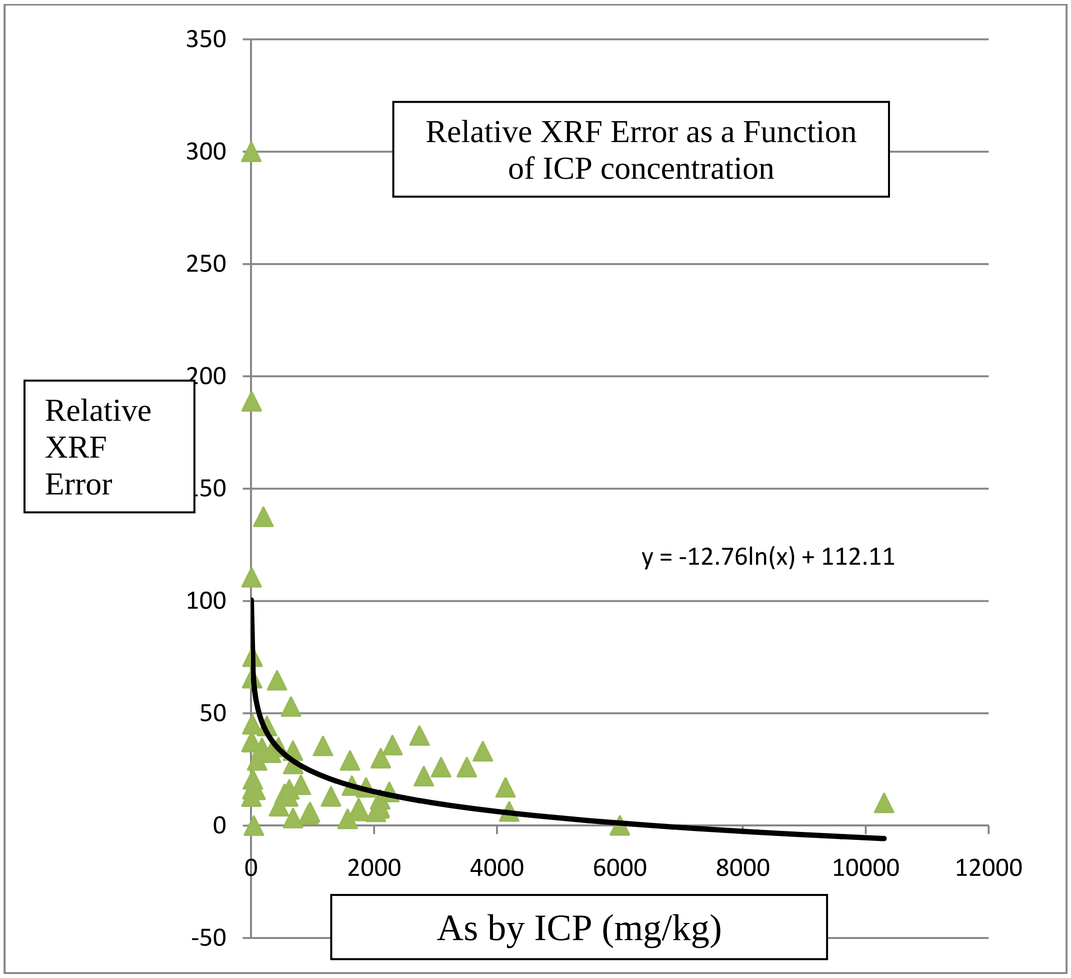


Figure 4b. Absolute XRF Error as a Function of ICP Concentration

Summary for Arsenic

- Mean and median values generated by the field XRF and the ICP determination are similar. The range in concentrations spans four orders of magnitude resulting in relative elevated standard deviations.

- Histograms of each data set indicate the arsenic data are not normally distributed. There are some slight differences with a greater number of samples with arsenic levels between 1500 and 2000 mg/kg (10 samples determined by XRF compared to 6 determined by ICP). Refer to Figure 1.
- A nonparametric paired t test, Signed Rank, indicated no significant difference between data sets (P = 0.521).

- Calculations of relative percent difference (RPD) indicated there are approximately the same number of negative RPD values (XRF concentration is greater than corresponding ICP value) as positive RPD values. The values vary from +75.7 to -120%, with a central value of -8.0%. Refer to Figure 2

- Linear regression analysis generated a best fit line with the following equation:

  As-XRF = 0.91 (As-ICP) + 49.2.

  The calculated 95 % confidence limits associated with the slope and intercept are $\pm$ 0.056 and $\pm$ 128.1, respectively. The ideal coefficient of 1 for the slope is not within the confidence limit, but zero is within the confidence limit for the intercept. However the intercept can vary from 177.1 to – 78.8 mg/kg, This may indicate systematic error in either the XRF or ICP determinations. Refer to Figure 3b. Note: the high data point shown in Figure 3a is not included in the regression equation is this summary statement.

- Calculation of the relative percent XRF error as a function of the corresponding ICP concentration are shown in Figure 4a and 4 b. Using the equation (Figure 4b) of this relationship, an ICP concentration of approximately 400 mg/kg (and greater) results in a relative xrf error of less than 35%.

Copper

Descriptive statistics

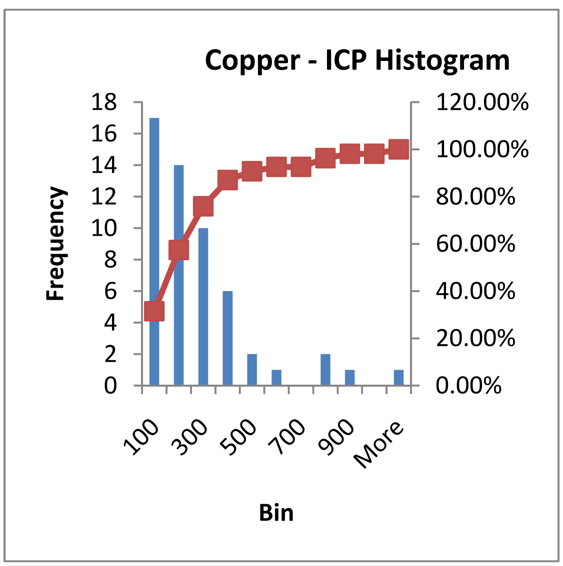
Descriptive statistics for each data set are shown in Table 3. Mean and median values are nearly identical. The range in concentrations spans three orders of magnitude resulting in relative elevated standard deviations.

Table 3. Descriptive statistics for copper concentrations determined by field XRF and laboratory ICP. All values in mg/kg.

	N	Mean Value	Standard Deviation	Median Value	Minimum Value	Maximum Value	Standard Error	95%C.I.
ICP	54	273.1	537.1	167.0	6.8	3900	73.1	146.6
XRF	54	276.2	507.2	179.5	2.4	3626	69.0	138.5

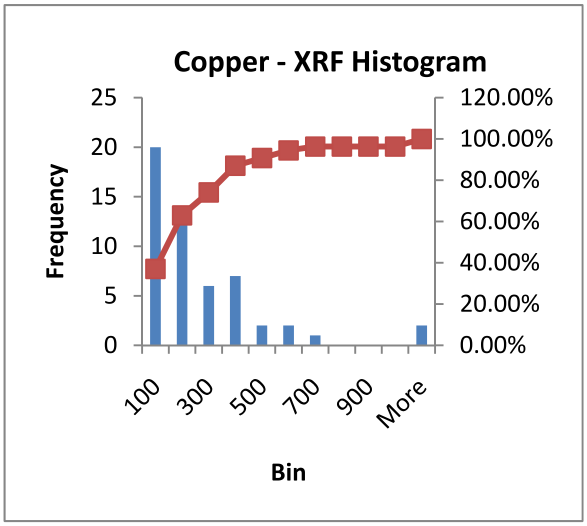
Histograms of Data Sets

Histograms of each data set (Figure 5a and 5b) are similar and indicate that the data are not normally distributed. There are some slight differences with a greater number of samples with copper levels between 200 and 300 mg/kg (10 samples determined by ICP compared to 6 determined by XRF).



Bin	*Frequency*	*Cumulative %*
100	17	31.48%
200	14	57.41%
300	10	75.93%
400	6	87.04%
500	2	90.74%
600	1	92.59%
700	0	92.59%
800	2	96.30%
900	1	98.15%
1000	0	98.15%
More	1	100.00%

Figure 5a. Histogram of Copper Data Generated by ICP.



Bin	*Frequency*	*Cumulative %*
100	20	37.04%
200	14	62.96%
300	6	74.07%
400	7	87.04%
500	2	90.74%
600	2	94.44%
700	1	96.30%
800	0	96.30%
900	0	96.30%
1000	0	96.30%
More	2	100.00%

Figure 5b. Histogram of Copper Data Generated by Field XRF.

Paired t tests

The traditional paired t test is not applicable as the data sets are not normally distributed; a nonparametric test, Signed Rank, indicated no significant difference between data sets (P = 0.193).

Table 4. Paired t-tests

Type	Normal distribution	Equal Variance	P Value	Significantly Different
Parametric	No	Yes	0.783	No
Signed Rank	NA	NA	0.193	No

Relative Percent Difference

The relative percent difference between each copper concentration determined by the two methods is a measure of inter method precision. Relative percent difference is calculated as:

[ICP value – XRF value/ (ICP value + XRF value)/2] x 100

Visual observation of Figure 6 indicated there are approximately the same number of negative RPD values (XRF concentration is greater than corresponding ICP value) as positive RPD values. The values vary from +79.4 to -149.9%, with a central value of -9.9%.

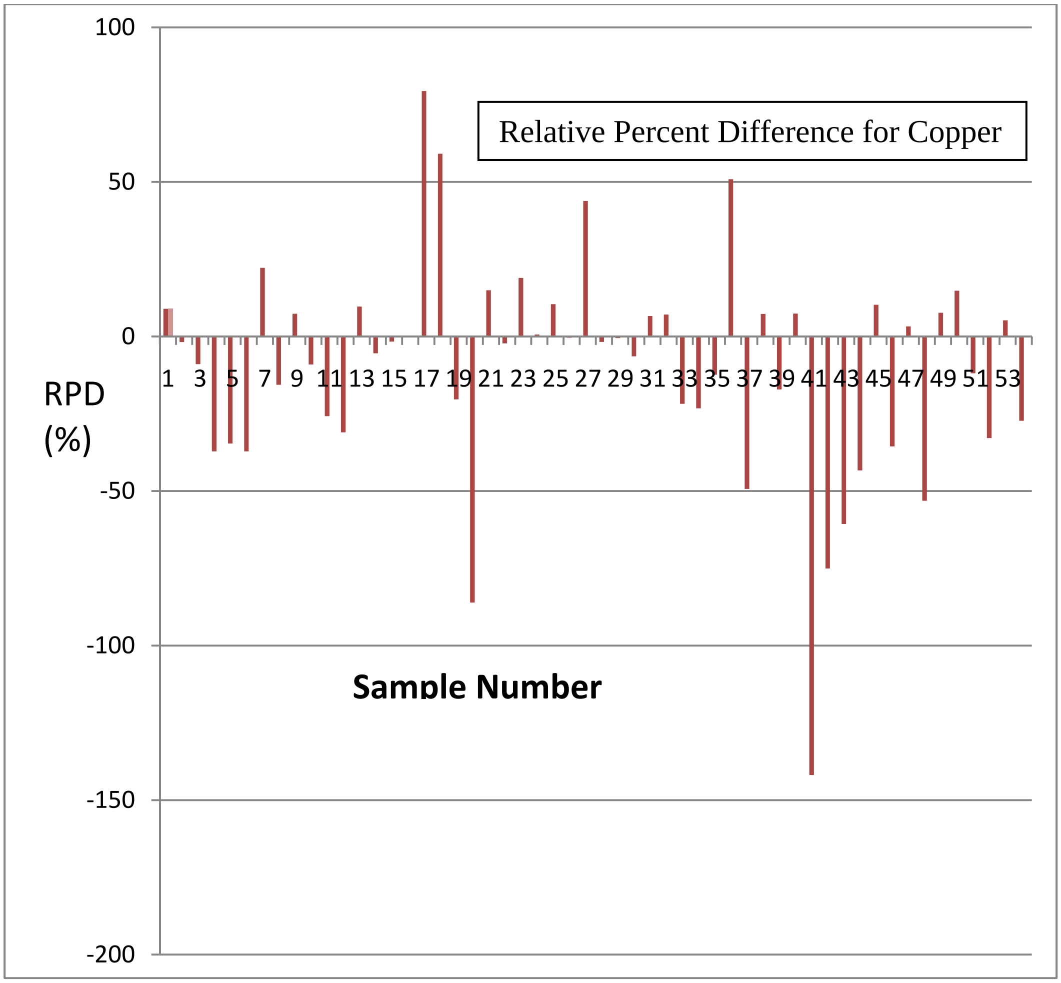
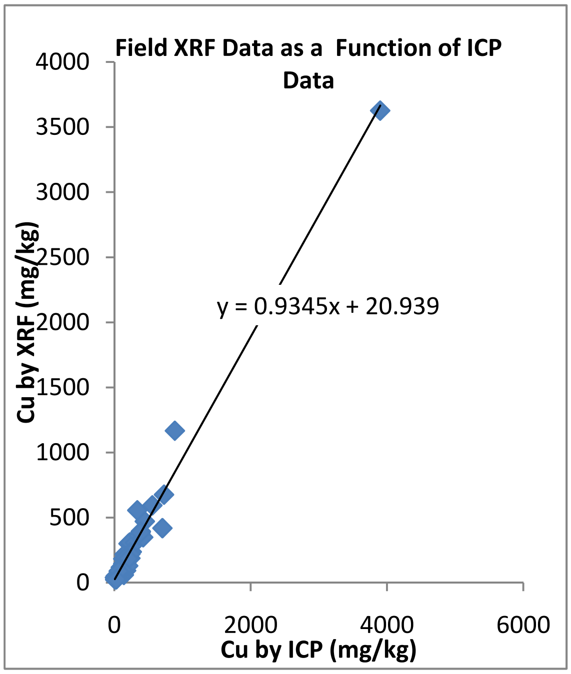


Figure 6. Relative Percent Difference for Copper.

Linear Regression Analysis

Data for the paired samples are plotted so that each point on the graph represents a sample analyzed by each technique. The slope, intercept, and correlation coefficient of the regression line are then calculated. If each laboratory generated the identical result for each sample, the regression line would have a slope equal to one, an intercept equal to zero, and a correlation coefficient of unity. Deviations from these values are indicative of systematic and/or random errors. In practice, it is determined if the slope and intercept values are significantly different from their ideal values, within some confidence limit, usually 95%.

In regression analysis, it is assumed that all errors are associated with data assigned to the y-axis (dependent variable) and that errors in the independent variable (x-axis) are negligible. For these comparative tests the Field XRF data were assigned to the y axis and the ICP laboratory generated data to the x-axis (Figure 7a and 7b). Obviously, both techniques are subject to error, but it is assumed that the ICP data are correct, non-biased, and of acceptable quality.



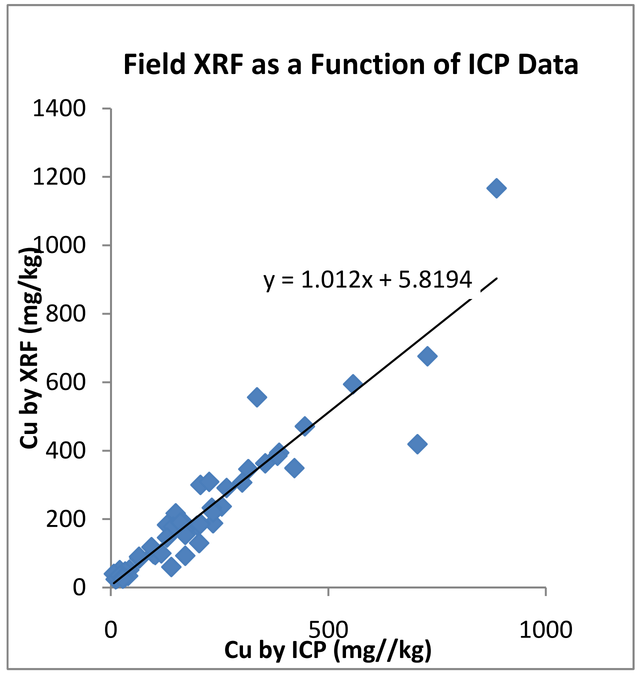


Figure 7a and 7b. Linear Regression Graphics and Coefficients for Copper Analysis

One data point, as shown in Figure 7a is much higher than the main set of points, and was removed from the regression analysis as shown in Figure 7b. The equation of the regression line in Figure 7b is Cu-XRF = 1.012 (Cu-ICP) + 5.82. The calculated 95 % confidence limits associated with the slope and intercept are $\pm$ 0.11 and $\pm$ 29.6, respectively. The ideal coefficients for the slope and intercept are both within the confidence limit. There is no reason to suspect systematic error. The apparent scatter of points at concentration above approximately 500 mg/kg may indicate random error in the ICP or XRF determinations or both.

XRF Error as a Function of ICP Concentration

The relative XRF error as a function of ICP concentration can be calculated as follows.

[XRF value – ICP value)/ICP value] x 100

These calculations are displayed in Figure 8a.

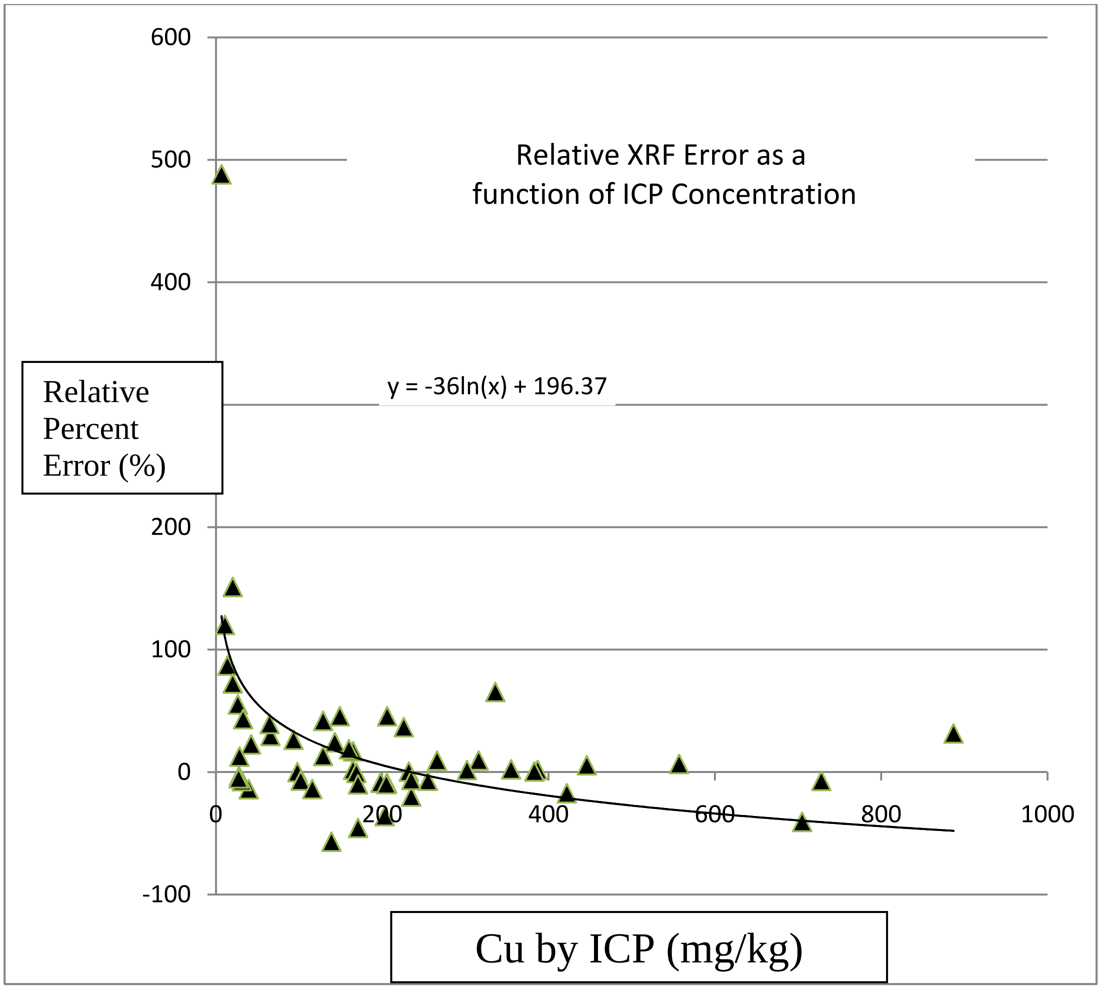


Figure 8. XRF Error as a Function of ICP Concentration

Summary for Copper

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- Mean and median values generated by the field XRF and the ICP determination are nearly identical. The range in concentrations spans three orders of magnitude resulting in relative elevated standard deviations

- Histograms of each data set indicate the copper data are not normally distributed. There are some slight differences with a greater number of samples with copper levels between 200 and 300 mg/kg (10 samples determined by ICP compared to 6 determined by XRF).

- A nonparametric paired t test, Signed Rank, indicated no significant difference between data sets (P = 0.193).

- Calculations of relative percent difference (RPD) indicated there are approximately the same number of negative RPD values (XRF concentration is greater than corresponding ICP value) as positive RPD values. The values vary from +79.4 to -149.9%, with a central value of -9.90%. Refer to Figure 6.

- Linear regression analysis generated a best fit line with the following equation:

  Cu-XRF = 1.012(Cu-ICP) + 5.82.

  The calculated 95 % confidence limits associated with the slope and intercept are ± 0.11 and ± 29.6, respectively. The ideal coefficients for the slope and intercept are both within the confidence limits. There is no reason to suspect systematic error. The apparent scatter of points at concentration above approximately 500 mg/kg may indicate random error in the ICP or XRF determinations or both. Refer to Figure 7b.

- Calculation of the relative percent XRF error as a function of the corresponding ICP concentration is shown in Figure 8. Using the equation (Figure 8) of this relationship, an ICP concentration of approximately 90 mg/kg (and greater) results in a relative xrf error of less than 35%.

Lead

Descriptive statistics

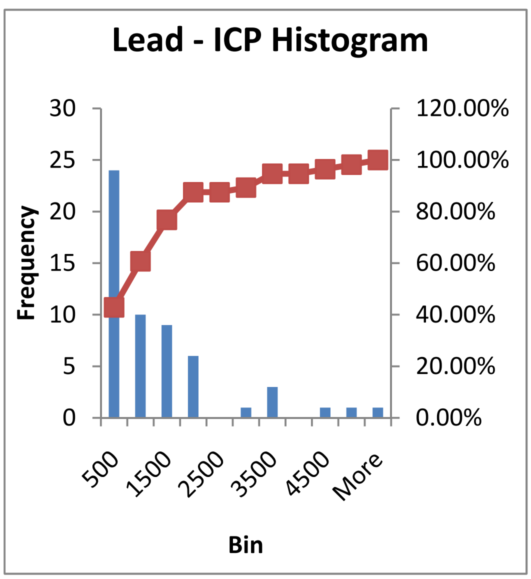
Descriptive statistics for each data set are shown in Table 5. Mean and median values are similar. The range in concentrations spans three orders of magnitude resulting in relative elevated standard deviations.

Table 5. Descriptive statistics for copper concentrations determined by field XRF and laboratory ICP. All values in mg/kg.

	N	Mean Value	Standard Deviation	Median Value	Minimum Value	Maximum Value	Standard Error	95%C.I.
ICP	56	1039.8	1221.5	630.5	9.9	5130	163.2	327.1
XRF	56	928.3	1204.0	586.5	23	6560	160.9	322.4

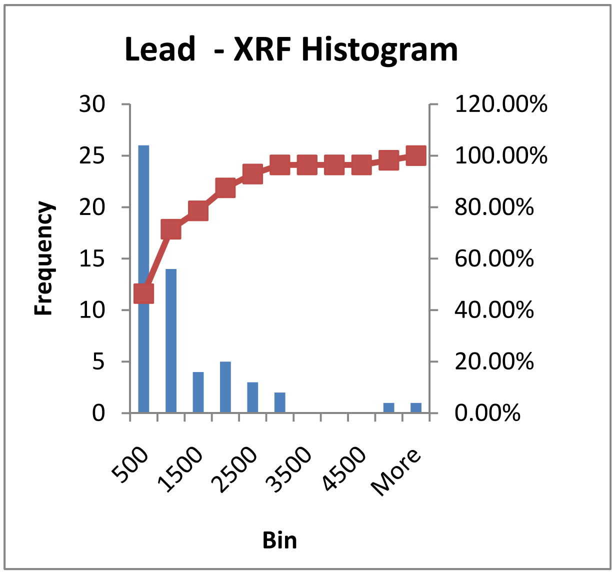
Histograms of Data Sets

Histograms of each data set (Figure 9a and 9b) are similar and indicate that the data are not normally distributed.



Bin	*Frequency*	*Cumulative %*
500	24	42.86%
1000	10	60.71%
1500	9	76.79%
2000	6	87.50%
2500	0	87.50%
3000	1	89.29%
3500	3	94.64%
4000	0	94.64%
4500	1	96.43%
5000	1	98.21%
More	1	100.00%

Figure 9a. Histogram for Lead Determined by ICP.



Bin	*Frequency*	*Cumulative %*
500	26	46.43%
1000	14	71.43%
1500	4	78.57%
2000	5	87.50%
2500	3	92.86%
3000	2	96.43%
3500	0	96.43%
4000	0	96.43%
4500	0	96.43%
5000	1	98.21%
More	1	100.00%

Figure 9b. Histogram for Lead determined by XRF.

Paired t tests

The traditional paired t test is not applicable as the data sets are not normally distributed; a nonparametric test, Signed Rank, indicated no significant difference between data sets (P = 0.193).

Table 6. Paired t-tests

Type	Normal distribution	Equal Variance	P Value	Significantly Different
Parametric	No	Yes	0.071	No
Signed Rank	NA	NA	0.152	No

Relative Percent Difference

The relative percent difference between each lead concentration determined by the two methods is a measure of inter method precision. Relative percent difference is calculated as:

[ICP value – XRF value/ (ICP value + XRF value)/2] x 100

Visual observation of Figure 10 indicated there are approximately the same number of negative RPD values (XRF concentration is greater than corresponding ICP value) as positive RPD values. The values vary from +149.0 to -119.4%, with a central value of -5.1%.

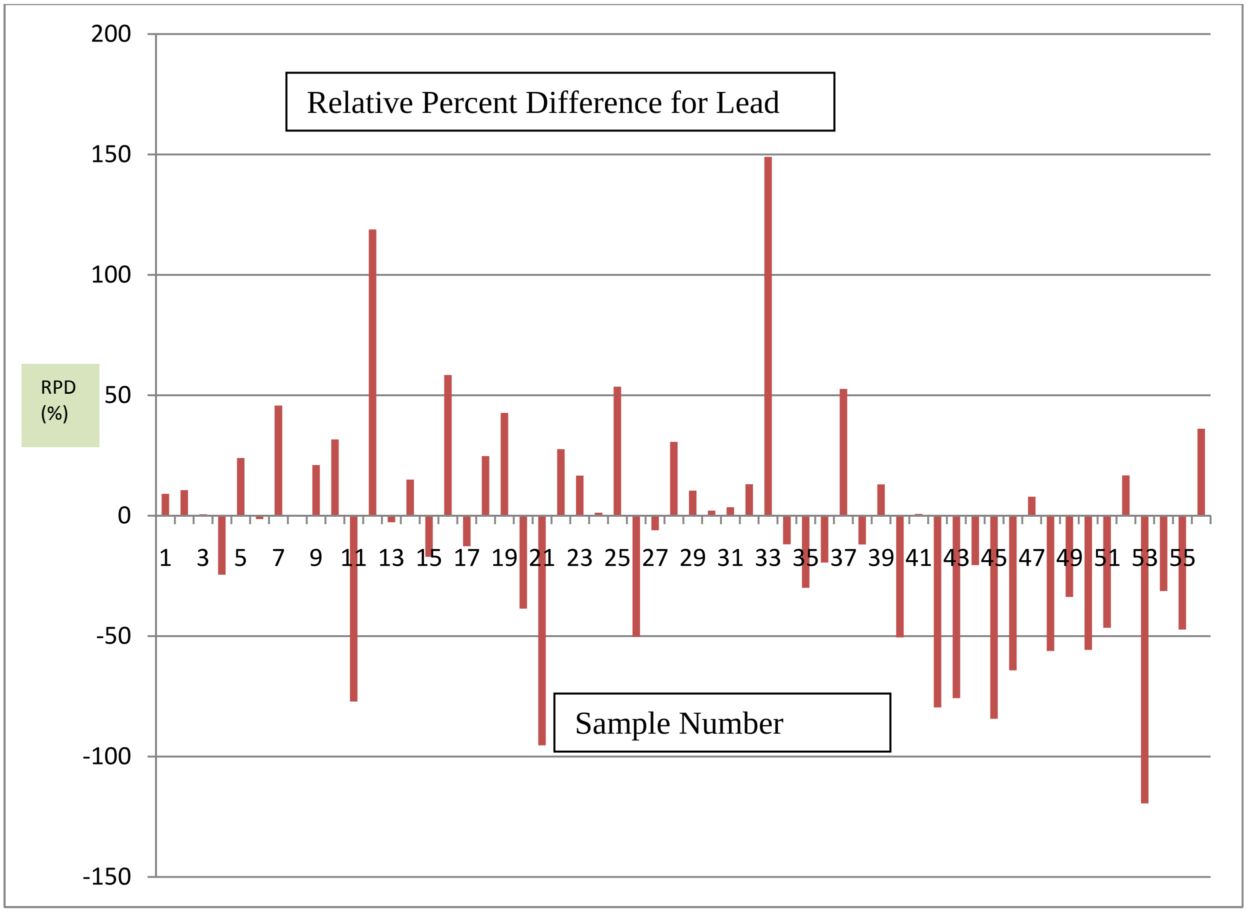


Figure 10. Relative Percent Difference for Lead.

Linear Regression Analysis

Data for the paired samples are plotted so that each point on the graph represents a sample analyzed by each technique. The slope, intercept, and correlation coefficient of the regression line are then calculated. If each laboratory generated the identical result for each sample, the regression line would have a slope equal to one, an intercept equal to zero, and a correlation coefficient of unity. Deviations from these values are indicative of systematic and/or random errors. In practice, it is determined if the slope and intercept values are significantly different from their ideal values, within some confidence limit, usually 95%.

In regression analysis, it is assumed that all errors are associated with data assigned to the y-axis (dependent variable) and that errors in the independent variable (x-axis) are negligible. For these comparative tests the Field XRF data were assigned to the y axis and the ICP laboratory generated data to the x-axis (Figure 7a and 7b). Obviously, both techniques are subject to error, but it is assumed that the ICP data are correct, non-biased, and of acceptable quality. Regression Analysis for Lead is exhibited in Figure 11.

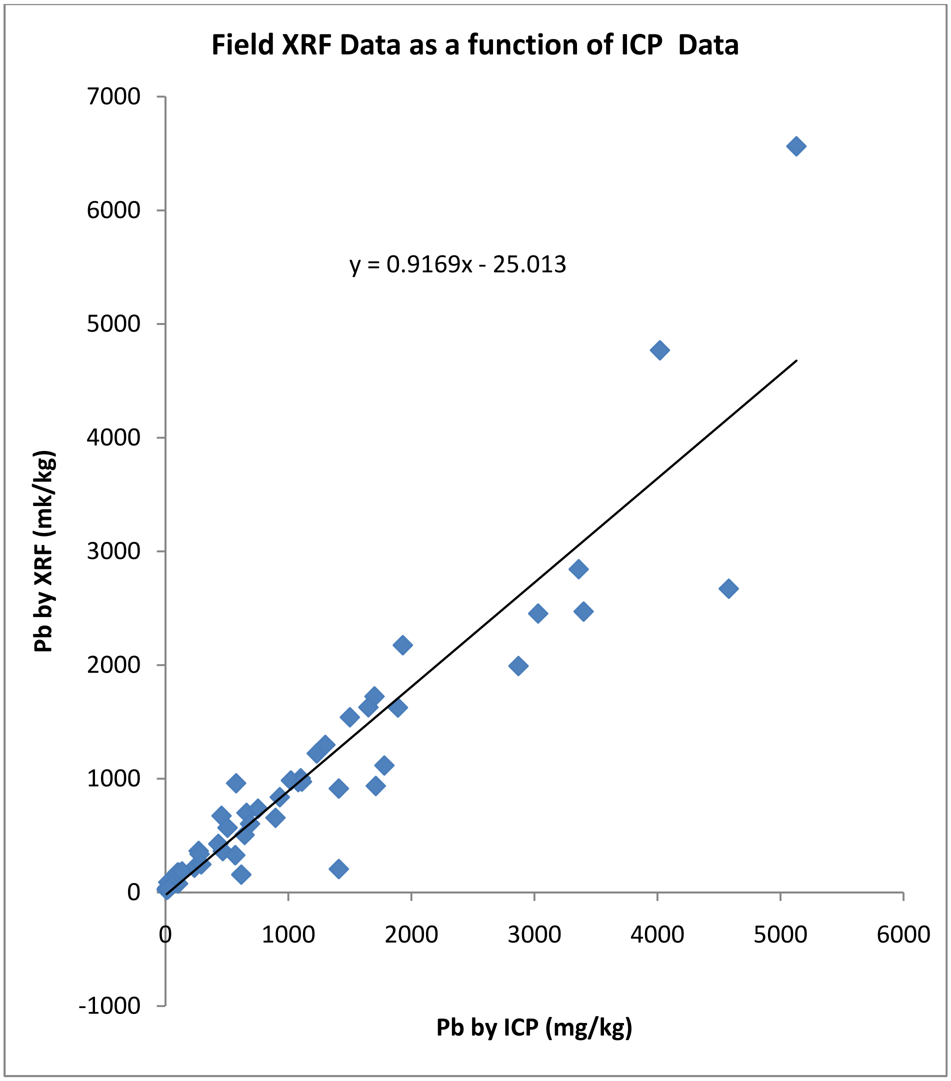


Figure 11. Linear Regression Graphic and Coefficients for Lead.

The equation of the regression line in Figure 11 is Pb-XRF = 0.917 (Pb-ICP) + 25.0. The calculated 95 % confidence limits associated with the slope and intercept are $\pm$ 0.10 and $\pm$ 149.0, respectively. The ideal coefficients for the slope and intercept are both within the confidence limits. There is no reason to suspect systematic error. The confident limits associated with the intercept value is large (nearly 300 mg/kg) indicating random error in the ICP or XRF determinations or both.

XRF Error as a Function of ICP Concentration

The relative XRF error as a function of ICP concentration can be calculated as follows.

[XRF value – ICP value)/ICP value] x 100

These calculations are displayed in Figure 12.

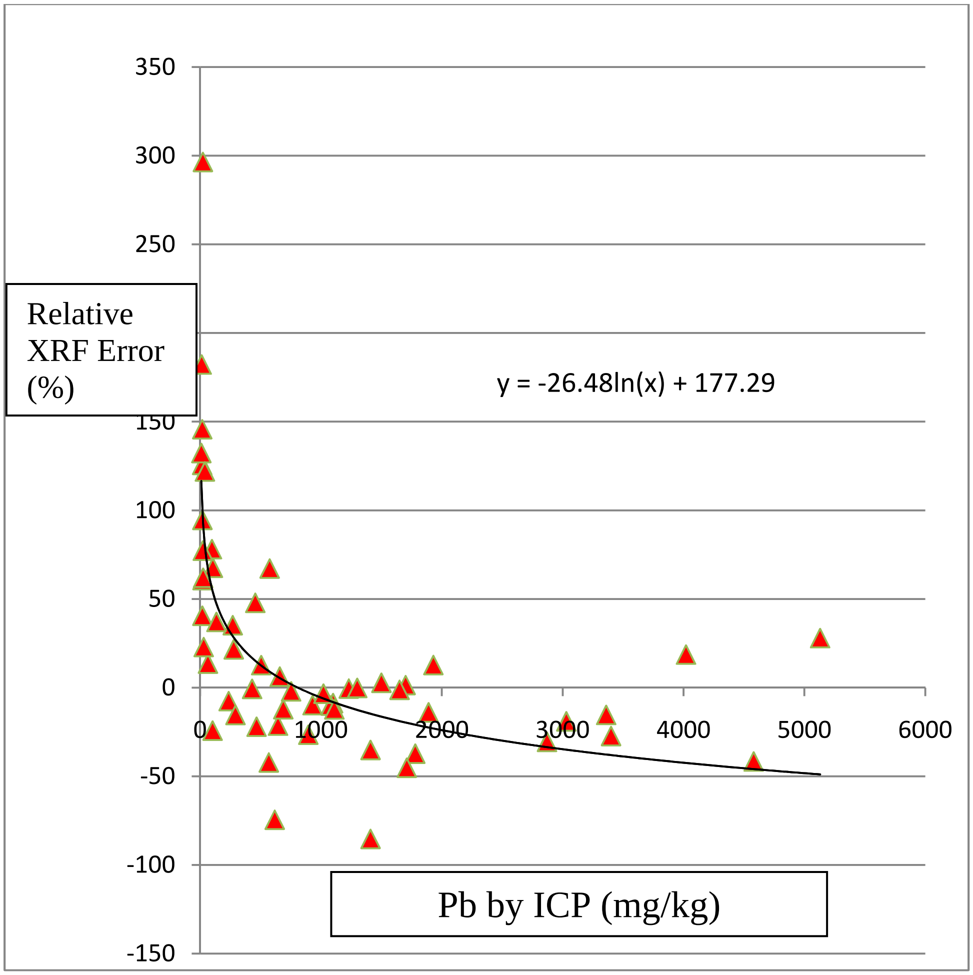


Figure 12. Relative XRF Error as a Function of ICP concentration.

Summary for Lead

.

- Mean and median values generated by the field XRF and the ICP determination are similar. The range in concentrations spans three orders of magnitude resulting in relative elevated standard deviations
- Histograms of each data set indicate the lead data are not normally distributed.
- A nonparametric paired t test, Signed Rank, indicated no significant difference between data sets (P = 0.152).
- Calculations of relative percent difference (RPD) indicated there are approximately the same number of negative RPD values (XRF concentration is greater than corresponding ICP value) as positive RPD values. The values vary from +149.0 to -119.4%, with a central value of -5.1%. Refer to Figure 10.

- Linear regression analysis generated a best fit line with the following equation:

$$\text{Pb-XRF} = 0.917(\text{Pb-ICP}) + 25.0.$$

- The calculated 95 % confidence limits associated with the slope and intercept are $\pm$ 0.10 and $\pm$ 149.0, respectively. The ideal coefficients for the slope and intercept are both within the confidence limits. There is no reason to suspect systematic error. However, the confident limits associated with the intercept value is large (nearly 300 mg/kg) indicating random error in the ICP or XRF determinations or both.

- Calculation of the relative percent XRF error as a function of the corresponding ICP concentration is shown in Figure 12. Using the equation (Figure 8) of this relationship, an ICP concentration of approximately 215 mg/kg (and greater) results in a relative xrf error of less than 35%.

Zinc

Descriptive statistics

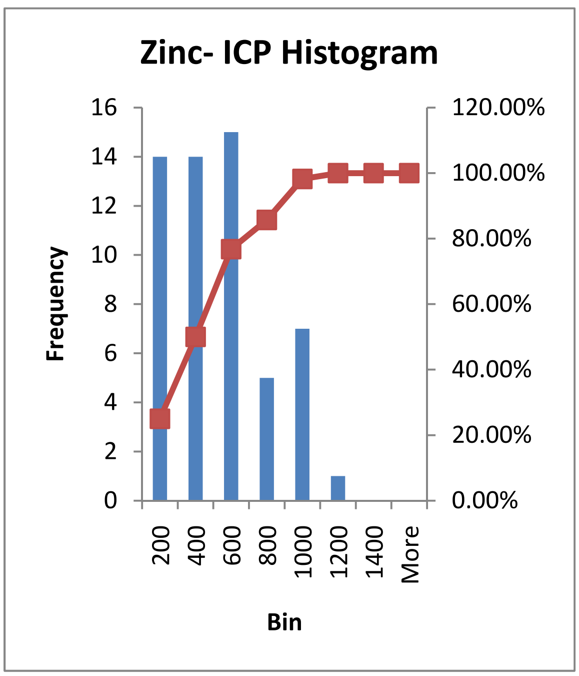
Descriptive statistics for each data set are shown in Table 7. Mean and median values are similar. The range in concentrations spans three orders of magnitude resulting in relative elevated standard deviations.

Table 7. Descriptive statistics for copper concentrations determined by field XRF and laboratory ICP. All values in mg/kg.

	N	Mean Value	Standard Deviation	Median Value	Minimum Value	Maximum Value	Standard Error	95%C.I.
ICP	56	423.8	283.0	405	17.3	1070	37.8	75.8
XRF	56	484.5	323.2	420	32	1233	43.2	86.6

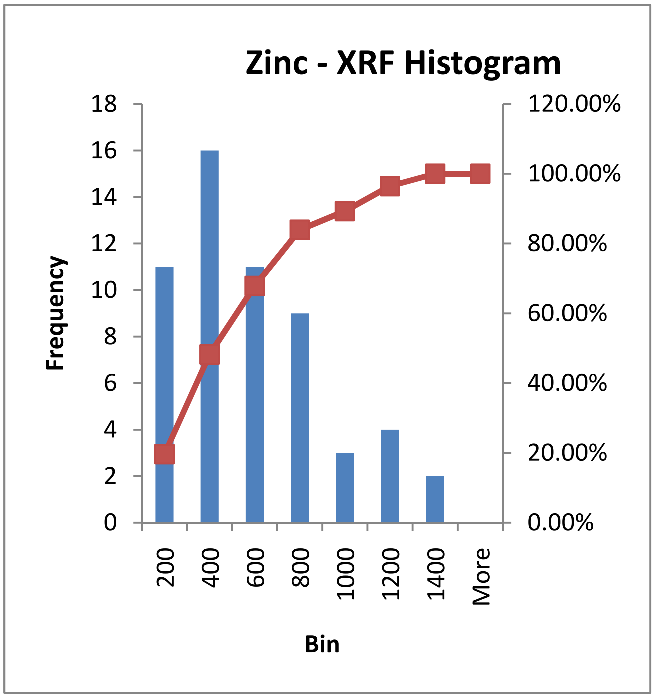
Histograms of Data Sets

Histograms of each data set (Figure 13a and 13b) are similar and indicate that the data are not normally distributed.



Bin	*Frequency*	*Cumulative %*
200	14	25.00%
400	14	50.00%
600	15	76.79%
800	5	85.71%
1000	7	98.21%
1200	1	100.00%
1400	0	100.00%
More	0	100.00%

Figure 13a. Histogram for Zn Determined by ICP.



Bin	*Frequency*	*Cumulative %*
200	11	19.64%
400	16	48.21%
600	11	67.86%
800	9	83.93%
1000	3	89.29%
1200	4	96.43%
1400	2	100.00%
More	0	100.00%

Figure 13b. Histogram for Zn Determined by XRF.

Paired t tests

The traditional paired t test is not applicable as the data sets are not normally distributed; a nonparametric test, Signed Rank, indicated a significant difference between data sets ($P < 0.001$).

Table 8. Paired t-tests

Type	Normal distribution	Equal Variance	P Value	Significantly Different
Parametric	No	Yes	<0.001	Yes
Signed Rank	NA	NA	<0.001	Yes

Relative Percent Difference

The relative percent difference between each zinc concentration determined by the two methods is a measure of inter method precision. Relative percent difference is calculated as:

[ICP value – XRF value/ (ICP value + XRF value)/2] x 100

Visual observation of Figure 14 indicates the vast majority of zinc concentrations determined by XRF were greater than those reported by ICP. Of the 56 paired concentrations, only ten were reported by ICP as greater than their corresponding XRF value. A more even d distribution, similar to arsenic (Figure 2), copper (Figure 6), and lead (Figure 10), is expected. The values vary from +35.7 to -70.2%, with a central value of -16.7%.

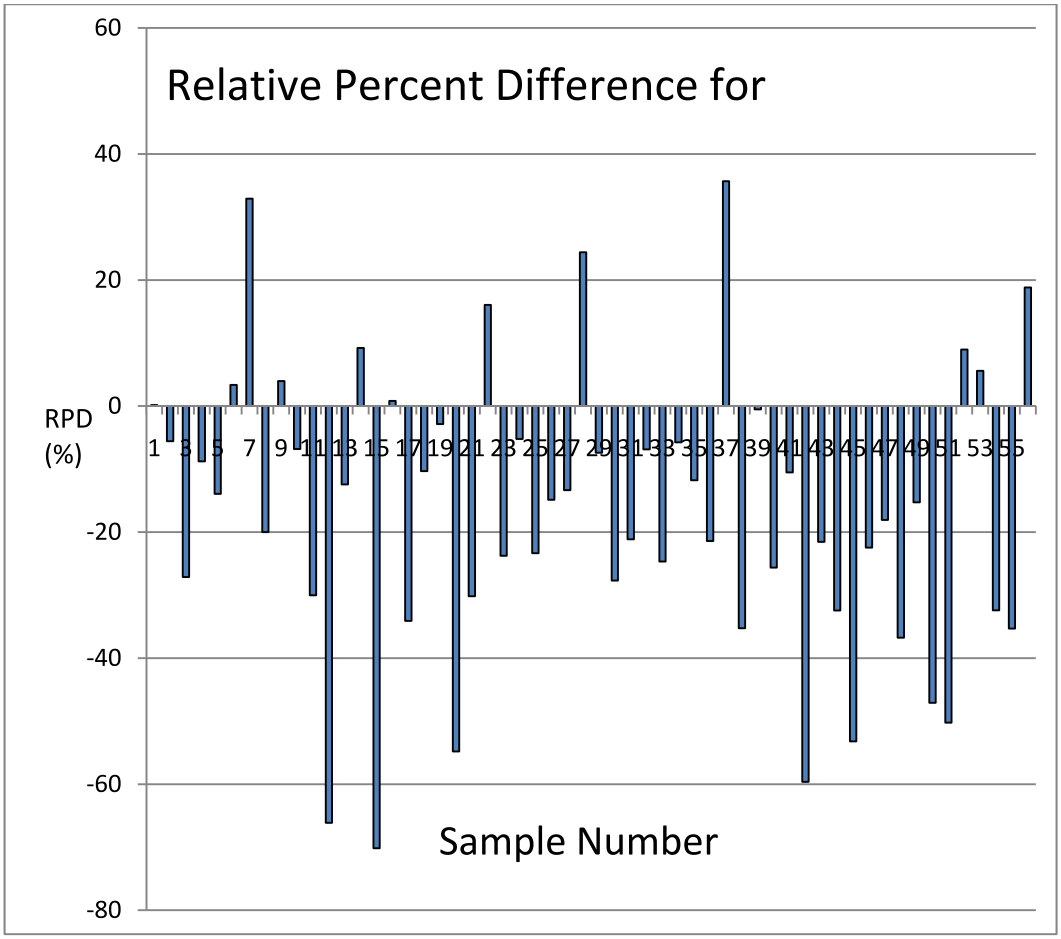


Figure 14. Relative Percent Difference for Zinc.

Linear Regression Analysis

Data for the paired samples are plotted so that each point on the graph represents a sample analyzed by each technique. The slope, intercept, and correlation coefficient of the regression line are then calculated. If each laboratory generated the identical result for each sample, the regression line would have a slope equal to one, an intercept equal to zero, and a correlation coefficient of unity. Deviations from these values are indicative of systematic and/or random errors. In practice, it is determined if the slope and intercept values are significantly different from their ideal values, within some confidence limit, usually 95%.

In regression analysis, it is assumed that all errors are associated with data assigned to the y-axis (dependent variable) and that errors in the independent variable (x-axis) are negligible. For these comparative tests the Field XRF data were assigned to the y axis and the ICP laboratory generated data to the x-axis (Figure 7a and 7b). Obviously, both techniques are subject to error, but it is assumed that the ICP data are correct, non-biased, and of acceptable quality. Regression Analysis for Lead is exhibited in Figure 15.

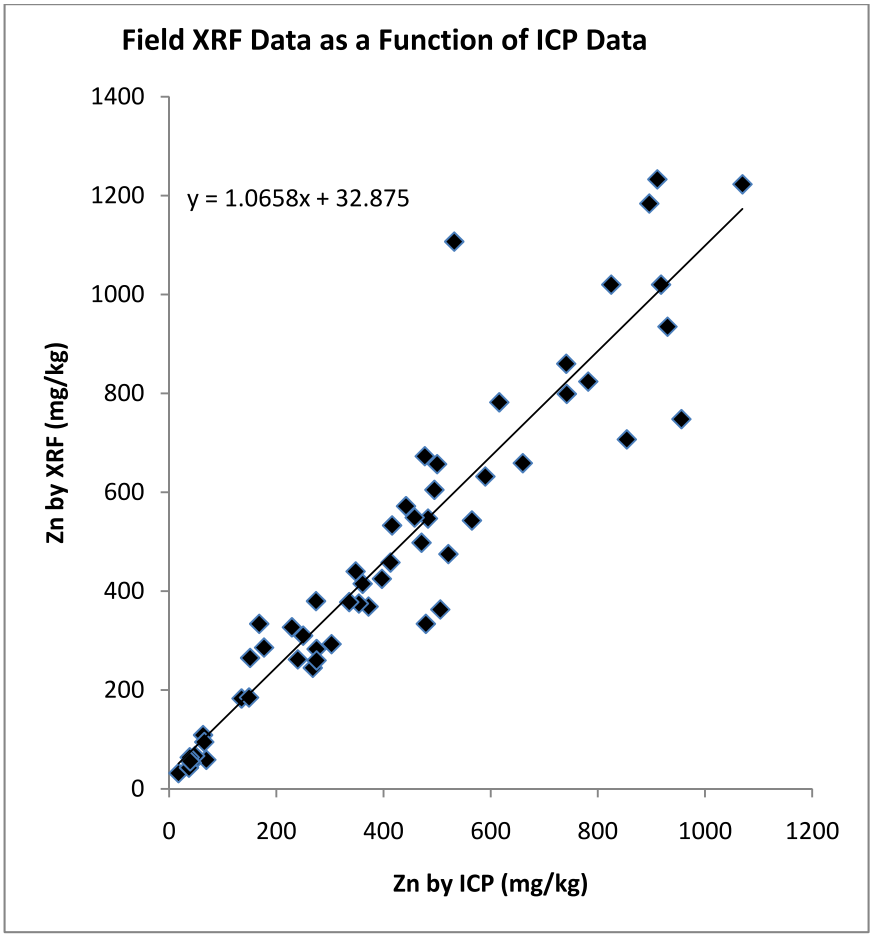


Figure 15. Linear Regression Graphic and Coefficients for Zinc.

The equation of the regression line in Figure 11 is Zn-XRF = 1.06 (Zn-ICP) + 32.8. The calculated 95 % confidence limits associated with the slope and intercept are $\pm$ 0.11 and $\pm$ 56.9, respectively. The ideal coefficients for the slope and intercept are both within the confidence limits. There is no reason to suspect systematic error.

XRF Error as a Function of ICP Concentration

The relative XRF error as a function of ICP concentration can be calculated as follows.

[XRF value – ICP value)/ICP value] x 100

These calculations are displayed in Figure 16.

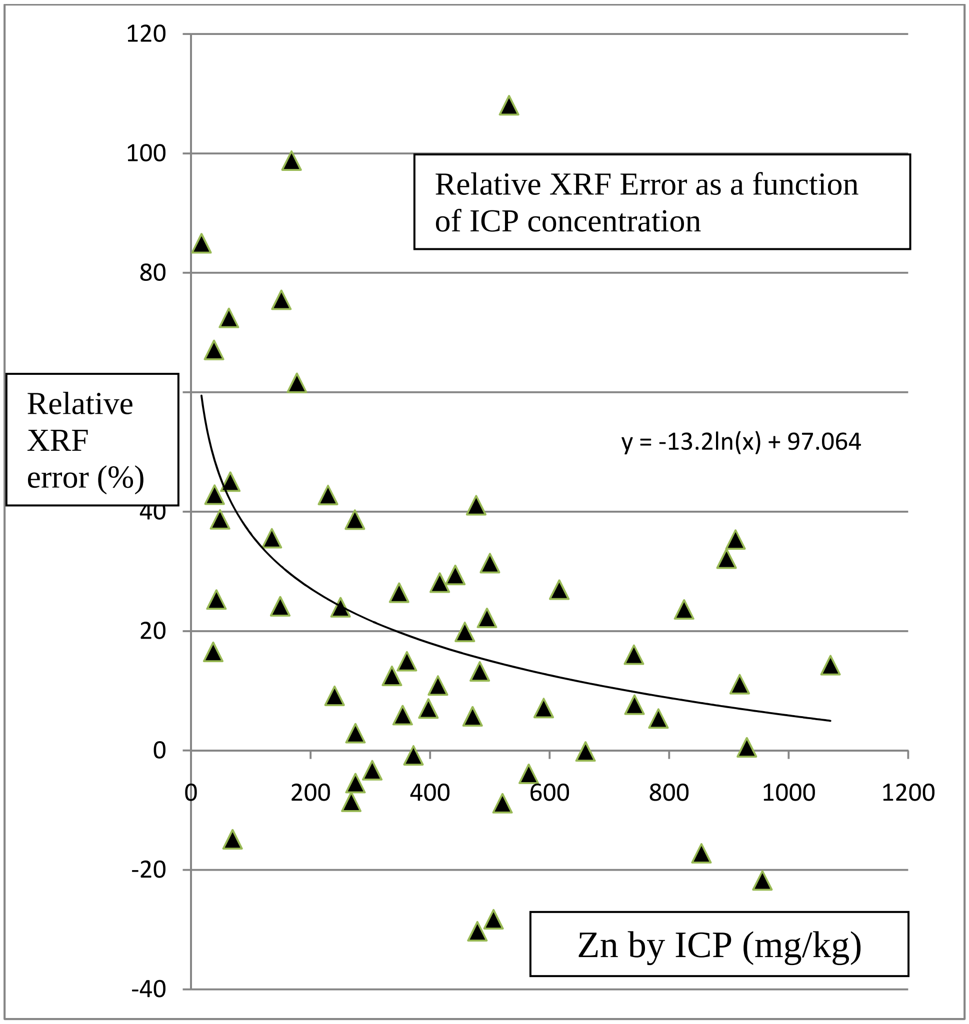


Figure 16. Relative XRF Error as a Function of ICP Concentration.

Using the equation (Figure 16) of this relationship, an ICP concentration of approximately 110 mg/kg (and greater) results in a relative xrf error of less than 35%. However there is much variation in the error as shown in the Figure

Summary for Zinc

.

- Mean and median values generated by the field XRF and the ICP determination are similar. The standard deviations values are less than their respective mean values. The range in concentrations is of the same order of magnitude resulting in relative low standard deviations.

- Histograms of each data set indicate the zinc data are not normally distributed.

- A nonparametric paired t test, Signed Rank, indicated a significant difference between data sets ($P < 0.001$).

- Calculations of relative percent difference (RPD) indicated Visual observation of Figure 14 indicates the vast majority of zinc concentrations determined by XRF were greater than those reported by ICP. Of the 56 paired concentrations, only ten were reported by ICP as greater than their corresponding XRF value. A more even distribution, similar to arsenic (Figure 2), copper (Figure 6), and lead (Figure 10), is expected. The values vary from +35.7 to -70.2%, with a central value of -16.7%.

- Linear regression analysis generated a best fit line with the following equation:

$$\text{Zn-XRF} = 1.06\ (\text{Zn-ICP}) + 32.8$$

The calculated 95 % confidence limits associated with the slope and intercept are $\pm$ 0.11 and $\pm$ 56.9, respectively. The ideal coefficients for the slope and intercept are both within the confidence limits. There is no reason to suspect systematic error.

- Calculation of the relative percent XRF error as a function of the corresponding ICP concentration is shown in Figure 16. Using the equation (Figure 16) of this relationship, an ICP concentration of approximately 110 mg/kg (and greater) results in a relative xrf error of less than 35%. However there is much variation in the error as shown in the Figure.

Cadmium

Almost all the cadmium concentrations determined by the field XRF were reported at the limit of detection (LOD). No statistical comparisons were made for this element.

Appendix M
ProUCL Output Summaries

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Aluminum 0-10"

General Statistics

Number of Valid Observations	5	Number of Distinct Observations	5
Number of Missing Values	21		

Raw Statistics		Log-transformed Statistics	
Minimum	13800	Minimum of Log Data	9.532
Maximum	16500	Maximum of Log Data	9.711
Mean	15060	Mean of log Data	9.618
Geometric Mean	15029	SD of log Data	0.0714
Median	15000		
SD	1078		
Std. Error of Mean	482.3		
Coefficient of Variation	0.0716		
Skewness	0.269		

Warning: A sample size of 'n' = 5 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!

If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 5 Values in this data

Note: It should be noted that even though bootstrap methods may be performed on this data set,

the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.977	Shapiro Wilk Test Statistic	0.98
Shapiro Wilk Critical Value	0.762	Shapiro Wilk Critical Value	0.762
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	16088	95% H-UCL	N/A
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	17155
95% Adjusted-CLT UCL (Chen-1995)	15915	97.5% Chebyshev (MVUE) UCL	18062
95% Modified-t UCL (Johnson-1978)	16098	99% Chebyshev (MVUE) UCL	19843
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	98.13	Data appear Normal at 5% Significance Level	
Theta Star	153.5		
MLE of Mean	15060		
MLE of Standard Deviation	1520		
nu star	981.3		
Approximate Chi Square Value (.05)	909.6	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0086	95% CLT UCL	15853
Adjusted Chi Square Value	878.9	95% Jackknife UCL	16088
		95% Standard Bootstrap UCL	15762
Anderson-Darling Test Statistic	0.194	95% Bootstrap-t UCL	16279
Anderson-Darling 5% Critical Value	0.678	95% Hall's Bootstrap UCL	16186
Kolmogorov-Smirnov Test Statistic	0.183	95% Percentile Bootstrap UCL	15760
Kolmogorov-Smirnov 5% Critical Value	0.357	95% BCA Bootstrap UCL	15760
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	17162
		97.5% Chebyshev(Mean, Sd) UCL	18072
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	19859
95% Approximate Gamma UCL (Use when n >= 40)	16247		
95% Adjusted Gamma UCL (Use when n < 40)	16815		
Potential UCL to Use		Use 95% Student's-t UCL	16088

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)

and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Arsenic 0-10"

General Statistics

Number of Valid Data	26	Number of Detected Data	24
Number of Distinct Detected Data	22	Number of Non-Detect Data	2
		Percent Non-Detects	7.69%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	2.5	Minimum Detected	0.916
Maximum Detected	1496	Maximum Detected	7.311
Mean of Detected	195.5	Mean of Detected	4.303
SD of Detected	313.9	SD of Detected	1.527
Minimum Non-Detect	18	Minimum Non-Detect	2.89
Maximum Non-Detect	20	Maximum Non-Detect	2.996

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	8
Number treated as Detected	18
Single DL Non-Detect Percentage	30.77%

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.594	Shapiro Wilk Test Statistic	0.954
5% Shapiro Wilk Critical Value	0.916	5% Shapiro Wilk Critical Value	0.916
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	181.2	Mean	4.145
SD	305.3	SD	1.567
95% DL/2 (t) UCL	283.5	95% H-Stat (DL/2) UCL	610.2
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	96.57	Mean in Log Scale	4.147
SD	385.9	SD in Log Scale	1.565
95% MLE (t) UCL	225.9	Mean in Original Scale	181.3
95% MLE (Tiku) UCL	232	SD in Original Scale	305.3
		95% t UCL	283.5
		95% Percentile Bootstrap UCL	292.4
		95% BCA Bootstrap UCL	353.4
		95% H UCL	608

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only	
k star (bias corrected)	0.58	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	337.4		
nu star	27.82		
A-D Test Statistic	0.749	**Nonparametric Statistics**	
5% A-D Critical Value	0.794	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.794	Mean	181.5
5% K-S Critical Value	0.186	SD	299.2
Data appear Gamma Distributed at 5% Significance Level		SE of Mean	59.94
		95% KM (t) UCL	283.9
Assuming Gamma Distribution		95% KM (z) UCL	280.1
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	283.8
Minimum	0.000001	95% KM (bootstrap t) UCL	392.7
Maximum	1496	95% KM (BCA) UCL	297.9
Mean	180.5	95% KM (Percentile Bootstrap) UCL	291.2
Median	58.25	95% KM (Chebyshev) UCL	442.8
SD	305.7	97.5% KM (Chebyshev) UCL	555.9
k star	0.292	99% KM (Chebyshev) UCL	778
Theta star	617.6		
Nu star	15.2	**Potential UCLs to Use**	
AppChi2	7.398	95% KM (Chebyshev) UCL	442.8
95% Gamma Approximate UCL (Use when n >= 40)	370.7		
95% Adjusted Gamma UCL (Use when n < 40)	389.6		

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Cadmium 0-10"

General Statistics

Number of Valid Observations	5	Number of Distinct Observations	5
Number of Missing Values	21		

Raw Statistics		Log-transformed Statistics	
Minimum	0.062	Minimum of Log Data	-2.781
Maximum	2.4	Maximum of Log Data	0.875
Mean	0.92	Mean of log Data	-0.759
Geometric Mean	0.468	SD of log Data	1.453
Median	0.36		
SD	0.998		
Std. Error of Mean	0.446		
Coefficient of Variation	1.085		
Skewness	0.99		

Warning: A sample size of 'n' = 5 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 5 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.857	Shapiro Wilk Test Statistic	0.951
Shapiro Wilk Critical Value	0.762	Shapiro Wilk Critical Value	0.762
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.872	95% H-UCL	203.8
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	3.541
95% Adjusted-CLT UCL (Chen-1995)	1.866	97.5% Chebyshev (MVUE) UCL	4.644
95% Modified-t UCL (Johnson-1978)	1.905	99% Chebyshev (MVUE) UCL	6.81
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.481	Data appear Normal at 5% Significance Level	
Theta Star	1.914		
MLE of Mean	0.92		
MLE of Standard Deviation	1.327		
nu star	4.808		
Approximate Chi Square Value (.05)	1.065	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0086	95% CLT UCL	1.655
Adjusted Chi Square Value	0.484	95% Jackknife UCL	1.872
		95% Standard Bootstrap UCL	1.569
Anderson-Darling Test Statistic	0.284	95% Bootstrap-t UCL	5.84
Anderson-Darling 5% Critical Value	0.695	95% Hall's Bootstrap UCL	9.748
Kolmogorov-Smirnov Test Statistic	0.247	95% Percentile Bootstrap UCL	1.584
Kolmogorov-Smirnov 5% Critical Value	0.366	95% BCA Bootstrap UCL	1.632
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	2.866
		97.5% Chebyshev(Mean, Sd) UCL	3.708
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	5.362
95% Approximate Gamma UCL (Use when n >= 40)	4.157		
95% Adjusted Gamma UCL (Use when n < 40)	9.146		
Potential UCL to Use		Use 95% Student's-t UCL	1.872

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Copper 0-10"

General Statistics

Number of Valid Data	26	Number of Detected Data	24
Number of Distinct Detected Data	23	Number of Non-Detect Data	2
		Percent Non-Detects	7.69%

Raw Statistics		**Log-transformed Statistics**	
Minimum Detected	20.3	Minimum Detected	3.011
Maximum Detected	259	Maximum Detected	5.557
Mean of Detected	65.41	Mean of Detected	3.931
SD of Detected	59.74	SD of Detected	0.652
Minimum Non-Detect	36	Minimum Non-Detect	3.584
Maximum Non-Detect	46	Maximum Non-Detect	3.829

Note: Data have multiple DLs - Use of KM Method is recommended		Number treated as Non-Detect	15
For all methods (except KM, DL/2, and ROS Methods),		Number treated as Detected	11
Observations < Largest ND are treated as NDs		Single DL Non-Detect Percentage	57.69%

UCL Statistics

Normal Distribution Test with Detected Values Only		**Lognormal Distribution Test with Detected Values Only**	
Shapiro Wilk Test Statistic	0.658	Shapiro Wilk Test Statistic	0.892
5% Shapiro Wilk Critical Value	0.916	5% Shapiro Wilk Critical Value	0.916
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	61.95	Mean	3.861
SD	58.59	SD	0.674
95% DL/2 (t) UCL	81.58	95% H-Stat (DL/2) UCL	79.41
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	19.11	Mean in Log Scale	3.891
SD	97.92	SD in Log Scale	0.642
95% MLE (t) UCL	51.91	Mean in Original Scale	62.72
95% MLE (Tiku) UCL	64.27	SD in Original Scale	58.09
		95% t UCL	82.18
		95% Percentile Bootstrap UCL	81.95
		95% BCA Bootstrap UCL	87.33
		95% H UCL	78.74

Gamma Distribution Test with Detected Values Only		**Data Distribution Test with Detected Values Only**	
k star (bias corrected)	1.916	Data do not follow a Discernable Distribution (0.05)	
Theta Star	34.14		
nu star	91.97		
A-D Test Statistic	1.604	**Nonparametric Statistics**	
5% A-D Critical Value	0.754	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.754	Mean	62.77
5% K-S Critical Value	0.18	SD	56.95
Data not Gamma Distributed at 5% Significance Level		SE of Mean	11.41
		95% KM (t) UCL	82.27
Assuming Gamma Distribution		95% KM (z) UCL	81.54
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	82.24
Minimum	19.61	95% KM (bootstrap t) UCL	103.4
Maximum	259	95% KM (BCA) UCL	83.95
Mean	62.58	95% KM (Percentile Bootstrap) UCL	83.03
Median	39	95% KM (Chebyshev) UCL	112.5
SD	58.22	97.5% KM (Chebyshev) UCL	134
k star	1.905	99% KM (Chebyshev) UCL	176.3
Theta star	32.84		
Nu star	99.08	**Potential UCLs to Use**	
AppChi2	77.12	95% KM (Chebyshev) UCL	112.5
95% Gamma Approximate UCL (Use when n >= 40)	80.41		
95% Adjusted Gamma UCL (Use when n < 40)	81.76		

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Iron 0-10"

General Statistics

Number of Valid Observations	5	Number of Distinct Observations	5
Number of Missing Values	21		

Raw Statistics		Log-transformed Statistics	
Minimum	16100	Minimum of Log Data	9.687
Maximum	18000	Maximum of Log Data	9.798
Mean	16880	Mean of log Data	9.733
Geometric Mean	16865	SD of log Data	0.0465
Median	16500		
SD	791.8		
Std. Error of Mean	354.1		
Coefficient of Variation	0.0469		
Skewness	0.76		

Warning: A sample size of 'n' = 5 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 5 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.902	Shapiro Wilk Test Statistic	0.906
Shapiro Wilk Critical Value	0.762	Shapiro Wilk Critical Value	0.762
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	17635	95% H-UCL	N/A
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	18408
95% Adjusted-CLT UCL (Chen-1995)	17591	97.5% Chebyshev (MVUE) UCL	19070
95% Modified-t UCL (Johnson-1978)	17655	99% Chebyshev (MVUE) UCL	20369
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	230.4	Data appear Normal at 5% Significance Level	
Theta Star	73.27		
MLE of Mean	16880		
MLE of Standard Deviation	1112		
nu star	2304		
Approximate Chi Square Value (.05)	2193	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0086	95% CLT UCL	17462
Adjusted Chi Square Value	2145	95% Jackknife UCL	17635
		95% Standard Bootstrap UCL	17397
Anderson-Darling Test Statistic	0.386	95% Bootstrap-t UCL	19289
Anderson-Darling 5% Critical Value	0.678	95% Hall's Bootstrap UCL	23979
Kolmogorov-Smirnov Test Statistic	0.302	95% Percentile Bootstrap UCL	17440
Kolmogorov-Smirnov 5% Critical Value	0.357	95% BCA Bootstrap UCL	17460
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	18424
		97.5% Chebyshev(Mean, Sd) UCL	19091
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	20403
95% Approximate Gamma UCL (Use when n >= 40)	17730		
95% Adjusted Gamma UCL (Use when n < 40)	18128		
Potential UCL to Use		Use 95% Student's-t UCL	17635

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Lead 0-10"

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24
Raw Statistics		**Log-transformed Statistics**	
Minimum	18.5	Minimum of Log Data	2.918
Maximum	192	Maximum of Log Data	5.257
Mean	74	Mean of log Data	4.02
Geometric Mean	55.7	SD of log Data	0.769
Median	46.5		
SD	56.85		
Std. Error of Mean	11.15		
Coefficient of Variation	0.768		
Skewness	0.905		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.832	Shapiro Wilk Test Statistic	0.906
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	93.05	95% H-UCL	105.5
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	126.7
95% Adjusted-CLT UCL (Chen-1995)	94.46	97.5% Chebyshev (MVUE) UCL	149.6
95% Modified-t UCL (Johnson-1978)	93.38	99% Chebyshev (MVUE) UCL	194.6
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	1.715	Data do not follow a Discernable Distribution (0.05)	
Theta Star	43.16		
MLE of Mean	74		
MLE of Standard Deviation	56.52		
nu star	89.16		
Approximate Chi Square Value (.05)	68.39	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	92.34
Adjusted Chi Square Value	67.19	95% Jackknife UCL	93.05
		95% Standard Bootstrap UCL	91.97
Anderson-Darling Test Statistic	1.121	95% Bootstrap-t UCL	94.47
Anderson-Darling 5% Critical Value	0.758	95% Hall's Bootstrap UCL	94.06
Kolmogorov-Smirnov Test Statistic	0.188	95% Percentile Bootstrap UCL	92.05
Kolmogorov-Smirnov 5% Critical Value	0.174	95% BCA Bootstrap UCL	93.95
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	122.6
		97.5% Chebyshev(Mean, Sd) UCL	143.6
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	184.9
95% Approximate Gamma UCL (Use when n >= 40)	96.48		
95% Adjusted Gamma UCL (Use when n < 40)	98.2		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	122.6

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Manganese 0-10"

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	26
Raw Statistics		**Log-transformed Statistics**	
Minimum	254	Minimum of Log Data	5.537
Maximum	1213	Maximum of Log Data	7.101
Mean	559.9	Mean of log Data	6.254
Geometric Mean	519.9	SD of log Data	0.381
Median	510		
SD	240		
Std. Error of Mean	47.08		
Coefficient of Variation	0.429		
Skewness	1.569		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.824	Shapiro Wilk Test Statistic	0.943
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	640.3	95% H-UCL	644.8
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	743.6
95% Adjusted-CLT UCL (Chen-1995)	652.8	97.5% Chebyshev (MVUE) UCL	824.1
95% Modified-t UCL (Johnson-1978)	642.7	99% Chebyshev (MVUE) UCL	982.4
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.136	Data appear Lognormal at 5% Significance Level	
Theta Star	91.25		
MLE of Mean	559.9		
MLE of Standard Deviation	226		
nu star	319.1		
Approximate Chi Square Value (.05)	278.7	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	637.3
Adjusted Chi Square Value	276.2	95% Jackknife UCL	640.3
		95% Standard Bootstrap UCL	633.9
Anderson-Darling Test Statistic	0.803	95% Bootstrap-t UCL	664.6
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	681.7
Kolmogorov-Smirnov Test Statistic	0.185	95% Percentile Bootstrap UCL	639.1
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	648
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	765.1
		97.5% Chebyshev(Mean, Sd) UCL	853.9
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1028
95% Approximate Gamma UCL (Use when n >= 40)	641		
95% Adjusted Gamma UCL (Use when n < 40)	646.8		
Potential UCL to Use		Use 95% Student's-t UCL	640.3
		or 95% Modified-t UCL	642.7
		or 95% H-UCL	644.8

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Nickle 0-10"

General Statistics

Number of Valid Observations	5	Number of Distinct Observations	5
Number of Missing Values	21		

Raw Statistics		Log-transformed Statistics	
Minimum	6.5	Minimum of Log Data	1.872
Maximum	9.1	Maximum of Log Data	2.208
Mean	7.8	Mean of log Data	2.048
Geometric Mean	7.754	SD of log Data	0.122
Median	7.7		
SD	0.938		
Std. Error of Mean	0.42		
Coefficient of Variation	0.12		
Skewness	0.00909		

Warning: A sample size of 'n' = 5 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 5 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.971	Shapiro Wilk Test Statistic	0.967
Shapiro Wilk Critical Value	0.762	Shapiro Wilk Critical Value	0.762
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	8.694	95% H-UCL	8.857
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	9.648
95% Adjusted-CLT UCL (Chen-1995)	8.492	97.5% Chebyshev (MVUE) UCL	10.45
95% Modified-t UCL (Johnson-1978)	8.695	99% Chebyshev (MVUE) UCL	12.02

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	34.32	Data appear Normal at 5% Significance Level	
Theta Star	0.227		
MLE of Mean	7.8		
MLE of Standard Deviation	1.331		
nu star	343.2		
Approximate Chi Square Value (.05)	301.3	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0086	95% CLT UCL	8.49
Adjusted Chi Square Value	283.9	95% Jackknife UCL	8.694
		95% Standard Bootstrap UCL	8.413
Anderson-Darling Test Statistic	0.254	95% Bootstrap-t UCL	8.69
Anderson-Darling 5% Critical Value	0.678	95% Hall's Bootstrap UCL	8.888
Kolmogorov-Smirnov Test Statistic	0.22	95% Percentile Bootstrap UCL	8.4
Kolmogorov-Smirnov 5% Critical Value	0.357	95% BCA Bootstrap UCL	8.34
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	9.629
		97.5% Chebyshev(Mean, Sd) UCL	10.42
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	11.97
95% Approximate Gamma UCL (Use when n >= 40)	8.886		
95% Adjusted Gamma UCL (Use when n < 40)	9.429		

Potential UCL to Use		Use 95% Student's-t UCL	8.694

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Selenium 0-10"

General Statistics

Number of Valid Data	5	Number of Detected Data	2
Number of Distinct Detected Data	2	Number of Non-Detect Data	3
Number of Missing Values	21	Percent Non-Detects	60.00%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.99	Minimum Detected	-0.0101
Maximum Detected	1.5	Maximum Detected	0.405
Mean of Detected	1.245	Mean of Detected	0.198
SD of Detected	0.361	SD of Detected	0.294
Minimum Non-Detect	0.69	Minimum Non-Detect	-0.371
Maximum Non-Detect	0.75	Maximum Non-Detect	-0.288

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	3
Number treated as Detected	2
Single DL Non-Detect Percentage	60.00%

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A	Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A	5% Shapiro Wilk Critical Value	N/A
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.714	Mean	-0.534
SD	0.517	SD	0.685
95% DL/2 (t) UCL	1.207	95% H-Stat (DL/2) UCL	2.544
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	N/A
		SD in Log Scale	N/A
		Mean in Original Scale	N/A
		SD in Original Scale	N/A
		95% t UCL	N/A
		95% Percentile Bootstrap UCL	N/A
		95% BCA Bootstrap UCL	N/A
		95% H-UCL	N/A

Selenium 0-10" continued

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only	
k star (bias corrected)	N/A	Data do not follow a Discernable Distribution (0.05)	
Theta Star	N/A		
nu star	N/A		
A-D Test Statistic	N/A	Nonparametric Statistics	
5% A-D Critical Value	N/A	Kaplan-Meier (KM) Method	
K-S Test Statistic	N/A	Mean	1.092
5% K-S Critical Value	N/A	SD	0.204
Data not Gamma Distributed at 5% Significance Level		SE of Mean	0.129
		95% KM (t) UCL	1.367
Assuming Gamma Distribution		95% KM (z) UCL	1.304
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	1.523
Minimum	N/A	95% KM (bootstrap t) UCL	N/A
Maximum	N/A	95% KM (BCA) UCL	1.5
Mean	N/A	95% KM (Percentile Bootstrap) UCL	1.5
Median	N/A	95% KM (Chebyshev) UCL	1.654
SD	N/A	97.5% KM (Chebyshev) UCL	1.898
k star	N/A	99% KM (Chebyshev) UCL	2.376
Theta star	N/A		
Nu star	N/A	Potential UCLs to Use	
AppChi2	N/A	95% KM (t) UCL	1.367
95% Gamma Approximate UCL (Use when n >= 40)	N/A	95% KM (% Bootstrap) UCL	1.5
95% Adjusted Gamma UCL (Use when n < 40)	N/A		

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Zinc 0-10"

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	25

Raw Statistics		**Log-transformed Statistics**	
Minimum	39.2	Minimum of Log Data	3.669
Maximum	1442	Maximum of Log Data	7.274
Mean	218.3	Mean of log Data	4.879
Geometric Mean	131.6	SD of log Data	0.903
Median	117		
SD	315.1		
Std. Error of Mean	61.8		
Coefficient of Variation	1.444		
Skewness	3.135		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.548	Shapiro Wilk Test Statistic	0.915
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	323.9	95% H-UCL	304.2
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	360.7
95% Adjusted-CLT UCL (Chen-1995)	360.5	97.5% Chebyshev (MVUE) UCL	433
95% Modified-t UCL (Johnson-1978)	330.2	99% Chebyshev (MVUE) UCL	575.1
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	1.021	Data do not follow a Discernable Distribution (0.05)	
Theta Star	213.9		
MLE of Mean	218.3		
MLE of Standard Deviation	216.1		
nu star	53.08		
Approximate Chi Square Value (.05)	37.34	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	319.9
Adjusted Chi Square Value	36.47	95% Jackknife UCL	323.9
		95% Standard Bootstrap UCL	318
Anderson-Darling Test Statistic	1.694	95% Bootstrap-t UCL	550.1
Anderson-Darling 5% Critical Value	0.77	95% Hall's Bootstrap UCL	769.1
Kolmogorov-Smirnov Test Statistic	0.206	95% Percentile Bootstrap UCL	331.3
Kolmogorov-Smirnov 5% Critical Value	0.176	95% BCA Bootstrap UCL	371.5
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	487.7
		97.5% Chebyshev(Mean, Sd) UCL	604.3
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	833.2
95% Approximate Gamma UCL (Use when n >= 40)	310.3		
95% Adjusted Gamma UCL (Use when n < 40)	317.7		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	487.7

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Aluminum 0-2'

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	11
Number of Missing Values	50		

Raw Statistics		**Log-transformed Statistics**	
Minimum	6560	Minimum of Log Data	8.789
Maximum	16500	Maximum of Log Data	9.711
Mean	12771	Mean of log Data	9.407
Geometric Mean	12171	SD of log Data	0.341
Median	14300		
SD	3774		
Std. Error of Mean	1138		
Coefficient of Variation	0.295		
Skewness	-0.696		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.841	Shapiro Wilk Test Statistic	0.817
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	14833	95% H-UCL	15991
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	18642
95% Adjusted-CLT UCL (Chen-1995)	14387	97.5% Chebyshev (MVUE) UCL	21157
95% Modified-t UCL (Johnson-1978)	14793	99% Chebyshev (MVUE) UCL	26098
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	7.743	Data do not follow a Discernable Distribution (0.05)	
Theta Star	1649		
MLE of Mean	12771		
MLE of Standard Deviation	4590		
nu star	170.3		
Approximate Chi Square Value (.05)	141.2	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	14642
Adjusted Chi Square Value	136.8	95% Jackknife UCL	14833
		95% Standard Bootstrap UCL	14453
Anderson-Darling Test Statistic	0.903	95% Bootstrap-t UCL	14530
Anderson-Darling 5% Critical Value	0.729	95% Hall's Bootstrap UCL	14216
Kolmogorov-Smirnov Test Statistic	0.276	95% Percentile Bootstrap UCL	14598
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	14394
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	17730
		97.5% Chebyshev(Mean, Sd) UCL	19876
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	24091
95% Approximate Gamma UCL (Use when n >= 40)	15411		
95% Adjusted Gamma UCL (Use when n < 40)	15898		
Potential UCL to Use		Use 95% Student's-t UCL	14833
		or 95% Modified-t UCL	14793

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Note: For highly negative-skewed data, confidence limits
(e.g., Chen, Johnson, Lognormal, and Gamma) may not be
reliable. Chen's and Johnson's methods provide
adjustments for positvely skewed data sets.

Antimony 0-2'

General Statistics

Number of Valid Data	11	Number of Detected Data	1
Number of Distinct Detected Data	1	Number of Non-Detect Data	10
Number of Missing Values	50	Percent Non-Detects	90.91%

Warning: Only one distinct data value was detected! ProUCL (or any other software) should not be used on such a data set!
It is suggested to use alternative site specific values determined by the Project Team to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Antimony 0-2' was not processed!

Arsenic 0-2'

General Statistics

Number of Valid Data	51	Number of Detected Data	48
Number of Distinct Detected Data	43	Number of Non-Detect Data	3
Number of Missing Values	10	Percent Non-Detects	5.88%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	2.5	Minimum Detected	0.916
Maximum Detected	3090	Maximum Detected	8.036
Mean of Detected	525.4	Mean of Detected	4.924
SD of Detected	772.6	SD of Detected	1.919
Minimum Non-Detect	17	Minimum Non-Detect	2.833
Maximum Non-Detect	20	Maximum Non-Detect	2.996

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	14
Number treated as Detected	37
Single DL Non-Detect Percentage	27.45%

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.703	Shapiro Wilk Test Statistic	0.944
5% Shapiro Wilk Critical Value	0.947	5% Shapiro Wilk Critical Value	0.947
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	495.1	Mean	4.765
SD	759	SD	1.969
95% DL/2 (t) UCL	673.2	95% H-Stat (DL/2) UCL	2153
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	317.1	Mean in Log Scale	4.77
SD	945.6	SD in Log Scale	1.962
95% MLE (t) UCL	539	Mean in Original Scale	495.1
95% MLE (Tiku) UCL	545.6	SD in Original Scale	759
		95% t UCL	673.2
		95% Percentile Bootstrap UCL	677.3
		95% BCA Bootstrap UCL	708.4
		95% H UCL	2125

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only	
k star (bias corrected)	0.461	Data do not follow a Discernable Distribution (0.05)	
Theta Star	1139		
nu star	44.3		
A-D Test Statistic	0.981	**Nonparametric Statistics**	
5% A-D Critical Value	0.819	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.819	Mean	495.2
5% K-S Critical Value	0.136	SD	751.5
Data not Gamma Distributed at 5% Significance Level		SE of Mean	106.3
		95% KM (t) UCL	673.4
Assuming Gamma Distribution		95% KM (z) UCL	670.1
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	673.3
Minimum	0.000001	95% KM (bootstrap t) UCL	704.4
Maximum	3090	95% KM (BCA) UCL	676.2
Mean	494.5	95% KM (Percentile Bootstrap) UCL	675.5
Median	200	95% KM (Chebyshev) UCL	958.7
SD	759.4	97.5% KM (Chebyshev) UCL	1159
k star	0.287	99% KM (Chebyshev) UCL	1553
Theta star	1724		
Nu star	29.27	Potential UCLs to Use	
AppChi2	17.92	97.5% KM (Chebyshev) UCL	1159
95% Gamma Approximate UCL (Use when n >= 40)	807.8		
95% Adjusted Gamma UCL (Use when n < 40)	819.6		

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Cadmium 0-2'

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	11
Number of Missing Values	50		

Raw Statistics		Log-transformed Statistics	
Minimum	0.032	Minimum of Log Data	-3.442
Maximum	45.1	Maximum of Log Data	3.809
Mean	10.2	Mean of log Data	0.212
Geometric Mean	1.236	SD of log Data	2.627
Median	1.5		
SD	16.14		
Std. Error of Mean	4.867		
Coefficient of Variation	1.582		
Skewness	1.495		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.694	Shapiro Wilk Test Statistic	0.927
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	19.02	95% H-UCL	9462
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	73.66
95% Adjusted-CLT UCL (Chen-1995)	20.55	97.5% Chebyshev (MVUE) UCL	98.31
95% Modified-t UCL (Johnson-1978)	19.39	99% Chebyshev (MVUE) UCL	146.7

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	0.295	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	34.53		
MLE of Mean	10.2		
MLE of Standard Deviation	18.77		
nu star	6.499		
Approximate Chi Square Value (.05)	1.9	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	18.21
Adjusted Chi Square Value	1.523	95% Jackknife UCL	19.02
		95% Standard Bootstrap UCL	17.88
Anderson-Darling Test Statistic	0.5	95% Bootstrap-t UCL	27.25
Anderson-Darling 5% Critical Value	0.816	95% Hall's Bootstrap UCL	17.77
Kolmogorov-Smirnov Test Statistic	0.192	95% Percentile Bootstrap UCL	18.41
Kolmogorov-Smirnov 5% Critical Value	0.275	95% BCA Bootstrap UCL	19.99
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	31.41
		97.5% Chebyshev(Mean, Sd) UCL	40.59
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	58.62
95% Approximate Gamma UCL (Use when n >= 40)	34.89		
95% Adjusted Gamma UCL (Use when n < 40)	43.53		

Potential UCL to Use		Use 95% Adjusted Gamma UCL	43.53

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Copper 0-2'

General Statistics

Number of Valid Data	51	Number of Detected Data	48
Number of Distinct Detected Data	43	Number of Non-Detect Data	3
Number of Missing Values	10	Percent Non-Detects	5.88%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	20.3	Minimum Detected	3.011
Maximum Detected	887	Maximum Detected	6.788
Mean of Detected	101.2	Mean of Detected	4.21
SD of Detected	136.1	SD of Detected	0.813
Minimum Non-Detect	35	Minimum Non-Detect	3.555
Maximum Non-Detect	46	Maximum Non-Detect	3.829

Note: Data have multiple DLs - Use of KM Method is recommended		Number treated as Non-Detect	23
For all methods (except KM, DL/2, and ROS Methods),		Number treated as Detected	28
Observations < Largest ND are treated as NDs		Single DL Non-Detect Percentage	45.10%

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.542	Shapiro Wilk Test Statistic	0.922
5% Shapiro Wilk Critical Value	0.947	5% Shapiro Wilk Critical Value	0.947
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	96.43	Mean	4.136
SD	133.3	SD	0.843
95% DL/2 (t) UCL	127.7	95% H-Stat (DL/2) UCL	115.4
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	30.38	Mean in Log Scale	4.16
SD	194.4	SD in Log Scale	0.814
95% MLE (t) UCL	76	Mean in Original Scale	97.01
95% MLE (Tiku) UCL	84.23	SD in Original Scale	133
		95% t UCL	128.2
		95% Percentile Bootstrap UCL	129.1
		95% BCA Bootstrap UCL	141.5
		95% H UCL	114

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only	
k star (bias corrected)	1.297	Data do not follow a Discernable Distribution (0.05)	
Theta Star	78.06		
nu star	124.5		
A-D Test Statistic	2.285	**Nonparametric Statistics**	
5% A-D Critical Value	0.77	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.77	Mean	97.09
5% K-S Critical Value	0.131	SD	131.7
Data not Gamma Distributed at 5% Significance Level		SE of Mean	18.63
		95% KM (t) UCL	128.3
Assuming Gamma Distribution		95% KM (z) UCL	127.7
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	128.3
Minimum	0.000001	95% KM (bootstrap t) UCL	156.3
Maximum	887	95% KM (BCA) UCL	133.2
Mean	95.66	95% KM (Percentile Bootstrap) UCL	131.2
Median	50	95% KM (Chebyshev) UCL	178.3
SD	133.8	97.5% KM (Chebyshev) UCL	213.5
k star	0.554	99% KM (Chebyshev) UCL	282.5
Theta star	172.8		
Nu star	56.47	Potential UCLs to Use	
AppChi2	40.2	95% KM (Chebyshev) UCL	178.3
95% Gamma Approximate UCL (Use when n >= 40)	134.4		
95% Adjusted Gamma UCL (Use when n < 40)	135.7		

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Iron 0-2'

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	11
Number of Missing Values	50		

Raw Statistics		Log-transformed Statistics	
Minimum	16100	Minimum of Log Data	9.687
Maximum	35400	Maximum of Log Data	10.47
Mean	20155	Mean of log Data	9.876
Geometric Mean	19451	SD of log Data	0.262
Median	17500		
SD	6376		
Std. Error of Mean	1923		
Coefficient of Variation	0.316		
Skewness	2.001		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.636	Shapiro Wilk Test Statistic	0.68
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	23639	95% H-UCL	23597
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	27032
95% Adjusted-CLT UCL (Chen-1995)	24556	97.5% Chebyshev (MVUE) UCL	30045
95% Modified-t UCL (Johnson-1978)	23832	99% Chebyshev (MVUE) UCL	35964

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	10.42	Data do not follow a Discernable Distribution (0.05)	
Theta Star	1935		
MLE of Mean	20155		
MLE of Standard Deviation	6245		
nu star	229.1		
Approximate Chi Square Value (.05)	195.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	23317
Adjusted Chi Square Value	190	95% Jackknife UCL	23639
		95% Standard Bootstrap UCL	23130
Anderson-Darling Test Statistic	1.79	95% Bootstrap-t UCL	40078
Anderson-Darling 5% Critical Value	0.729	95% Hall's Bootstrap UCL	44075
Kolmogorov-Smirnov Test Statistic	0.363	95% Percentile Bootstrap UCL	23245
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	24564
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	28535
		97.5% Chebyshev(Mean, Sd) UCL	32161
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	39284
95% Approximate Gamma UCL (Use when n >= 40)	23671		
95% Adjusted Gamma UCL (Use when n < 40)	24309		

Potential UCL to Use		Use 95% Student's-t UCL	23639
		or 95% Modified-t UCL	23832

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Lead 0-2'

General Statistics

Number of Valid Observations	51	Number of Distinct Observations	45
Number of Missing Values	10		

Raw Statistics		Log-transformed Statistics	
Minimum	18.5	Minimum of Log Data	2.918
Maximum	2870	Maximum of Log Data	7.962
Mean	168	Mean of log Data	4.384
Geometric Mean	80.2	SD of log Data	1.074
Median	86		
SD	399.5		
Std. Error of Mean	55.94		
Coefficient of Variation	2.378		
Skewness	6.435		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.354	Lilliefors Test Statistic	0.133
Lilliefors Critical Value	0.124	Lilliefors Critical Value	0.124
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	261.7	95% H-UCL	205.2
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	250.8
95% Adjusted-CLT UCL (Chen-1995)	313.9	97.5% Chebyshev (MVUE) UCL	298.6
95% Modified-t UCL (Johnson-1978)	270.1	99% Chebyshev (MVUE) UCL	392.4
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.768	Data do not follow a Discernable Distribution (0.05)	
Theta Star	218.6		
MLE of Mean	168		
MLE of Standard Deviation	191.6		
nu star	78.36		
Approximate Chi Square Value (.05)	58.97	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0453	95% CLT UCL	260
Adjusted Chi Square Value	58.48	95% Jackknife UCL	261.7
		95% Standard Bootstrap UCL	260.9
Anderson-Darling Test Statistic	2.457	95% Bootstrap-t UCL	481.7
Anderson-Darling 5% Critical Value	0.79	95% Hall's Bootstrap UCL	624.6
Kolmogorov-Smirnov Test Statistic	0.149	95% Percentile Bootstrap UCL	268.5
Kolmogorov-Smirnov 5% Critical Value	0.129	95% BCA Bootstrap UCL	356.1
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	411.8
		97.5% Chebyshev(Mean, Sd) UCL	517.3
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	724.6
95% Approximate Gamma UCL (Use when n >= 40)	223.2		
95% Adjusted Gamma UCL (Use when n < 40)	225.1		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	411.8

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Manganese 0-2'

General Statistics

Number of Valid Observations	51	Number of Distinct Observations	48
Raw Statistics		**Log-transformed Statistics**	
Minimum	199	Minimum of Log Data	5.293
Maximum	1809	Maximum of Log Data	7.501
Mean	597.1	Mean of log Data	6.28
Geometric Mean	533.6	SD of log Data	0.463
Median	512		
SD	319		
Std. Error of Mean	44.66		
Coefficient of Variation	0.534		
Skewness	1.779		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.231	Lilliefors Test Statistic	0.132
Lilliefors Critical Value	0.124	Lilliefors Critical Value	0.124
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	671.9	95% H-UCL	671
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	767.7
95% Adjusted-CLT UCL (Chen-1995)	682.5	97.5% Chebyshev (MVUE) UCL	843.4
95% Modified-t UCL (Johnson-1978)	673.8	99% Chebyshev (MVUE) UCL	992.1
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	4.348	Data do not follow a Discernable Distribution (0.05)	
Theta Star	137.3		
MLE of Mean	597.1		
MLE of Standard Deviation	286.4		
nu star	443.5		
Approximate Chi Square Value (.05)	395.7	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0453	95% CLT UCL	670.6
Adjusted Chi Square Value	394.4	95% Jackknife UCL	671.9
		95% Standard Bootstrap UCL	670.5
Anderson-Darling Test Statistic	1.188	95% Bootstrap-t UCL	683.7
Anderson-Darling 5% Critical Value	0.754	95% Hall's Bootstrap UCL	686.1
Kolmogorov-Smirnov Test Statistic	0.166	95% Percentile Bootstrap UCL	672.3
Kolmogorov-Smirnov 5% Critical Value	0.125	95% BCA Bootstrap UCL	678.7
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	791.8
		97.5% Chebyshev(Mean, Sd) UCL	876
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1041
95% Approximate Gamma UCL (Use when n >= 40)	669.3		
95% Adjusted Gamma UCL (Use when n < 40)	671.5		
Potential UCL to Use		Use 95% Student's-t UCL	671.9
		or 95% Modified-t UCL	673.8

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Nickle 0-2'

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	11
Number of Missing Values	50		

Raw Statistics		Log-transformed Statistics	
Minimum	6	Minimum of Log Data	1.792
Maximum	11.4	Maximum of Log Data	2.434
Mean	7.936	Mean of log Data	2.057
Geometric Mean	7.822	SD of log Data	0.176
Median	7.7		
SD	1.473		
Std. Error of Mean	0.444		
Coefficient of Variation	0.186		
Skewness	1.204		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.923	Shapiro Wilk Test Statistic	0.969
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	8.741	95% H-UCL	8.8
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	9.771
95% Adjusted-CLT UCL (Chen-1995)	8.839	97.5% Chebyshev (MVUE) UCL	10.57
95% Modified-t UCL (Johnson-1978)	8.768	99% Chebyshev (MVUE) UCL	12.13
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	25.23	Data appear Normal at 5% Significance Level	
Theta Star	0.315		
MLE of Mean	7.936		
MLE of Standard Deviation	1.58		
nu star	555.1		
Approximate Chi Square Value (.05)	501.4	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	8.667
Adjusted Chi Square Value	493.1	95% Jackknife UCL	8.741
		95% Standard Bootstrap UCL	8.65
Anderson-Darling Test Statistic	0.222	95% Bootstrap-t UCL	8.951
Anderson-Darling 5% Critical Value	0.729	95% Hall's Bootstrap UCL	9.743
Kolmogorov-Smirnov Test Statistic	0.114	95% Percentile Bootstrap UCL	8.736
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	8.827
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	9.873
		97.5% Chebyshev(Mean, Sd) UCL	10.71
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	12.36
95% Approximate Gamma UCL (Use when n >= 40)	8.785		
95% Adjusted Gamma UCL (Use when n < 40)	8.934		
Potential UCL to Use		Use 95% Student's-t UCL	8.741

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Selenium 0-2'

General Statistics

Number of Valid Data	11	Number of Detected Data	2
Number of Distinct Detected Data	2	Number of Non-Detect Data	9
Number of Missing Values	50	Percent Non-Detects	81.82%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.99	Minimum Detected	-0.0101
Maximum Detected	1.5	Maximum Detected	0.405
Mean of Detected	1.245	Mean of Detected	0.198
SD of Detected	0.361	SD of Detected	0.294
Minimum Non-Detect	0.48	Minimum Non-Detect	-0.734
Maximum Non-Detect	0.75	Maximum Non-Detect	-0.288

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	9
Number treated as Detected	2
Single DL Non-Detect Percentage	81.82%

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A	Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A	5% Shapiro Wilk Critical Value	N/A
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.506	Mean	-0.847
SD	0.384	SD	0.538
95% DL/2 (t) UCL	0.716	95% H-Stat (DL/2) UCL	0.724
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	N/A
		SD in Log Scale	N/A
		Mean in Original Scale	N/A
		SD in Original Scale	N/A
		95% t UCL	N/A
		95% Percentile Bootstrap UCL	N/A
		95% BCA Bootstrap UCL	N/A
		95% H-UCL	N/A

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only
k star (bias corrected)	N/A	Data do not follow a Discernable Distribution (0.05)
Theta Star	N/A	
nu star	N/A	

Selenium 0-2' continued

A-D Test Statistic	N/A	**Nonparametric Statistics**	
5% A-D Critical Value	N/A	Kaplan-Meier (KM) Method	
K-S Test Statistic	N/A	Mean	1.036
5% K-S Critical Value	N/A	SD	0.147
Data not Gamma Distributed at 5% Significance Level		SE of Mean	0.0625
		95% KM (t) UCL	1.15
Assuming Gamma Distribution		95% KM (z) UCL	1.139
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	1.388
Minimum	N/A	95% KM (bootstrap t) UCL	1.036
Maximum	N/A	95% KM (BCA) UCL	1.5
Mean	N/A	95% KM (Percentile Bootstrap) UCL	1.5
Median	N/A	95% KM (Chebyshev) UCL	1.309
SD	N/A	97.5% KM (Chebyshev) UCL	1.427
k star	N/A	99% KM (Chebyshev) UCL	1.658
Theta star	N/A		
Nu star	N/A	**Potential UCLs to Use**	
AppChi2	N/A	95% KM (t) UCL	1.15
95% Gamma Approximate UCL (Use when n >= 40)	N/A	95% KM (% Bootstrap) UCL	1.5
95% Adjusted Gamma UCL (Use when n < 40)	N/A		

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Silver 0-2'

General Statistics

Number of Valid Data	11	Number of Detected Data	2
Number of Distinct Detected Data	2	Number of Non-Detect Data	9
Number of Missing Values	50	Percent Non-Detects	81.82%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.79	Minimum Detected	-0.236
Maximum Detected	29.2	Maximum Detected	3.374
Mean of Detected	15	Mean of Detected	1.569
SD of Detected	20.09	SD of Detected	2.553
Minimum Non-Detect	0.46	Minimum Non-Detect	-0.777
Maximum Non-Detect	0.5	Maximum Non-Detect	-0.693

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	9
Number treated as Detected	2
Single DL Non-Detect Percentage	81.82%

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A	Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A	5% Shapiro Wilk Critical Value	N/A
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	2.922	Mean	-0.886
SD	8.717	SD	1.458
95% DL/2 (t) UCL	7.685	95% H-Stat (DL/2) UCL	7.348
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	N/A
		SD in Log Scale	N/A
		Mean in Original Scale	N/A
		SD in Original Scale	N/A
		95% t UCL	N/A
		95% Percentile Bootstrap UCL	N/A
		95% BCA Bootstrap UCL	N/A
		95% H-UCL	N/A

Silver 0-2' continued

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only	
k star (bias corrected)	N/A	Data do not follow a Discernable Distribution (0.05)	
Theta Star	N/A		
nu star	N/A		
A-D Test Statistic	N/A	Nonparametric Statistics	
5% A-D Critical Value	N/A	Kaplan-Meier (KM) Method	
K-S Test Statistic	N/A	Mean	3.373
5% K-S Critical Value	N/A	SD	8.167
Data not Gamma Distributed at 5% Significance Level		SE of Mean	3.483
		95% KM (t) UCL	9.685
Assuming Gamma Distribution		95% KM (z) UCL	9.101
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	22.98
Minimum	N/A	95% KM (bootstrap t) UCL	3.373
Maximum	N/A	95% KM (BCA) UCL	29.2
Mean	N/A	95% KM (Percentile Bootstrap) UCL	29.2
Median	N/A	95% KM (Chebyshev) UCL	18.55
SD	N/A	97.5% KM (Chebyshev) UCL	25.12
k star	N/A	99% KM (Chebyshev) UCL	38.02
Theta star	N/A		
Nu star	N/A	Potential UCLs to Use	
AppChi2	N/A	99% KM (Chebyshev) UCL	38.02
95% Gamma Approximate UCL (Use when n >= 40)	N/A		
95% Adjusted Gamma UCL (Use when n < 40)	N/A		

Warning: Recommended UCL exceeds the maximum observation

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Zinc 0-2'

General Statistics

Number of Valid Observations	51	Number of Distinct Observations	49

Raw Statistics		**Log-transformed Statistics**	
Minimum	36.9	Minimum of Log Data	3.608
Maximum	1442	Maximum of Log Data	7.274
Mean	255.3	Mean of log Data	5.069
Geometric Mean	159	SD of log Data	0.947
Median	154		
SD	298.7		
Std. Error of Mean	41.82		
Coefficient of Variation	1.17		
Skewness	2.388		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.258	Lilliefors Test Statistic	0.101
Lilliefors Critical Value	0.124	Lilliefors Critical Value	0.124
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	325.4	95% H-UCL	336.5
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	410.8
95% Adjusted-CLT UCL (Chen-1995)	339.1	97.5% Chebyshev (MVUE) UCL	482.2
95% Modified-t UCL (Johnson-1978)	327.8	99% Chebyshev (MVUE) UCL	622.5
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	1.137	Data appear Lognormal at 5% Significance Level	
Theta Star	224.6		
MLE of Mean	255.3		
MLE of Standard Deviation	239.5		
nu star	116		
Approximate Chi Square Value (.05)	92.09	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0453	95% CLT UCL	324.1
Adjusted Chi Square Value	91.47	95% Jackknife UCL	325.4
		95% Standard Bootstrap UCL	324.4
Anderson-Darling Test Statistic	1.486	95% Bootstrap-t UCL	350.8
Anderson-Darling 5% Critical Value	0.775	95% Hall's Bootstrap UCL	344.4
Kolmogorov-Smirnov Test Statistic	0.133	95% Percentile Bootstrap UCL	323.6
Kolmogorov-Smirnov 5% Critical Value	0.127	95% BCA Bootstrap UCL	336.3
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	437.6
		97.5% Chebyshev(Mean, Sd) UCL	516.5
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	671.5
95% Approximate Gamma UCL (Use when n >= 40)	321.5		
95% Adjusted Gamma UCL (Use when n < 40)	323.7		
Potential UCL to Use		Use 95% H-UCL	336.5

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Aluminum 0-10'

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	11
Number of Missing Values	50		

Raw Statistics		Log-transformed Statistics	
Minimum	6560	Minimum of Log Data	8.789
Maximum	16500	Maximum of Log Data	9.711
Mean	12771	Mean of log Data	9.407
Geometric Mean	12171	SD of log Data	0.341
Median	14300		
SD	3774		
Std. Error of Mean	1138		
Coefficient of Variation	0.295		
Skewness	-0.696		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.841	Shapiro Wilk Test Statistic	0.817
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	14833	95% H-UCL	15991
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	18642
95% Adjusted-CLT UCL (Chen-1995)	14387	97.5% Chebyshev (MVUE) UCL	21157
95% Modified-t UCL (Johnson-1978)	14793	99% Chebyshev (MVUE) UCL	26098
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	7.743	Data do not follow a Discernable Distribution (0.05)	
Theta Star	1649		
MLE of Mean	12771		
MLE of Standard Deviation	4590		
nu star	170.3		
Approximate Chi Square Value (.05)	141.2	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	14642
Adjusted Chi Square Value	136.8	95% Jackknife UCL	14833
		95% Standard Bootstrap UCL	14540
Anderson-Darling Test Statistic	0.903	95% Bootstrap-t UCL	14604
Anderson-Darling 5% Critical Value	0.729	95% Hall's Bootstrap UCL	14359
Kolmogorov-Smirnov Test Statistic	0.276	95% Percentile Bootstrap UCL	14503
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	14321
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	17730
		97.5% Chebyshev(Mean, Sd) UCL	19876
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	24091
95% Approximate Gamma UCL (Use when n >= 40)	15411		
95% Adjusted Gamma UCL (Use when n < 40)	15898		
Potential UCL to Use		Use 95% Student's-t UCL	14833
		or 95% Modified-t UCL	14793

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Note: For highly negative-skewed data, confidence limits
(e.g., Chen, Johnson, Lognormal, and Gamma) may not be
reliable. Chen's and Johnson's methods provide
adjustments for positvely skewed data sets.

Antimony 0-10'

General Statistics

Number of Valid Data	11	Number of Detected Data	1
Number of Distinct Detected Data	1	Number of Non-Detect Data	10
Number of Missing Values	50	Percent Non-Detects	90.91%

Warning: Only one distinct data value was detected! ProUCL (or any other software) should not be used on such a data set!
It is suggested to use alternative site specific values determined by the Project Team to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Antimony 0-10' was not processed!

Arsenic 0-10'

General Statistics

Number of Valid Data	53	Number of Detected Data	50
Number of Distinct Detected Data	45	Number of Non-Detect Data	3
Number of Missing Values	10	Percent Non-Detects	5.66%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	2.5	Minimum Detected	0.916
Maximum Detected	3090	Maximum Detected	8.036
Mean of Detected	510.8	Mean of Detected	4.92
SD of Detected	760.4	SD of Detected	1.885
Minimum Non-Detect	17	Minimum Non-Detect	2.833
Maximum Non-Detect	20	Maximum Non-Detect	2.996

Note: Data have multiple DLs - Use of KM Method is recommended		Number treated as Non-Detect	14
For all methods (except KM, DL/2, and ROS Methods),		Number treated as Detected	39
Observations < Largest ND are treated as NDs		Single DL Non-Detect Percentage	26.42%

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.694	Shapiro Wilk Test Statistic	0.948
5% Shapiro Wilk Critical Value	0.947	5% Shapiro Wilk Critical Value	0.947
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	482.4	Mean	4.767
SD	747.3	SD	1.936
95% DL/2 (t) UCL	654.3	95% H-Stat (DL/2) UCL	1972
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	316.2	Mean in Log Scale	4.772
SD	921	SD in Log Scale	1.93
95% MLE (t) UCL	528.1	Mean in Original Scale	482.5
95% MLE (Tiku) UCL	532.9	SD in Original Scale	747.3
		95% t UCL	654.4
		95% Percentile Bootstrap UCL	646.7
		95% BCA Bootstrap UCL	686.2
		95% H UCL	1949

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only	
k star (bias corrected)	0.469	Data appear Lognormal at 5% Significance Level	
Theta Star	1089		
nu star	46.92		
A-D Test Statistic	1.011	Nonparametric Statistics	
5% A-D Critical Value	0.818	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.818	Mean	482.5
5% K-S Critical Value	0.133	SD	740.2
Data not Gamma Distributed at 5% Significance Level		SE of Mean	102.7
		95% KM (t) UCL	654.5
Assuming Gamma Distribution		95% KM (z) UCL	651.5
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	654.4
Minimum	0.000001	95% KM (bootstrap t) UCL	697.2
Maximum	3090	95% KM (BCA) UCL	670.7
Mean	481.9	95% KM (Percentile Bootstrap) UCL	661.2
Median	200	95% KM (Chebyshev) UCL	930.2
SD	747.7	97.5% KM (Chebyshev) UCL	1124
k star	0.294	99% KM (Chebyshev) UCL	1504
Theta star	1642		
Nu star	31.11	Potential UCLs to Use	
AppChi2	19.37	97.5% KM (Chebyshev) UCL	1124
95% Gamma Approximate UCL (Use when n >= 40)	774		
95% Adjusted Gamma UCL (Use when n < 40)	784.5		

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Cadmium 0-10'

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	11
Number of Missing Values	50		

Raw Statistics		**Log-transformed Statistics**	
Minimum	0.032	Minimum of Log Data	-3.442
Maximum	45.1	Maximum of Log Data	3.809
Mean	10.2	Mean of log Data	0.212
Geometric Mean	1.236	SD of log Data	2.627
Median	1.5		
SD	16.14		
Std. Error of Mean	4.867		
Coefficient of Variation	1.582		
Skewness	1.495		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.694	Shapiro Wilk Test Statistic	0.927
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	19.02	95% H-UCL	9462
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	73.66
95% Adjusted-CLT UCL (Chen-1995)	20.55	97.5% Chebyshev (MVUE) UCL	98.31
95% Modified-t UCL (Johnson-1978)	19.39	99% Chebyshev (MVUE) UCL	146.7
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.295	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	34.53		
MLE of Mean	10.2		
MLE of Standard Deviation	18.77		
nu star	6.499		
Approximate Chi Square Value (.05)	1.9	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	18.21
Adjusted Chi Square Value	1.523	95% Jackknife UCL	19.02
		95% Standard Bootstrap UCL	17.61
Anderson-Darling Test Statistic	0.5	95% Bootstrap-t UCL	26.34
Anderson-Darling 5% Critical Value	0.816	95% Hall's Bootstrap UCL	18.26
Kolmogorov-Smirnov Test Statistic	0.192	95% Percentile Bootstrap UCL	18.58
Kolmogorov-Smirnov 5% Critical Value	0.275	95% BCA Bootstrap UCL	20.03
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	31.41
		97.5% Chebyshev(Mean, Sd) UCL	40.59
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	58.62
95% Approximate Gamma UCL (Use when n >= 40)	34.89		
95% Adjusted Gamma UCL (Use when n < 40)	43.53		
Potential UCL to Use		Use 95% Adjusted Gamma UCL	43.53

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Copper 0-10'

General Statistics

Number of Valid Data	53	Number of Detected Data	50
Number of Distinct Detected Data	44	Number of Non-Detect Data	3
Number of Missing Values	10	Percent Non-Detects	5.66%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	20.3	Minimum Detected	3.011
Maximum Detected	887	Maximum Detected	6.788
Mean of Detected	98.73	Mean of Detected	4.187
SD of Detected	133.8	SD of Detected	0.805
Minimum Non-Detect	35	Minimum Non-Detect	3.555
Maximum Non-Detect	46	Maximum Non-Detect	3.829

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	25
Number treated as Detected	28
Single DL Non-Detect Percentage	47.17%

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	0.535	Shapiro Wilk Test Statistic	0.914
5% Shapiro Wilk Critical Value	0.947	5% Shapiro Wilk Critical Value	0.947
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	94.25	Mean	4.118
SD	131.2	SD	0.832
95% DL/2 (t) UCL	124.4	95% H-Stat (DL/2) UCL	111.3
Maximum Likelihood Estimate(MLE) Method		Log ROS Method	
Mean	22.75	Mean in Log Scale	4.142
SD	196.4	SD in Log Scale	0.804
95% MLE (t) UCL	67.93	Mean in Original Scale	94.83
95% MLE (Tiku) UCL	77.29	SD in Original Scale	130.9
		95% t UCL	124.9
		95% Percentile Bootstrap UCL	126.4
		95% BCA Bootstrap UCL	137.4
		95% H UCL	110.1

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only	
k star (bias corrected)	1.307	Data do not follow a Discernable Distribution (0.05)	
Theta Star	75.54		
nu star	130.7		
A-D Test Statistic	2.577	**Nonparametric Statistics**	
5% A-D Critical Value	0.77	Kaplan-Meier (KM) Method	
K-S Test Statistic	0.77	Mean	94.9
5% K-S Critical Value	0.128	SD	129.6
Data not Gamma Distributed at 5% Significance Level		SE of Mean	17.99
		95% KM (t) UCL	125
Assuming Gamma Distribution		95% KM (z) UCL	124.5
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	125
Minimum	0.000001	95% KM (bootstrap t) UCL	150.7
Maximum	887	95% KM (BCA) UCL	129.4
Mean	93.57	95% KM (Percentile Bootstrap) UCL	127.9
Median	49	95% KM (Chebyshev) UCL	173.3
SD	131.7	97.5% KM (Chebyshev) UCL	207.2
k star	0.569	99% KM (Chebyshev) UCL	273.9
Theta star	164.6		
Nu star	60.27	**Potential UCLs to Use**	
AppChi2	43.42	95% KM (Chebyshev) UCL	173.3
95% Gamma Approximate UCL (Use when n >= 40)	129.9		
95% Adjusted Gamma UCL (Use when n < 40)	131.1		

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Iron 0-10'

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	11
Number of Missing Values	50		

Raw Statistics		Log-transformed Statistics	
Minimum	16100	Minimum of Log Data	9.687
Maximum	35400	Maximum of Log Data	10.47
Mean	20155	Mean of log Data	9.876
Geometric Mean	19451	SD of log Data	0.262
Median	17500		
SD	6376		
Std. Error of Mean	1923		
Coefficient of Variation	0.316		
Skewness	2.001		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.636	Shapiro Wilk Test Statistic	0.68
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	23639	95% H-UCL	23597
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	27032
95% Adjusted-CLT UCL (Chen-1995)	24556	97.5% Chebyshev (MVUE) UCL	30045
95% Modified-t UCL (Johnson-1978)	23832	99% Chebyshev (MVUE) UCL	35964

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	10.42	Data do not follow a Discernable Distribution (0.05)	
Theta Star	1935		
MLE of Mean	20155		
MLE of Standard Deviation	6245		
nu star	229.1		
Approximate Chi Square Value (.05)	195.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	23317
Adjusted Chi Square Value	190	95% Jackknife UCL	23639
		95% Standard Bootstrap UCL	23223
Anderson-Darling Test Statistic	1.79	95% Bootstrap-t UCL	41788
Anderson-Darling 5% Critical Value	0.729	95% Hall's Bootstrap UCL	43978
Kolmogorov-Smirnov Test Statistic	0.363	95% Percentile Bootstrap UCL	23264
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	24591
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	28535
		97.5% Chebyshev(Mean, Sd) UCL	32161
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	39284
95% Approximate Gamma UCL (Use when n >= 40)	23671		
95% Adjusted Gamma UCL (Use when n < 40)	24309		

Potential UCL to Use			
		Use 95% Student's-t UCL	23639
		or 95% Modified-t UCL	23832

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Lead 0-10'

General Statistics

Number of Valid Observations	53	Number of Distinct Observations	47
Number of Missing Values	10		

Raw Statistics		Log-transformed Statistics	
Minimum	18.5	Minimum of Log Data	2.918
Maximum	2870	Maximum of Log Data	7.962
Mean	163.8	Mean of log Data	4.37
Geometric Mean	79.06	SD of log Data	1.057
Median	67		
SD	392.3		
Std. Error of Mean	53.89		
Coefficient of Variation	2.396		
Skewness	6.556		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.356	Lilliefors Test Statistic	0.127
Lilliefors Critical Value	0.122	Lilliefors Critical Value	0.122
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	254	95% H-UCL	195.9
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	238.9
95% Adjusted-CLT UCL (Chen-1995)	304.2	97.5% Chebyshev (MVUE) UCL	283.4
95% Modified-t UCL (Johnson-1978)	262.1	99% Chebyshev (MVUE) UCL	370.9
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.78	Data do not follow a Discernable Distribution (0.05)	
Theta Star	210		
MLE of Mean	163.8		
MLE of Standard Deviation	185.4		
nu star	82.66		
Approximate Chi Square Value (.05)	62.71	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0455	95% CLT UCL	252.4
Adjusted Chi Square Value	62.22	95% Jackknife UCL	254
		95% Standard Bootstrap UCL	251.9
Anderson-Darling Test Statistic	2.562	95% Bootstrap-t UCL	468.8
Anderson-Darling 5% Critical Value	0.79	95% Hall's Bootstrap UCL	601.5
Kolmogorov-Smirnov Test Statistic	0.148	95% Percentile Bootstrap UCL	265
Kolmogorov-Smirnov 5% Critical Value	0.127	95% BCA Bootstrap UCL	326.6
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	398.7
		97.5% Chebyshev(Mean, Sd) UCL	500.3
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	700
95% Approximate Gamma UCL (Use when n >= 40)	215.9		
95% Adjusted Gamma UCL (Use when n < 40)	217.5		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	398.7

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Manganese 0-10'

General Statistics

Number of Valid Observations	53	Number of Distinct Observations	50
Raw Statistics		**Log-transformed Statistics**	
Minimum	199	Minimum of Log Data	5.293
Maximum	1809	Maximum of Log Data	7.501
Mean	596	Mean of log Data	6.282
Geometric Mean	534.6	SD of log Data	0.456
Median	512		
SD	313.4		
Std. Error of Mean	43.04		
Coefficient of Variation	0.526		
Skewness	1.811		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.219	Lilliefors Test Statistic	0.122
Lilliefors Critical Value	0.122	Lilliefors Critical Value	0.122
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	668.1	95% H-UCL	666.9
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	760.2
95% Adjusted-CLT UCL (Chen-1995)	678.3	97.5% Chebyshev (MVUE) UCL	833
95% Modified-t UCL (Johnson-1978)	669.9	99% Chebyshev (MVUE) UCL	976.2
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	4.499	Data do not follow a Discernable Distribution (0.05)	
Theta Star	132.5		
MLE of Mean	596		
MLE of Standard Deviation	281		
nu star	476.9		
Approximate Chi Square Value (.05)	427.3	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0455	95% CLT UCL	666.8
Adjusted Chi Square Value	426	95% Jackknife UCL	668.1
		95% Standard Bootstrap UCL	664.3
Anderson-Darling Test Statistic	1.217	95% Bootstrap-t UCL	686.3
Anderson-Darling 5% Critical Value	0.754	95% Hall's Bootstrap UCL	686.5
Kolmogorov-Smirnov Test Statistic	0.155	95% Percentile Bootstrap UCL	668.8
Kolmogorov-Smirnov 5% Critical Value	0.122	95% BCA Bootstrap UCL	677.4
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	783.7
		97.5% Chebyshev(Mean, Sd) UCL	864.8
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1024
95% Approximate Gamma UCL (Use when n >= 40)	665.3		
95% Adjusted Gamma UCL (Use when n < 40)	667.3		
Potential UCL to Use		Use 95% Student's-t UCL	668.1
		or 95% Modified-t UCL	669.9

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Nickle 0-10'

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	11
Number of Missing Values	50		

Raw Statistics		Log-transformed Statistics	
Minimum	6	Minimum of Log Data	1.792
Maximum	11.4	Maximum of Log Data	2.434
Mean	7.936	Mean of log Data	2.057
Geometric Mean	7.822	SD of log Data	0.176
Median	7.7		
SD	1.473		
Std. Error of Mean	0.444		
Coefficient of Variation	0.186		
Skewness	1.204		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.923	Shapiro Wilk Test Statistic	0.969
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	8.741	95% H-UCL	8.8
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	9.771
95% Adjusted-CLT UCL (Chen-1995)	8.839	97.5% Chebyshev (MVUE) UCL	10.57
95% Modified-t UCL (Johnson-1978)	8.768	99% Chebyshev (MVUE) UCL	12.13
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	25.23	Data appear Normal at 5% Significance Level	
Theta Star	0.315		
MLE of Mean	7.936		
MLE of Standard Deviation	1.58		
nu star	555.1		
Approximate Chi Square Value (.05)	501.4	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	8.667
Adjusted Chi Square Value	493.1	95% Jackknife UCL	8.741
		95% Standard Bootstrap UCL	8.63
Anderson-Darling Test Statistic	0.222	95% Bootstrap-t UCL	9.093
Anderson-Darling 5% Critical Value	0.729	95% Hall's Bootstrap UCL	9.711
Kolmogorov-Smirnov Test Statistic	0.114	95% Percentile Bootstrap UCL	8.691
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	8.864
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	9.873
		97.5% Chebyshev(Mean, Sd) UCL	10.71
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	12.36
95% Approximate Gamma UCL (Use when n >= 40)	8.785		
95% Adjusted Gamma UCL (Use when n < 40)	8.934		
Potential UCL to Use		Use 95% Student's-t UCL	8.741

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Selenium 0-10'

General Statistics

Number of Valid Data	11	Number of Detected Data	2
Number of Distinct Detected Data	2	Number of Non-Detect Data	9
Number of Missing Values	50	Percent Non-Detects	81.82%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.99	Minimum Detected	-0.0101
Maximum Detected	1.5	Maximum Detected	0.405
Mean of Detected	1.245	Mean of Detected	0.198
SD of Detected	0.361	SD of Detected	0.294
Minimum Non-Detect	0.48	Minimum Non-Detect	-0.734
Maximum Non-Detect	0.75	Maximum Non-Detect	-0.288

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	9
Number treated as Detected	2
Single DL Non-Detect Percentage	81.82%

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A	Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A	5% Shapiro Wilk Critical Value	N/A
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	0.506	Mean	-0.847
SD	0.384	SD	0.538
95% DL/2 (t) UCL	0.716	95% H-Stat (DL/2) UCL	0.724
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	N/A
		SD in Log Scale	N/A
		Mean in Original Scale	N/A
		SD in Original Scale	N/A
		95% t UCL	N/A
		95% Percentile Bootstrap UCL	N/A
		95% BCA Bootstrap UCL	N/A
		95% H-UCL	N/A

Selenium 0-10' continued

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only	
k star (bias corrected)	N/A	Data do not follow a Discernable Distribution (0.05)	
Theta Star	N/A		
nu star	N/A		
A-D Test Statistic	N/A	Nonparametric Statistics	
5% A-D Critical Value	N/A	Kaplan-Meier (KM) Method	
K-S Test Statistic	N/A	Mean	1.036
5% K-S Critical Value	N/A	SD	0.147
Data not Gamma Distributed at 5% Significance Level		SE of Mean	0.0625
		95% KM (t) UCL	1.15
Assuming Gamma Distribution		95% KM (z) UCL	1.139
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	1.388
Minimum	N/A	95% KM (bootstrap t) UCL	N/A
Maximum	N/A	95% KM (BCA) UCL	N/A
Mean	N/A	95% KM (Percentile Bootstrap) UCL	1.5
Median	N/A	95% KM (Chebyshev) UCL	1.309
SD	N/A	97.5% KM (Chebyshev) UCL	1.427
k star	N/A	99% KM (Chebyshev) UCL	1.658
Theta star	N/A		
Nu star	N/A	Potential UCLs to Use	
AppChi2	N/A	95% KM (t) UCL	1.15
95% Gamma Approximate UCL (Use when n >= 40)	N/A	95% KM (% Bootstrap) UCL	1.5
95% Adjusted Gamma UCL (Use when n < 40)	N/A		

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Silver 0-10'

General Statistics

Number of Valid Data	11	Number of Detected Data	2
Number of Distinct Detected Data	2	Number of Non-Detect Data	9
Number of Missing Values	50	Percent Non-Detects	81.82%

Raw Statistics		Log-transformed Statistics	
Minimum Detected	0.79	Minimum Detected	-0.236
Maximum Detected	29.2	Maximum Detected	3.374
Mean of Detected	15	Mean of Detected	1.569
SD of Detected	20.09	SD of Detected	2.553
Minimum Non-Detect	0.46	Minimum Non-Detect	-0.777
Maximum Non-Detect	0.5	Maximum Non-Detect	-0.693

Note: Data have multiple DLs - Use of KM Method is recommended
For all methods (except KM, DL/2, and ROS Methods),
Observations < Largest ND are treated as NDs

Number treated as Non-Detect	9
Number treated as Detected	2
Single DL Non-Detect Percentage	81.82%

Warning: Data set has only 2 Distinct Detected Values.
This may not be adequate enough to compute meaningful and reliable test statistics and estimates.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Unless Data Quality Objectives (DQOs) have been met, it is suggested to collect additional observations.

The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values for bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10 to 15 or more observations for accurate and meaningful results and estimates.

UCL Statistics

Normal Distribution Test with Detected Values Only		Lognormal Distribution Test with Detected Values Only	
Shapiro Wilk Test Statistic	N/A	Shapiro Wilk Test Statistic	N/A
5% Shapiro Wilk Critical Value	N/A	5% Shapiro Wilk Critical Value	N/A
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
DL/2 Substitution Method		DL/2 Substitution Method	
Mean	2.922	Mean	-0.886
SD	8.717	SD	1.458
95% DL/2 (t) UCL	7.685	95% H-Stat (DL/2) UCL	7.348
Maximum Likelihood Estimate(MLE) Method	N/A	Log ROS Method	
MLE method failed to converge properly		Mean in Log Scale	N/A
		SD in Log Scale	N/A
		Mean in Original Scale	N/A
		SD in Original Scale	N/A
		95% t UCL	N/A
		95% Percentile Bootstrap UCL	N/A
		95% BCA Bootstrap UCL	N/A
		95% H-UCL	N/A

Silver 0-10' continued

Gamma Distribution Test with Detected Values Only		Data Distribution Test with Detected Values Only	
k star (bias corrected)	N/A	Data do not follow a Discernable Distribution (0.05)	
Theta Star	N/A		
nu star	N/A		
A-D Test Statistic	N/A	Nonparametric Statistics	
5% A-D Critical Value	N/A	Kaplan-Meier (KM) Method	
K-S Test Statistic	N/A	Mean	3.373
5% K-S Critical Value	N/A	SD	8.167
Data not Gamma Distributed at 5% Significance Level		SE of Mean	3.483
		95% KM (t) UCL	9.685
Assuming Gamma Distribution		95% KM (z) UCL	9.101
Gamma ROS Statistics using Extrapolated Data		95% KM (jackknife) UCL	22.98
Minimum	N/A	95% KM (bootstrap t) UCL	3.373
Maximum	N/A	95% KM (BCA) UCL	29.2
Mean	N/A	95% KM (Percentile Bootstrap) UCL	N/A
Median	N/A	95% KM (Chebyshev) UCL	18.55
SD	N/A	97.5% KM (Chebyshev) UCL	25.12
k star	N/A	99% KM (Chebyshev) UCL	38.02
Theta star	N/A		
Nu star	N/A	Potential UCLs to Use	
AppChi2	N/A	99% KM (Chebyshev) UCL	38.02
95% Gamma Approximate UCL (Use when n >= 40)	N/A		
95% Adjusted Gamma UCL (Use when n < 40)	N/A		

Warning: Recommended UCL exceeds the maximum observation

Note: DL/2 is not a recommended method.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
For additional insight, the user may want to consult a statistician.

Zinc 0-10'

General Statistics

Number of Valid Observations	53	Number of Distinct Observations	51

Raw Statistics		Log-transformed Statistics	
Minimum	36.9	Minimum of Log Data	3.608
Maximum	1442	Maximum of Log Data	7.274
Mean	250	Mean of log Data	5.056
Geometric Mean	156.9	SD of log Data	0.931
Median	152		
SD	294.1		
Std. Error of Mean	40.4		
Coefficient of Variation	1.177		
Skewness	2.453		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.259	Lilliefors Test Statistic	0.09
Lilliefors Critical Value	0.122	Lilliefors Critical Value	0.122
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	317.7	95% H-UCL	323.4
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	393.9
95% Adjusted-CLT UCL (Chen-1995)	331	97.5% Chebyshev (MVUE) UCL	460.7
95% Modified-t UCL (Johnson-1978)	319.9	99% Chebyshev (MVUE) UCL	592.1
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	1.157	Data appear Lognormal at 5% Significance Level	
Theta Star	216.1		
MLE of Mean	250		
MLE of Standard Deviation	232.4		
nu star	122.6		
Approximate Chi Square Value (.05)	98.07	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0455	95% CLT UCL	316.5
Adjusted Chi Square Value	97.45	95% Jackknife UCL	317.7
		95% Standard Bootstrap UCL	314.6
Anderson-Darling Test Statistic	1.619	95% Bootstrap-t UCL	343
Anderson-Darling 5% Critical Value	0.775	95% Hall's Bootstrap UCL	335.7
Kolmogorov-Smirnov Test Statistic	0.133	95% Percentile Bootstrap UCL	319.8
Kolmogorov-Smirnov 5% Critical Value	0.125	95% BCA Bootstrap UCL	331.2
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	426.1
		97.5% Chebyshev(Mean, Sd) UCL	502.3
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	652
95% Approximate Gamma UCL (Use when n >= 40)	312.6		
95% Adjusted Gamma UCL (Use when n < 40)	314.6		
Potential UCL to Use		Use 95% H-UCL	323.4

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

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General UCL Statistics for Full Data Sets

User Selected Options

From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Bullion Mine % As IVBA

General Statistics

Number of Valid Observations	7	Number of Distinct Observations	7

Raw Statistics		Log-transformed Statistics	
Minimum	3.564	Minimum of Log Data	1.271
Maximum	48.11	Maximum of Log Data	3.874
Mean	22.18	Mean of log Data	2.806
Geometric Mean	16.54	SD of log Data	0.927
Median	21.73		
SD	15.4		
Std. Error of Mean	5.82		
Coefficient of Variation	0.694		
Skewness	0.52		

Warning: A sample size of 'n' = 7 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 7 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.963	Shapiro Wilk Test Statistic	0.921
Shapiro Wilk Critical Value	0.803	Shapiro Wilk Critical Value	0.803
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	33.49	95% H-UCL	95.32
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	59.66
95% Adjusted-CLT UCL (Chen-1995)	32.97	97.5% Chebyshev (MVUE) UCL	75.29
95% Modified-t UCL (Johnson-1978)	33.68	99% Chebyshev (MVUE) UCL	106

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	1.154	Data appear Normal at 5% Significance Level	
Theta Star	19.22		
MLE of Mean	22.18		
MLE of Standard Deviation	20.64		
nu star	16.16		
Approximate Chi Square Value (.05)	8.073	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0158	95% CLT UCL	31.75
Adjusted Chi Square Value	6.426	95% Jackknife UCL	33.49
		95% Standard Bootstrap UCL	31.12
Anderson-Darling Test Statistic	0.251	95% Bootstrap-t UCL	35.16
Anderson-Darling 5% Critical Value	0.717	95% Hall's Bootstrap UCL	36.16
Kolmogorov-Smirnov Test Statistic	0.177	95% Percentile Bootstrap UCL	31.36
Kolmogorov-Smirnov 5% Critical Value	0.316	95% BCA Bootstrap UCL	32.03
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	47.54
		97.5% Chebyshev(Mean, Sd) UCL	58.52
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	80.08
95% Approximate Gamma UCL (Use when n >= 40)	44.38		
95% Adjusted Gamma UCL (Use when n < 40)	55.76		

Potential UCL to Use		Use 95% Student's-t UCL	33.49

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

General UCL Statistics for Full Data Sets

User Selected Options

From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Bullion Mine Pb %RBA Predicted based on Drexler and Brattin, 2007

General Statistics

Number of Valid Observations	7	Number of Distinct Observations	7
Raw Statistics		**Log-transformed Statistics**	
Minimum	7.962	Minimum of Log Data	2.075
Maximum	47.33	Maximum of Log Data	3.857
Mean	18.42	Mean of log Data	2.747
Geometric Mean	15.59	SD of log Data	0.581
Median	12.87		
SD	13.44		
Std. Error of Mean	5.079		
Coefficient of Variation	0.729		
Skewness	2.127		

Warning: A sample size of 'n' = 7 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 7 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.738	Shapiro Wilk Test Statistic	0.912
Shapiro Wilk Critical Value	0.803	Shapiro Wilk Critical Value	0.803
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	28.29	95% H-UCL	34.47
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	35.29
95% Adjusted-CLT UCL (Chen-1995)	31.14	97.5% Chebyshev (MVUE) UCL	42.78
95% Modified-t UCL (Johnson-1978)	28.97	99% Chebyshev (MVUE) UCL	57.49
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	1.897	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	9.712		
MLE of Mean	18.42		
MLE of Standard Deviation	13.38		
nu star	26.55		
Approximate Chi Square Value (.05)	15.81	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0158	95% CLT UCL	26.77
Adjusted Chi Square Value	13.37	95% Jackknife UCL	28.29
		95% Standard Bootstrap UCL	26.3
Anderson-Darling Test Statistic	0.521	95% Bootstrap-t UCL	44.33
Anderson-Darling 5% Critical Value	0.712	95% Hall's Bootstrap UCL	58.6
Kolmogorov-Smirnov Test Statistic	0.229	95% Percentile Bootstrap UCL	27.62
Kolmogorov-Smirnov 5% Critical Value	0.314	95% BCA Bootstrap UCL	29.6
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	40.56
		97.5% Chebyshev(Mean, Sd) UCL	50.14
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	68.95
95% Approximate Gamma UCL (Use when n >= 40)	30.95		
95% Adjusted Gamma UCL (Use when n < 40)	36.59		
Potential UCL to Use		Use 95% Approximate Gamma UCL	30.95

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Appendix N
Human Health Exposure and Risk Calculation Summary Tables

Appendix N-1
Risk Estimation for Reasonable Maximum Exposure - Intermittent Worker Scenario - ELCR and HI
Soil (0 to 10 in bgs)
Bullion Mine Remedial Investigation

Analyte Name	Intake Oral (mg/kg*day)	Intake Inhale (ug/m3)	Oral Risk	Inhale Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg*day)	Intake Inhale (mg/m3)	Oral HQ	Inhale HQ	Total HQ	Percent Contribution
Aluminum	2.7E-04	4.6E-05					3.8E-03	6.5E-07	0.00	0.00	0.00	3.0%
Arsenic	2.5E-06	1.3E-06	3.7E-06	5.5E-09	**3.7E-06**	100.0%	3.5E-05	1.8E-08	0.12	0.00	0.12	90.0%
Cadmium	3.1E-08	5.4E-09		9.7E-12	9.7E-12	0.0%	4.4E-07	7.5E-11	0.00	0.00	0.00	0.3%
Copper	1.9E-06	3.2E-07					2.6E-05	4.5E-09	0.00		0.00	0.5%
Iron	3.0E-04	5.1E-05					4.1E-03	7.1E-07	0.01		0.01	4.5%
Manganese	1.1E-05	1.8E-06					1.5E-04	2.6E-08	0.00	0.00	0.00	1.2%
Nickel	1.5E-07	2.5E-08		6.5E-12	6.5E-12	0.0%	2.0E-06	3.5E-10	0.00	0.00	0.00	0.1%
Selenium	2.3E-08	3.9E-09					3.2E-07	5.5E-11	0.00	0.00	0.00	0.0%
Zinc	8.2E-06	1.4E-06					1.1E-04	2.0E-08	0.00		0.00	0.3%
	Sum of Route of Exposure =		**3.7E-06**	**5.5E-09**			**Sum of Route of Exposure =**		**0.13**	**0.0018**		
				Cummulative ELCR =	**4E-06**					**Cummulative HI =**	**0.1**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-2
Risk Estimation for Central Tendency Exposure - Intermittent Worker Scenario - ELCR and HI
Soil (0 to 10 in bgs)
Bullion Mine Remedial Investigation

Analyte Name	Intake Oral (mg/kg*day)	Intake Inhale (ug/m3)	Oral Risk	Inhale Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg*day)	Intake Inhale (mg/m3)	Oral HQ	Inhale HQ	Total HQ	Percent Contribution
Aluminum	1.8E-05	6.2E-06					6.3E-04	2.2E-07	0.00	0.00	0.00	3.1%
Arsenic	1.7E-07	1.7E-07	2.5E-07	7.3E-10	2.5E-07	100.0%	5.8E-06	5.9E-09	0.02	0.00	0.02	89.6%
Cadmium	2.1E-09	7.2E-10		1.3E-12	1.3E-12	0.0%	7.3E-08	2.5E-11	0.00	0.00	0.00	0.3%
Copper	1.3E-07	4.3E-08					4.4E-06	1.5E-09	0.00		0.00	0.5%
Iron	2.0E-05	6.8E-06					6.9E-04	2.4E-07	0.00		0.00	4.5%
Manganese	7.2E-07	2.5E-07					2.5E-05	8.6E-09	0.00	0.00	0.00	1.6%
Nickel	9.7E-09	3.3E-09		8.7E-13	8.7E-13	0.0%	3.4E-07	1.2E-10	0.00	0.00	0.00	0.1%
Selenium	1.5E-09	5.2E-10					5.4E-08	1.8E-11	0.00	0.00	0.00	0.0%
Zinc	5.5E-07	1.9E-07					1.9E-05	6.5E-09	0.00		0.00	0.3%
	Sum of Route of Exposure =		**2.5E-07**	**7.3E-10**			**Sum of Route of Exposure =**		**0.021**	**0.00061**		
				Cummulative ELCR =	**2E-07**					**Cummulative HI =**	**0.02**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-3
Risk Estimation for Reasonable Maximum Exposure - Adult Recreational User Scenario - ELCR and HI
Soil (0 to 10 in bgs)
Bullion Mine Remedial Investigation

Analyte Name	Intake Oral (mg/kg*day)	Intake Inhale (ug/m3)	Oral Risk	Inhale Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg*day)	Intake Inhale (mg/m3)	Oral HQ	Inhale HQ	Total HQ	Percent Contribution
Aluminum	1.1E-03	1.9E-01					3.3E-03	5.6E-04	0.00	0.11	0.12	6.8%
Arsenic	1.0E-05	5.3E-03	1.6E-05	2.3E-05	**3.8E-05**	99.8%	3.0E-05	1.6E-05	0.10	1.03	1.13	66.2%
Cadmium	1.3E-07	2.2E-05		4.0E-08	4.0E-08	0.1%	3.8E-07	6.6E-08	0.00	0.00	0.00	0.2%
Copper	7.9E-06	1.4E-03					2.3E-05	3.9E-06	0.00		0.00	0.0%
Iron	1.2E-03	2.1E-01					3.6E-03	6.2E-04	0.01		0.01	0.3%
Manganese	4.5E-05	7.7E-03					1.3E-04	2.2E-05	0.00	0.45	0.45	26.2%
Nickel	6.1E-07	1.0E-04		2.7E-08	2.7E-08	0.1%	1.8E-06	3.0E-07	0.00	0.00	0.00	0.2%
Selenium	9.5E-08	1.6E-05					2.8E-07	4.8E-08	0.00	0.00	0.00	0.0%
Zinc	3.4E-05	5.9E-03					9.9E-05	1.7E-05	0.00		0.00	0.0%
	Sum of Route of Exposure =		**1.6E-05**	**2.3E-05**			**Sum of Route of Exposure =**		**0.11**	**1.6**		
			Cummulative ELCR =		**4E-05**					**Cummulative HI =**	**2**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-4
Risk Estimation for Central Tendency Exposure - Adult Recreational User Scenario - ELCR and HI
Soil (0 to 10 in bgs)
Bullion Mine Remedial Investigation

Analyte Name	Intake Oral (mg/kg*day)	Intake Inhale (ug/m3)	Oral Risk	Inhale Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg*day)	Intake Inhale (mg/m3)	Oral HQ	Inhale HQ	Total HQ	Percent Contribution
Aluminum	7.6E-05	1.0E-02					4.4E-04	6.1E-05	0.00	0.01	0.01	6.7%
Arsenic	7.0E-07	2.9E-04	1.0E-06	1.2E-06	**2.3E-06**	100%	4.1E-06	1.7E-06	0.01	0.11	0.12	66.6%
Cadmium	8.8E-09	1.2E-06		2.2E-09	2.2E-09	0%	5.1E-08	7.1E-09	0.00	0.00	0.00	0.2%
Copper	5.3E-07	7.3E-05					3.1E-06	4.2E-07	0.00		0.00	0.0%
Iron	8.3E-05	1.1E-02					4.8E-04	6.7E-05	0.00		0.00	0.4%
Manganese	3.0E-06	4.1E-04					1.8E-05	2.4E-06	0.00	0.05	0.05	25.8%
Nickel	4.1E-08	5.6E-06		1.5E-09	1.5E-09	0%	2.4E-07	3.3E-08	0.00	0.00	0.00	0.2%
Selenium	6.4E-09	8.8E-07					3.7E-08	5.2E-09	0.00	0.00	0.00	0.0%
Zinc	2.3E-06	3.2E-04					1.3E-05	1.8E-06	0.00		0.00	0.0%
	Sum of Route of Exposure =		**1.0E-06**	**1.2E-06**			**Sum of Route of Exposure =**		**0.015**	**0.17**		
				Cummulative ELCR =	**2E-06**					**Cummulative HI =**	**0.2**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-5
Risk Estimation for Reasonable Maximum Exposure - Adolescent Recreational User Scenario - ELCR and HI
Soil (0 to 10 in bgs)
Bullion Mine Remedial Investigation

Analyte Name	Intake Oral (mg/kg*day)	Intake Inhale (ug/m3)	Oral Risk	Inhale Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg*day)	Intake Inhale (mg/m3)	Oral HQ	Inhale HQ	Total HQ	Percent Contribution
Aluminum	1.1E-03	4.8E-02					1.3E-02	5.6E-04	0.01	0.11	0.13	6.2%
Arsenic	1.0E-05	1.3E-03	1.5E-05	5.7E-06	**2.1E-05**	99.9%	1.2E-04	1.6E-05	0.39	1.03	1.42	70.0%
Cadmium	1.3E-07	5.6E-06		1.0E-08	1.0E-08	0.0%	1.5E-06	6.6E-08	0.00	0.00	0.00	0.2%
Copper	7.6E-06	3.4E-04					8.8E-05	3.9E-06	0.00		0.00	0.1%
Iron	1.2E-03	5.3E-02					1.4E-02	6.2E-04	0.02		0.02	1.0%
Manganese	4.3E-05	1.9E-03					5.0E-04	2.2E-05	0.00	0.45	0.45	22.3%
Nickel	5.8E-07	2.6E-05		6.8E-09	6.8E-09	0.0%	6.8E-06	3.0E-07	0.00	0.00	0.00	0.2%
Selenium	9.2E-08	4.1E-06					1.1E-06	4.8E-08	0.00	0.00	0.00	0.0%
Zinc	3.3E-05	1.5E-03					3.8E-04	1.7E-05	0.00		0.00	0.1%
	Sum of Route of Exposure =		**1.5E-05**	**5.7E-06**			**Sum of Route of Exposure =**		**0.43**	**1.6**		
			Cummulative ELCR =		**2E-05**					**Cummulative HI =**	**2**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-6
Risk Estimation for Central Tendency Exposure - Adolescent Recreational User Scenario - ELCR and HI
Soil (0 to 10 in bgs)
Bullion Mine Remedial Investigation

Analyte Name	Intake Oral (mg/kg*day)	Intake Inhale (ug/m3)	Oral Risk	Inhale Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg*day)	Intake Inhale (mg/m3)	Oral HQ	Inhale HQ	Total HQ	Percent Contribution
Aluminum	7.3E-05	2.6E-03					1.7E-03	6.1E-05	0.00	0.01	0.01	6.0%
Arsenic	6.7E-07	7.2E-05	1.0E-06	3.1E-07	1.3E-06	100%	1.6E-05	1.7E-06	0.05	0.11	0.16	71.0%
Cadmium	8.5E-09	3.0E-07		5.4E-10	5.4E-10	0%	2.0E-07	7.1E-09	0.00	0.00	0.00	0.2%
Copper	5.1E-07	1.8E-05					1.2E-05	4.2E-07	0.00		0.00	0.1%
Iron	8.0E-05	2.9E-03					1.9E-03	6.7E-05	0.00		0.00	1.2%
Manganese	2.9E-06	1.0E-04					6.8E-05	2.4E-06	0.00	0.05	0.05	21.2%
Nickel	3.9E-08	1.4E-06		3.7E-10	3.7E-10	0%	9.2E-07	3.3E-08	0.00	0.00	0.00	0.2%
Selenium	6.2E-09	2.2E-07					1.4E-07	5.2E-09	0.00	0.00	0.00	0.0%
Zinc	2.2E-06	7.9E-05					5.2E-05	1.8E-06	0.00		0.00	0.1%
	Sum of Route of Exposure =		**1.0E-06**	**3.1E-07**			**Sum of Route of Exposure =**		**0.058**	**0.17**		
			Cummulative ELCR =		**1E-06**					**Cummulative HI =**	**0.2**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-7
Risk Estimation for Reasonable Maximum Exposure - Hypothetical Excavation Worker Scenario - ELCR and HI
Soil (0 to 10 ft bgs)
Bullion Mine Remedial Investigation

Analyte Name	Intake Oral (mg/kg*day)	Intake Inhale (ug/m3)	Oral Risk	Inhale Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg*day)	Intake Inhale (mg/m3)	Oral HQ	Inhale HQ	Total HQ	Percent Contribution
Aluminum	3.6E-04	1.9E-05					3.8E-03	2.0E-07	0.00	0.00	0.00	0.9%
Antimony	3.4E-06	1.8E-07					3.6E-05	1.9E-09	0.09		0.09	20.5%
Arsenic	9.2E-06	1.4E-06	1.4E-05	6.1E-09	**1.4E-05**	100.0%	9.7E-05	1.5E-08	0.32	0.00	0.33	73.1%
Cadmium	1.1E-06	5.5E-08		9.9E-11	9.9E-11	0.0%	1.1E-05	5.8E-10	0.01	0.00	0.01	2.5%
Copper	4.2E-06	2.2E-07					4.5E-05	2.3E-09	0.00		0.00	0.3%
Iron	5.8E-04	3.0E-05					6.1E-03	3.2E-07	0.01		0.01	2.0%
Manganese	1.6E-05	8.5E-07					1.7E-04	9.0E-09	0.00	0.00	0.00	0.3%
Nickel	2.1E-07	1.1E-08		2.9E-12	2.9E-12	0.0%	2.3E-06	1.2E-10	0.00	0.00	0.00	0.0%
Selenium	2.8E-08	1.5E-09					3.0E-07	1.5E-11	0.00	0.00	0.00	0.0%
Silver	7.1E-07	3.7E-08					7.5E-06	3.9E-10	0.00		0.00	0.3%
Zinc	7.9E-06	4.1E-07					8.4E-05	4.3E-09	0.00		0.00	0.1%
	Sum of Route of Exposure =		**1.4E-05**	**6.2E-09**			**Sum of Route of Exposure =**		**0.44**	**0.0013**		
				Cummulative ELCR =	**1E-05**					**Cummulative HI =**	**0.4**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-8
Risk Estimation for Central Tendency Exposure - Hypothetical Excavation Worker Scenario - ELCR and HI
Soil (0 to 10 ft bgs)
Bullion Mine Remedial Investigation

Analyte Name	Intake Oral (mg/kg*day)	Intake Inhale (ug/m3)	Oral Risk	Inhale Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg*day)	Intake Inhale (mg/m3)	Oral HQ	Inhale HQ	Total HQ	Percent Contribution
Aluminum	2.7E-05	1.4E-06					1.9E-03	9.9E-08	0.00	0.00	0.00	0.9%
Antimony	2.6E-07	1.4E-08					1.8E-05	9.5E-10	0.05		0.05	20.5%
Arsenic	6.9E-07	1.1E-07	1.0E-06	4.6E-10	1.0E-06	100.0%	4.9E-05	7.5E-09	0.16	0.00	0.16	73.1%
Cadmium	8.0E-08	4.2E-09		7.5E-12	7.5E-12	0.0%	5.6E-06	2.9E-10	0.01	0.00	0.01	2.5%
Copper	3.2E-07	1.7E-08					2.2E-05	1.2E-09	0.00		0.00	0.3%
Iron	4.4E-05	2.3E-06					3.1E-03	1.6E-07	0.00		0.00	2.0%
Manganese	1.2E-06	6.4E-08					8.6E-05	4.5E-09	0.00	0.00	0.00	0.3%
Nickel	1.6E-08	8.4E-10		2.2E-13	2.2E-13	0.0%	1.1E-06	5.9E-11	0.00	0.00	0.00	0.0%
Selenium	2.1E-09	1.1E-10					1.5E-07	7.7E-12	0.00	0.00	0.00	0.0%
Silver	5.4E-08	2.8E-09					3.8E-06	2.0E-10	0.00		0.00	0.3%
Zinc	6.0E-07	3.1E-08					4.2E-05	2.2E-09	0.00		0.00	0.1%
	Sum of Route of Exposure =		**1.0E-06**	**4.7E-10**			**Sum of Route of Exposure =**		**0.22**	**0.00063**		
				Cummulative ELCR =	**1E-06**					**Cummulative HI =**	**0.2**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-9
Risk Estimation for Reasonable Maximum Exposure - Industrial Worker Scenario - ELCR and HI
Soil (0 to 10 in bgs)
Bullion Mine Remedial Investigation

Analyte Name	Intake Oral (mg/kg*day)	Intake Inhale (ug/m3)	Oral Risk	Inhale Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg*day)	Intake Inhale (mg/m3)	Oral HQ	Inhale HQ	Total HQ	Percent Contribution
Aluminum	2.8E-03	4.8E-04					7.9E-03	1.4E-06	0.01	0.00	0.01	3.0%
Arsenic	2.6E-05	1.3E-05	3.9E-05	5.7E-08	**3.9E-05**	100.0%	7.3E-05	3.7E-08	0.24	0.00	0.24	90.0%
Cadmium	3.3E-07	5.6E-08		1.0E-10	1.0E-10	0.0%	9.2E-07	1.6E-10	0.00	0.00	0.00	0.3%
Copper	2.0E-05	3.4E-06					5.5E-05	9.4E-09	0.00		0.00	0.5%
Iron	3.1E-03	5.3E-04					8.6E-03	1.5E-06	0.01		0.01	4.5%
Manganese	1.1E-04	1.9E-05					3.1E-04	5.4E-08	0.00	0.00	0.00	1.2%
Nickel	1.5E-06	2.6E-07		6.8E-11	6.8E-11	0.0%	4.3E-06	7.3E-10	0.00	0.00	0.00	0.1%
Selenium	2.4E-07	4.1E-08					6.7E-07	1.1E-10	0.00	0.00	0.00	0.0%
Zinc	8.5E-05	1.5E-05					2.4E-04	4.1E-08	0.00		0.00	0.3%
	Sum of Route of Exposure =		**3.9E-05**	**5.7E-08**			**Sum of Route of Exposure =**		**0.27**	**0.0038**		
				Cummulative ELCR =	**4E-05**					**Cummulative HI =**	**0.3**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-10
Risk Estimation for Central Tendency Exposure - Industrial Worker Scenario - ELCR and HI
Soil (0 to 10 in bgs)
Bullion Mine Remedial Investigation

Analyte Name	Intake Oral (mg/kg*day)	Intake Inhale (ug/m3)	Oral Risk	Inhale Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg*day)	Intake Inhale (mg/m3)	Oral HQ	Inhale HQ	Total HQ	Percent Contribution
Aluminum	3.7E-04	1.3E-04					3.9E-03	1.4E-06	0.00	0.00	0.00	3.1%
Arsenic	3.4E-06	3.5E-06	5.1E-06	1.5E-08	**5.1E-06**	100.0%	3.6E-05	3.7E-08	0.12	0.00	0.12	89.6%
Cadmium	4.3E-08	1.5E-08		2.7E-11	2.7E-11	0.0%	4.6E-07	1.6E-10	0.00	0.00	0.00	0.3%
Copper	2.6E-06	8.9E-07					2.8E-05	9.4E-09	0.00		0.00	0.5%
Iron	4.1E-04	1.4E-04					4.3E-03	1.5E-06	0.01		0.01	4.5%
Manganese	1.5E-05	5.1E-06					1.6E-04	5.4E-08	0.00	0.00	0.00	1.6%
Nickel	2.0E-07	6.9E-08		1.8E-11	1.8E-11	0.0%	2.1E-06	7.3E-10	0.00	0.00	0.00	0.1%
Selenium	3.2E-08	1.1E-08					3.3E-07	1.1E-10	0.00	0.00	0.00	0.0%
Zinc	1.1E-05	3.9E-06					1.2E-04	4.1E-08	0.00		0.00	0.3%
	Sum of Route of Exposure =		**5.1E-06**	**1.5E-08**			**Sum of Route of Exposure =**		**0.13**	**0.0038**		
				Cummulative ELCR =	**5E-06**					**Cummulative HI =**	**0.1**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-11
Risk Estimation for Reasonable Maximum Exposure - Adult Recreational User Exposure Scenario - ELCR and HI
Surface Water
Bullion Mine Remedial Investigation

Analyte Name	Surface Water EPC (ug/L)	Intake Oral (mg/kg-day)	Oral Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg-day)	Oral HQ	Total HQ	Percent Contribution
Aluminum	1.0.E+03	1.0E-03				2.4E-03	0.00	0.00	0.5%
Arsenic	3.9.E+01	4.0E-05	6.0E-05	**6.0E-05**	100.0%	9.3E-05	0.31	0.31	67.3%
Cadmium	2.3.E+01	2.3E-05				5.4E-05	0.05	0.05	11.7%
Copper	4.8.E+02	4.9E-04				1.2E-03	0.03	0.03	6.2%
Iron	6.2.E+03	6.4E-03				1.5E-02	0.02	0.02	4.6%
Manganese	1.3.E+03	1.3E-03				3.1E-03	0.02	0.02	4.8%
Nickel	6.0.E+00	6.2E-06				1.4E-05	0.00	0.00	0.2%
Zinc	2.7.E+03	2.7E-03				6.4E-03	0.02	0.02	4.6%
	Sum of Route of Exposure =		**6.0E-05**		**Sum of Route of Exposure =**		**0.46**		
		Cummulative ELCR =		**6E-05**		**Cummulative HI =**		**0.5**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-12
Risk Estimation for Central Tendency Exposure - Adult Recreational User Scenario - ELCR and HI
Surface Water
Bullion Mine Remedial Investigation

Analyte Name	Surface Water EPC (ug/L)	Intake Oral (mg/kg-day)	Oral Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg-day)	Oral HQ	Total HQ	Percent Contribution
Aluminum	1.0.E+03	3.7E-04				8.6E-04	0.00	0.00	0.5%
Arsenic	3.9.E+01	1.4E-05	2.1E-05	**2.1E-05**	100.0%	3.3E-05	0.11	0.11	67.3%
Cadmium	2.3.E+01	8.2E-06				1.9E-05	0.02	0.02	11.7%
Copper	4.8.E+02	1.7E-04				4.0E-04	0.01	0.01	6.2%
Iron	6.2.E+03	2.3E-03				5.3E-03	0.01	0.01	4.6%
Manganese	1.3.E+03	4.7E-04				1.1E-03	0.01	0.01	4.8%
Nickel	6.0.E+00	2.2E-06				5.1E-06	0.00	0.00	0.2%
Zinc	2.7.E+03	9.6E-04				2.2E-03	0.01	0.01	4.6%
	Sum of Route of Exposure =		**2.1E-05**		**Sum of Route of Exposure =**		**0.16**		
			Cummulative ELCR =	**2E-05**			**Cummulative HI =**	**0.2**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-13
Risk Estimation for Reasonable Maximum Exposure - Adult Recreational User Exposure Scenario - ELCR and HI
Springs/Seeps
Bullion Mine Remedial Investigation

Analyte Name	Springs/Seeps EPC (ug/L)	Intake Oral (mg/kg-day)	Oral Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg-day)	Oral HQ	Total HQ	Percent Contribution
Aluminum	3.6.E+04	3.7E-02				8.6E-02	0.09	0.09	1.3%
Antimony	7.7.E+00	8.0E-06				1.9E-05	0.05	0.05	0.7%
Arsenic	2.6.E+02	2.7E-04	4.1E-04	**4.1E-04**	100.0%	6.4E-04	2.12	**2.12**	31.4%
Cadmium	6.2.E+02	6.4E-04				1.5E-03	1.50	**1.50**	22.2%
Copper	1.3.E+04	1.4E-02				3.2E-02	0.80	0.80	11.9%
Iron	2.5.E+05	2.6E-01				6.0E-01	0.85	0.85	12.6%
Manganese	3.5.E+04	3.6E-02				8.4E-02	0.60	0.60	8.9%
Nickel	1.6.E+02	1.6E-04				3.7E-04	0.02	0.02	0.3%
Selenium	8.4.E+00	8.7E-06				2.0E-05	0.00	0.00	0.1%
Silver	1.9.E+00	2.0E-06				4.6E-06	0.00	0.00	0.0%
Thallium	4.4.E-01	4.5E-07				1.1E-06	0.11	0.11	1.6%
Zinc	7.7.E+04	7.9E-02				1.9E-01	0.62	0.62	9.1%
	Sum of Route of Exposure =		**4.1E-04**		**Sum of Route of Exposure =**		**6.8**		
		Cummulative ELCR =		**4E-04**		**Cummulative HI =**		**7**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-14
Risk Estimation for Central Tendency Exposure - Adult Recreational User Scenario - ELCR and HI
Springs/Seeps
Bullion Mine Remedial Investigation

Analyte Name	Springs/Seeps EPC (ug/L)	Intake Oral (mg/kg-day)	Oral Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg-day)	Oral HQ	Total HQ	Percent Contribution
Aluminum	3.6.E+04	1.3E-02				3.0E-02	0.03	0.03	1.3%
Antimony	7.7.E+00	2.8E-06				6.5E-06	0.02	0.02	0.7%
Arsenic	2.6.E+02	9.6E-05	1.4E-04	**1.4E-04**	100.0%	2.2E-04	0.75	0.75	31.4%
Cadmium	6.2.E+02	2.3E-04				5.3E-04	0.53	0.53	22.2%
Copper	1.3.E+04	4.8E-03				1.1E-02	0.28	0.28	11.9%
Iron	2.5.E+05	9.0E-02				2.1E-01	0.30	0.30	12.6%
Manganese	3.5.E+04	1.3E-02				3.0E-02	0.21	0.21	8.9%
Nickel	1.6.E+02	5.6E-05				1.3E-04	0.01	0.01	0.3%
Selenium	8.4.E+00	3.0E-06				7.1E-06	0.00	0.00	0.1%
Silver	1.9.E+00	6.9E-07				1.6E-06	0.00	0.00	0.0%
Thallium	4.4.E-01	1.6E-07				3.7E-07	0.04	0.04	1.6%
Zinc	7.7.E+04	2.8E-02				6.5E-02	0.22	0.22	9.1%
	Sum of Route of Exposure =		**1.4E-04**		**Sum of Route of Exposure =**		**2.4**		
			Cummulative ELCR =	**1E-04**			**Cummulative HI =**	**2**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-15
Risk Estimation for Reasonable Maximum Exposure - Adolescent Recreational User Exposure Scenario - ELCR and HI
Surface Water
Bullion Mine Remedial Investigation

Analyte Name	Surface Water EPC (ug/L)	Intake Oral (mg/kg-day)	Oral Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg-day)	Oral HQ	Total HQ	Percent Contribution
Aluminum	1.0.E+03	3.1E-04				7.2E-04	0.00	0.00	0.5%
Arsenic	3.9.E+01	1.2E-05	1.8E-05	**1.8E-05**	100.0%	2.8E-05	0.09	0.09	67.3%
Cadmium	2.3.E+01	6.9E-06				1.6E-05	0.02	0.02	11.7%
Copper	4.8.E+02	1.5E-04				3.4E-04	0.01	0.01	6.2%
Iron	6.2.E+03	1.9E-03				4.4E-03	0.01	0.01	4.6%
Manganese	1.3.E+03	4.0E-04				9.3E-04	0.01	0.01	4.8%
Nickel	6.0.E+00	1.8E-06				4.3E-06	0.00	0.00	0.2%
Zinc	2.7.E+03	8.1E-04				1.9E-03	0.01	0.01	4.6%
	Sum of Route of Exposure =		**1.8E-05**		**Sum of Route of Exposure =**		**0.14**		
		Cummulative ELCR =		**2E-05**		**Cummulative HI =**		**0.1**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-16
Risk Estimation for Central Tendency Exposure - Adolescent Recreational User Scenario - ELCR and HI
Surface Water
Bullion Mine Remedial Investigation

Analyte Name	Surface Water EPC (ug/L)	Intake Oral (mg/kg-day)	Oral Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg-day)	Oral HQ	Total HQ	Percent Contribution
Aluminum	1.0.E+03	8.8E-05				2.1E-04	0.00	0.00	0.5%
Arsenic	3.9.E+01	3.4E-06	5.1E-06	**5.1E-06**	100.0%	7.9E-06	0.03	0.03	67.3%
Cadmium	2.3.E+01	2.0E-06				4.6E-06	0.00	0.00	11.7%
Copper	4.8.E+02	4.2E-05				9.8E-05	0.00	0.00	6.2%
Iron	6.2.E+03	5.4E-04				1.3E-03	0.00	0.00	4.6%
Manganese	1.3.E+03	1.1E-04				2.7E-04	0.00	0.00	4.8%
Nickel	6.0.E+00	5.2E-07				1.2E-06	0.00	0.00	0.2%
Zinc	2.7.E+03	2.3E-04				5.4E-04	0.00	0.00	4.6%
	Sum of Route of Exposure =		**5.1E-06**		**Sum of Route of Exposure =**		**0.039**		
		Cummulative ELCR =		**5E-06**		**Cummulative HI =**		**0.04**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-17
Risk Estimation for Reasonable Maximum Exposure - Adolescent Recreational User Exposure Scenario - ELCR and HI
Springs/Seeps
Bullion Mine Remedial Investigation

Analyte Name	Springs/Seeps EPC (ug/L)	Intake Oral (mg/kg-day)	Oral Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg-day)	Oral HQ	Total HQ	Percent Contribution
Aluminum	3.6.E+04	1.1E-02				2.5E-02	0.03	0.03	1.3%
Antimony	7.7.E+00	2.4E-06				5.5E-06	0.01	0.01	0.7%
Arsenic	2.6.E+02	8.1E-05	1.2E-04	**1.2E-04**	100.0%	1.9E-04	0.63	0.63	31.4%
Cadmium	6.2.E+02	1.9E-04				4.5E-04	0.45	0.45	22.2%
Copper	1.3.E+04	4.1E-03				9.5E-03	0.24	0.24	11.9%
Iron	2.5.E+05	7.6E-02				1.8E-01	0.25	0.25	12.6%
Manganese	3.5.E+04	1.1E-02				2.5E-02	0.18	0.18	8.9%
Nickel	1.6.E+02	4.7E-05				1.1E-04	0.01	0.01	0.3%
Selenium	8.4.E+00	2.6E-06				6.0E-06	0.00	0.00	0.1%
Silver	1.9.E+00	5.8E-07				1.4E-06	0.00	0.00	0.0%
Thallium	4.4.E-01	1.3E-07				3.1E-07	0.03	0.03	1.6%
Zinc	7.7.E+04	2.4E-02				5.5E-02	0.18	0.18	9.1%
	Sum of Route of Exposure =		**1.2E-04**		**Sum of Route of Exposure =**		**2.0**		
		Cummulative ELCR =		**1E-04**		**Cummulative HI =**		**2**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5

Appendix N-18
Risk Estimation for Central Tendency Exposure - Adolescent Recreational User Scenario - ELCR and HI
Springs/Seeps
Bullion Mine Remedial Investigation

Analyte Name	Springs/Seeps EPC (ug/L)	Intake Oral (mg/kg-day)	Oral Risk	Total ELCR	Percent Contribution	Intake Oral (mg/kg-day)	Oral HQ	Total HQ	Percent Contribution
Aluminum	3.6.E+04	3.1E-03				7.3E-03	0.01	0.01	1.3%
Antimony	7.7.E+00	6.7E-07				1.6E-06	0.00	0.00	0.7%
Arsenic	2.6.E+02	2.3E-05	3.5E-05	**3.5E-05**	100.0%	5.4E-05	0.18	0.18	31.4%
Cadmium	6.2.E+02	5.5E-05				1.3E-04	0.13	0.13	22.2%
Copper	1.3.E+04	1.2E-03				2.7E-03	0.07	0.07	11.9%
Iron	2.5.E+05	2.2E-02				5.1E-02	0.07	0.07	12.6%
Manganese	3.5.E+04	3.1E-03				7.1E-03	0.05	0.05	8.9%
Nickel	1.6.E+02	1.4E-05				3.2E-05	0.00	0.00	0.3%
Selenium	8.4.E+00	7.3E-07				1.7E-06	0.00	0.00	0.1%
Silver	1.9.E+00	1.7E-07				3.9E-07	0.00	0.00	0.0%
Thallium	4.4.E-01	3.8E-08				9.0E-08	0.01	0.01	1.6%
Zinc	7.7.E+04	6.7E-03				1.6E-02	0.05	0.05	9.1%
	Sum of Route of Exposure =		**3.5E-05**		**Sum of Route of Exposure =**		**0.57**		
		Cummulative ELCR =		**3E-05**		**Cummulative HI =**		**0.6**	

Notes:
Bolded values exceed an ELCR=1.5E-6 and an HQ=1.5