RECLAMATION INVESTIGATION REPORT
LILLY/ORPHAN BOY MINE SITE, POWELL COUNTY, MONTANA

CONTENTS

CONTENTS (Continued)

TABLES

TABLES (Continued)

FIGURE

5.0 RECLAMATION INVESTIGATION

As requested by the Montana DEQ/MWCB under Contract 407026 Task Order 33, Tetra Tech completed a reclamation investigation (RI) for the Lilly/Orphan Boy Mine Site. The RI delineates the nature and extent of wastes at the site, estimates the risks these wastes may pose to human health and the environment, and presents data pertinent to potential reclamation.

5.1 INTRODUCTION

The Lilly/Orphan Boy Mine Site is an abandoned hard rock mine listed on the Montana DEQ/MWCB priorities sites list and is located on the western edge of the Continental Divide in Powell County, 7 miles south of Elliston, Montana. The mine is situated at an elevation of 7,000 feet above mean sea level (amsl) and is composed of 1½ acres of land contaminated by metal mining along Telegraph Creek. Characteristics of the site include a headframe and 250-foot shaft; three adits; and three waste rock piles (Waste Rock Piles 1 through 3), including one that spans Telegraph Creek (Waste Rock Pile 3). Maps provided by the Montana Bureau of Mines and Geology (MBMG) showing the surface of the mine and a cross-section of the mine workings are presented in Appendix A.

Water present in the mineshaft and underground adits was originally identified in the Lilly/Orphan Boy Mine Site Reclamation Work Plan (RWP) as groundwater. After additional consideration, it was determined that this term was not accurate for describing the water present in the mine workings. For the purpose of this RI, water in the underground workings will be referred to as mine water.

The Lilly/Orphan Boy Mine Site was originally scored on the Abandoned and Inactive Mines Scoring System (AIMSS) scoresheet with a recreational user value of 5 (moderate)(Montana Department of State Lands/Pioneer 1993). Due to the presence of two cabins within a ½ mile radius of the site and fairly well-traveled forest service roads providing good access to the area, the recreational user value was increased to 10 (high) for risk assessment purposes as part of this RI. A high recreational user value for the Lilly/Orphan Boy Mine Site is more accurate given current conditions at the site and provides a better basis for performing the human health and ecological risk assessments as part of the RI.

The objectives of this RI report are to: (1) describe the field activities conducted at the site for the RI; (2) present observations and data collected during field activities for the RI; (3) interpret the results derived from the field activities as they pertain to the nature and extent of contamination; and (4) summarize the human health and ecological risks associated with the site in its current state.

5.2 FIELD ACTIVITIES

The field activities for the RI, conducted on October 9 and October 27, 2008, focused on collecting sufficient data to support the human health and ecological risk assessments and a detailed analysis of reclamation and land use alternatives. The information required to support the risk assessment, as described in the RWP, includes:

- Determining the magnitude and extent of metal contamination from waste in surface soil
- Evaluating the magnitude and extent of metal contamination in sediment
- Delineating the magnitude of metal contamination in surface and mine water
- Establishing the background concentrations of metals in soil.

The following evaluations were also needed to support the detailed analysis of reclamation alternatives at the Lilly/Orphan Boy Mine Site:

- Developing accurate estimates of the area and volume of solid waste that requires reclamation
- Identifying reclamation requirements for disturbed areas, including liming requirements, soil texture and grain size, fertilizer requirements, percent organic matter, and native plant species
- Identifying and characterizing potential repository sites
- Identifying potential borrow areas for clay, cover soil, and limestone.

The following samples were collected at the Lilly/Orphan Boy Mine Site (summarized in Table 5-1, below): (1) surface soil and waste rock potentially contaminated with metals; (2) background soil; (3) stream sediment; (4) surface water; and (5) groundwater.

The RI field activities for solid-matrix and water sampling efforts are discussed below. Additional detailed information on the specific field sampling procedures used for this RI is provided in the Lilly/Orphan Boy Mine Site RWP, which contains the field sampling plan (FSP).

5.2.1 Solid-Matrix Sampling

The locations for the solid-matrix samples were selected to characterize wastes and the extent of elevated concentrations of metals at the Lilly/Orphan Boy Mine Site. Figure 5-1 shows the locations of the solid matrix samples collected during the field investigation. The sample locations were chosen based on various visible characteristics, including texture, staining, lack of vegetation, and topography.

TABLE 5-1

SOLID-MATRIX AND WATER SAMPLE COLLECTION AND ANALYSIS
LILLY/ORPHAN BOY MINE SITE

Sample Type	Metals	Particle Size	Cation Exchange Capacity	Agronomic Analysis
Surface soil*	17	3	3	3
Background Soil	3	1	1	1
Stream Sediment	5	0	0	0
Total Soil Samples*	**25**	**4**	**4**	**4**
Surface Water	4	0	0	0
Groundwater*	3	0	0	0
Total Soil and Water Samples*	**34**	**4**	**4**	**4**
Duplicate Soil Samples	1	0	0	0
Duplicate Water Samples	1	0	0	0
Total Duplicate Samples	**2**	**0**	**0**	**0**
Total Laboratory Samples	**36**	**4**	**4**	**4**

* Total does not include duplicate sample

Three background soil samples were collected in the vicinity of the waste rock piles where native vegetation was present and there was no evidence of prior disturbance to the landscape. All samples of surface waste and soil were collected with a metal trowel from the 0- to 3-inch depth interval. The trowel was decontaminated between each sample collected. Surface litter and duff were brushed aside from the ground surface before samples were collected in vegetated areas. Six soil samples were collected in and around Waste Rock Pile 1, five samples from in and around Waste Rock Pile 2, four samples in and around Waste Rock Pile 3, and two samples from an old road heading north from Waste Rock Pile 3 on the east side of Telegraph Creek (Figure 5-1).

Stream sediment samples were collected with a trowel from the bottom of the stream channel. Sediment was collected from upstream and downstream of Waste Rock Pile 3, from the pond south of Waste Rock Pile 3, from the exposed portion of the lower adit, and from the north side of Waste Rock Pile 3 (Figure 5-1).

Figure 5-1 Site Map

Twenty-five solid-matrix samples and one duplicate solid-matrix sample were collected from the project area at the Lilly/Orphan Boy Mine Site during the combined site survey and RI field efforts. All solid-matrix samples were analyzed for metals at Energy Laboratories, Helena, MT. Reclamation objectives were met by submitting four solid-matrix samples for analysis of particle size, cation exchange capacity (CEC), and complete agronomic (nutrient) analysis. Physical descriptions of the sample locations and materials sampled were recorded in a field logbook. A photocopy of the project field logbook is contained in Appendix B. Site photographs are presented in Appendix C.

5.2.2 Surface and Mine Water Sampling

Locations for surface water samples were selected to characterize the concentrations of metals in surface water. Two surface water samples were collected from Telegraph Creek, one upgradient and one downgradient of Waste Rock Pile 3. One surface water sample was obtained from a small seep on the north side of Waste Rock Pile 3, east of Telegraph Creek. In addition, a surface water sample was obtained from the discharging portion of the lower adit (Figure 5-1). One duplicate water sample was also collected.

Each of the four surface water samples was collocated with a sediment sample. The water samples were collected by immersing the sample container in the water with the opening pointed upstream and were obtained before sediment samples were collected. All surface water samples were sent to Energy Laboratories, Helena, MT for analysis of total metals, pH, conductivity, hardness, chloride, sulfate, acidity, alkalinity, and nitrate/nitrite.

Mine water was evaluated on October 9, 2008 by collecting water level measurements from each of the previously installed monitoring and injection wells on-site (a total of 5 wells). See section 5.3.5 for explanation of monitoring well installation. Table 5-2 displays the water level measurements obtained at this time. Mine water at the Lilly/Orphan Boy Mine Site was sampled at the time of the site survey on October 27, 2008. Three mine water samples were retrieved from monitoring and injection wells on site: one from the "shaft" monitoring well at the top of Waste Rock Pile 1 south of the headframe, one from the western injection well (referred to as Injection Well #2) at the top of Waste Rock Pile 2, and one from the monitoring well labeled "LOB III" at the base of Waste Rock Pile 2 near the road. A water level measurement was obtained from each well before samples were collected. The water quality parameters pH, specific conductivity, oxidation-reduction potential (ORP), and temperature were also measured before samples were collected. Table 5-2 outlines the measured static water level and water quality parameters.

TABLE 5-2

**MINE WATER FIELD MEASUREMENTS
LILLY/ORPHAN BOY MINE SITE**

Sample	Date	Sample Location	SWL (ft btoc)	pH	SC (µS/cm)	ORP (mV)	Temp. (°C)
N/A	10/9/2008	"Drift" monitoring well	81.16	---	---	---	---
N/A	10/9/2008	"Shaft" monitoring well	74.81	---	---	---	---
LOB-GW-01	10/27/2008	"Shaft" monitoring well	74.85	6.0	62	140	5.5
N/A	10/9/2008	Injection Well #1	48.18	---	---	---	---
N/A	10/9/2008	Injection Well #2	48.25	---	---	---	---
LOB-GW-02	10/27/2008	Injection Well #2	48.34	6.8	318	11	5.3
N/A	10/9/2008	"LOB III" monitoring well	18.93	---	---	---	---
LOB-GW-03	10/27/2008	"LOB III" monitoring well	18.98	3.7	198	388	5.4

Notes:

ft btoc	Feet below top of casing	SWL	Static Water Level
µS/cm	Microsiemens per centimeter	SC	Specific Conductivity
mV	Millivolts	ORP	Oxidation Reduction Potential
°C	Degrees Celsius	Temp.	Temperature
LOB	Lilly/Orphan Boy	N/A	Not applicable
GW	Groundwater		

Before each sample was collected, a disposable bailer was used to remove approximately 2½ gallons of water from each well, and water quality parameters were measured. The analytical requirements of the project did not necessitate use of low-flow sampling such as with a submersible pump. In addition, snow cover at the site prevented direct vehicle access, which limited power supply options for sampling equipment. All samples were submitted to Energy Laboratories, Helena, MT for analysis of total metals and hardness. Mine water samples were not analyzed for nitrate/nitrite, sulfate, and conductivity as specified in the RWP because samples were preserved for analysis of metals (these analyses could not be performed on preserved water samples).

5.3 SITE AND WASTE CHARACTERIZATION

This section describes the characteristics and analytical results for the solid matrix samples, surface water samples, and mine water samples collected for the Lilly/Orphan Boy Mine Site RI. Included in this section is information on the various waste types, the locations and approximate volumes, and other physical properties of the wastes. Characterization of the waste types is used to assess (1) the potential risk to human health and the environment and (2) the specific waste material volumes associated with the reclamation alternatives for this site.

To help plan reclamation actions, the Environmental Protection Agency (EPA) Region 9 has developed risk-based regional screening levels (RSLs) for metals in soil. In addition, the DEQ/MWCB has developed a conservative set of risk-based guidelines that are calculated for different contaminants using a recreational visitor exposure scenario. For the purpose of this RI, the analytical data presented in this section are compared with DEQ/MWCB risk-based recreational cleanup levels for metals at sites with maximum use (50-day gold panner/rock hound scenario), and with screening levels for aquatic life in surface water and sediment, deer ingestion, and plant phytoxicity. The risk characterization and methodology are described in detail in section 5.5 (Human Health Risk Assessment) and 5.6 (Ecological Risk Assessment).

5.3.1 Background Soil

Three soil samples were collected to evaluate the ambient (background) concentration of metals in surface soils near the Lilly/Orphan Boy Mine Site. Soil samples LOB-BG-01, LOB-BG-02, and LOB-BG-03 were collected beyond the visually identified edges of Waste Rock Pile 1 to the southeast, east, and northeast. The sample collection locations are shown on Figure 5-1. The background soil samples were analyzed for metals at Energy Laboratories, Helena, MT. Table 5-3 lists the concentrations of metals detected in the background samples. Complete analytical results are contained in Appendix D and Appendix E contains the data validation report.

The Montana DEQ established soil arsenic action level of 40 milligrams per kilogram (mg/kg) was not used as a screening criterion for arsenic at the Lilly/Orphan Boy Mine Site since background arsenic levels are typically higher than 40 mg/kg in areas supporting mining operations (the parent rock, and soils derived from it, naturally have higher concentrations). The recreational cleanup guideline established by the DEQ/MWCB of 323 mg/kg is a more appropriate screening level for arsenic at the Lilly/Orphan Boy Mine Site. All metals analyzed for in the background soil samples were compared to DEQ/MWCB recreational cleanup guidelines.

All detected metals in the background soil samples were below DEQ/MWCB recreational cleanup guidelines. The mean background concentration was calculated for each of the metals as well; these calculated means were also below recreational cleanup guidelines (Table 5-3). All of the solid waste (soil) samples collected at the Lilly/Orphan Boy Mine Site exceed the mean background concentration for arsenic and lead. In addition, the concentrations of antimony, cadmium, copper, manganese, and zinc in several of the samples also exceed mean background concentrations. A more detailed discussion of solid waste samples is presented in section 5.3.2.

TABLE 5-3

BACKGROUND CONCENTRATIONS OF METALS IN SOIL (mg/kg)
LILLY/ORPHAN BOY MINE SITE

Sample ID	Description	Antimony	Arsenic	Barium	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Nickel	Silver	Zinc
LOB-BG-01	Southeast of WR pile 1	5UJ	21	94	2	7	45	9,990	35	759	<0.5	9	<5	120
LOB-BG-02	East of WR pile 1	5UJ	159	79	2	8	47	15,800	228	1,240	<0.5	6	<5	205
LOB-BG-03	Northeast of WR pile 1	5UJ	57	74	<1	9	26	16,000	42	259	<0.5	8	<5	160
Mean Background Concentrations		<5	79	82.3	2	8	39.3	13,930	101.7	752.7	<0.5	7.7	<5	161.7
Recreational Cleanup Guidelines [a]		586	323	1.03E+05	1,750	1.47E+06	54,200	N/A	2,200	7,330	440	29,300	N/A	4.40E+05

Note:

[a] Recreational cleanup guidelines based on 50-day gold panner/rock hound exposure scenario (Tetra Tech 1996).
< Less than
mg/kg Milligrams per kilogram
N/A Not applicable
UJ Analyte was not detected, but is considered estimated for quality control reasons.
WR Waste rock

The levels of arsenic (159 mg/kg) and lead (228 mg/kg) in background soil sample LOB-BG-02 are considerably higher than in the other two background soil samples. Based on these results, LOB-BG-02 may not be a valid background sample. Although it was collected in an undisturbed location among native vegetation, it is possible the area was impacted by wind deposition of metal laden dust from the Lilly/Orphan Boy waste piles or from other nearby former mining sites. In addition, two former exploratory shafts and an ore dump were located uphill (east) from where the LOB-BG-02 was collected (see historic mine surface map in Appendix A) at one point in time. Migration of waste material from these locations could have affected the arsenic and lead concentrations at the site where LOB-BG-02 was collected.

5.3.2 Site Solid Waste Materials

The area at the Lilly/Orphan Boy Mine Site includes three waste rock piles. The largest of these, referred to as Waste Rock Pile 1, is situated on the eastern end and topographically highest portion of the Lilly/Orphan Boy claim. A timber headframe spanning a 250-foot-deep shaft is present at the top of Waste Rock Pile 1; a protective red metal grate covers the shaft opening. A chain-link fence surrounds the headframe, shaft, and a collapsed area where a drift adit has subsided. A small wood cabin sits south of the headframe. There are two smaller waste rock piles (Waste Rock Piles 2 and 3) that lie west of, and below, Waste Rock Pile 1. Waste Rock Pile 3 is situated perpendicular to Telegraph Creek and is bisected by the creek. Water has collected on the south side of Waste Rock Pile 3 and has created a small pond. No vegetation grows on the waste rock piles, and each is stained reddish-yellow in places. Three adits exist at the site; the lower adit stems from the main shaft and runs west below Waste Rock Pile 2 before it becomes exposed a short distance above Telegraph Creek. This is the only adit on-site that is visible at the surface; the other 2 adits are underground. Photographs of the site area are contained in Appendix C.

Solid waste (soil) samples LOB-SS-01 through LOB-SS-17 were collected from the site and included samples of waste rock from each of the piles, soil samples from the fringes of the waste rock piles, and samples from former roads within and adjacent to the site. One soil duplicate sample was collected at sampling location LOB-SS-10. All soil samples were collected from a 0-3 inch depth interval. Figure 5-1 shows the locations of the surface soil samples. Table 5-4 presents the concentrations of metals in solid waste samples at the site, with the exception of those metals that had low detections (chromium and nickel) or were not detected (mercury). A complete set of sample data is presented in Appendix D and a data validation report is included in Appendix E.

TABLE 5-4

CONCENTRATIONS OF METALS IN SOLID WASTE SAMPLES (mg/kg)
LILLY/ORPHAN BOY MINE SITE

Sample ID	Sample Type	Antimony	Arsenic	Barium	Cadmium	Copper	Iron	Lead	Manganese	Silver	Zinc
LOB-SS-01	Soil, S WR pile 1	5UJ	140	68	<1	29	11,900	117	579	<5	123
LOB-SS-02	Waste, WR pile 1	177	**6,420**	70	6	116	33,300	**7,840**	764	43	322
LOB-SS-03	Waste, WR pile 1	**972**	**36,600**	17	15	267	66,900	**43,800**	13	302	1,250
LOB-SS-04	Soil, SW WR pile 1	14	**444**	44	3	45	14,200	501	838	<5	241
LOB-SS-05	Soil, E WR pile 2	21	**1,370**	78	3	60	15,800	1,190	234	<5	143
LOB-SS-06	Soil, NE WR pile 1	5UJ	188	46	2	29	11,800	244	389	<5	186
LOB-SS-07	Soil, NW WR pile 1	21	**11,600**	36	3	48	28,600	**2,300**	164	8	218
LOB-SS-08	Soil, N WR pile 2	5UJ	**793**	31	3	61	15,200	608	202	<5	254
LOB-SS-09	Waste, WR pile 2	95	**8,180**	31	4	91	19,300	**19,900**	9	97	220
LOB-SS-10	Soil, S WR pile 2	23	**734**	40	<1	75	12,400	909	247	<5	137
LOB-SS-10 (Dup)	Same as above	13	**833**	35	2	63	12,300	902	137	<5	130
LOB-SS-11	Soil, W WR pile 2	19	**6,640**	33	1	58	27,000	622	624	<5	172
LOB-SS-12	Waste, WR pile 3	30	**5,060**	43	4	107	34,900	**6,040**	22	6	386
LOB-SS-13	Waste, WR pile 3	456	**74,100**	7	35	94	171,000	**7,440**	<5	66	453
LOB-SS-14	Soil, S WR pile 3	31	**5,120**	81	7	103	24,100	1,610	277	7	757
LOB-SS-15	Soil, E WR pile 3	15	**31,200**	54	3	38	185,000	1,320	44	<5	129
LOB-SS-16	Soil, Road by T.C.	12	**725**	34	<1	28	9,910	534	197	<5	142
LOB-SS-17	Soil, Road by T.C.	<5	**641**	24	1	78	16,800	834	130	<5	326
Recreational Cleanup Guideline		586	323	1.03E+05	1,750	54,200	N/A	2,200	7,330	N/A	440,000

Notes:
Bold values exceed recreational cleanup guidelines based on the 50-day gold panner/rock hound exposure scenario (Tetra Tech 1996).

<	Less than
Dup	Duplicate sample
mg/kg	Milligrams per kilogram
N/A	Not applicable
T.C.	Telegraph Creek
UJ	Analyte was not detected, but is considered estimated for quality control reasons.
WR	Waste rock
N, NE, NW, E, S, W, SW	North, Northeast, Northwest, East, South, West, Southwest

Metal concentrations in the soil samples were screened against the DEQ/MWCB risk-based recreational cleanup guidelines for the 50-day gold panner/rock hound scenario to identify preliminary contaminants of concern (COC). Samples with metal concentrations exceeding recreational cleanup guidelines are identified in Table 5-4 in bold text. Those metals identified as preliminary COC were incorporated into the human health risk assessment calculations to determine which were the most hazardous and could be considered COC for the Lilly/Orphan Boy Mine Site. The human health risk assessment is presented in section 5.5.

Fifteen solid matrix samples collected at the Lilly/Orphan Boy Mine Site contained arsenic at concentrations (444 to 74,100 mg/kg) above the recreational cleanup guideline of 323 mg/kg for the 50-day gold panner/rock hound exposure scenario. Six samples contained lead above the recreational cleanup guideline of 2,200 mg/kg, and one sample (LOB-SS-03) contained antimony above the recreational cleanup guideline of 586 mg/kg. All other concentrations of metals in soil were below recreational cleanup guidelines. Comparisons of the background soil metal concentrations to the metal concentrations in soil samples from the study area indicate that antimony, arsenic, iron, lead, manganese, and zinc are elevated at the site. The elevated levels of antimony and iron corresponded with the higher concentrations of arsenic and lead; any potential reclamation or remediation efforts that clean up arsenic- and lead-contaminated soils would also clean up areas contaminated by antimony and iron.

The samples with the highest concentrations of arsenic and lead were collected directly from the three waste rock piles (LOB-SS-02, LOB-SS-03, LOB-SS-09, LOB-SS-12, and LOB-SS-13). The volume of these three waste rock piles is estimated at 1,630 cubic yards (yd^3) for Waste Rock Pile 1,490 yd^3 for Waste Rock Pile 2, and 310 yd^3 for Waste Rock Pile 3, as shown in Table 5-5. The volume of waste rock was calculated from elevation measurements collected during the site survey on October 27, 2008. A significant portion of Waste Rock Pile 1 appears to be native material that was used to construct a working bench area around the upper mine shaft and may be less contaminated than the waste rock removed from the mine shaft itself. Soil samples collected on the perimeter of the three waste rock piles also demonstrate elevated concentrations of arsenic and lead, particularly on the west-northwest side of Waste Rock Pile 1 where surface runoff of waste material is moving downhill toward Telegraph Creek (LOB-SS-07).

TABLE 5-5

WASTE ROCK VOLUME SUMMARY
LILLY/ORPHAN BOY MINE SITE

Waste Rock Pile	Volume(yd^3)
Waste Rock Pile 1	1,630
Waste Rock Pile 2	1,490
Waste Rock Pile 3	310
Total	**3,430**

Notes:
yd^3 cubic yards

5.3.3 Stream Sediment

The objectives of sampling stream sediment were to characterize the extent of metals contamination in stream sediment associated with surface water at the Lilly/Orphan Boy Mine Site and to assess the potential for downstream migration of metals in sediments from the site. Five stream sediment samples (LOB-SD-01 through LOB-SD-05) were collected during the RI. Sediment samples from Telegraph Creek, LOB-SD-01 and LOB-SD-03, were collected upgradient and downgradient of Waste Rock Pile 3, respectively. Sample LOB-SD-02 was collected from the exposed portion of the discharging lower adit. One sediment sample (LOB-SD-04) was obtained from the seep on the north side of Waste Rock Pile 3, east of Telegraph Creek, and another sediment sample (LOB-SD-05) was collected from the pond upstream of Waste Rock Pile 3. Sediment in Telegraph Creek was light brown to tan and consisted of coarse sand, organic matter, and silts. Sediment collected from the pond behind Waste Rock Pile 3 was rich in organic matter and dark brown, whereas sediment collected from the exposed portion of the lower adit and adjacent to Waste Rock Pile 3 was notably orange and presumably covered with algae and microbial biofilm. Figure 5-1 depicts the sediment sampling locations.

All sediment samples were analyzed for total metals at Energy Laboratories, Helena, MT. Table 5-6 presents the concentrations of metals in stream sediment samples, with the exception of those metals that were not detected (chromium, mercury, nickel, and silver). Complete analytical results are contained in Appendix D. Appendix E contains the data validation report. The analytical results from the sediment samples were screened against the Washington State Department of Ecology freshwater sediment quality values (Probable Apparent Effects Thresholds [PAET]) and DEQ/MWCB recreational cleanup guidelines to determine metals of potential concern in sediment. Washington State PAET values were used since the

TABLE 5-6

CONCENTRATIONS OF METALS IN SEDIMENT (mg/kg)
LILLY/ORPHAN BOY MINE SITE

Sample	Description	Antimony	Arsenic	Barium	Cadmium	Copper	Iron	Lead	Manganese	Zinc
LOB-SD-01	T.C. Upgradient	5UJ	**327**	80	1	9	24,600	34	**1,670**	362
LOB-SD-02	Adit sediment	11	**19,300**	6	4	27	113,000	**298**	29	140
LOB-SD-03	T.C. Downgradient	<5	**294**	48	**21**	52	11,300	50	**5,930**	**823**
LOB-SD-04	N side WR pile 3	31	**24,400**	<5	**13**	42	106,000	**562**	55	**554**
LOB-SD-05	Pond sediment	<5	**160**	47	6	14	12,300	13	768	**967**
Washington Freshwater Sediment PAET		35	19	N/A	7.6	340	N/A	240	1,400	500
Recreational Cleanup Guideline		586	323	1.03E+05	1,750	54,200	N/A	2,200	7,330	440,000

Note:

Bold values exceed Washington State Freshwater Sediment Quality Probable Apparent Effects Thresholds (PAET) screening values (Washington State Department of Ecology 1997).

Bold/shaded values exceed both Washington State PAET sediment values and recreational cleanup guidelines based on the 50-day gold panner/rock hound exposure scenario (Tetra Tech 1996).

< Less than

mg/kg Milligrams per kilogram

N/A Not applicable

UJ Analyte was not detected, but is considered estimated for quality control reasons.

state of Montana does not have established sediment quality standards. Samples with metal concentrations exceeding PAET values are identified in Table 5-6 in bold text; concentrations that exceed both Washington State PAET and recreational cleanup guidelines are shown in a gray shaded box in bold text. The Washington State PAET sediment values are shown for reference only. Sediment samples were treated like soil samples for the risk assessment purposes of this RI. The human health (recreational) risk assessment is presented in section 5.5.

All five sediment samples contained arsenic at concentrations above the Washington Freshwater Sediment PAET screening value of 19 mg/kg. Three of the five sediment samples had arsenic concentrations exceeding the recreational cleanup guideline of 323 mg/kg. Two samples contained cadmium, lead, and manganese at concentrations greater than the PAET sediment screening values. Zinc was found in three sediment samples above the PAET screening value of 500 mg/kg. The downstream sediment sample (LOB-SD-03) had greater concentrations of cadmium, copper, lead, manganese, and zinc than the upstream sediment sample (LOB-SD-01), but lower concentrations of arsenic and iron. The metals in sediment were greatest in the samples from the adit (LOB-SD-02) and near Waste Rock Pile 3 (LOB-SD-04). Metal concentrations in sediment were elevated in the adit due to the precipitation of arsenic and lead as a result of iron oxidation. Metals migrating from Waste Rock Pile 3 into the adjacent sediment accounts for the elevated concentrations in sample LOB-SD-04.

Appendix F contains a copy of the table "Probable Apparent Effects Thresholds (PAETs) for *Hyalella azteca* and Microtox®" from the Washington State Department of Ecology report (Table 7a)(1997). This table presents screening levels (PAETs) for metals in sediment for both *Hyalella azteca* and Microtox sp. based on bioassay studies conducted by the Washington Department of Ecology. For this RI, the most conservative value between the two listed for *Hyalella azteca* and Microtox sp. was chosen as the sediment screening level (for example, arsenic). If only one of the two species had a metal screening value published (i.e. copper), then this became the default screening criteria.

5.3.4 Surface Water

Surface water at the Lilly/Orphan Boy Mine Site exists in Telegraph Creek, the pond behind Waste Rock Pile 3, the exposed portion of the lower adit, and water discharging from the lower adit onto the ground around Waste Rock Pile 3 (Figure 5-1). A small stream of surface water is present to the east of Telegraph Creek on the north side of Waste Rock Pile 3. It is presumed this water is coming from the pond behind Waste Rock Pile 3 or from the discharging lower adit and is seeping through the waste rock pile.

Four surface water samples were obtained from the Lilly/Orphan Boy Mine Site during the RI field work. Surface water samples LOB-SW-01 and LOB-SW-03 were collected from Telegraph Creek upgradient and downgradient of Waste Rock Pile 3. One sample was obtained from the exposed portion of the adit (LOB-SW-02) and the fourth surface water sample (LOB-SW-04) was collected from the north side of Waste Rock Pile 3, east of Telegraph Creek. All of the surface water sampling locations were collocated with sediment samples (with the exception of LOB-SD-05; only a sediment sample was collected from that location).

Surface water samples were submitted to Energy Laboratories in Helena, MT for total metals analysis. Analytical results from the surface water samples were screened against the DEQ/MWCB recreational cleanup guidelines. The results were also compared to Montana state water quality standards for aquatic life and human health (DEQ-7 Numeric Water Quality Standards, February 2008). The ecological risk assessment (presented in section 5.6) evaluates metal concentrations in surface water using the DEQ-7 acute aquatic life standards to determine COC for surface water at the Lilly/Orphan Boy Mine Site. Table 5-7 presents the concentrations of detected metals in surface water samples as compared to DEQ/MWCB risk-based recreational cleanup guidelines and Table 5-8 presents concentrations of detected metals as compared to the DEQ-7 water quality standards. Complete analytical results are contained in Appendix D and a data validation report is included in Appendix E. Figure 5-1 shows the sampling locations.

Arsenic and manganese in samples LOB-SW-02 and LOB-SW-04 exceeded the 50-day gold panner/rock hound recreational cleanup guidelines for surface water. All other metal concentrations in surface water were below recreational cleanup guidelines. Surface water sample LOB-SW-02 was collected from the lower adit and was a primary source sample. Concentrations of arsenic, cadmium, iron, manganese, and zinc were greater in the Telegraph Creek downstream sample (LOB-SW-03) than in the Telegraph Creek upstream sample (LOB-SW-01).

TABLE 5-7

CONCENTRATIONS OF METALS IN SURFACE WATER COMPARED TO RECREATIONAL CLEANUP GUIDELINES (µg/L) LILLY/ORPHAN BOY MINE SITE

Sample	Description	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Nickel	Zinc
LOB-SW-01	T.C. Upgradient	<5	<1	<10	370	<10	180	<10	30
LOB-SW-02	Adit Discharge/Flow	**874**	163	40	29,600	70	**5,640**	30	17,700
LOB-SW-03	T.C. Downgradient	14	3	<10	610	<10	740	<10	610
LOB-SW-04	N side WR pile 3	**854**	67	100	8,280	50	**5,250**	20	9,310
Recreational Cleanup Guidelines		153	256	18,900	N/A	220	2,560	10,200	153,000

Notes:
Bold values exceed recreational cleanup guidelines based on the 50-day gold panner/rock hound ingestion of surface or adit water (noncarcinogenic basis) exposure scenario (Tetra Tech 1996).
< Less than
N/A Not applicable
T.C. Telegraph Creek
µg/L Micrograms per liter
WR Waste rock

Table 5-8 (below) compares the metal concentrations in surface water at the Lilly/Orphan Boy Mine Site to DEQ-7 acute aquatic life water quality standards. Concentrations exceeding acute criteria are shown in bold text. The DEQ-7 chronic aquatic life and human health water quality standards displayed in Table 5-8 have been provided for reference purposes only. Chronic aquatic life standards would be applicable if multiple sampling events had occurred such that enough data had been generated to assess hydrologic conditions and calculate chronic concentrations over time. The human health standards are provided to compare metal concentrations at the site with levels considered safe for human consumption (although that is not a current scenario at the site).

Surface water samples from the adit (LOB-SW-02) and adjacent to Waste Rock Pile 3 (LOB-SW-04) exceed acute aquatic life standards for arsenic, cadmium, copper, lead, and zinc. In addition, the downstream Telegraph Creek sample, LOB-SW-03, exceeds acute aquatic life standards for cadmium and zinc. Based on these results it appears as if the adit discharge is adversely impacting the water quality of Telegraph Creek.

TABLE 5-8

CONCENTRATIONS OF METALS IN SURFACE WATER COMPARED TO DEQ-7 WATER QUALITY STANDARDS (µg/L) LILLY/ORPHAN BOY MINE SITE

Sample	Description	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Nickel	Zinc
LOB-SW-01	T.C. Upgradient	<5	<1	<10	370	<10	180	<10	30
LOB-SW-02	Adit Discharge/Flow	**874**	**163**	**40**	29,600	**70**	5,640	30	**17,700**
LOB-SW-03	T.C. Downgradient	14	**3**	<10	610	<10	740	<10	**610**
LOB-SW-04	N side WR pile 3	**854**	**67**	**100**	8,280	**50**	5,250	20	**9,310**
DEQ-7 Acute Aquatic Life Standard		340	*0.52*	*3.79*	N/A	*13.98*	N/A	*145*	*37*
DEQ-7 Chronic Aquatic Life Standard [a]		150	*0.097*	*2.85*	1,000	*0.545*	N/A	*16.1*	*37*
DEQ-7 Human Health Standard [a]		10	5	1,300	300[b]	15	50[b]	100	2,000

Notes:
Bold values exceed DEQ-7 acute aquatic life numeric water quality standards (DEQ 2008).
Italic water quality standards based on 25 milligrams per liter (mg/L) hardness.
a DEQ-7 chronic aquatic life and human health standards are provided for reference.
b Secondary Maximum contaminant levels (MCL) have been established for iron and manganese (300 and 50 µg/L), which are based on aesthetic properties such as taste, odor, and staining.
< Less than
N/A Not applicable
T.C. Telegraph Creek
µg/L Micrograms per liter
WR Waste rock

5.3.5 Mine Water

Mine water is present at the Lilly/Orphan Boy Mine Site and consists of water collected in the mine workings such as the main shaft and adits. The lower adit is partially collapsed. Mine water seeps through the collapsed material and discharges above Telegraph Creek.

Four mine water samples were obtained from the Lilly/Orphan Boy Mine Site during the RI field activities, including one duplicate water sample (LOB-GW-04). Mine water sample LOB-GW-01 was collected from the "shaft" monitoring well, LOB-GW-02 was collected from Injection Well #2, and LOB-GW-03 and LOB-GW-04 were collected from monitoring well "LOB III". Sampling locations are shown on Figure 5-1.

Mine water samples were analyzed for total metals by Energy Laboratories in Helena, MT. Analytical results from the surface water samples were screened against the DEQ/MWCB recreational cleanup guidelines. Similar to surface water, the results were also compared to Montana state water quality standards for aquatic life and human health (DEQ 2008). Table 5-9 presents the concentrations of detected metals in mine water samples as compared to DEQ/MWCB risk-based recreational cleanup guidelines and Table 5-10 presents concentrations of detected metals as compared to the DEQ-7 water quality standards. Sample LOB-SW-02 is included in the table because it is hydrologically connected to the other samples. Metals that were not detected in mine water samples (antimony, barium, chromium, mercury, and silver) are not displayed in the tables. Complete analytical results are contained in Appendix D. Appendix E contains the data validation report.

Arsenic exceeded the recreational cleanup guideline of 153 micrograms per liter (µg/L) in the mine water sample retrieved from Injection Well #2 (LOB-GW-02). Manganese exceeded the recreational cleanup guideline of 2,560 µg/L in the samples collected from monitoring well "LOB III" (LOB-GW-04 is a duplicate sample of LOB-GW-03). These concentrations were lower than the arsenic and manganese concentrations detected in the adit surface water sample, LOB-SW-02. The monitoring and injection well locations from which mine water was retrieved are upgradient from where the adit surface water sample was collected (see Figure 5-1). All other metal concentrations in surface water were below recreational cleanup guidelines.

TABLE 5-9

CONCENTRATIONS OF METALS IN MINE WATER COMPARED TO RECREATIONAL CLEANUP GUIDELINES (µg/L) LILLY/ORPHAN BOY MINE SITE

Sample	Description	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Nickel	Zinc
LOB-GW-01	"Shaft" Well	131	1	<10	1,680	<10	2,050	<10	780
LOB-GW-02	Injection Well #2	**236**	<1	<10	52,500	<10	1,640	<10	20
LOB-GW-03	"LOB III" Well	138	65	140	13,600	80	**3,300**	10	9,450
LOB-GW-04	LOB-GW-03 (Dup)	95	66	150	13,400	80	**3,380**	10	9,570
LOB-SW-02	Adit Discharge/Flow	**874**	163	40	29,600	70	**5,640**	30	17,700
Recreational Cleanup Guidelines		153	256	18,900	N/A	220	2,560	10,200	153,000

Notes:
Bold values exceed recreational cleanup guidelines based on the 50-day gold panner/rock hound ingestion of surface or adit water (noncarcinogenic basis) exposure scenario (Tetra Tech 1996).
Dup Duplicate
< Less than
N/A Not applicable
T.C. Telegraph Creek
µg/L Micrograms per liter
WR Waste rock

Table 5-10 (below) compares the metal concentrations in mine water at the Lilly/Orphan Boy Mine Site to DEQ-7 acute aquatic life water quality standards. Concentrations exceeding acute criteria are shown in bold text. The DEQ-7 chronic aquatic life and human health water quality standards have been provided for reference purposes only.

TABLE 5-10

CONCENTRATIONS OF METALS IN SURFACE WATER COMPARED TO DEQ-7 WATER QUALITY STANDARDS (µg/L) LILLY/ORPHAN BOY MINE SITE

Sample	Description	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Nickel	Zinc
LOB-GW-01	"Shaft" Well	131	**1**	<10	1,680	<10	2,050	<10	**780**
LOB-GW-02	Injection Well #2	236	<1	<10	52,500	<10	1,640	<10	20
LOB-GW-03	"LOB III" Well	138	**65**	**140**	13,600	**80**	3,300	10	**9,450**
LOB-GW-04	LOB-GW-03 (Dup)	95	**66**	**150**	13,400	**80**	3,380	10	**9,570**
LOB-SW-02	Adit Discharge/Flow	**874**	**163**	**40**	29,600	**70**	5,640	30	**17,700**
DEQ-7 Acute Aquatic Life Standard		340	*0.52*	*3.79*	N/A	*13.98*	N/A	*145*	*37*
DEQ-7 Chronic Aquatic Life Standard [a]		150	*0.097*	*2.85*	1,000	*0.545*	N/A	*16.1*	*37*
DEQ-7 Human Health Standard [a]		10	5	1,300	300[b]	15	50[b]	100	2,000

Notes:
Bold values exceed DEQ-7 acute aquatic life numeric water quality standards (DEQ 2008).
Italic water quality standards based on 25 milligrams per liter (mg/L) hardness.
a DEQ-7 chronic aquatic life and human health standards are provided for reference.
b Secondary Maximum contaminant levels (MCL) have been established for iron and manganese (300 and 50 µg/L), which are based on aesthetic properties such as taste, odor, and staining.
< Less than
N/A Not applicable
T.C. Telegraph Creek
µg/L Micrograms per liter
WR Waste rock

Cadmium and zinc exceeded acute aquatic life standards in the sample from the "shaft" monitoring well (LOB-GW-01). Elevated concentrations of cadmium, copper, lead, and zinc were found in the samples (LOB-GW-03 and duplicate LOB-GW-04) from the "LOB III" monitoring well.

The mine water samples are interpreted to occur along a continuous flow path from the "shaft" well to Injection Well #2 to monitoring well "LOB III" to the exposed/discharging adit. The mine site was the location of an in situ treatment system installed by MSE. Bags of compost were suspended in the shaft and compost was injected into each of the injection wells on-site. In general, water quality decreases as the water flows toward the adit discharge. The compost injected into Injection Well #2 appears to cause a spike in the concentration of arsenic and iron. From Injection Well #2 to monitoring well "LOB III" the water quality degrades due to increased concentrations of cadmium, lead, and zinc. The concentrations of all metals except lead substantially increase from monitoring well "LOB III" to where the water discharges from the adit. The increase in concentration may be due to mine water flowing through metal-laden rock that has collapsed in the adit.

Comparison of the shaft elevation and depth to water (6870 feet above mean sea level [ft amsl] - 74 feet = 6,796 ft amsl) to the lower adit discharge elevation (6,788 ft amsl), indicates there is approximately 8 feet of water backed up in the underground mine workings above the lower adit. Assuming the lower adit is roughly 4 feet wide and 6 feet high and is completely full of water between the lower adit discharge and the shaft (approximately 300 feet), the quantity of water back upped in the lower adit could easily exceed 50,000 gallons. If this adit extends a significant distance east of the shaft as suggested by the map of the underground workings obtained from the Montana Bureau of Mines and Geology (Appendix A), this volume of water could be significantly greater than 50,000 gallons.

Based on the results of mine water sampling, any discharge of mine water to Telegraph Creek as a result of dewatering the shaft or re-opening of the lower adit at flow rates in excess of that already occurring under present conditions would likely result in violation of the Montana water quality standards (DEQ-7 numeric standards). If dewatering of the adit and shaft is required to allow expanded investigation of the underground workings, then treatment of the discharging mine water will be required to ensure Montana water quality standards are not violated.

5.4 RECLAMATION AND LAND USE CHARACTERIZATION

Physical and agronomic (nutrient) properties of selected soils and mining-related wastes associated with the Lilly/Orphan Boy Mine Site were evaluated to better define the nature of contamination and to assist in the generation of reclamation alternatives for the site.

Four of the solid waste samples collected as part of the RI sampling on October 7, 2008 were submitted to Energy Laboratories in Helena, MT for particle size, CEC, and agronomic analyses (LOB-BG-02, LOB-SS-02, LOB-SS-08, and LOB-SS-14). These additional analyses were helpful to quantify and evaluate potential toxic and inhibitory properties in soil and waste material at the site and to assess which in situ reclamation alternatives might be possible.

5.4.1 Particle Size Analysis

- Particle size analysis (soil texture) is a common measurement for soils and is related to soil-water movement, soil fertility, and other agronomic characteristics.

Particle size was determined for four surface samples from the Lilly/Orphan Boy Mine Site; the results are listed in Table 5-11. The laboratory report is in Appendix D. The four samples were collected from native soil, waste material, and surface soils affected by past mining. The native and mine-impacted soils are generally coarse-textured, have a potential to leach metals, and would retain less plant-available nutrients. These coarse-textured soils are derived from Cretaceous Boulder batholith granitic parent materials.

TABLE 5-11

PARTICLE SIZE ANALYSIS
LILLY/ORPHAN BOY MINE SITE

Sample	Waste Type	Particle Size Distribution		
		% Sand	% Silt	% Clay
LOB-BG-02	Background (native) soil	62	24	14
LOB-SS-02	Waste from WR pile 1	64	16	20
LOB-SS-08	Vegetated soil near WR pile 2	50	36	14
LOB-SS-14	Surface soil south of WR pile 3	52	33	15

Notes:
WR Waste rock

5.4.2 Cation Exchange Capacity

CEC is a measure of the soil's ability to adsorb exchangeable cations (most plant nutrients are cations). CEC values are generally lower in coarse-textured soils with 1 to 1 clay mineral types. CEC values in the Lilly/Orphan Boy Mine wastes and soil are in the typical range for the coarse-textured granitic soils and are at levels that will provide and support a revegetation cover. However, the mine wastes and soils are highly acidic and have other plant-inhibitory properties (see discussion in section 5.4.3). Table 5-12 displays the CEC values measured in samples from the site.

TABLE 5-12

**CATION EXCHANGE CAPACITY
LILLY/ORPHAN BOY MINE SITE**

Sample	Waste Type	CEC meq/100g
LOB-BG-02	Background (native) soil	23.4
LOB-SS-02	Waste from WR pile 1	19.9
LOB-SS-08	Vegetated soil near WR pile 2	18.8
LOB-SS-14	Surface soil south of WR pile 3	30.0

Notes:
CEC Cation exchange capacity
meq/100g Milliequivalents per 100 grams of soil
WR Waste rock

5.4.3 Agronomic Analysis

Some of the disturbed areas at the Lilly/Orphan Boy Mine Site have begun to naturally revegetate with coniferous trees and grasses. Agronomic or agricultural analysis was performed on four samples from the site. The samples included a background soil sample (LOB-BG-02), a waste rock sample (LOB-SS-02), and two additional surface soil samples from around the waste rock piles (LOB-SS-08 and LOB-SS-14). The results are summarized in Table 5-13; complete analytical results are contained in Appendix D. The soils are strongly acidic (pH less than 5.0) and have phytotoxic levels of arsenic and other metals that will severely limit adequate revegetation. Adjusting the pH of the soil to more moderate pH levels (pH 5.0 to 6.0) will be necessary if in-situ revegetation is desired. Approximately 5 tons per acre of agricultural-grade lime should be incorporated into the upper 9 inches of surface soil.

The existing surface soils and mine wastes at the Lilly/Orphan Boy mine site also have very low levels of nitrogen, phosphorus, and potassium. A blended fertilizer mixture should be applied and incorporated into the upper 9-inches of soils that provides 50 pounds of actual nitrogen, 5 pounds of actual phosphorus, and 30 pounds of actual potassium (K). The fertilizer blend should contain both a fast-acting and a slow-release form of nitrogen. If available and practicable, amending the soil with compost or another organic-matter amendment would provide long-lasting benefits for revegetation.

TABLE 5-13

**AGRONOMIC ANALYSIS
LILLY/ORPHAN BOY MINE SITE**

Sample	Description	pH	Cond. (mmhos/ cm)	Organic Matter (%)	Nitrate (mg/kg)	Phosphorous (mg/kg)	Potassium (available, mg/kg)	Total Nitrogen (mg/kg)	Lime (Tons/1,000)
LOB-BG-02	Background (native) soil	4.4	0.15	4.42	<1	6.5	127	1,700	3
LOB-SS-02	Waste from WR pile 1	2.5	1.37	2.96	1	17	14.5	820	4
LOB-SS-08	Vegetated soil near WR pile 2	3.5	0.15	3.78	<1	8.8	69.4	1,100	5
LOB-SS-14	Surface soil south of WR pile 3	3.2	0.88	4.03	2	13	137	1,600	<1

Notes:

S.U.	Standard units
Cond.	Conductivity
mg/kg	Milligrams per kilogram
tons/1,000	Tons lime per 1,000 tons of soil
<	Less than
TKN	Total Kjehdahl Nitrogen

5.4.4 Potential Locations for Borrow Soil and a Waste Repository

Although areas with soils that do not contain metals at concentrations greater than recreational guidelines are found near the mine, adequate volumes of acceptable cover soil are not available on site. Suitable borrow soil of adequate volume is available on privately owned land to the north along Telegraph Creek or the Little Blackfoot River. Haul distances for this material will be about 5 miles. Further investigation will be required to identify specific areas with willing owners to obtain acceptable cover soil.

The only potential waste repository site on the mine site is the constructed bench surrounding the upper mine shaft. This site may be suitable for use as a waste repository if appropriate measures are taken to either seal the shaft or to otherwise isolate the shaft from the waste placed in the repository. If it is concluded that a bottom liner is required for the repository, significant waste relocation and re-grading of the site will be required to allow placement of the liner. Off-site waste repositories are also limited in the near vicinity of the mine site. Additional engineering investigation will be required to locate off-site repository sites.

5.5 HUMAN HEALTH RISK ASSESSMENT

Field samples were collected from the Lilly/Orphan Boy Mine Site and analyzed for heavy metals to conduct a screening-level human health risk assessment to meet one of the objectives of the RI. The risk assessment was conducted using current guidance set forth in (1) "Risk-Based Cleanup Guidelines for Abandoned Site Sites" (Tetra Tech 1996); (2) standardized risk assessment spreadsheets developed by DEQ/MWCB; and (3) guidance established by EPA (1989a). Risk assessment data and calculation spreadsheets are in Appendix G.

The assessment involved five steps: (1) hazard identification; (2) exposure assessment; (3) toxicity assessment; (4) risk characterization; and (5) calculation of risk-based cleanup goals. The following sections discuss these five steps in greater detail.

5.5.1 Hazard Identification

Hazard identification is conducted to identify potential COC for the site. Each COC must meet four criteria established by EPA (1989a): (1) the constituent is present at the site; (2) the measured concentrations of the constituent are significantly above background concentrations; (3) 20 percent of the measured concentrations of the constituent must be above the method detection limit; and (4) the analytical results for each constituent must meet the quality assurance/quality control (QA/QC) criteria established for the data set. The determination of preliminary COC also includes screening against DEQ/MWCB risk-based recreational cleanup guidelines.

Twenty-five solid-matrix samples, four surface water samples, and three mine water samples were collected during the RI for the Lilly/Orphan Boy Mine Site. All samples were analyzed at Energy Laboratories, Helena, MT for total metals. Solid matrix samples included three background soil samples, 17 surface soil samples, and five sediment samples.

Solid Matrix

Metal concentrations in solid matrix samples (surface soil and sediment) were evaluated against the four EPA COC criteria outlined above and screened against DEQ/MWCB risk-based recreational cleanup levels (50-day gold panner/rock hound scenario) to identify preliminary COC. The metals that met the EPA criteria in surface soil were antimony, arsenic, cadmium, copper, iron, lead, silver, and zinc; however, only antimony, arsenic, and lead exceeded recreational cleanup guidelines. The metals in sediment that met EPA COC criteria were antimony, arsenic, cadmium, iron, lead, manganese, and zinc (the Telegraph Creek upstream sediment sample, LOB-SD-01, was used as the background sample). Arsenic was the only metal to exceed recreational cleanup guidelines in sediment.

Surface and Mine Water

Identification of potentially hazardous metals was performed by comparing metal concentrations to the EPA COC criteria, to risk-based recreational cleanup guidelines, and to Montana state water quality standards (DEQ-7). Seven metals in both surface and mine water met the EPA criteria for being a potential COC: arsenic, cadmium, copper, iron, lead, manganese, and zinc. All of these metals, with the exception of iron, exceeded DEQ-7 acute aquatic life standards in both surface and mine water. Arsenic and manganese (in both surface and mine water) were the only two metals to exceed recreational cleanup guidelines.

All metals identified as preliminary COC, either by exceeding the DEQ/MWCB recreational cleanup guidelines and/or meeting the EPA criteria, were used to conduct the exposure assessment (section 5.5.2 below) and determine human health (recreational) risk. All metals that posed a risk (hazard quotient [HQ] >1 or carcinogenic value > 1.0E-06) were then considered actual COC for the Lilly/Orphan Boy Mine Site. The following sections go into further detail regarding the human health risk process.

5.5.2 Exposure Assessment

The exposure assessment identifies the human receptors that may be exposed, the exposure routes through which the receptors may come into contact with hazardous constituents, and the assumptions and data used to quantify the exposure to metals identified through the hazard identification process above. The exposure assessment is conducted by calculating exposure point concentrations using standardized risk assessment spreadsheets developed by DEQ/MWCB.

The main exposure scenario developed for the Lilly/Orphan Boy Mine Site is for on-site recreation. Risks to recreational receptors at the site are included in the gold panner/rock hound exposure scenario that was evaluated in the "Risk-Based Cleanup Guidelines for Abandoned Site Sites" (Tetra Tech 1996). The all-terrain vehicle/motorcycle rider (ATV/MR) exposure scenario was not evaluated since no tailings are present at the Lilly/Orphan Boy Mine Site. The fisherman exposure scenario was not evaluated because it is not the best representative of the types of potential recreation at the site and, in general, has less conservative cleanup guidelines than the gold panner/rock hound scenario. As stated previously, the Lilly/Orphan Boy Mine Site originally received an AIMSS recreational use score of 5 (moderate). It was determined for this RI that the potential for recreational use at the site is high based on its location off

Telegraph Creek road and its proximity to the surrounding communities of Elliston, Avon, and Helena. The use should also be ranked high based on the presence of two cabins within a half-mile radius of the site. Both cabins are recreational; one of the owners has grandchildren that visit at the cabin (Newman 2009).

Exposure point concentrations for this risk assessment were generated using ProUCL software by calculating the 95^{th} percentile upper confidence level (95% UCL) for metals in solid matrix (EPA 2008b), which better accounts for a larger sample size with multiple detections. The 95% UCL was calculated for each of the metals in surface soil and sediment that were identified as preliminary COC and exceeded risk-based recreational cleanup guidelines as described in section 5.5.1. Due to a smaller sample size, the surface water values did not require the calculation of upper confidence levels. The maximum total metal value in a true surface water sample (adit water is not considered surface water for the purpose of risk analysis) was used for the exposure point concentration calculations. The exposure to mine water is not evaluated in the recreational risk analysis because typically contact with mine water is not an exposure pathway of concern. Although metal concentrations in the mine water are not specifically addressed in the recreational risk analysis, the adverse effects of the mine water discharging into Telegraph Creek are taken into consideration by using maximum metal concentrations from surface water samples (since mine water is discharging into surface water and impacting Telegraph Creek). Once determined, the soil and sediment UCL values and the maximum metal concentrations in surface water were then used as the exposure point concentrations for risk calculations performed in the risk assessment spreadsheet. Appendix G contains a copy of the ProUCL input worksheet, which displays the data used to generate the 95% UCL values, as well as the ProUCL 95% UCL output and the recreational risk assessment spreadsheet. Table 5-14 presents the solid matrix 95% UCL and maximum total metal values in surface water that were used as the exposure point concentrations.

The recreational risk assessment spreadsheet demonstrates that the metals that pose the greatest risks to recreational users at the Lilly/Orphan Boy Mine Site are arsenic, lead, and manganese. These three metals have HQ values greater than 1.0 (72.13, 7.63, and 2.29 respectively; see page 6 of the risk assessment spreadsheet in Appendix G) and are considered COC for the site. The concentration of arsenic ranged from 140 to 74,100 mg/kg, with a mean of 10,658 mg/kg. Lead concentrations at the Lilly/Orphan Boy Mine Site ranged from 13 to 43,800 mg/kg, with an average of 4,398 mg/kg and manganese ranged from 9 to 5,930 mg/kg, with an average of 625.2 mg/kg. A table of summary statistics for the metals evaluated in the risk assessment is provided in Appendix G. No other metals were found to be hazardous to human health for the recreational scenario evaluated. Although arsenic, lead, and manganese are the only metals considered to pose a risk to recreational users, a reclamation plan targeting their removal will clean up the other metals associated with the site.

TABLE 5-14

**EXPOSURE POINT CONCENTRATIONS
LILLY/ORPHAN BOY MINE SITE**

Waste Type	Antimony	Arsenic	Cadmium	Copper	Iron	Lead	Manganese	Silver	Zinc
Surface Soil (mg/kg) 95% UCL	384.1	21,495	17.24	87.94	92,208	16,284	1,766	53.49	500
Surface Water (µg/L) Max Conc.	---	854	67	100	8,280	50	5,250	---	9,310

Notes:
mg/kg Milligrams per kilogram
µg/L Micrograms per liter
--- Not included in the risk calculation for the medium shown; metal did not exceed recreational cleanup guidelines or meet EPA COC criteria.

5.5.3 Toxicity Assessment

The toxicity assessment phase evaluates the potential for COC to cause adverse carcinogenic or noncarcinogenic effects in exposed populations. The most hazardous COC identified at the Lilly/Orphan Boy Mine Site are arsenic, lead, and manganese. The following sections summarize the potential adverse effects and dose-response relationships for only these three metals. The other metals do not pose a significant risk to potential human receptors and were, therefore, excluded.

Arsenic

Arsenic is the twentieth most abundant element in the earth's crust and is present in virtually all living organisms. Freshwater supplies in certain areas of the United States and Canada contain up to 1.4 mg/L. Seafood can contain significant concentrations of arsenic, ranging from 2 mg/kg for freshwater fish to 22 mg/kg for lobsters, most of which is organically (protein) bound. The average adult dietary intake of arsenic is between 0.025 and 0.033 milligrams per kilogram per day (mg/kg/d). This amount is nearly twice the level EPA considers to produce adverse health effects in humans (that is, the lowest observed adverse effects level [LOAEL] = 0.17 mg/L or 0.014 mg/kg/d). The largest source of human exposure to arsenic is arsenical pesticides, which account for 80 percent of the industrial consumption of arsenic worldwide. However, other principal uses of arsenic include manufacture of pharmaceuticals, glass, ceramic products, and metallurgy.

Arsenic (and arsenic compounds), especially organic arsenicals, are readily absorbed into the body after inhalation, ingestion, or dermal contact. When they are ingested, soluble arsenic compounds, including solutions, are almost completely absorbed through the gastrointestinal tract. Conversely, insoluble arsenic compounds are poorly absorbed, if at all. An orally administered dose of arsenic is distributed rapidly to virtually all tissue compartments (probably bound to protein), with the highest concentrations subsequently detected in the muscle, followed by the liver, hair, nails, and kidney. Excretion by the kidney is almost complete within 6 days and accounts for more than 90 percent of the dose. In liver tissue, trivalent arsenic (As^{+3}) is converted by microsomal enzyme systems and excreted in urine as multiple metabolites, including dimethylarsenic acid (50 percent), methyl arsenic acid (14 percent), pentavalent arsenic (8 percent), and trivalent arsenic (8 percent). Organo-arsenic compounds as are typically found in crabmeat and other types of seafood are excreted essentially unchanged.

These "detoxification" processes effectively increase the molecular weight and polarity of the metal complex, thereby enhancing the rate of excretion in aqueous urine (half-life [$t_{1/2}$] = 7 hours). Like lead, mercury, and other heavy metals, arsenic is readily incorporated in fingernails, toenails, bone, and hair, providing an additional means of assessing historical exposure.

Symptoms of acute arsenic exposure include vomiting and diarrhea caused by severe gastrointestinal distress and general vascular collapse. The estimated lethal doses for humans are 60 milligrams of trivalent arsenic (As^{+3}) and 250 milligrams of pentavalent arsenic (As^{+5}). The most frequently noted and characteristic effects of chronic arsenic toxicity in humans include skin lesions, peripheral vascular disease, cardiovascular abnormalities, and peripheral neuropathy. However, the most significant toxic effect of chronic or prolonged low-level exposure to arsenic is carcinogenicity, including increases in the incidence of respiratory and skin cancers. For example, repeated epidemiological studies have found an increased incidence of skin and respiratory tract tumors in persons exposed to arsenic fumes and dusts. Some studies have also reported increased bladder cancers. One study of elderly males in villages with arsenic-tainted drinking water showed a dose- and time-dependent response curve, with rates of skin cancer as high as 26 percent in men exposed to water containing more than 0.6 mg/L of arsenic. However, results of ingestion studies with animals have been generally equivocal.

Most reports of chronic arsenic toxicity have been in occupational settings from workers exposed to fumes and dusts, causing local irritation of the mucous membranes of the eyes and nose. Exposure is best diagnosed by measuring concentrations in the hair or urine. For example, concentrations of arsenic in the hair for unexposed persons are typically less than 1 mg/kg (average 0.5 mg/kg), whereas concentrations in subjects of chronic poisoning are often between 1 and 5 mg/kg and can range as high as 47 mg/kg.

Given its systemic distribution, arsenic is readily transported across the placenta to fetal tissues, but teratogenicity (birth defects) and other reproductive effects have not been reported in laboratory animals at low to moderate parental dosages. However, chromosomal aberrations have been documented in humans exposed to industrial sources of arsenic, and select arsenic compounds have been found to be mutagenic in both *in vivo* and *in vitro* studies.

Arsenic is a Class A (that is, known) human carcinogen. Its oral slope factor is listed in EPA's Integrated Risk Information System (IRIS) substance file (last updated April 10, 1998), as 1.5 mg/kg/d. No dermal slope factor was available for arsenic when this report was written. However, a dermal slope factor of 20 times the oral slope factor has been derived and employed on the basis that 5 percent of an ingested dose is absorbed by the gastrointestinal tract (EPA 1989a). The oral reference dose (RfD) reported in IRIS (EPA 1998) for arsenic toxicity in humans is 0.0003 mg/kg/d based on a chronic exposure study that produced hyper-pigmentation, teratosis, and possible vascular complications. The confidence level reported for this oral RfD was "medium." Unfortunately, no direct RfD for arsenic is available for the inhalation or dermal exposure pathways. As above, a dermal RfD value equal to 5 percent of the oral RfD has been derived, assuming that approximately 5 percent of the ingested arsenic will be absorbed by the gastrointestinal tract (EPA 1989a). No RfD was calculated for the inhalation pathway since there is no standard relationship between oral and inhalation RfDs for inorganic compounds (EPA 1989a). An uncertainty factor of three is deemed adequate for the arsenic RfD to account for outlying groups or effects, including so-called "sensitive" individuals, potential reproductive impacts, and other toxicological data gaps.

Lead

Lead and inorganic lead compounds are found in a variety of commercial products and industrial materials, including paints, plastics, storage batteries, bearing alloys, insecticides, and ceramics. In addition, lead is naturally occurring in soils of the western United States at an average concentration of 17 mg/kg (Shacklette and Boerngen 1984).

Humans are in a state of positive lead balance from the day of birth, such that a relatively slow accumulation occurs until a total body burden of approximately 50 to 350 milligrams of lead has amassed by age 60. Normal adults have been shown to absorb approximately 5 percent of an oral dosage of various lead compounds, although absorption depends entirely on the individual and the nature of the lead compound in question. Research has shown that men typically have higher concentrations of lead in nearly all tissues than do women, and furthermore, that the developing fetus and adolescent children are the two most sensitive subpopulations.

More than 90 percent of absorbed lead is deposited in bone, primarily dense bone, with only minor amounts excreted in hair, nails, or urine. However, the average absorption of lead in children may be significantly higher than in adults (that is, as high as 50 percent). Inhalation studies have shown that about half the lead deposited in the alveoli of the lung is absorbed directly into the blood stream, and that most of the dosage (90 to 95 percent) is subsequently deposited in skeletal bone, where the half-life is estimated to be 7 to 10 years. Although the predominant elimination pathway for lead (and most heavy metals) is urine, the rate of urinary excretion is notably slow.

Lead has been shown to adversely affect many enzyme systems, but the overall health effects from exposure to lead are typically related to elevated blood-lead concentrations that can result in a variety of toxicological effects, depending on the level of exposure. For example, the most noteworthy clinical indices of lead toxicity in humans are its effects on heme (blood) synthesis, resulting in erythrocyte anomalies, and imbalances of porphyrin, protoporphyrin, and aminolevulinic acid. Generally, a concentration of 40 micrograms per deciliter (µg/dL) is considered the normal upper limit for blood lead, 99 percent of which is typically contained within erythrocytes.

The general symptoms of chronic lead poisoning include gastrointestinal disturbances, anemia, insomnia, weight loss, motor weakness, muscle paralysis, and nephropathy. For example, blood-lead concentrations greater than 40 µg/dL have been associated with damage to the central nervous system and kidneys, as well as pernicious anemia. Concentrations on this order have also been associated with reproductive effects, miscarriage in pregnant woman, and sterility in males. Blood concentrations of 30 µg/dL and higher have been associated with defects in vitamin D metabolism and with learning deficits in exposed children.

The effects of exposure to lead at blood concentrations of 20 µg/dL and lower are more difficult to define. Some studies have reported increased blood pressure in males, starting at blood concentrations of about 10 µg/dL. Low-level exposure to lead during early childhood can cause multiple effects, including impaired intellectual and neurobehavioral development. In fact, it appears that some of these effects — particularly changes in the levels of certain blood enzymes and impaired neurobehavioral development of children — may occur at blood-lead levels so low as to be essentially without a "threshold." Similar low-level exposures to lead during pregnancy have been shown to cause reduced birth weight and preterm births. This sensitivity to lead toxicity extends from the fetal stage until growth ceases after puberty.

Studies of blood-lead concentrations in children of industrially exposed fathers revealed that the blood-lead concentration in as many as 42 percent of the children was greater than 30 μg/dL and exceeded 80 μg/dL in more than 10 percent of the children as a result of lead carried home on contaminated clothing.

On the basis of bioassay results in rats and mice, EPA has classified lead as a Class B2 (that is, probable) human carcinogen. Controlled dosage studies in humans have produced renal tumors after dietary and subcutaneous exposures to soluble lead salts. However, dosages that typically induce cancer in humans are higher than are associated with other health effects of exposure to lead, such as reproductive and developmental toxicity and increased blood pressure.

Unfortunately, no standard carcinogenic slope factors or RfDs are available for lead. Although the "uptake biokinetic" model is used to calculate the risk to children in a *residential* land-use scenario, the model cannot be used to calculate risks to adults or children in *recreational* exposure settings. Therefore, a cancer slope factor or RfD must first be obtained or calculated to estimate the recreational risks from lead to the adult and child. Using the uptake biokinetic model with standard residential assumptions, the maximum safe concentration of lead for noncancerous effects has been set at 400 mg/kg. Therefore, standard residential child exposure assumptions were combined with an exposure point concentration of 400 mg/kg to calculate oral and dermal RfDs. The RfD was then adjusted until the HQ was equal to 1.0. The dermal RfD was calculated to be 5 percent of the oral RfD, assuming that approximately 5 percent of ingested lead is absorbed by the gastrointestinal tract (EPA 1989a). No RfD was calculated for inhalation since there is no standard relationship between inhalation and oral RfDs for inorganic compounds (EPA 1989a). Using the above derivation methods, the RfDs were calculated at 0.0026 mg/kg/d oral and 0.00013 mg/kg/d dermal.

Manganese

Manganese is an abundant element, typically present in U.S. soils at an average concentration of 525 mg/kg (Kabata-Pendias and Pendias 1989). It is widely used in the industrial manufacture of steel alloys, dry-cell batteries, electrical coils, ceramics, matches, glass, dyes, fertilizers, welding rods, oxidizing agents, and a variety of food additives, and is naturally present in many foods. The biochemical role of manganese is to serve as an activator of several enzymes, including hydrolases, kinases, decarboxylase, and transferases. Thus, as a required co-enzyme for a number of metabolic reactions, manganese is an essential trace element and a necessary dietary nutrient for humans. The average adult dietary consumption of manganese is the range of 2 to 9 mg/day.

Occupational exposures to manganese usually occur by inhalation or ingestion of fumes and dusts produced in refining manganese ores or treatment of manganese alloys. Most inhaled manganese is mobilized up the trachea and then swallowed. Like lead, the efficiency of gastrointestinal absorption of manganese is low, usually less than 10 percent, but is variable and appears to correlate inversely with the amount of the element available for absorption. The absorbed manganese leaves the blood quickly and is stored primarily in organ tissues; the half-life ($t_{1/2}$) for excretion of manganese from the body in normal subjects is about 40 days.

When chronic overexposure to manganese occurs, it is typically manifest by a syndrome of neurologic and psychiatric disorders including headaches, restlessness, irritability, personality change, hallucinations, and hearing impairment. Severe toxicity can result in muscle weakness, rigidity, and tremor. Acute occupational exposures to manganese via inhalation have been reported to produce pneumonitis; chronic occupational exposure via inhalation has been reported to produce manganism. The latter disease (involving the central nervous system after exposure to high concentrations), produces cirrhosis of the liver and encephalopathy, when behavioral and neurological changes similar to Parkinson's disease are manifest. Acute toxicity studies in experimental animals have revealed histopathological changes, pulmonary congestion, and edema of the lungs. Different compounds of manganese are reported to produce opposing effects in the blood, including damage to erythrocytes. In addition, studies of humans and experimental animals suggest that oral exposure to elevated levels of manganese affect the cardiovascular and central nervous systems and can result in decreased fertility.

Manganese is known to be sequestered primarily in the liver, followed by the kidney, intestine, and pancreas. Homeostatic mechanisms in the body maintain relatively constant tissue concentrations and are perhaps responsible for the lack of systemic toxicity after chronic oral exposure. However, absorption levels after inhalation and dermal exposures to manganese have not been well characterized. In fact, results of absorption studies conducted with manganese show significant disparities between exposed adults and newborns. (Blood absorption has been reported at 3 percent for orally dosed adults and at 70 percent for orally dosed newborns.)

Information available in EPA's IRIS database indicates that the oral RfD for manganese is 0.14 mg/kg/d. However, perhaps more than most metals, individual requirements for, as well as adverse reactions to, manganese may be highly variable. Some individuals may, in fact, consume a diet that contributes more than 10 mg/day (more than four times the oral RfD) without cause for concern. This information, in conjunction with the essential nutrient of manganese, warranted a confidence level in the RfD of "medium" and an uncertainty factor of 1.

5.5.4 Risk Characterization

Risk characterization is completed using the exposure assumptions and toxicity assessment data to calculate the carcinogenic and noncarcinogenic risk for adults for a recreational exposure scenario. The following sections describe the risk calculations and the associated uncertainty.

Risk Calculations

The carcinogenic and noncarcinogenic risks to potential human receptors from antimony, arsenic, cadmium, copper, iron, lead, manganese, silver, and zinc in solid matrix and surface water were calculated for the Lilly/Orphan Boy Mine Site. Data from the Lilly/Orphan Boy Mine Site were evaluated using the 50-day gold panner/rock hound recreational exposure scenario. The recreational risk assessment spreadsheets that summarize the calculations are located in Appendix G. The individual HQ values and relative percent contributions to total risk for arsenic, lead, and manganese in solid matrix and surface water are summarized in Table 5-15. The other metals were not included because their total HQs were less than 1.0 and are not COC. Table 5-16 lists the total (soil and water) carcinogenic (E-06) and noncarcinogenic hazard index (HI) risk values for the recreational exposure scenario. The HI is the sum of the HQs for individual metals.

TABLE 5-15

RECREATIONAL SCENARIO
CONTAMINANT-SPECIFIC HQ VALUES FOR SOLID MATRIX AND WATER
LILLY/ORPHAN BOY MINE SITE

Site	Exposure Scenario	Hazard Quotient for Solid Matrix and Water			
		Arsenic	Lead	Manganese	Total HQ
Lilly/Orphan Boy Mine Site	Gold panner/Rock hound	72.13 (0.87)	7.63 (0.09)	2.29 (0.03)	83.15 [a]

Notes:

[a] The total HQ is greater than the sum of arsenic, lead, and manganese because of the contribution of all the other metals.

(#) Percent contribution to total HQ.

HQ Hazard quotient (relative toxicity value for a single metal in a single medium)

TABLE 5-16

RECREATIONAL SCENARIO
CARCINOGENIC AND NONCARCINOGENIC RISKS FOR SOLID MATRIX AND WATER
LILLY/ORPHAN BOY MINE SITE

Site	Exposure Scenario	Risk	Total
Lilly/Orphan Boy Mine Site	Gold panner/Rock hound	Carcinogenic (E-06)	2.09 E-02
		Noncarcinogenic (HI)	83.15 [a]

Notes:
[a] Includes risk from exposure to soil.
E-06 Per million subjects exposed.
HI Hazard index (the sum of hazard quotients [HQ] for all metals).

EPA uses a carcinogenic risk of 1.0E-06 and an HI of 1.0 as the threshold levels for assessing the need for contaminant cleanup. As can be seen in Table 5-16, the gold panner/rock hound recreational exposure scenario resulted in carcinogenic risk and HI values above the threshold levels (that is, risk = 2.09 E-02 and HI = 83.15) for the Lilly/Orphan Boy Mine Site. As can be seen in Table 5-15, arsenic accounted for the most risk (87 percent) followed by lead (9 percent) and manganese (3 percent) for the gold panner/rock hound exposure scenario. Arsenic accounted for all of the carcinogenic risk at the site.

Uncertainties in the Risk Calculations

Uncertainty in the calculated risk values can be introduced by a number of factors, including: (1) exclusion of exposure pathways from the risk calculation, (2) inaccurate land use and exposure values, (3) the accuracy of the toxicity values, (4) the accuracy of the exposure point concentrations, and (5) exclusion of potentially hazardous constituents. Each uncertainty factor is discussed below.

(1) **Exclusion of exposure pathways from the risk calculation**. The exclusion of exposure pathways from risk calculations as a result of data gaps or the lack of applicable toxicity values will underestimate potential risk. The total site risk is the sum of the individual risks posed by each pathway (for example, soil, waste rock, or surface water).

(2) **Inaccurate land use and exposure values**. The exclusion of potentially hazardous constituents caused by unreliable field data will underestimate risk. The total site risk is the sum of all risks from potentially hazardous constituents present in all media. The exclusion of contaminants from the risk calculations as a result of inferior data quality reduces the calculated risk values. All potentially hazardous constituents detected at the site were subjected to risk calculations. The amount of underestimation for risk posed by these metals is unknown, but is probably less than one order of magnitude.

(3) **Accuracy of the toxicity values**. Conservative estimations for land use and exposure assumptions will overestimate site risks. The land use assumptions were based on a visual inspection of the site. All areas with the potential for recreational use by humans were included in the recreational risk area. The exposure assumptions used in the risk assessment are standard values thought to be conservative. The amount of overestimation of risk caused by these assumptions is unknown, but is not likely to exceed one order of magnitude.

(4) **Accuracy of the exposure point concentrations**. The magnitude of toxicity values strongly affects the risk value calculated. However, the reference toxicity values used in the current risk assessment were conservative, likely overestimating risk. The methodology used to develop reference toxicity values assures that the value will overestimate rather than underestimate the potential risk. The toxicity values calculated during this risk assessment are also likely to be conservative since they are derived from conservative starting points using conservative assumptions. The amount of overestimation from the use of toxicity values is unknown, but should not exceed one order of magnitude.

(5) **Exclusion of potentially hazardous constituents**. The accuracy of calculated exposure point concentrations is unknown. However, the calculated exposure point concentrations used in this risk assessment likely underestimate site risk. A mean or average concentration of the metal in soil was used in the risk assessment, although concentrations of metals are above average in many areas. Thus, the risk to a receptor exposed to areas with higher concentrations of metals would be underestimated. Depending on the metal in question, the risk posed may be greater or less than was estimated by the risk assessment.

Table 5-17 summarizes the relative effect of these error sources on the calculated risk values.

TABLE 5-17

SUMMARY OF UNCERTAINTIES FOR RISK ASSESSMENT
LILLY/ORPHAN BOY MINE SITE

Source of Uncertainty	Probable Effect
Exclusion of exposure pathways from the risk calculation	Underestimate risk by <1 OM
Exclusion of potentially hazardous constituents	Underestimate risk by <1 OM
Inaccurate land use and exposure values	Overestimate risk up to 1 OM
Accuracy of the toxicity values	Overestimate risk up to 1 OM
Accuracy of the exposure point concentrations	Over- or under-estimate risk by <1 OM

Source: Developed by C. Reynolds at Tetra Tech as an accompaniment to the text.

Notes:
OM Order of magnitude

5.5.5 Risk-Based Cleanup Goals

Risk-based cleanup goals are calculated to allow for the design and implementation of reclamation alternatives. Table 5-16 shows the carcinogenic and noncarcinogenic risks for the recreational exposure scenario at the Lilly/Orphan Boy Mine Site. Table 5-18 lists the cleanup goals for soil (by individual analyte) for carcinogenic and noncarcinogenic risks posed in a recreational land use scenario.

TABLE 5-18

RECREATIONAL RISK-BASED CLEANUP GOALS
LILLY/ORPHAN BOY MINE SITE

High Recreational Use Value (10)	**50-Day Gold panner/Rock hound Scenario**	
Metal	**Soil (mg/kg)**	**Water (µg/L)**
Arsenic	323[a] (139)	153[b] (66.2)
Lead	2,200	220
Manganese	7,330	2,560

Notes:

a The noncarcinogenic cleanup guideline for soil is 323 mg/kg. The carcinogenic cleanup guideline for soil is 139 mg/kg (Tetra Tech 1996).

b The noncarcinogenic cleanup guideline for water is 153 µg/L. The carcinogenic cleanup guideline for water is 66.2 µg/L (Tetra Tech 1996).

mg/kg Milligrams per kilogram

µg/L Micrograms per liter

5.5.6 Risk Characterization Summary

The risk values summarized for the Lilly/Orphan Boy Mine Site in Tables 5-15 and 5-16 indicate that the site poses a potential risk to recreational users. The calculated HI can be used to decide whether human receptors are potentially exposed to harmful doses of site-related contaminants via the high-use recreational scenario evaluated.

Arsenic posed most of the noncarcinogenic risk, followed by lead and manganese, for the 50-day gold panner/rock hound exposure scenario. The carcinogenic risks calculated for the Lilly/Orphan Boy Mine Site exceed the threshold level of 1.0E-06 for assessing the need for contaminant cleanup. These HQs, carcinogenic risks, and various qualitative observations demonstrate that contaminants at the site constitute probable adverse human health effects for the recreational land use scenario. Consequently, cleanup measures for the site are warranted.

5.6 ECOLOGICAL RISK ASSESSMENT

A baseline ecological risk assessment was conducted at the Lilly/Orphan Boy Mine Site for terrestrial plant communities, aquatic life communities, and terrestrial wildlife exposure scenarios using contaminant concentrations measured during the RI conducted in the fall of 2008. The assessment involved initial identification of COC, followed by the development of an exposure assessment, an ecological effects assessment, and a risk characterization.

The ecological risk assessment was carried out for the Lilly/Orphan Boy Mine Site using several key federal guidance documents, including (1) EPA's "Risk Assessment Guidance for Superfund: Volume II — Environmental Evaluation Manual" (EPA 1989b); (2) EPA's "Framework for Ecological Risk Assessment" (EPA 1992); (3) EPA's "Wildlife Exposure Factors Handbook" (EPA 1993); and (4) EPA's "Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment" (EPA 1994). The ecological risk assessment was also performed using standardized risk assessment spreadsheets developed by DEQ/MWCB. Risk assessment data and calculation spreadsheets are contained in Appendix G.

The mining waste at the site poses a potential risk not only to humans but also to plants and animals that come into contact with them. Ecological risk assessments exclude the potential for effects on people and domesticated species, such as livestock. However, the health of people and domesticated species is inextricably linked to the quality of the environment shared with other species. The ecological evaluation that follows is intended as a qualitative screening-level ecological risk assessment because of the limited and indirect nature of the data available for the site.

The ecological risk assessment estimates the effects of taking no action at the site and involves four steps: (1) identification of contaminants, ecological receptors, and ecological effects of concern; (2) exposure assessment; (3) ecological effects assessment; and (4) risk characterization. These four tasks are accomplished by evaluating available data and selecting contaminants, species, and exposure routes of concern, estimating exposure point concentrations and intakes, assessing the ecological toxicity of the COC, and characterizing overall risk by integrating the results of the toxicity and exposure assessments.

Environmental contaminants at the Lilly/Orphan Boy Mine Site that could affect ecological receptors include high concentrations of metals in the waste rock and adit discharge. The vegetative communities on site have been affected by metals toxicity, as evidenced by the lack of vegetation on the waste rock piles. The waste materials and vegetation in the area are easily accessible to wildlife and could result in significant ecological effects. The objective of this ecological risk assessment is to estimate current and future effects of implementing the no-action alternative at the Lilly/Orphan Boy Mine Site.

5.6.1 Contaminants and Receptors of Concern

This ecological risk assessment evaluated the potential for contact between ecological receptors and the COC. The qualitative results of the ecological risk analysis may be used to identify the need for, and the extent of, reclamation efforts.

Contaminants of Concern

To be considered a COC for ecological risk assessment, a contaminant must meet the following criteria: (1) be detected at the site; (2) be represented by data that meet the QA/QC criteria; and (3) be present at concentrations above background. The metals that met these requirements for soil and sediment were antimony, arsenic, cadmium, copper, iron, lead, silver, manganese, and zinc. The recreational risk assessment analysis (section 5.5) identified arsenic, lead, and manganese as COC for the Lilly/Orphan Boy Mine Site. Six metals were detected in surface water from Telegraph Creek that meet the COC criteria for the ecological risk assessment: arsenic, cadmium, copper, iron, lead, and zinc.

Data tables in section 5.3 summarize the detectable concentrations for metals in samples of soils, sediment, and surface water. These concentrations are characteristic of hard rock wastes and should reliably represent contamination associated with mining at the Lilly/Orphan Boy Mine Site. However, no ecological toxicity data are available for several of these contaminants to evaluate potential effects. The following toxicological data pertain to the primary COC identified for the ecological risk assessment (arsenic, cadmium, copper, lead, and zinc).

Arsenic

Although arsenic is an essential nutrient and occurs naturally in the environment and in all organisms, it is also a teratogen and a “known” carcinogen that can traverse placental barriers and produce fetal death and malformations in many species of mammals (Eisler 1988a). Its bioavailability and toxicity are modified by many biotic and abiotic factors that include the physical and chemical forms of arsenic, the route of exposure, the dosage, and the species of affected organism. In general, inorganic arsenic compounds are more toxic than are organic arsenic compounds (that is, arsenicals), and trivalent species are more toxic than pentavalent species. Arsenic has been demonstrated to bioconcentrate, but not biomagnify, in certain organisms (Eisler 1988a).

Terrestrial plants accumulate arsenic by root uptake from the soil and by adsorption of airborne arsenic deposited on the leaves. Studies have shown that certain plant species can accumulate substantial levels (Agency for Toxic Substances and Disease Registry [ATSDR] 1993a). The effects of arsenic on mammals vary by species, exposure route or pathway, and the physical and chemical form of the arsenic. Many mammals can rapidly excrete ingested inorganic arsenic (Eisler 1988a). However, arsenic is distributed to most tissue compartments, including placental and fetal tissues.

Cadmium

Cadmium is considered a nonessential element for plants and animals. The solubility of cadmium has been determined to be pH-dependent. Cadmium can be readily solubilized during natural soil weathering processes. Cadmium is most mobile in acidic soil and may be easily taken up by plants under these conditions. Elevated concentrations of cadmium have been shown to retard plant growth by causing root damage, chlorosis in the leaves, and red-brown coloration of leaf margins or veins (Kabata-Pendias and Pendias 1989). Studies of plant growth have found that uptake of cadmium by roots and foliar systems may be reduced by the presence of plant-available zinc.

Copper

Copper forms several common minerals in soils, the primary are simple and complex sulfides. These sulfide minerals are easily solubilized during the soil weathering processes, when copper ions are released and commonly accumulate in the upper soil horizons. Copper is one of the more mobile "heavy metals," especially in acidic soil environments. Once it has been absorbed into plant tissues, copper appears to be far less mobile. Copper is considered the most toxic common heavy metal to aquatic organisms. This toxicity is inversely related to the hardness of the water, however: the harder the water, the less toxic copper is to aquatic organisms. Studies indicate that copper is also highly toxic to plants and will cause chlorosis and root malformation (Kabata-Pendias and Pendias 1989). Some plants, such as redtop (*Agrostis tenuis*) and tufted hairgrass (*Deschampsia caespitosa*) have been shown to evolve tolerance to elevated levels of copper in soils. Continued ingestion of copper by animals can lead to accumulation in tissues, particularly in the liver (Underwood 1971).

Lead

Lead has been known to be a common pollutant and a potent environmental poison that is capable of altering normal blood formation and nervous system functions of the human body (Eisler 1988b). When absorbed in excessive amounts, lead can have carcinogenic properties, impair reproduction and liver and thyroid function, and interfere with resistance to infectious disease (EPA 1984). Lead is toxic in most of its chemical forms and can be incorporated into the body via inhalation, ingestion, dermal absorption, and placental transfer. Lead is also a known mutagen and teratogen.

The fate of lead in soil and soil solutions is affected by a variety of factors, including precipitation of sparingly soluble forms of lead; formation of relatively stable organic-metal complexes or chelates with soil organic matter; the soil's pH, CEC, and organic matter content; and the amount of lead in the soil (ATSDR 1993b). Most forms of lead are retained rather strongly in soil; thus, very little tends to leach from the soil. Lead can be transported via erosion of lead-containing soil particulates, which can then be deposited in surface waters (ATSDR 1993b). Lead is not an essential element for plants, and excessive amounts have been shown to inhibit growth (Eisler 1988b). The effects of lead on mammals can include growth retardation, delays in maturation, and reduced body weight.

Zinc

Zinc is found in fairly uniform concentrations in rocks and soils and may range from about 10 parts per million (ppm) to 120 ppm (Kabata-Pendias and Pendias 1989). Zinc is considered an essential nutrient for both plants and animals. Soluble forms of zinc are easily taken up by plants, particularly by the root systems. Zinc will commonly accumulate in the upper soil horizons during weathering processes. Zinc is not considered highly phytotoxic, but its toxicity is more prevalent in acidic soils. Several plant species and genotypes are known to have evolved a degree of tolerance to elevated levels of zinc in soils, and some species may accumulate large amounts of the metal without showing overt symptoms of toxicity. Chlorosis (seen mainly in newly developed leaves) and depressed plant growth are the common symptoms of zinc toxicity (Kabata-Pendias and Pendias 1989).

Ecological Receptors of Concern

A variety of plants, birds, amphibians, and mammals are part of the general food web for the Lilly/Orphan Boy Mine Site, and many more species could be included in a more extensive ecological assessment. This ecological risk assessment has identified three groups of receptors that are potentially affected by metal contamination at the Lilly/Orphan Boy Mine Site. The first group of potential receptors is the terrestrial plant communities, which are noticeably absent on some of the waste rock piles. This may be caused by toxic and inhibitory levels of metals in the plant root zone, along with other detrimental physical and chemical (infertility) properties of the soil. Plant communities are a concern because they represent the first trophic level in the food chain and are consumed by many higher trophic level animals.

The second group of potential ecological receptors is the terrestrial wildlife that may use the area as part of a home range, including elk and mule deer. Tetra Tech personnel observed evidence of use by elk and mule deer during the RI field investigation. Grazing by wildlife species at this site is a concern because of the potential to consume contaminated vegetation, soil, and evaporative salts. The only terrestrial wildlife receptors evaluated in a quantitative manner in this ecological risk assessment are deer. Deer are assumed to represent the highest level of exposure to site contaminants, and the effects to deer can apply to other potential receptors.

The third group of potential receptors is the aquatic life communities. Telegraph Creek provides suitable habitat for aquatic life. The stream is perennial; however, the flow rate is low.

5.6.2 Exposure Assessment

The exposure assessment evaluates the risk to the identified ecological receptors of concern (terrestrial plants, terrestrial wildlife, and aquatic life) using various contaminant concentrations measured at the site. The risk to terrestrial plant communities was evaluated using the exposure point concentrations for the recreational user listed in Table 5-14. As discussed in section 5.5.2, the exposure point concentrations were generated by calculating the 95% UCL for all soil and sediment samples (except background soil) collected at the Lilly/Orphan Boy Mine Site. Terrestrial wildlife was evaluated using data from sample LOB-SW-02, which was collected from the discharging lower adit. The discharging adit water is accessible to deer and other wildlife. Aquatic life was evaluated using data for water sample LOB-SW-04 and sediment sample LOB-SD-04. Both samples LOB-SW-04 and LOB-SD-04 were collected from surface water and sediment present in the seep adjacent to Waste Rock Pile 3.

Contaminant criteria and toxicological indices used to assess both contamination and risk for the exposure scenarios were compiled from the following primary documents:

- Terrestrial plant communities: Gough and others 1979; Shacklette and Boerngen 1984; Kabata-Pendias and Pendias 1989; CH2M Hill 1987
- Terrestrial wildlife: Eisler 1988a and b; ATSDR 1993a and b; EPA 1993; Beyer and others 1994
- Aquatic life: Eisler 1988a and b; Long and Morgan 1991; Tetra Tech 1996

Terrestrial Plant — Phytotoxicity Scenario

This scenario involves the limited ability of various plant species to grow in soils or wastes with high concentrations of arsenic, cadmium, copper, iron, lead, silver, and zinc. Plant sensitivity to certain arsenic compounds is so great that these compounds were used as herbicides for many years. Phytotoxic criteria reported in the literature for total arsenic in soils ranged from 15 to 50 mg/kg; the 50 mg/kg hazard level was considered appropriate for the Helena Valley, Montana (CH2M Hill 1987). Cadmium is toxic to plants at concentrations greater than 8 mg/kg. Lead is also considered toxic to plants. Numerous phytotoxic concentrations are reported in the literature and generally range from 100 mg/kg (Kabata-Pendias and Pendias 1989) to 1,000 mg/kg (John and Van Laerhoven 1972, CH2M Hill 1987). A moderate concentration of 400 mg/kg was chosen for the ecological risk analysis. Zinc is only moderately toxic to plants at concentrations more than 300 mg/kg (Kabata-Pendias and Pendias 1989). A tolerable concentration of 200 mg/kg zinc in soil has been previously cited for the Helena Valley (CH2M Hill 1987). The upper end of the range for zinc (400 mg/kg) was used in the ecological risk analysis.

Terrestrial Wildlife - Ingestion by Deer Scenario

Estimates of total intake dosage for deer are based on reported literature values and the following assumptions: (1) the currently unvegetated areas do not provide habitat for deer; (2) native vegetation is growing across most areas of the site and would be available to deer that graze in the area; and (3) the average weight of an individual adult deer is 68.04 kilograms (150 pounds).

Intake of Contaminated Soil and Salt

The daily uptake of salt for deer is based on data in “Elk of North America” (USDA 1995), which reported a range of 1 to 11 pounds (average 6 pounds) in 1 month for a herd of 50 to 75 elk (average 63 head). Assuming deer require 50 percent of the volume of salt for elk, a median exposure (non-conservative) approach would equate to an average salt use of 3 pounds per month. Using the average herd size of 63, the average individual salt uptake would equal 0.0016 pounds per day (lbs/day), or 0.00072 kilograms per day (kg/day). Beyer and others (1994) estimated that ingestion of soil accounts for less than 2 percent of the average Wyoming mule deer's diet of 1.39 kg/day of vegetation, which would equal 0.0278 kg/day of soil. The 95% UCL concentrations of metals for the surface soils across the site were used for both the salt and soil levels since these values were the highest calculated.

Intake of Metals in Vegetation

Beyer and others (1994) estimated that an average mule deer ingests 1.39 kg of vegetation per day in summer. No vegetation samples were collected for analysis during the RI. The concentrations of arsenic (50 ppm), lead (25 ppm), and zinc (50 ppm) used in this calculation were the tolerable levels in vegetation (the lowest phytotoxic tissue levels) from the East Helena assessment (CH2M Hill 1987). The concentration for copper (15 ppm) was estimated based on data obtained from Kabata-Pendias and Pendias (1989). The metals-contaminated areas at the Lilly/Orphan Boy Mine Site cover about an acre and a half. This area would represent 0.4 percent of an estimated average mule deer's home range of 90 to 600 acres (average of 345 acres; Beyer and others 1994).

Aquatic Life Scenario

This scenario involves the limited ability of aquatic organisms to survive in waters that have been contaminated with mining wastes, and specifically metals. Toxicity of metals to aquatic organisms depends on the concentration in the surface water and sediment, as well as other conditions such as water hardness, temperature, and pH. Surface water criteria for the ecological risk assessment were derived from the Montana DEQ-7 acute aquatic life water quality standards. Sediment criteria were derived from values published in Long and Morgan (1991).

Arsenic

Arsenic can be lethal to fish and insects and has been found to impair reproduction at low concentrations. Although it is known to bioconcentrate, arsenic has not been found to biomagnify in the food chain (Eisler 1988a; Long and Morgan 1991). The concentrations of arsenic in water are normally less than 10 µg/L (Eisler 1988a), and approximately 1 mg/kg (dry weight basis) is reported to be a no-effect level for freshwater fish (Schmitt and Brumbaugh 1990).

Cadmium

Cadmium can be lethal to fish and insects and has been found to impair growth at low concentrations. Cadmium toxicity has been shown to be inversely related to water hardness. Cadmium is known to bioconcentrate in the food chain.

Copper

Copper has been shown to be the most common heavy metal that causes toxicity to aquatic organisms. Copper toxicity has been shown to be inversely related to water hardness.

Lead

Concentrations of lead have been shown to affect early life stages of aquatic macrophytes, especially in soft water at warmer temperatures. Nonlethal effects of lead on fish include excess mucus formation that interferes with respiration, spinal curvature, damage to organs, and reduced swimming ability. Lead is only minimally biomagnified in the food chain.

Zinc

Although zinc is an essential nutrient to aquatic biota, toxic effects at high concentrations can include mortality, reduced growth, and inhibited reproduction. Embryos and juveniles have been found to be most sensitive to the effects of zinc. In addition, the effects of zinc on aquatic organisms are increased by the presence of other metals such as cadmium and mercury.

5.6.3 Ecological Effects Assessment

The effects of the COC at this site are available from several literature sources and are not repeated here. No site-specific toxicity tests were performed to support this ecological risk assessment. Instead, only existing and proposed toxicity-based criteria and standards were used for the assessment. The following sections detail the specific standards and data that were used for comparison to the analytical results of the RI field sampling investigation.

Terrestrial Plant — Phytotoxicity Scenario

A summary of the phytotoxicity for selected metals of concern (Kabata-Pendias and Pendias 1989) is provided in Table 5-19. These concentrations were used for comparison to concentrations of metals in waste rock. The availability of contaminants to plants and the potential for plant toxicity depends on many factors, including soil pH, soil texture, nutrients, and plant species.

TABLE 5-19

SUMMARY OF TOLERABLE AND PHYTOTOXIC SOIL CONCENTRATIONS (mg/kg dry weight) LILLY/ORPHAN BOY MINE SITE

Element	Tolerable Soil Level (CH2M Hill 1987)	Phytotoxic Soil Concentrations (Kabata-Pendias and Pendias 1989)	Mean Soil Concentration [a] Lilly/Orphan Boy Mine Site (mg/kg)
Arsenic	50	15 to 50	10,599
Cadmium	Not determined	4 to 8	6.1
Copper	Not determined	60 to 125	77.2
Lead	25	100 to 400	5,373
Zinc	50	70 to 400	310.5

Notes:
[a] Mean concentration for soil samples only (sediment excluded).
mg/kg Milligrams per kilogram

Terrestrial Wildlife - Ingestion by Deer Scenario

Adverse effects data for test animals were obtained from the ATSDR toxicological profiles (1993a; 1993b), and from other literature sources (Eisler 1988a; 1988b). The data consist of dose (intake) levels that either cause no observed adverse effects levels (NOAEL) or the LOAEL in laboratory animals. The use of effects data for other species introduces an uncertainty factor to the assessment; however, effects data for all metals are not available for the species of concern (deer). The lethal arsenic dose of 34 mg/kg/d for deer (Eisler 1988a) is also included. Data for laboratory animals (primarily rats) have been adjusted only for increased body weight. These data are listed in Table 5-20. Check SML for better comparison.

TABLE 5-20

**MAMMALIAN TOXICOLOGICAL DATA FOR INORGANIC METALS
LILLY/ORPHAN BOY MINE SITE**

Dose	Arsenic	Cadmium	Copper	Lead	Zinc
NOAEL[a] - Rat	3.2	0.271	22.5	0.05	55
LOAEL[b] - Rat	6.4	2.706	90	0.005	571
References	ATSDR 1993a	Sample and others 1996	NAS 1980	ATSDR 1993b; Eisler 1988b	Maita and others 1981
Lethal – Deer	34	NA	NA	NA	NA
Reference:	Eisler 1988a	NA	NA	NA	NA

Notes:
a No observed adverse effects level (NOAEL)
b Lowest observed adverse effects level (LOAEL)
NA Not available
NAS National Academy of Sciences
ATSDR Agency for Toxic Substances and Disease Registry
All units are milligrams per kilogram per day (mg/kg/d)

<u>Aquatic Life Scenario</u>

Montana water quality standards were compared with analytical data from surface water collected adjacent to Telegraph Creek (sample LOB-SW-04). Analytical results were adjusted for conditions such as water hardness, temperature, and pH, which can affect the toxicity of metals to aquatic organisms in the surface water bodies. Montana water quality standards for aquatic life are presented in Table 5-21. Appendix G contains a copy of the ecological risk assessment spreadsheet.

TABLE 5-21

MONTANA SURFACE WATER QUALITY AQUATIC LIFE STANDARDS (μg/L)

Metal	Acute Toxicity	Chronic Toxicity	LOB Surface Water Concentrations[e]
Antimony	88[a]	30[a]	ND
Arsenic - inorganic	340	150	14
Barium	1,000[b]	--	ND
Cadmium	1.7[c]	0.2[c]	3
Chromium (as Cr^{+3})	579[d]	27.7[d]	ND
Copper	11.3[c]	7.7[c]	ND
Iron	--	1,000	8,280
Lead	61.5[c]	2.4[c]	50
Manganese	50[b]	--	5,250
Mercury - total	2.4[d]	0.012[d]	ND
Nickel	145[d]	16.1[d]	20
Zinc	99[c]	99[c]	9,310

Notes:
a U.S. EPA (2002) criteria used since the contaminant is not included in Montana standards.
b Ambient water quality standards for protection of human health for consumption of fish.
c At an measured hardness of 80 mg/L.
d At an assumed hardness of 25 mg/L.
e Metal concentrations as measured in surface water sample LOB-SW-04 from the seep on the north side of Waste Rock Pile 3, east of Telegraph Creek.
-- Standard has not been adapted or information is currently unavailable.
ND Analyte was not detected.
Reference: Circular DEQ-7 Montana Numeric Water Quality Standards, February 2008.

5.6.4 Risk Characterization and Summary

This section combines the ecological exposure estimates and concentrations presented in section 5.6.2 and the ecological effects data presented in section 5.6.3 to provide a screening-level estimate of potential adverse ecological impacts for the two scenarios evaluated. This screening-level estimate was achieved by generating "ecological impact quotients" (EQ) that are analogous to the HQs calculated for human exposure to noncarcinogenic metals. EQs were calculated for each contaminant of concern by exposure scenario or receptor type and are summarized in Table 5-22. Contaminant-specific EQs were generated by dividing the specific intake estimate or concentration by available ecological effect values or concentrations. Tables that summarize the risk calculations are found in Appendix G. As with HIs, adverse ecological impacts are not expected at the Lilly/Orphan Boy Mine Site if EQs are less than 1.0.

TABLE 5-22

ECOLOGICAL IMPACT QUOTIENTS
LILLY/ORPHAN BOY MINE SITE

Receptor	Arsenic	Cadmium	Copper	Lead	Zinc	Total EQ By Receptor
Plant Phytotoxicity	429.90 (91)	1.25 (0.2)	0.7035 (0.1)	40.71 (8.6)	1.25 (0.2)	473.81 (100)
Deer Ingestion	0.07 (0.1)	0.009 (0.2)	0.0001 (0)	53.84 (99)	0.0046(0)	53.93 (100)
Aquatic Life – Surface Water	2.51 (1.7)	39.41 (27)	8.81 (6)	0.81 (0.5)	93.87 (65)	145.42 (100)
Aquatic Life – Sediment	287.06 (97)	1.44 (0.5)	0.11 (0.03)	5.11 (1.7)	2.05 (0.6)	295.77 (100)
TOTAL EQ BY COC	719.54 (74)	42.11 (4.3)	9.63 (0.9)	100.48 (10)	97.65 (10)	968.94 (100)

Notes:
( ) Percent contribution to total receptor EQ.
EQ Ecological impact quotient (relative toxicity value for a single metal in a single medium)
COC Contaminant of concern

Terrestrial Plant - Phytotoxicity Scenario

Maximum concentrations of metals collected from the source area at the Lilly/Orphan Boy Mine Site were compared with high values of the range of plant phytotoxicity derived from the literature. One limitation of this comparison is that the phytotoxicity ranges are not species-specific; instead, they represent toxicity to species that may or may not be present at the Lilly/Orphan Boy Mine Site. Additionally, other physical characteristics of the waste materials may create microenvironments that limit growth and survival of terrestrial plants directly or in combination with substrate toxicity.

Concentrations of metals are likely to be elevated in waste materials at the site; in addition, organic content is low, nutrients are limited, and the materials may harden enough to resist root penetration. The results of the EQ calculations for this scenario are presented in Table 5-22.

The EQs calculated for plant phytotoxicity at the Lilly/Orphan Boy Mine Site were greater than 1.0 for arsenic, cadmium, lead, and zinc. The non-conservative assumption of using the high end of the phytotoxicity range to derive the EQs may underestimate the potential phytotoxic effect to some plant communities. However, several other factors in addition to phytotoxicity combine to adversely affect plant establishment and successful reestablishment on waste materials. In addition, the maximum concentrations of metals in soil were used as the plant dosage value in the EQ calculation, so that an overly conservative EQ is likely.

Terrestrial Wildlife - Ingestion by Deer Scenario

Estimated deer ingestion doses were compared with the higher of the literature-derived toxicological effect levels (that is, the LOAEL). The contaminant-specific EQs were generated by dividing the total intake estimates by the toxicological effect values. Again, the comparison is limited because of the use of effects data for other species (rat) that were adjusted only for increased body weight. The species used in the toxicological studies may have been more or less susceptible to the contaminant in question than are deer. The results of the EQ calculations for this scenario are also presented in Table 5-22.

The EQs calculated for the deer ingestion scenario exceeded 1.0 for lead. This EQ indicates a potential risk to deer and other wildlife as a result of lead in surface soils.

The assumptions used to derive the uptake dose and the comparison to rat toxicity may incorrectly estimate the actual average contaminant intake for deer. This potential for an adverse effect can be extended to other wildlife that may also use the area for a source of food and salt.

Aquatic Life Scenario

Maximum concentrations in surface water and sediment collected from the Lilly/Orphan Boy Mine Site were compared with acute aquatic water quality criteria and other toxicity standards derived from Long and Morgan (1991). Acute aquatic water quality criteria were applied to this scenario because surface water and sediments were not sampled over the entire range of hydrologic conditions at the site, resulting in insufficient quantities of data for the calculation of chronic concentrations. The presence of metals in surface water and sediments has the potential to significantly affect aquatic life in Telegraph Creek. The results of the EQ calculations for this scenario are presented in Table 5-22.

Information presented in Table 5-22 indicates that the potential exists for adverse ecological impacts from surface water and sediment to aquatic life communities at the Lilly/Orphan Boy Mine Site. The acute EQs calculated for surface water were greater than 1.0 for arsenic, cadmium, copper, and zinc. The EQs for sediment were greater than 1.0 for arsenic, cadmium, lead and zinc.

Risk Characterization Summary

The calculated EQs can be used to evaluate whether ecological receptors are potentially exposed to harmful dosages of site-related contaminants via the three ecological scenarios evaluated. The EQs calculated for the Lilly/Orphan Boy Mine Site indicate that arsenic is the greatest overall risk driver for the site, with an EQ of 719. The risk posed by arsenic is divided among plant phytotoxicity (EQ = 430), aquatic life-sediment (EQ = 287), aquatic life-surface water (EQ = 2.5), and ingestion by deer (EQ = 0.1). Lead (EQ = 54) poses virtually all (97 percent) of the risk to deer, and arsenic (EQ = 430) poses almost all (91 percent) of the risk to plants. Zinc (EQ = 94) poses the greatest risk to aquatic life-surface water and arsenic (EQ = 287) to aquatic life-sediment.

Collectively, these calculated EQs and qualitative observations demonstrate that contaminants at the site constitute probable adverse ecological effects for plants, deer, and aquatic life at the Lilly/Orphan Boy Mine Site and adequately justify cleanup measures.

5.7 RECLAMATION OBJECTIVES AND GOALS

The overall objective of the Lilly/Orphan Boy Mine Site reclamation project is to protect human health and the environment in accordance with the guidelines set forth by the DEQ/MWCB. Specifically, site reclamation must limit human and ecological exposure to mine-related contaminants and reduce the mobility of those contaminants through associated solid media and surface water exposure pathways.

There are currently no promulgated standards for metal concentrations in soil. The Montana DEQ has developed a conservative set of risk-based recreational cleanup guidelines that are calculated for different contaminants using a recreational visitor exposure pathway scenario. The guidelines take into account the possibility of exposure through multiple exposure routes. Action levels for reclamation of soils at Lilly/Orphan Boy Mine Site have been determined based on these recreational cleanup guidelines. The soil recreational cleanup levels for the metals of concern at the Lilly/Orphan Boy Mine Site are listed in Table 5-18. The Montana DEQ also has surface water quality standards for aquatic life listed in Table 5-21.

5.8 PRELIMINARY ASSESSMENTS FOR RECLAMATION

Preliminary assessments for reclamation of the Lilly/Orphan Boy Mine Site include the identification of applicable or relevant and appropriate requirements (ARARs) and reclamation alternatives. Both of these topics are outlined in greater detail below.

5.8.1 Preliminary Applicable or Relevant and Appropriate Requirements (ARAR)

Reclamation activities at the Lilly/Orphan Boy Mine Site will incorporate federal and state cleanup requirements. The standards, requirements, criteria, or limitations that will be used to conduct reclamation activities for this site are commonly referred to as ARARs. The DEQ/MWCB has developed a summary of federal and state ARARs for reclamation projects that may apply to the Lilly/Orphan Boy Mine Site. This summary is attached as Appendix H. Table 5-23 is a list of these ARARs and indicates whether or not the ARAR is likely applicable, possibly applicable, or not likely applicable to the Lilly/Orphan Boy Mine Site reclamation project.

As part of the reclamation alternative development completed as part of the Expanded Engineering Evaluation and Cost Analysis (EEE/CA) process, applicable ARARs will be further defined.

5.8.2 Preliminary Identification of Reclamation Alternatives

The appropriate reclamation alternatives for the Lilly/Orphan Boy Mine Site will be selected based on the following: (1) the type of waste, for example waste rock or contaminated sediment; (2) the location of the waste; (2) the concentration of metals and other contaminants in the waste materials; (3) the volume of waste materials; and (4) the applicability of the reclamation alternatives. As part of the EEE/CA reclamation alternatives will be developed and subjected to three phases of screening or evaluation during the reclamation selection process. These phases include initial screening, alternative screening, and detailed analysis (EPA 1988).

However, based on such screening and evaluation at similar abandoned mine sites, it can be assumed reclamation of the Lilly/Orphan Boy Mine Site will probably include either (1) partial waste excavation and consolidation of the waste and capping, or (2) waste excavation and relocation into either an on-site or off-site mine waste repository. The type of waste cap used will include site specific revegetation and may include the use of geotextile membranes (geomembrane) to limit water infiltration into the waste. On-site and off site waste repositories will also be capped and depending upon location may also include a multi-layer geomembrane bottom liner to protect groundwater.

TABLE 5-23

PRELIMINARY IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) LILLY/ORPHAN BOY MINE SITE

ARARs for Reclamation Projects		Likely Applicable	Possibly Applicable[1]	Not Likely Applicable
3.1	**Federal Contaminant-Specific ARARs**			
3.1.1	Safe Drinking Water Act			X
3.1.2	Clean Water Act	X		
3.1.3	National Ambient Air Quality Standards	X		
3.2	**State Contaminant-Specific ARARs**			
3.2.1	Groundwater Protection		X	
3.2.2	Montana Water Quality Act	X		
3.2.3	Montana Ambient Air Quality Regulations	X		
4.1	**Federal Location-Specific ARARs**			
4.1.1	National Historic Preservation Act			X
4.1.2	Archaeological and Historic Preservation Act	X		
4.1.3	Historic Sites Act of 1935	X		
4.1.4	Protection and Enhancement of the Cultural Environmental	X		
4.1.5	The Archaeological Resources Protection Act of 1979	X		
4.1.6	American Indian Religious Freedom Act		X	
4.1.7	Native American Graves Protection and Repatriation Act		X	
4.1.8	Fish and Wildlife Coordination Act		X	
4.1.9	Endangered Species Act		X	
4.1.10	Floodplain Management Regulations		X	
4.1.11	Protection of Wetlands Regulations	X		
4.1.12	Clean Water Act	X		
4.1.13	Migratory Bird Treaty Act		X	
4.1.14	Bald Eagle Protection Act		X	
4.1.15	Resource Conservation and Recovery Act	X		
4.2	**State Location-Specific ARARs**			
4.2.1	Montana Antiquities Act		X	
4.2.2	Montana Human Skeletal Remains and Burial Site Protection Act	X		
4.2.3	Montana Floodplain and Floodway Management Act		X	
4.2.4	Montana Stream Protection Requirements	X		
4.2.5	Montana Solid Waste Management Act	X		
4.2.6	Endangered Species and Wildlife		X	

TABLE 5-23
(Continued)
PRELIMINARY IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)
LILLY/ORPHAN BOY MINE SITE

ARARs for Reclamation Projects		Likely Applicable	Possibly Applicable[1]	Not Likely Applicable
5.0	**Action-Specific ARARs**			
5.1	Federal and State Water Protection Requirements	X		
5.1.1	Clean Water Act	X		
5.1.2	Montana Pollutant Discharge Elimination System Requirements		X	
5.1.3	Water Quality Statutes and Regulations	X		
5.1.4	Stormwater Runoff Control Requirements	X		
5.2	Federal and State RCRA Subtitle C Requirements	X		
5.3	Federal and State RCRA Subtitle D and Solid Waste Management Requirements	X		
5.3.1	Federal Requirements		X	
5.3.2	State of Montana Solid Waste Requirements	X		
5.4	Federal and State Mine Reclamation Requirements	X		
5.4.1	Surface Mining Control and Reclamation Act	X		
5.4.2	Montana Statutory and Regulatory Requirements	X		
5.5	Air Requirements	X		
5.6	Noxious Weeds	X		
6.0	**To Be Considered Documents**	X		
7.0	**Other Laws (Non-Exclusive List)**	X		
7.1	Other Federal Laws			
	Occupational Safety and Health Regulations	X		
7.2	Other State Laws			
A	Groundwater Act		X	
B	Public Water Supply Regulations			X
C	Water Rights	X		
D	Controlled Ground Water Areas		X	
E	Occupational Health Act, Section 50-70-101, et.seq., MCA.	X		
F	Montana Safety Act	X		
G	Employee and Community Hazardous Chemical Information	X		

5.9 SUMMARY AND CONCLUSIONS

The field activities for the Lilly/Orphan Boy Mine Site RI were successful in collecting the data necessary to delineate the nature and extent of waste present at the site, evaluate the reclamation alternatives for this site, and evaluate the risks to human health and the environment. As indicated by the recreational risk analysis, arsenic, lead, and manganese are considered COC for human health at the Lilly/Orphan Boy Mine Site. Arsenic, cadmium, copper, lead, and zinc are all present in surface water at elevated concentrations and pose an unacceptable risk to the environment.

There are three waste types present at the Lilly/Orphan Boy Mine Site: waste rock and soil that has been in contact with waste rock, surface water, and sediment. The following sections discuss the waste types.

Waste Rock

The Lilly/Orphan Boy Mine Site contains an approximate total of 2,430 yd^3 of waste rock, divided among three individual waste rock piles. No suitably flat upland area of sufficient size is available at the mine site for an on-site repository. However, an engineered off-site repository could be constructed. A significant portion of the waste rock contains potentially hazardous concentrations of metals (compared with recreational cleanup levels); the waste rock should be isolated from contact with recreational users and stabilized to reduce impacts from erosion and sedimentation to Telegraph Creek. The area should be regraded to more gentle and natural slopes that are amenable for reclamation and revegetation. An estimated 2,500 yd^3 of cover soil would be required to provide an 18-inch reclamation soil cover over the 1.5 acres after waste rock has been removed. Virtually every soil sample collected at the Lilly/Orphan Boy Mine Site contained levels of arsenic above the recreational cleanup guideline; therefore, the extent of contamination at the site was not fully characterized. Additional sampling or the visual delineation of contamination may be required during site reclamation to determine the full extent of contamination.

Surface Water and Sediment

The RI indicates that elevated concentrations of arsenic, cadmium, copper, lead, manganese, and zinc are present in the sediment and surface water of Telegraph Creek adjacent to, and downstream of, the Lilly/Orphan Boy Mine Site. Potential environmental impacts and ecological receptors have been identified during the RI. Removal or isolation of the waste rock near Telegraph Creek and selective removal of the streambank materials in the most affected section of Telegraph Creek would improve sediment and surface water quality. Isolation of the waste rock that contains elevated concentrations of metals should help reduce the amount of metals that enter Telegraph Creek over time.

Mine Water

The RI indicates elevated concentrations of arsenic, cadmium, copper, lead, manganese, and zinc in the mine water that would result in violations of water quality standards should the water be allowed to continue to discharge into Telegraph Creek. If the existing lower adit mine closure was removed to allow subsurface investigation of the adit to evaluate potential blocking to reduce flow, it will be necessary to provide treatment of the mine water prior to adit opening.

REFERENCES CITED

Agency for Toxic Substances and Disease Registry (ATSDR). 1993a. *Toxicological Profile for Arsenic.* Agency for Toxic Substances and Disease Registry, Atlanta, Georgia.

ATSDR. 1993b. *Toxicological Profile for Lead.* Agency for Toxic Substances and Disease Registry, Atlanta, Georgia.

Beyer, W.N., E.E. Connor, and S. Gerould. 1994. "Estimates of Soil Ingestion by Wildlife." *J. Wildlife Management Volume 58 (Number 2): 375-382.*

CH2M Hill. 1987. "Assessment of the Toxicity of Arsenic, Cadmium, Lead, and Zinc in Soil, Plants, and Livestock in the Helena Valley of Montana." Prepared for: U.S. Environmental Protection Agency, Work Assignment No. 68-8L30.0.

DEQ. 2005. Montana Department of Environmental Quality Remediation Division. *Action Level for Arsenic in Surface Soil*. April.

DEQ. 2008. *Circular DEQ-7 Montana Numeric Water Quality Standards*. Montana Department of Environmental Quality Planning, Prevention, and Assistance Division – Water Quality Standards Section. February.

Eisler, R. 1988a. "Arsenic Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review." U.S. Fish and Wildlife Service, Biological Report No. 85 (1.12). 92pp.

Eisler, R. 1988b. "Lead Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review." U.S. Fish and Wildlife Service, Biological Report No. 85 (1.14). 134pp.

Gough, L.P., H.T. Shacklette, and A.A. Case. 1979. "Element Concentrations Toxic to Plants, Animals, and Man." U.S. Geological Survey, Washington D.C.

John, M.K. and C. Van Laerhoven. 1972. "Lead (Pb) Uptake by Lettuce and Oats as Affected by Lime, Nitrogen, and Sources of Lead." *J. Environmental Quality Volume 1:169-171.*

Kabata-Pendias, A. and H. Pendias. 1989. "Trace Elements in Soil and Plants." 2nd Ed. CRC Press, Inc., Boca Raton, FL.

Long, E.R., and L.G. Morgan. 1991. "The Potential for Biological Effects of Sediment-sorbed Contaminants Tested in the National Status and Trends Program." National Oceanic and Atmospheric Administration *(*NOAA) Technical Memorandum NOS OMA 52. National Oceanographic and Atmospheric Administration, Seattle, Washington.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environmental Management 19:81-97.

Maita, K. and others. 1981. "Subacute Toxicity Studies with Zinc Sulfate in Mice and Rats." *J. Pest. Sci. 6:327-336.*

Montana Department of Environmental Quality (DEQ). 2001. Montana Numeric Water Quality Standards (Circular WQB-7). December.

Montana Department of State Lands/Pioneer. 1993. Abandoned and Inactive Mines Scoring System (AIMSS) Scoresheet. From the "Hazardous Materials Inventory Report." April 9.

National Academy of Sciences. 1980. "Recommended Daily Allowances." 9th Ed. pp. 151-154. National Academy of Sciences, Food and Nutrition Board, Washington, D.C.

Newman, Dave. 2009. Personal interview with Dave Newman regarding Lilly/Orphan Boy Mine Site history and area information. Conducted by Pebbles Clark (DEQ) and Jessica Allewalt (Tetra Tech) on January 15.

Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996. "Toxicological Benchmarks for Wildlife: 1996 Revision." ES/ER/TM-86/R3. Environmental Sciences Division, Oak Ridge National Laboratory. Oak Ridge, Tennessee. June.

Shacklette, H.T. and J.G. Boerngen. 1984. "Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States." U.S. Geological Survey, Professional Paper 1270. Washington, D.C.

Schmitt, C.J. and W.G. Brumbaugh. 1990. National Contaminant Biomonitoring Program: Concentrations of arsenic, cadmium, copper, lead, mercury, selenium, and zinc in U.S. freshwater fish, 1976-1984. Archives of Environmental Contamination and Toxicology. 19:731-747.

Tetra Tech, Inc. 1996. "Risk Based Cleanup Guidelines for Abandoned Site Sites: Final Report." Prepared for DEQ, Abandoned Site Reclamation Bureau. February.

Underwood, E.J. 1971. "Trace Elements in Human and Animal Nutrition, 3rd Ed." New York and London, Academic Press, Inc., 543pp.

U.S. Environmental Protection Agency (EPA). 1984. "Health Effects Assessment for Lead." Office of Research and Development, Cincinnati, Ohio. EPA/54D/1-86-055. 43pp.

U.S. Environmental Protection Agency (EPA). 1988. "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCA)." U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA. 1989a. "Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Interim Final)." Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002.

EPA. 1989b. "Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (Interim Final)." Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/001.

EPA. 1992. "Framework for Ecological Risk Assessment." Risk Assessment Forum. EPA/630/R-92/001.

EPA. 1993. "Wildlife Exposure Factors Handbook, Volumes 1 and 2." EPA 600/R-93/187a and b. Washington, D.C.

EPA. 1994. "Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments." Office of Emergency and Remedial Response, Washington, D.C.

EPA. 1998. "Retrieval from the Integrated Risk Information System (IRIS)." Office of Health and Environmental Assessment.

EPA. 2002. "Region IX Preliminary Remediation Goals." October 1.

EPA. 2008. Region 9 Superfund Program. Regional Screening Levels for Chemical Contaminants at Superfund Sites (Table). September 12. http://www.epa.gov/region09/waste/sfund/prg/index.html

EPA 2008b. ProUCL Version 4.00.02. Statistical inference software. December. Software download site: http://www.epa.gov/esd/tsc/download.htm

U.S. Department of Agriculture (USDA). 1995. "Personal Communication with USDA Forest Service, Helena National Forest personnel." Salt ingestion data taken from "Elk of North America."

Washington State Department of Ecology. 1997. Creation and Analysis of Freshwater Sediment Quality Values in Washington State. July. Publication Number: 97-323a.

APPENDIX A

HISTORIC SURFACE AND CROSS-SECTION MAPS OF MINE WORKINGS

APPENDIX B

FIELD LOGBOOK

APPENDIX C

SITE PHOTOGRAPHS

APPENDIX D

RECLAMATION INVESTIGATION ANALYTICAL DATA

APPENDIX E

DATA VALIDATION REPORT

APPENDIX F

WASHINGTON STATE PAET TABLE 7a

APPENDIX G

RISK ASSESSMENT SPREADSHEETS AND DATA

APPENDIX H

APPLICABLE AND RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)