FINAL

BASELINE ECOLOGICAL RISK ASSESSMENT FOR THE EUREKA MILLS SUPERFUND SITE EUREKA, UTAH

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LIST OF ACRONYMS AND ABBREVIATIONS

AUF	Area Use Factor
BAF	Bioaccumulation Factor
bgs	below ground surface
BERA	Baseline Ecological Risk Assessment
BOR	Bureau of Reclamation
BW	Body Weight
C	Concentration
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLP	Contract Laboratory Program
COPC	Chemical of Potential Concern
CSM	Conceptual Site Model
CVAA	Cold Vapor Atomic Absorption
DF	Dietary Fraction
DQA	Data Quality Assessment
EA	Exposure Area
EcoSSL	Ecological Soil Screening Level
EPA	Environmental Protection Agency
EPC	Exposure Point Concentration
EU	Exposure Unit
ha	hectare
HDPE	High-Density Polyethylene
HQ	Hazard Quotient
HQ_{max}	Maximum Hazard Quotient
HQ_t	Total Hazard Quotient
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectroscopy
ICP-MS	Inductively Coupled Plasma Mass Spectroscopy
IR	Intake Rate
LCV	Lowest Chronic Value
LOAEL	Lowest Observed Adverse Effect Level
LOEC	Lowest Observed Effect Concentration
NAWQC	National Ambient Water Quality Criteria
NPL	National Priority List
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration
ORNL	Oak Ridge National Laboratory
PEC	Probable Effect Concentration
PEL	Probable Effect Level
QAPP	Quality Assurance Project Plan
QC	Quality Control

RC	Reference area - Cole Canyon
RG	Reference area - Gardner Canyon
RBA	Relative Bioavailability
ROS	Regression on Order Statistics
SAP	Sampling and Analysis Plan
SAV	Secondary Acute Value
SCV	Secondary Chronic Value
SLERA	Screening-Level Ecological Risk Assessment
TAL	Target Analyte List
TEC	Threshold Effect Concentration
TEL	Threshold Effect Level
TOC	Total Organic Carbon
TRV	Toxicity Reference Value
UCL	Upper Confidence Limit
UDEQ	Utah Department of Environmental Quality
UDRR	Utah Division of Response and Remediation
UDWR	Utah Division of Wildlife Resources
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	Unites States Fish and Wildlife Service
USGS	United States Geological Survey
XRF	X-Ray Florescence

EXECUTIVE SUMMARY

PURPOSE AND SCOPE OF BASELINE ECOLOGICAL RISK ASSESSMENT

The purpose of this Baseline Ecological Risk Assessment (BERA) is to describe the likelihood, nature, and extent of adverse effects to ecological receptors (plants and animals) that may occur from exposure to mining-related contaminants remaining at the Eureka Mills Superfund Site (Site) after the remedial actions undertaken to protect humans that live within or visit the Site are complete. This information is intended to help risk managers decide if any additional cleanup actions are needed at the Site to protect ecological receptors.

There are a number of ecological receptors that may come into contact with chemicals at the Site including plants, soil invertebrates, aquatic insects, and a variety of birds and mammals. Based on an evaluation of different ways ecological receptors may be exposed to contaminated environmental media at the Site, the following scenarios were selected for evaluation in this risk assessment:

ECOLOGICAL RECEPTOR	EXPOSURE SCENARIO
Aquatic Receptors (aquatic insects)	▪ Direct contact with surface water ▪ Direct contact with sediment
Plants and Soil Invertebrates	▪ Direct contact with soil
Birds and Mammals	▪ Incidental ingestion of soil ▪ Incidental ingestion of sediment ▪ Ingestion of surface water ▪ Ingestion of food items (plants, insects, worms, small mammals)

METHODS FOR CHARACTERIZING RISKS

Three methods were used to evaluate the potential adverse effects to ecological receptors:

- Predicted Risks (Hazard Quotients). This method compared the level of exposure of receptors to site media to a benchmark level that is believed to be safe to receptors. The ratio of the exposure level to the benchmark level is called the Hazard Quotient (HQ). If the HQ is less than 1, exposures were considered to be below a level of concern. If the value is above 1, adverse effects could occur. In addition, HQ values at the site may be compared to "reference areas" (either the site itself before the impact occurred, or some similar site that has not been impacted). If the HQ values are similar to those observed at reference areas, then the HQs may not be related to exposure to media at the site. If HQ values are greater than HQ values observed in reference areas, than the observed differences may be due to conditions at the site.

- Site-specific toxicity tests. This method exposed organisms to Site media under laboratory conditions. The effect of site contamination was evaluated by comparing the response of the organisms exposed to site media (e.g., soil) to the responses observed in organisms exposed to uncontaminated media and media from reference areas.
- Population and community demographics. This method made direct observations of an ecological population at the Site to determine whether the population had fewer numbers of individuals than expected, or whether the types of species present were different than expected. Direct observations of an ecological population were also made at reference areas for comparison with observations made at the site.

Each of these methods has advantages and limitations. For this reason, conclusions based on only one method of evaluation may be misleading. Therefore, whenever data permitted, conclusions in this assessment were based on "weight of evidence" evaluation. If all of the available methods yield similar conclusions, confidence in the conclusion is greatly increased. If different methods yield different conclusions, then a careful review must be performed to identify the basis of the discrepancy, and to decide which approach provides the most reliable information.

RESULTS

The results of the baseline risk assessment are summarized in Table ES-1 and are briefly discussed below.

Aquatic Insects

Risks to aquatic insects that may live all or part of their life at Knight's Spring pond were evaluated using the HQ Method. The results from this one line of evidence indicated that concentrations of cadmium, zinc and other chemicals in surface water may cause adverse effects in aquatic receptors. The HQ method further indicated that aquatic insects may be at risk of adverse effects from direct contact with several chemicals in sediment in Knight's Spring (mainly cadmium, lead and zinc). These conclusions are uncertain due to the lack of information from other lines of evidence (site-specific toxicity tests, community surveys), low confidence in the benchmark values used in the sediment HQ calculations, and also knowledge regarding the identity and relative sensitivity of insect species that may reside in the pond to chemicals in surface water.

Plants

The baseline risk assessment evaluated the potential for adverse effects to plants growing at the Site that are in direct contact with chemicals in soil using all three methods. The HQ method predicted that plants are likely to be impacted at a number of locations at the Site, and that the effect could be large in some locations. However, site-specific toxicity tests of switchgrass (*Panicum virgatum*), tailcup lupine (*Lupinus caudatus*), and big sagebrush (*Artemesia tridentata*) indicated a low frequency and magnitude of adverse effects in plants, suggesting that phytotoxicity is not widespread across the Site, but is restricted to a few plant species in a few locations. The plant community survey results for 29 dominant species present at the site (including 7 grass species, 5 forb species and 17 shrub/tree species) also indicate that the overall health and reproduction of the plant community is fair or better at most locations, with only a few locations where the health of individual species is less than fair.

Taken together, the weight of evidence supports the conclusion that the concentrations of metals in Site soil are generally not of concern to plants in most areas, but may cause reductions in growth and diversity to individual plant species at some locations.

Soil Invertebrates

The baseline risk assessment evaluated the potential for adverse effects to soil invertebrates (worms) living at the Site that have direct contact with chemicals in soil, using two different lines of evidence. The HQ approach predicted a high frequency of risk to soil invertebrates at most of the Site, the magnitude of which was very high at some locations. However, site-specific toxicity tests of redworms (*Eisenia fetida*) did not support this conclusion, indicating that mortality was not expected at any location, and that growth reductions occurred at only a few locations. In considering these two lines of evidence, greater confidence was placed on the Site-specific toxicity tests than the HQ predictions. This is because the HQ predictions rely on uncertain benchmark values that are likely to be overly conservative, while Site-specific toxicity testing offers a direct measure of effect on receptors of concern.

Based on these lines of evidence, it is concluded that the concentrations of metals in Site soil are present at levels that may cause some reduction in soil invertebrate growth at some locations, but that the overall survival of soil invertebrates at the Site is not likely to be adversely impacted.

Birds and Mammals

The risk assessment evaluated the potential for adverse effects to birds and mammals that may come into contact with chemicals at the Site by ingestion of chemicals in soil, sediment, surface water, and food items (plants, insects, worms, small mammals). Effects were evaluated using the HQ method for 10 different types of birds and mammals, which differed in their feeding habits and their home range size.

The results from this one line of evidence suggest that risks to most birds and mammals with large home ranges are likely to be minimal. Potentially significant population-level risks may occur for some small- and medium-home range birds and mammals due mainly to the ingestion of contaminants (primarily arsenic, lead and zinc) in soil, and also from contaminants that have been taken up into food items (primarily lead and other chemicals in insect tissue). Because only one line of evidence is available, these conclusions must be recognized as uncertain, and additional studies would be needed to determine if the HQ predictions of risk to these receptors are accurate.

Table ES-1. Summary of the Baseline Risk Assessment Findings

Receptor	Exposure Pathway	Weight-of-Evidence Conclusion	Uncertainties
Aquatic Insects	Direct Contact with Surface Water	Surface water in Knight's Spring may cause adverse effects in aquatic insects.	· Lack of knowledge regarding the identity and relative sensitivity of insect species that may reside in the pond to chemicals in surface water. · Lack of information from other lines of evidence. Overall uncertainty is moderate.
	Direct Contact with Sediment	Sediment in Knight's Spring may cause adverse effects in aquatic insects.	· Low confidence in benchmark values. · Lack of information from other lines of evidence. Overall uncertainty is moderate to high.
Plants	Direct Contact with Soil	Concentrations of metals in Site soil are generally not of concern in most areas, but may cause slight phytotoxicity to individual plant species at isolated locations.	· Low confidence in benchmark values. Overall uncertainty is low (due to multiple lines of evidence).
Soil Invertebrates (worms)	Direct Contact with Soil	Concentrations of metals in Site soil are present at levels that may cause some reduction in soil invertebrate growth at some locations, but the overall survival of soil invertebrates at the site is not likely to be adversely impacted.	· Low confidence in benchmark values. Overall uncertainty is low (due to multiple lines of evidence).
Birds and Mammals	Ingestion of Soil, Sediment and Food Items	Risks to most birds and mammals with large home ranges are judged to be minimal, but potentially significant population-level risks may occur for small- and medium-home range birds and mammals. These risks are due to ingestion of chemicals in soil and sediment and also from the ingestion of chemicals in food items (primarily insect tissue) at the Site.	· Lack of information from other lines of evidence. Overall uncertainty is moderate.

1.0 INTRODUCTION

1.1 PURPOSE OF THIS DOCUMENT

This document is a Baseline Ecological Risk Assessment (BERA) for the Eureka Mills Superfund Site (Site) located in Eureka, Utah. Removal and remedial action have been taken at the Site to address human health concerns. The purpose of the BERA is to describe the likelihood, nature, and extent of adverse effects to ecological receptors resulting from post-remedy Site conditions. This information, along with other relevant information, will be used by risk managers to decide whether further remedial actions are needed to protect the ecological receptors and habitat from Site-related releases.

1.2 OVERVIEW OF THE ECOLOGICAL RISK ASSESSMENT PROCESS

This BERA was performed in accordance with current United States Environmental Protection Agency (USEPA) guidance for ecological risk assessments (USEPA, 1992; 1997; 1998). The general sequence of steps used to carry out an ecological risk assessment at a Superfund Site is illustrated in Figure 1-1 (USEPA, 1997).

As shown in Figure 1-1, the ecological risk assessment process consists of eight steps. The first two steps are screening-level evaluations that are intentionally simplified and conservative, and usually tend to overestimate the amount of potential risk. This allows for the elimination of those factors that are not associated with risk, allowing subsequent efforts to focus on factors that are of potential concern. These two screening level steps have been completed previously, and are presented in the Screening Level Ecological Risk Assessment for the Eureka Mills Site (USEPA and USACE 2007a).

The remaining steps of the 8-step process are intended to support the development of the baseline assessment. This includes the process of problem formulation (Step 3), collection of data needed to support the baseline assessment (Steps 4-6), evaluation and interpretation of the data (Step 7), and use of the data to make risk management decisions (Step 8). It is important to realize that the steps shown in Figure 1-1 are not intended to represent a linear sequence of mandatory tasks. Rather, some tasks may proceed in parallel, some tasks may be performed in a phased or iterative fashion, and some tasks may be judged to be unnecessary at certain sites.

1.3 DOCUMENT ORGANIZATION

In addition to this introduction, this report is organized into the following sections:

Section 2. This section summarizes the location, history, and environmental setting of the Site.

Section 3. This section summarizes the available data for performing the baseline ecological assessment at the Site.

Section 4. This section presents the ecological problem formulation, including a summary of the preliminary findings and conclusions, the site conceptual model, the assessment and measurement endpoints, and a description of the basic methods used in the assessment.

Section 5. This section presents the ecological risk characterization for aquatic receptors.

Section 6. This section presents the ecological risk characterization for terrestrial plants and soil invertebrates.

Section 7. This section presents the ecological risk characterization for birds and mammals.

Section 8. This section provides citations for all data, methods, studies, and reports utilized in the BERA.

2.0 SITE CHARACTERIZATION

2.1 SITE OVERVIEW

2.1.1 Site Location

The Eureka Mills Superfund Site is located in the extreme northeast portion of Juab County, in the East Tintic Mountains, approximately 80 miles southwest of Salt Lake City, Utah (see Figure 2-1). As shown in Figure 2-2, the Site includes the town of Eureka and adjacent mines, mills, and mine waste areas.

It should be noted that the Site boundary shown in Figure 2-2 was based on the results of the human health risk assessment. The boundaries of ecological concern have not been established. However, for the purposes of collecting samples to support the baseline ecological risk assessment, a study area for ecological exposure was established based on a consideration of potential transport of contaminants from the Site by wind and/or surface water runoff (USEPA and USACE 2007b). The extent of this study area is shown in Figure 2-3.

2.1.2 Site History

The town of Eureka is part of Utah's historic Tintic Mining District. Eureka was founded in 1870, upon the discovery of a high-grade mineralized outcrop containing silver and lead, as well as other minerals including gold, copper, and arsenic. The area was extensively mined until 1958, and has experienced sporadic mining activity since that time (USEPA 2006). Most of the mining activity since 1958 has occurred in the East Tintic Mining District, a few miles to the east and south of the town of Eureka. There are no current mining activities in the Tintic Mining District. However, at least two entities have recently conducted mining feasibility studies in the Tintic Mining District, which indicates that there is a potential for mining activities to resume in the future.

There are several significant historical mines located within the Site, including: Bullion Beck Mine, Eureka Hill Mine, Gemini Mine, Chief Mine #1, Chief Mine #2, Eagle Blue Bell Mine, Godiva Mine and May Day Mine. Due to the high transportation costs in the early stages of mining, only the richest ores were mined and shipped for milling and smelting, whereas the lesser quality (“second class”) ores were stockpiled on the mine dumps. To concentrate second class ores and make them more profitable for shipping, a number of mills were constructed in and around Eureka. Up to 11 historic mill sites may have been present in Eureka. Early mills utilized the mercury amalgamation process, and amalgamation mills were built at the Bullion Beck and Eureka Hill Mines after the depression of 1893 (UDEQ 2000). The process had limited success due to the abundance of antimony in the ore which caused the mercury to "flour" (produce very small droplets of mercury that are no longer viable for amalgamating metals).

2.1.3 Basis for Concern

Mining and milling operations are often associated with the generation and release of various types of waste materials which contain elevated concentrations of metals. Environmental media which may be impacted by environmental releases include surface soil, subsurface soil, groundwater, surface water, and sediment. Most metals in mine/mill wastes can cause adverse effects in ecological receptors if concentrations and exposure levels are high enough.

The potential sources of chief concern at the Eureka Superfund Site are historic mining- and milling-related solid wastes and other solid and liquid wastes generated and disposed of at the Site. Mine waste is found throughout Eureka as a result of mining activities, milling operations, use in construction in Eureka, and by wind and water erosion (USEPA 2006). A tailings impoundment failure below the Eureka Hill area also resulted in mill tailings being distributed across the lower portion of the western part of the valley, below Eureka (WGI 2002). These wastes may currently exist in both surface and subsurface soils. Leaching from surface and subsurface sources may also result in an increase in the concentration of metals in groundwater, which could migrate off-site.

2.1.4 Response Actions

Elevated levels of lead and arsenic in soil, combined with elevated blood lead levels in children living in Eureka led to time critical soil removal action at the Site and listing on the National Priority List in 2002. Remedial Action to remediate 15 mine waste areas (piles and mill sites) and approximately 700 residential properties began in August 2003 and is expected to continue until 2009 (USEPA 2006). To date, no response actions have been taken in response to any potential ecological risks.

2.2 PHYSICAL SETTING

2.2.1 Topography

Eureka is situated in a southwest trending valley on the west side of the East Tintic Mountains at an elevation ranging from 6,300 to 6,500 feet above mean sea level (see Figure 2-4). Large waste rock piles and associated waste material resulting from mining operations are primarily located on the south sides of the valley, adjacent to the town. Many of these large waste areas have undergone remedial action, and have been capped with rock. Smaller waste piles and abandoned prospects are scattered within the Site and throughout the surrounding landscape.

2.2.2 Climate

The climate at the site is typified by warm summers and cold winters. Average monthly temperatures vary from a high of around 86°F in July to a low of around 17°F in January (WGI 2002).

The area is semiarid , with an annual average total precipitation of approximately 17 inches. Monthly average precipitation ranges from 1.1 to 1.8 inches. The average annual total snowfall is 120.3 inches, which generally occurs during the months of November through March (WRCC 2007). While the direction of the prevailing wind in Eureka has not been scientifically documented, anecdotal information from residents and workers in Eureka indicate that the prevailing wind is from the southwest, parallel to the southwest trending valley in which it is situated.

2.2.3 Hydrology

Eureka sits at the head of Eureka Gulch, a drainage that runs through the middle of town, alongside and north of Highway 6. The Gulch is usually dry, but intermittent surface-water flow from rain and snow-melt events in the area tend to drain into Eureka Gulch. Eureka has experienced several historic floods associated with torrential rains (UDEQ 2000). As shown in Figure 2-5, Eureka Gulch flows west/southwest and joins with Tanner Creek, approximately 6.5 miles southwest of the Site. Eureka is located within the Sevier River Drainage Basin, just west of the Sevier River/Utah Lake drainage basin divide. Based on a review of United States Geological Survey (USGS) topographic maps, it does not appear that Tanner Creek ever reaches the Sevier River.

There are no perennial streams in the East Tintic Mountains, but several springs are found there (Butler et al. 1920). Figure 2-6 shows the location of springs and other surface water bodies located within 2 miles of the Site. Water in ephemeral drainages either evaporates or infiltrates unconsolidated basin soils to recharge groundwater (UDEQ 2000).

2.2.4 Soils

Figure 2-7 shows the soil types present at the Eureka Mills Site. As seen, there are predominantly three soil types at the Site: Deer Creek loam, Lizzant loam, and Pits-Dumps complex. The Deer Creek loam is present throughout most of the town, north of Main Street (Highway 6). It is very deep, well drained, and is found on alluvial fans. It has low permeability and a water capacity of 6 to 8.5 inches. Lizzant loam is present on the south side of Main Street and extends to a small area adjacent to Main Street on the north side. The soil is also present in locations adjacent to mine waste areas on the south and west sides of town. It is very deep, well drained, and is found on mountainsides, hillsides, and alluvial fans. The permeability of Lizzant loam is moderate and it has a water capacity of 5.5 to 7 inches. Pits-Dumps complex is present at source areas of the Site, including settling ponds that have been used during and after mining operations and land that has been covered by material eroded from mine dumps (WGI 2002).

2.2.5 Geology

Beckrock formations at the Site belong to two distinct groups, both of which have been subjected to prolonged weathering and erosion:

- Paleozoic limestones and quartzites which are found on the western end of the Site and on higher elevations to the north and south.
- Igneous rock (lavas) of Tertiary age which invaded lower elevations, including nearly the entire valley in which Eureka is situated. Packard Peak is believed to be the center of an eruption from which a relatively gentle outwelling of viscous lava occurred approximately 32 million years ago. The primary volcanic rock associated with this formation is Packard Rhyolite. The lower unweathered rock is nearly impervious, but the upper weathered rock and sediments overlying the rock are relatively porous (Meinzer, 1911).

The mines at Eureka were developed on large replacement ore bodies in the Paleozoic limestones and quartzites. The ores consisted of native silver, gold, and sulfides and sulpho-salts of silver, lead, copper, iron, zinc, cadmium, and bismuth associated with jasperiod, barite, quartz, calcite, dolomite, and ankerite (UDEQ 2000).

Mines on the east side of Eureka (May Day and Godiva) are located on the Godiva Ore Zone. The Chief No.1 and Blue Bell mining areas are located on the Mammoth Chief Ore Zone that runs under the center of town. Mines on the west side of town are located on the Gemini Ore Zone, including: the Bullion Beck, Eureka Hill, Gemini, and the Eureka Centennial mines (WGI 2002).

2.2.6 Hydrogeology

The Paleozoic limestones and quartzites are barren of water to great depths. It is believed the fractures in these formations allow ground water to descend to great depths. This is evidenced by several of the mines reaching elevations more than 1,000 feet below the ground surface without encountering water (Meinzer, 1911).

In areas invaded by the igneous rock, the unweathered rock acts as an aquaclude for water percolating down through the overlying sediments and the weathered upper portion of the strata. Seeps in this region are found where the unweathered igneous rock formation is exposed at the surface. Historically, numerous wells have been installed in Eureka to tap the aquifer formed in the igneous strata (Meinzer, 1911).

Wells and infiltration galleries in sediments and weathered strata overlying the igneous bedrock east of Eureka were historically used as the potable water source for Eureka. In 2002, Eureka City completed a Culinary Water Improvement Project that included installation of a production well located in the Tintic Valley west of Eureka, and a pipeline from the well to Eureka City. This well and pipeline currently supplies Eureka will an ample, high quality, potable water. The wells and infiltration galleries east of Eureka are still connected to the Eureka water supply system and are used to supply water to the system.

2.3 ECOLOGICAL SETTING

2.3.1 Surface Water Features

The surface water features at the site are shown in Figures 2-2, 2-5, 2-6, 2-8 and 2-9. Each feature is briefly described in the following sections.

Knight's Spring. Of the springs and surface water bodies shown in Figure 2-4, Knight's Spring is the only permanent water body located within the Site boundary. It is located adjacent to Knightsville Road near the Godiva tunnel (see Figure 2-2). The pond is approximately 24 feet in diameter (see Figure 2-8, Panel A). This water body serves as a watering source for sheep that utilize the surrounding land for grazing. It serves as a watering source for birds and other mammals, and may serve as habitat for aquatic organisms (benthic macroinvertebrates and aquatic insects).

Dam Downgradient of Knight's Spring. A small dam, approximately 3-4 feet high, is present at the Site and is located adjacent to Knightsville Road north of Knight's Spring Pond (see Figure 2-2). The dam was apparently constructed in the Spring of 2007 by the landowner or by a lessee to the landowner. A surface water body has formed upgradient from this dam that is approximately 20 feet in diameter and contains approximately 2 feet of water (see Figure 2-8, Panel B). It is not known if this water body is a perennial or ephemeral feature at the Site. This water body serves as a watering source for sheep that utilize the surrounding land for grazing. This water body may also serve as a watering source for birds and other mammals.

Knightsville Sedimentation Ponds. Man-made sedimentation ponds are located at the base of the Knightsville Drainage (see Figure 2-2 and Figure 2-8, Panel C). Additional drainage ponds are planned to be constructed within Gardner Canyon Drainage within the next two years (see Gardner Canyon Sedimentation Ponds in Figure 2-2). These ponds capture potentially contaminated run-off from residual sources in the canyon during storm and spring melt periods to prevent the recontamination of remediated areas at the Site. The ponds vary in size from approximately 0.1 to 0.6 acres and are lined with rip-rap. Anecdotal reports indicate that the ponds may contain water for a few weeks during the year. The ponds could possibly serve as a temporary watering source for birds and mammals and possibly as a temporary habitat for some types of aquatic insects.

Dust Suppression Pond. This man-made pond is located in Eureka within the Chief Mine No. 1 remedial action boundary (see Figure 2-2). The pond is lined with High-Density Polyethylene (HDPE) and contains approximately 3-4 feet of water, year-round (see Figure 2-8, Panel D). The water is used for the suppression of dust generated during construction activities associated with remedial/removal actions at the site. The source of the water is groundwater that is piped from a well that is completed in the same aquifer that provides drinking water to the town of Eureka. This man-made pond is a temporary feature that will be demolished at the completion of remedial action at the Site. Thus, it is not considered part of the post-remedial conditions evaluated in this BERA.

Eureka Gulch. Eureka Gulch is an ephemeral stream that passes through the central part of Eureka, alongside Highway 6 (see Figure 2-2). Within the Eureka Mills Superfund Site Response Action Structures, Eureka Gulch is lined with rip-rap (see Figure 2-9, Panel A). West of the Site boundary, the gulch has not been altered and has a natural, cobbled bottom (see Figure 2-9, Panel B). Through the town of Eureka, Eureka Gulch flows through a variety of unlined and lined open channels and culverts of various sizes. It reportedly contains water following precipitation events and spring snowmelt. Eureka Gulch joins with Tanner Creek, approximately 6.5 miles southwest of the Site (see Figure 2-5). The extent that Eureka Gulch discharges to Tanner Creek is not known. Observations by Site personnel following storm events suggest that storm-water run-off usually infiltrates into the ground after exiting the Site. Because of its ephemeral nature, Eureka Gulch is not considered to be viable aquatic habitat, but could serve as a temporary watering source for birds and mammals.

During the summer of 2007, a small pool of water was frequently observed after rain events in a portion of lower Eureka Gulch. The pool of water was reportedly 1-2 feet in diameter and a few inches deep. This water is not thought to be naturally occurring, but is believed to be related to the daily discharge of decontamination water from a decontamination station into the Eagle Blue Bell Drainage Channel (see Figure 2-2), which eventually discharges into lower Eureka Gulch. During the construction season, discharge of 3,000 – 5,000 gallons of decontamination water per day occurs six days a week. The approximate distance from the decontamination station discharge point to lower Eureka Gulch is around 3,000 feet. The combination of the regular discharge of decontamination water and a rain event occurring at the Site are speculated to be the source of the small pool of water that was observed in this part of Eureka Gulch. Anectodal reports by field personnel suggest that that the occurrence of surface water at this location is highly intermittent, and when present, exists for only short durations (1-2 days). The decontamination station is a temporary Site feature associated with remedial action activities and will be discontinued after the remedy is complete. Based on this, this small pool of water observed in lower Eureka Gulch is not considered to be a significant source of water for ecological receptors.

2.3.2 Terrestrial Features

The Site is typical of the west desert portion of Utah's Basin and Range country. The town of Eureka sits in a low mountain saddle, between the ridgelines of a few of the surrounding peaks of the Tintic Mountains to the south and to the foothills to the north. Much of this topography is very rugged, with steep, rocky mountainsides and ridges, deep gullies and drainages throughout, and dry, rocky shrub-steppe vegetation. The Site is comprised of a range of elevations and habitats, including: sagebrush and pinyon-juniper stands, thick mountain shrublands, and wooded areas of deciduous and mixed coniferous trees. These habitats provide ample forage and nesting opportunities for numerous bird and mammal species. However, some parts of the Site have been recently disturbed by removal of mining debris, contouring, removal of contaminated soils and covering with clean rock (riprap). Other reclaimed sites have had the mining debris removed, contoured and revegetated with native species. These recently reclaimed and disturbed sites provide very few if any nesting and cover opportunities, and probably low forage utility. This is because the recently reclaimed areas tend to have: (a) reduced plant species diversity which limits the available habitat niches for all animals (i.e. birds, mammals, insects, etc.); (b) lack of cover to support high numbers of species or individuals because of the lack of well structured habitats; and (c) reduced foraging opportunities because of either the immature stage of the vegetative communities (reclaimed areas) or the lack of healthy, native vegetation species combined with the dominance of noxious weeds and unpalatable, invasive species (disturbed sites) (HDR 2007).

Low precipitation (an annual average of 17 inches with monthly averages distributed between just over 1" to just under 1.75"), extreme temperatures (ranging from below freezing to close to 100 degrees F) along with the Site's long history of mining contributes to a fragile ecosystem, sensitive to disturbance and slow to respond to natural or man-made reclamation attempts (HDR 2007).

2.3.3 Wildlife Species

Based on the available habitats, the site may be suitable for a range of avian and mammalian species representing several different feeding guilds, including insectivores, herbivores, omnivores, and carnivores.

A survey of mammals has not been conducted at the site. However Table 2-1 lists a number of species that might be expected to occur at the site, based on professional judgment (HDR 2007).

In June 2008, USFWS (2008) conducted a breeding bird survey at the site. The bird species observed during the survey are presented in Table 2-2 and the field report is provided electronically in Appendix A. Other species not seen during the June 2008 survey that might also be expected to occur at the site, based on professional judgment (HDR 2007), are presented in Table 2-3.

2.3.4 State and Federal Listed Species

Table 2-4 identifies species that are considered threatened, endangered, or are of special concern to the Federal government and/or the State of Utah, and which are known to occur in Juab County (UDWR 2006a and 2006b).

Note that not all of the species in Table 2-4 are equally likely to utilize the types of habitat that occur at or in the vicinity of the Site. The Utah Division of Wildlife Resources (UDWR) was consulted (UDWR 2007a and 2007b) for assistance in identifying species that are known to occur or might reasonably be expected to occur at the Site. UDWR (2007a) searched their plant and animal occurrence records for species that were present within the Site boundary and also within 0.5 miles, 1.0 miles and 5.0 miles of the Site boundary. This database consists of data from many sources, including: the Utah Division of Wildlife Resources, the Utah Reclamation Mitigation and Conservation Commission, the United States National Park Service, the United States Forest Service, the United States Fish and Wildlife Service, the United States Bureau of Land Management, Utah State University, the University of Utah, Brigham Young University, the network of state/province Natural Heritage Programs and Conservation Data Centers, The Nature Conservancy, NatureServe, various museums, and numerous individuals. The results of the search are shown in Table 2-5. As seen, no records of the occurrence of any state or federally listed plant/animal species were reported either at the Site or within 1/2 mile of the Site (UDWR 2007a). Records were located to indicate the occurrence of two Utah Sensitive Species (Townsend's big-eared bat and the Eureka mountainsnail) within 1 mile of the Site, and three additional Utah Sensitive Species (Greater sage-grouse, Milksnake, Peregrine falcon) within 5 miles of the Site (UDWR 2007a). Further consultation with UDWR (2007b) indicated that the Ferruginous hawk and the Fringed myotis might also occur in the vicinity of the Site. This determination was based on both a quantitative assessment of occurrence records and a qualitative evaluation of the likely presence of these species.

Note that the absence of occurrence data for a species in the UDWR database could be due to one or both of the following: (1) the area was surveyed and no listed species were observed; or

(2) the area was not surveyed for listed species. While it is not known, which of the above reasons is applicable to the Site, the species identified in Table 2-5 were identified by UDWR based on both a quantitative evaluation of occurrence (based on observations) and a qualitative evaluation of occurrence (based on habitat and known range), thus minimizing any potential uncertainties associated with the completeness of the occurrence database.

3.0 SUMMARY OF AVAILABLE DATA

Four studies have been performed to collect samples of environmental and/or biological media at or in the vicinity of the Site in order to characterize the nature and extent of mining-related environmental contamination. These studies include the Site Inspection (UDEQ 2000), Preliminary Removal Assessment (URS 2001), the Source Areas and Open Areas Investigation (PRI 2003), and the Ecological Risk Assessment Investigation (USEPA and USACE 2007b). Additionally, a laboratory study (Fort Environmental Laboratories, Inc. 2007) investigated the toxicity of Site soils to ecological receptors (plants and earthworms). Tables 3-1 through 3-5 summarize the environmental, biological, and toxicity data collected during these studies. A brief description of the environmental, biological and laboratory data available for use in this risk assessment report are presented in Sections 3.1 – 3.3. Section 3.4, evaluates the available data and selects data that are appropriate for use in the risk assessment. Section 3.5 describes the reference data set used in the risk assessment and Section 3.6 presents summary statistics for the concentrations of metals measured in each media.

3.1 ENVIRONMENTAL DATA

3.1.1 Soil

Four investigations collected soil samples at or in the vicinity of the Site. Each investigation is briefly described below and summarized in Table 3-1. Sample locations are shown in Figures 3-1 through 3-3.

Site Inspection (UDEQ 2000)

In July 2000, Utah Department of Environmental Quality (UDEQ), Division of Environmental Response and Remediation (DERR) conducted a Site Inspection to assess if further action was needed at the Eureka Mills Superfund Site. Although one of the objectives of the investigation was to *evaluate both human and environmental targets surrounding mine operations* (UDEQ 2000), the investigation emphasized evaluating potential exposure of human receptors. During the inspection, a total of 49 soil samples were collected. This included the collection of 36 soil samples from mine/mill waste sources and surrounding areas and the collection of 4 background soil samples. Sample depth was not reported, so all samples were assumed to be surface soil. A total of 9 sediment samples were collected from a 1.2 mile stretch of Eureka Gulch and also from the stream channel adjacent to Knightsville Road. Samples that were classified as "sediment" in this study were treated as soil samples for the risk assessment because these drainages contain water only intermittently. Sample locations are shown in Figure 3-1.

Samples were collected in accordance with UDEQ/DERR, CERCLA Quality Assurance Project Plan (QAPP) and the Work Plan developed for the Site (UDEQ/DERR 1999 and UDEQ 2000). Samples were analyzed for the 23 Target Analyte List (TAL) metals by USEPA's Contract Laboratory Program (CLP) using Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) and Cold Vapor Atomic Absorption (CVAA) for the analysis of mercury. Cyanide was also measured in 15 samples collected from the Godiva, May Day, Uncle Sam and Chief Mill source areas. The analytical results were validated according to USEPA's CLP National Functional Guidelines for Inorganic Review (USEPA 1994). The data collected during this investigation are provided electronically in Appendix A.

Eureka Mills Outside Preliminary Removal Assessment (URS 2001)

In October 2000, URS Operating Services, Inc. conducted an assessment of non-residential locations around the perimeter of Eureka to support removal action decisions and a human health risk assessment for the Site. A total of 326 soil samples were collected from 25 non-residential areas surrounding Eureka and 7 background locations (areas with no apparent impact from mining activities). This included the collection of 265 field samples (132 surface and 133 depth samples), 18 background samples and 43 Quality Control (QC) samples (field blanks, field splits, field duplicates). Composite surface soil samples (0-2" or 0-6") and discrete depth samples (0-6", 6-12", 12-18") were collected from most of the sample locations. Composite samples were comprised of 10 grab samples collected at a depth of 0-6" at mine/mill waste areas and at a depth of 0-2" at all other locations. Sample locations are shown in Figure 3-1.

Samples were collected and analyzed in accordance with the URS Sampling and Analysis Plan (URS 2000). Soil samples were air dried, sieved (60-mesh/250 micrometer), and analyzed for 25 metals by X-Ray Florescence (XRF) (Spectrace 9000 Field Portable XRF) at an onsite laboratory. A total of 36 samples (10%) were sent to a commercial laboratory for confirmation analysis of the 23 TAL metals by ICP-AES and CVAA (mercury). Confirmation sample results were validated in accord with USEPA's CLP National Functional Guidelines for Inorganic Review (USEPA 1994). The data collected during this investigation are provided electronically in Appendix A.

Source Area and Open Area Investigation (PRI 2003)

During August 2002, Project Resources, Inc. (PRI) conducted soil sampling at the Site to supplement the data collected during the removal preliminary assessment/remedial investigation and to support remedial design activities for the Site (PRI 2003). This included the collection of soil samples from source areas (mine waste rock/mill tailing areas), open areas (undeveloped properties that are used recreationally), and dirt paths/unpaved roads/drainage ways located in and around Eureka, Utah. Soil samples were also collected from potential borrow pit locations (undisturbed land located outside of the Eureka City limits) for consideration as backfill and cover materials in the residential remediation.

A total of 848 soil samples (804 field samples and 44 QC field duplicate samples) were collected from 616 stations in accordance with the Surface Soil Investigation Report (PRI, 2003). Surface soil samples from source areas and open areas were collected from 200 foot grids at depths of 0-6” below ground surface (bgs). Surface soil samples collected from trails, unpaved roads, and from around selected areas of concern on 100 foot grid intervals, typically at depths of 0-2” bgs. Surface soil samples collected from potential borrow pit locations were collected as composite samples at a depth of 0-6” bgs. Subsurface samples (6-12” bgs and 12-18” bgs) were collected from 93 locations, primarily from areas outside of mine waste piles (source areas). Sample locations are shown in Figure 3-1 (source area and open area sample locations) and Figure 3-2 (potential borrow pit sample locations).

All soil samples were analyzed for 15 metals by XRF at the Bureau of Reclamation (BOR) field lab in Eureka, Utah. A total of 89 samples (approximately 10% of all soil samples) were sent to the CLP laboratory for confirmation analysis for the 23 TAL Metals by ICP-AES and CVAA (mercury). Confirmation sample results were validated in accord with USEPA’s CLP National Functional Guidelines for Inorganic Review (USEPA 1994). The data collected during this investigation are provided electronically in Appendix A.

Ecological Risk Assessment Investigation (USEPA and USACE 2007b)

During June and July of 2007, the USEPA and USACE conducted a field investigation to collect environmental and biological data to support an ecological risk assessment of the Site (USEPA and USACE 2007b). The study area for this investigation is shown in Figure 3-3 and was selected to approximately encompass all areas that have been potentially impacted by the release of site-related contaminants. The 8 exposure areas of potential concern shown in Figure 3-3 were selected based on a consideration of the following: potential transport of contaminants by wind and/or surface water runoff, topography, the locations of historical mining/milling activities, and potential habitat use. The approximate area of each exposure area varied from as small as 15 hectares (at Exposure Area 8) to as large as 69 hectares (at Exposure Area 6), with an average size of 49 hectares. Additionally, a total of 2 reference areas were established, based on consideration of geology, soil type, elevation, and the absence of visible impacts from mining/milling activities. A total of 130 surface soil samples were collected from 8 ecological exposure areas surrounding the town of Eureka and 2 reference areas. The number of composite samples collected at an ecological exposure area ranged from 4-20. The number of samples collected varied in order to achieve the goal of having approximately 20 surface soil samples at each exposure area for use in the risk assessment, when the surface soil data from the 2007 investigation were combined with the surface soil data analyzed using ICP from the historical investigations. Composite samples, comprised of 5 grab samples collected at a depth of 0-6 inches (0-6"), were collected at each sample location from the approximate center and four corners of a 100 foot by 100 foot grid (a 10,000 square foot area). The sample locations and the extent of the study area are shown in Figure 3-3.

Samples were collected and analyzed in accordance with the Quality Assurance and Sampling and Analysis Plan (USEPA and USACE 2007b). Each soil sample was split into two aliquots. One aliquot from each sample location was analyzed for 23 Target Analyte List (TAL) metals by USEPA's CLP using ICP-AES and CVAA (mercury). One aliquot from each sample location was analyzed for pH by Accutest Laboratories of New Jersey (Accutest). The analytical results were validated according to USEPA's CLP National Functional Guidelines for Inorganic Review (USEPA 2004), the analytical method (CLP ILM05.4), and project plan Quality Control criteria (USEPA and USACE 2007b). The data collected during this investigation and the data validation report are both provided electronically in Appendix A.

3.1.2 Surface Water and Sediment

Sample Collection

During May through September of 2007, the USEPA and USACE collected environmental and biological data to support an ecological risk assessment of the Site (USEPA and USACE 2007b). This included the collection of surface water and sediment samples from both permanent and ephemeral surface water bodies at the Site. The number and type of surface water and sediment samples collected at each surface water body are described below and are summarized in Table 3-2. Sample locations are shown in Figure 3-4.

Knight's Spring Pond

Field measurements in May 2007 found Knight's Spring Pond to be approximately 24 feet in diameter and 3.5 feet deep. A total of 6 surface water and 10 sediment samples were collected from Knight's Spring Pond during the 2007 field investigation. Grab samples of surface water were collected from both the north side and south side of the pond on a monthly basis, over a period of 3 months (May – July 2007). All of the surface water samples from Knight's Spring Pond were collected on the day that a rain event occurred at the Site (see Table 3-3). Measurements of both the dissolved and total fractions of metals in surface water were collected during each sampling event.

Samples of both shallow and deep sediments were collected from the pond. A total of 6 grab samples of shallow sediment (0-2") were collected from along the northern and southern margins of the pond, co-located with the surface water grab samples, over a period of 3 months (May – July 2007). A total of 4 grab samples of sediment (0-6") were collected from bottom of the pond in May 2007, with each sample representing a quadrant of the bottom of the pond.

Knightsville Sedimentation Ponds

The Sampling and Analysis Plan (USEPA and USACE 2007b) called for the collection of surface water and sediment samples from locations at the 2 sedimentation ponds at the Site, when water has been present for at least 24 hours. A total of 4 stations (2 stations per sedimentation pond) were monitored for the presence of standing surface water and the presence of sediment material over a 4 month period (May-September 2007). No surface water samples were collected from the sedimentation ponds during the 2007 field season because surface water was not present in either sedimentation pond during the monitoring period. Additionally, sediment samples were not collected from either sedimentation pond during the 2007 field season due to insufficient sediment material in the ponds during the monitoring period.

Eureka Gulch

The Sampling and Analysis Plan (USEPA and USACE 2007b) called for the collection of surface water and sediment samples from locations along Eureka Gulch where water has been present for at least 24 hours. Figure 3-4 shows the 8 stations in Eureka Gulch (W3 – W10) that were monitored for the presence of surface water during a 4 month period (May – September 2007). Of these 8 stations, a total of 2 stations (W4 and W5) contained surface water for a period of at least 24 hours after a rain event and were sampled during the field season (see Tables 3-2 and 3-3). At station W4 (upper Eureka Gulch), 1 surface water and 1 sediment sample were collected during the field season. At station W5 (lower Eureka Gulch), a total of 5 surface water and 5 sediment samples were collected from station W5 (lower Eureka Gulch). Figure 3-5 shows the water present at station W5 during the June sampling event. As shown in Table 3-3, all surface water samples from Eureka Gulch were collected within 1-2 days following a rain event at the Site. Unfiltered surface water samples were collected during each sampling event for the analysis of total metals.

Dam Downgradient of Knight's Spring Pond

Although sampling from the surface water impoundment located adjacent to Knightsville Road and north of Knight's Spring Pond was not known to exist at the time the Quality Assurance and

Sampling and Analysis Plan (USEPA and USACE 2007b) was prepared, one grab sample of surface water was collected in 2007 and this was analyzed for the 23 TAL Metals in the total fraction.

Sample Analysis and Verification

All surface water and sediment samples were collected in accordance with the Quality Assurance and Sampling and Analysis Plan (USEPA and USACE 2007b). Samples were analyzed for the 23 Target Analyte List (TAL) metals by USEPA's CLP. Sediment samples were analyzed by ICP-AES and CVAA (mercury), whereas surface water samples were analyzed by ICP-MS and CVAA (mercury). Additionally, in order to obtain results for 7 analytes not included in the ICP-Mass Spectroscopy (MS) analysis suite (aluminum, calcium, iron, magnesium, mercury, potassium, sodium), surface water samples were also analyzed by ICP-AES. The analytical results were validated according to USEPA's CLP National Functional Guidelines for Inorganic Review (USEPA 2004), the CLP analytical method (ILM05.4), and project plan Quality Control criteria (USEPA and USACE 2007b). The data collected during this investigation and the data validation report are both provided electronically in Appendix A.

3.2 BIOLOGICAL DATA

3.2.1 Plant Community

As part of the field investigation to support ecological risk assessment at the Site (USEPA and USACE 2007b), observations of the terrestrial plant community were collected from 8 exposure areas and 2 reference areas during late May – early June 2007. The sample locations were selected in the field by ecologists, based on professional judgment, examination of aerial photographs, and ground surveys of the Site. Sample locations were selected based on the different ecological habitat types (e.g., sagebrush grassland, juniper-piyon upland, disturbed/mined area) present within an exposure area/reference area, so that 2-3 plant community surveys (or replicates) were collected from each habitat type at an exposure area/reference area. A total of 23 unique Exposure Area-Habitat Type pairs were identified at the Site. With 2-3 surveys collected at each Exposure Area-Habitat Type, a total of 53 plant community surveys were collected at the Site (44 surveys from the 8 exposure areas and 9 surveys from the 2 reference areas). Figure 3-6 shows the habitat types present at the Site and the sample locations where plant community observations were collected.

At each sample location, ecologists recorded the plant cover by species and species vigor, based on knowledge of these species in different areas of Utah. Species vigor refers to the health and vitality of each species at each site. Vigor classifications were assigned based on professional judgment, using the following 5-point scale:

Vigor Class	Vigor	Comments
5	Excellent	Above average health relative to the species, high success of reproduction.
4	Good	Average to slightly above average health relative to the species, some success in reproduction.
3	Fair	Slightly below average health, little to no signs of reproduction.
2	Poor	Far below average health, under some stress, no reproduction; merely “hanging on.”
1	Dying	Under extreme stress, dying, and may not continue to persist at the site.

Percent aerial cover of each species at each site was estimated as a range of seven percentage cover classes. Vigor and aerial cover were both estimated within a 30-ft (9.1-m) diameter circular plot, using the relevé method (developed by Braun-Blanquet). The relevé method is quick and non-mathematical and should detect nearly all plant species in a given community. This method may be most efficient and useful for large scale ecological restoration projects, provided that the biologists performing the initial analysis are sufficiently knowledgeable about the region's vegetation. In the relevé method, a surveyor walks though each sample point location recording all of the species observed and assigning an aerial cover class value to each species within that sample location. With this method, cover is estimated from seven cover-classes rather than given as a precise percentage of cover (Barbour and others 1987). Thus, an estimate of percent cover is thought to give a false sense of precision, and cover estimates from multiple observers rarely agree. Although some precision is lost, the categorical classification of the relevé method has good repeatability.

At each sample location, ecologists also recorded estimates of percent cover using the Braun-Blanquet cover scale:

Cover Class	Range of Percent Cover	Midpoint
1	75 to 100	87.5
2	50 to < 75	62.5
3	25 to < 50	37.5
4	5 to < 25	15
5	1 to < 5	3
+	0.5 to < 1	0.75
R*	< 0.5	0.2

R = individuals occurring seldom or only once (Mueller-Dombois and Ellenburg 1974)

The results were used to calculate the mean percent cover, the dominant species, and the average vigor of each species by habitat type for each of the 23 Exposure Area/Habitat Type pairs. The results from the plant community survey are provided electronically in Appendix A. The results of the plant community survey were also used to guide the plant tissue collection (see Section 3.2.2).

3.2.2 Plant Tissue

As part of the field investigation to support ecological risk assessment at the Site (USEPA and USACE 2007b), samples of plant tissue were collected at the Site from June 21 – 27, 2007. A total of 23 composite plant tissue samples were collected, one from each of the 23 unique Exposure Area-Habitat Type pairs identified during the plant community surveys. Each composite sample was comprised of approximately 2-3 aliquots collected from Relevé plots located within the same Exposure Area-Habitat Type. Figure 3-6 shows the habitat types within each exposure/reference area and the location of the aliquots used in composite sampling.

To ensure that each sample was representative of the average plant community in each Relevé plot, tissue samples were collected in proportion to the dominance of species recorded during the plant community analysis. For example, if the cover in the Sagebrush habitat within Exposure Area 1 was comprised of 50% species A, 25% species B, 20% species C, and 5% of 5 other species, then approximately 50% of the approximate weight of the composite plant tissue sample would be comprised of species A and 25% of the weight comprised from species B, etc. The softer, more palatable, leafy plant tissue, as opposed to the woody plant material, was collected during the tissue sampling.

Samples were analyzed for the 23 Target Analyte List (TAL) metals using ICP-AES and CVAA (mercury). The analytical results were validated according to USEPA's CLP National Functional Guidelines for Inorganic Review (USEPA 2004), the analytical method (SW846 6010B), and project plan Quality Control criteria (USEPA and USACE 2007b). The data collected during this investigation and the data validation report are both provided electronically in Appendix A.

3.2.3 Insect Tissue

Data on the concentration of metals terrestrial insects were collected as part of the field investigation to support ecological risk assessment at the site (USEPA and USACE 2007b). The details on the collection and analysis are described below and summarized in Table 3-4. Terrestrial insect tissue samples were collected at the site from June 21 – 27, 2007. A total of 23 composite insect tissue samples were collected from each of the 23 unique Exposure Area-Habitat Type pairs identified during the plant community surveys. Each composite sample was comprised of approximately 2-3 aliquots of terrestrial insects collected from Relevé plots located within the same habitat type at an Exposure Area/Reference Area. Figure 3-6 shows the habitat types within each exposure/reference area and the location of the aliquots used in composite sampling.

Terrestrial insect samples were collected in accordance with the Quality Assurance and Sampling and Analysis Plan (USEPA and USACE 2007b) by using heavy duty muslin bags to sweep trees, shrubs and ground cover for insects within the sample plot. Additionally, ants from ground nests and any flying insects (e.g., butterflies) moving through the sample plots were also collected whenever possible. Insects from each sample location (each habitat type within each area) were transferred from the sweep nets into a killing jar that contained a fresh paper towel moistened with 100% acetone.

During field collection of the insects, it was noted that the yield of insects from each relevé area was low, so the size of the sampling areas were expanded to approximately 50-60 feet in diameter in an attempt to increase sample mass. However, despite this effort, the yield of insects remained low, ranging from 0.03 to 0.5 grams per sample for a total of 3.9 grams collected across the entire Site (see Appendix A). The reason for the low yield of insects is not certain, but might be related to one or more of the following factors:

- the arid nature of the Site may not support a high density of insect life
- insect density at the site may be reduced due to the impacts (physical and/or chemical) of past mining activities in the area
- samples were collected in the heat of the day when some insects may have sought shelter in locations not readily accessible to collection.
- sampling activity was not planned to coincide with the emergence pattern of any particular insect species, when higher yield of that species might have been possible.

Because of the low yield, field sampling efforts to collect insect samples for field duplicates and matrix spike analyses were not attempted.

Once the collecting was complete at an individual location, the entire contents of the killing jar, including the paper towel, was transferred into the appropriately marked, sealable plastic bag. Samples were shipped on ice to the laboratory for analysis of the TAL metals by ICP-AES and CVAA (mercury). Prior to shipping the insect samples to the laboratory for analysis, all samples were sorted to remove other potential contaminants such as soil or plant tissue. The insects were also inventoried and the number of insects collected were classified to the level of Order (e.g., Lepidoptera, Coleoptera, Odonata, Diptera, etc.) in order to provide data on the types the types of insects present at the Site and on the diversity of the samples collected in each area.

Despite field efforts to increase the size of the samples, upon receipt at the laboratory, it was determined that none of the samples had sufficient mass for reliable chemical analysis. Thus, the 23 composite tissue samples were combined into 9 tissue samples (8 exposure area samples and 1 reference sample), based on the exposure area/reference area from which the sample was collected. To ensure adequate sample mass for analysis of TAL metals, the laboratory QC analyses specified in the QAPP/SAP (USEPA and USACE 2007b) were not performed.

Due to the lack of field and laboratory QC samples, a limited data validation was conducted according to USEPA's CLP National Functional Guidelines for Inorganic Review (USEPA 2004), the analytical method (SW846 6010B), and project plan Quality Control criteria (USEPA and USACE 2007b). The data collected during this investigation and the data validation report are both provided electronically in Appendix A.

3.2.4 Earthworm Tissue

Collection of worms from the Site to measure the concentration of metals in tissue was not attempted. Instead, the uptake into tissue from Site soils was measured in the laboratory, in conjunction with the Site-specific earthworm toxicity study (see section 3.3.2 for a description of the toxicity testing). The concentration of metals in worm tissue were measured in soils from 10 locations (8 exposure areas and 2 reference areas), as shown on Figure 3-3. Worms were exposed to the Site and reference soils for 28 days, according to ASTM Standard E-1676-04. At the end of the 28-day period, the worms were depurated for 24 hours and sent to the laboratory on dry ice for analysis. A total of 10 composite earthworm tissue samples were analyzed for the 23 TAL metals by ICP-AES and CVAA (mercury). Each composite sample was comprised of the 5 replicates of a test soil used in the toxicity testing.

The earthworm tissue data were validated according to USEPA's CLP National Functional Guidelines for Inorganic Review (USEPA 2004), the analytical method (SW846 6010B), and project plan Quality Control criteria (USEPA and USACE 2007b). The earthworm tissue data and the data validation report are both provided electronically in Appendix A.

3.3 SITE-SPECIFIC TOXICITY TESTING

Fort Laboratories, Inc. in Stillwater, Oklahoma (Fort Labs) measured the toxicity of Site soils to plants and earthworms. The available data from each test are briefly described in the following sections and are summarized in Table 3-5. The toxicity testing report summarizing the results of both tests is provided electronically in Appendix A.

3.3.1 Phytotoxicity Testing

Phytotoxicity testing of 10 soil samples (8 exposure area soils, 2 reference soils) was conducted in accordance with ASTM Method E 1963-02 by Fort Labs. The locations of the soil samples collected for use in the tests are shown in Figure 3-3 and the details of the test design are summarized in Table 3-5. Three test species that were representative of the type of plants that are present at the Site (grass, forb, shrub) were tested. These included: switchgrass (*Panicum virgatum*), Tailcup lupine (*Lupinus caudatus*), and Big sagebrush (*Artemesia tridentata*). The endpoints evaluated in the study were germination and root/shoot length. In accordance with Method E 1963-02, a total of 5 replicates were prepared from each soil sample. The seeds used in the toxicity testing were purchased from the Granite Seed Company in Lehi, Utah. The soil samples used in phytotoxicity testing were analyzed for TAL Metals, pH, total organic carbon (TOC), nitrogen, and phosphorus.

3.3.2 Earthworm Toxicity Testing

Earthworm toxicity testing was conducted on 10 soil samples (8 Site soils, 2 reference soils) in accordance with ASTM Method E 1676-04 by Fort Labs in Stillwater, Oklahoma. The locations of the soil samples collected for the tests are shown in Figure 3-3, and the details of the test design are summarized in Table 3-5. The 28-day test evaluated the survival, growth and bioaccumulation of metals in redworms (*Eisenia fetida*). The worms used in the toxicity testing were purchased from Aquatic Research Organisms (ARO) in Hampton, New Hampshire. A total of 5 replicates were prepared from each soil sample used in the study. Additionally, the soil samples were analyzed for TAL Metals, pH, total organic carbon (TOC), nitrogen, and phosphorus.

3.4 DATA USABILITY ASSESSMENT

The data described above were reviewed to determine their usability in the baseline risk assessment. In brief, the data sets were reviewed to determine if they were collected under the guidance of a QAPP that included the use of Quality Control (QC) samples, that appropriate analytical techniques were used, that the data were validated, that no potential problems were encountered in the field that could influence the accuracy of the results, and that the target detection limits were achieved. All available data are considered appropriate for use in the risk assessment, except as noted below.

Soil

XRF vs ICP

As described above in Section 3.1.1, concentrations of metals in soil were analyzed by two different methods: XRF and ICP. In some cases, XRF data may be less accurate than ICP data. Thus, whenever ICP data were available at a sampling location, these data were preferred over XRF data from the same station. If only XRF data were available for a station, then the XRF results were included if they were determined to be adequate for use in risk assessment.

The adequacy of the two XRF data sets (URS 2001 and PRI 2003) for use in the risk assessment was evaluated by conducting a Data Quality Assessment (DQA). This assessment is presented in Appendix B. In brief, the detection frequency and detection limits for a chemical obtained by XRF were compared to levels needed for risk assessment purposes. A comparison of XRF vs. ICP data was also performed. In order for XRF data for a chemical to be included in the risk assessment, both the detection limit and the correlation with ICP must be adequate. Based on the

DQA in Appendix B, the XRF data for the following chemicals from each investigation were determined to be adequate for use in the risk assessment:

Investigation	Analytes with Adequate XRF Data
URS 2001	calcium, lead, zinc
PRI 2003	lead, zinc

The XRF data for these chemicals were adjusted to estimate the ICP-equivalent concentrations, using the chemical-specific parameters from the ICP/XRF regressions (see Appendix B for details):

[ICP-equivalent concentration] = a + b · [XRF concentration]

where:

a = intercept from the ICP/XRF regression line for chemical “i”
b = slope from the ICP/XRF regression line for chemical “i”

Current vs Historic Site Conditions

Most of the investigations that collected soil data from the Site were conducted prior to removal/remedial action activities. Removal and replacement of soil from residential areas and capping of soil/mine waste with rock currently prevent exposure by ecological receptors to soil at several areas of the Site. These areas are shown in Figure 3-1 (remedial action structures and residential remedial action boundary). For the purpose of evaluating risks to ecological receptors under current Site conditions, soil samples collected from within these boundaries were excluded from the risk assessment. Areas that are scheduled for, but have not yet been remediated (e.g, Chief Mine No.1, Chief Mill Site No.1, Chief No.1 Mill Tailing/Chief Mill No.1) were also excluded from the assessment.

Detection Limit Evaluation

The detection limits were evaluated by comparing the mean non-detected concentration to a risk based concentration (RBC). The detection limits were considered adequate if the mean non-detected concentration (at ½ of the detection limit) results in a HQ < 0.5 (USEPA and USACE 2007b). The details of this evaluation are presented in Appendix B2 and the chemicals with inadequate detection limits are shown in the following table, for each media:

Medium	Chemicals with Inadequate Detection Limits	
Surface soil	antimony	selenium
Sediment	antimony	
Plant Tissue	antimony selenium	thallium
Insect Tissue	antimony arsenic cadmium lead mercury	nickel selenium thallium vanadium
Earthworm Tissue	antimony selenium	thallium

As seen, there are several chemicals with inadequate detection limits, especially in insect tissue. Although using data for these chemicals may tend to overestimate the actual concentration in a medium, these data were used in the risk assessment as a conservative estimate of potential risks to ecological receptors. The potential influence of the use of non-detect data with inadequate (elevated) detection limits on risk estimates were addressed in the uncertainty section(s), as appropriate.

Summary of Useable Soil Data

Figure 3-7 summarizes the soil data selected for use in the risk assessment. This includes a total of 690 soil samples (524 surface soil and 166 subsurface soil).

Surface Water

During the 2007 field season, surface water sample station W5 in lower Eureka Gulch (see Figure 3-4 and 3-5) consistently had surface water present for sampling. As described in Section 2.3.1, water present at this sample location is not thought to be naturally occurring, but is believed to occur as the result of the combination of the regular discharge of decontamination water and a rain event occurring at the Site.

Because the surface water collected from station W5 during the 2007 field season is attributed to the discharge of decontamination water, as opposed to natural surface water run-off, and because the discharge of decontamination water is a temporary Site feature associated with remedial action activities and will be discontinued after the remedy is complete, surface water data collected from this station were excluded from evaluation by the risk assessment. However, sediment data collected from this sample location will be utilized in the risk assessment. Because water will not typically be present at this station once decontamination procedures cease, the sediment data collected at W5 were treated as surface soil data.

3.5 REFERENCE DATA SET

Performance of an ecological risk assessment is strengthened by the availability of data from a suitable reference area. Comparison of data between Site locations and the reference area provides a direct measure of the degree of mining impacts, and adds an important weight-of-evidence technique to the evaluation.

Due to differences in geology between the northern and southern foothills around the Site (areas located on the southern and north-western margins of the Site are underlain by ore deposits, whereas areas on the northern/north-eastern margins of the Site are not), two reference areas were selected for sampling (see Figure 3-3):

<u>Southern Reference Area</u>. Gardner Canyon was identified as a potential reference area during a Site visit. The topography of the Canyon appears to isolate it from surface water run-off and wind transport of mining-related contaminants. Further reconnaissance of Gardner Canyon showed that, although there are a few waste piles from prospects and adits in the lower and middle portions of the canyon, most areas in Gardner Canyon do not appear to be impacted by mining activities. The Gardner Canyon Reference Area is similar in elevation and soil type to the adjacent mined and un-mined areas located on the southern side of the Site.

Note that the Gardner Canyon reference area is located within Exposure Area 4 (see Figure 3-3). Although it is unusual for a reference area to be located within an exposure area, this is considered to be necessary and appropriate in this case because a) no other area south of the Site appears to be well matched for soil type and conditions, and b) the area selected as the reference area is known to be relatively unimpacted by mining, and the QAPP/SAP (USEPA and USACE 2007b) specifically required that samples from this portion of Gardner Canyon not be collected near or downgradient of mine prospects/adits/waste piles, if present.

During the collection of soil samples from this reference location, field personnel observed that the physical characteristics of the soil (soil moisture, soil type, etc.) collected from Gardner

Canyon were very different than the soil samples collected at other locations throughout the study area. Additionally, chemical analyses of soil samples from this reference area indicated that it had the highest TOC and high levels of nitrogen. Thus, for some parameters (soil type, soil nutrient levels, and soil moisture levels) this location may not be representative of the soil found at the Site.

Northern Reference Area. Cole Canyon was identified during a previous investigation (PRI 2003) as an area located near the Site that was undisturbed by mining and/or development. This area is similar in elevation and soil type to the proposed Exposure Area 1 and portions of Exposure Area 2. Additional soil samples are also available from the PRI (2003) investigation from another potential reference area, located approximately 1.5 miles northeast of this Site, near Homansville (see Figure 3-2). It is similar in soil type to Exposure Area 1. Because Cole Canyon is located near the Site, approximately similar in elevation as the Gardner Canyon Reference Area to the south, it was retained as the Northern Reference Area for the BERA.

Descriptions of the data collected from these 2 reference areas are described in Sections 3.1 through 3.3.

3.6 SUMMARY STATISTICS

Tables 3-6 through 3-12 present summary statistics for chemicals measured in environmental and biological media from both Site and reference areas. In accord with USEPA guidance (1989), concentrations that were reported as “not detected” or “U” qualified were adjusted so that the concentrations were equal to one-half of the detection limit. As seen, several metals, including those typically associated with mining-related activities (arsenic, cadmium, copper, lead, mercury, and zinc) were generally higher in Site soils than in reference soils, with maximum lead and arsenic concentrations of 38,000 mg/kg and 1,200 mg/kg, respectively. Tables 3-11 and 3-12 show that concentrations of lead measured in insect tissue and earthworm tissue are higher in samples collected from the Site that from reference areas.

4.0 PROBLEM FORMULATION

Problem formulation is a planning step that identifies the major concerns and issues to be considered in an ecological risk assessment, along with a description of the basic approaches that will be used to characterize the potential risks that may exist.

4.1 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

As noted previously, the problem formulation step is an iterative process that begins with an initial screening level ecological risk assessment (SLERA). The SLERA is performed using whatever data are available at the time, and employing intentionally simplified and conservative approaches. The purpose of the SLERA is to help refine the initial problem formulation by determining which, if any, exposure pathways may be excluded from further assessment, and to identify data gaps that limit confidence in the risk characterization. A screening-level assessment was completed for the Eureka Mills Site in November 2007 (USEPA and USACE 2007a).

This section summarizes the main findings of the SLERA, which were used to refine the problem formulation step for the BERA.

4.1.1 Screening-Level Conceptual Site Model

One of the earliest steps in problem formulation is development of a Conceptual Site Model (CSM). The purpose of the CSM is to summarize current understanding of the primary sources of environmental contamination at a Site, and identify the exposure pathways by which environmental receptors at or near the Site might be exposed to Site-related contaminants.

Figure 4-1 presents the CSM that was developed for the screening-level evaluation at the Eureka Mills Site. As seen, there are a number of exposure pathways by which ecological receptors may come into contact with Site-related contaminants, the most important of which are:

- Direct contact of terrestrial plants and soil invertebrates with soil
- Ingestion of soil, food items, surface water, and sediment by birds and mammals
- Direct contact of aquatic receptors with surface water
- Direct contact of aquatic receptors with sediment

4.1.2 Screening-Level Risk Assessment Findings

Table 4-1 provides a summary of the screening level risk findings presented in the SLERA. As seen, screening level risks were above a level of potential concern for both terrestrial (plants, soil invertebrates) from exposure to metals in soil and to wildlife (birds and mammals) receptors from the ingestion of soil and food items. Based on the preliminary, screening-level risk characterization in the SLERA, it was concluded that none of the potential exposure scenarios identified in the CSM could be excluded from further consideration, and the following were recommended for further assessment in the baseline assessment:

- Direct contact of plants and soil invertebrates with surface and subsurface soil
- Ingestion of contaminated soil by wildlife
- Ingestion of contaminated food items by wildlife
- Ingestion of surface water and sediment by wildlife
- Exposure of aquatic receptors to surface water and sediment in permanent and ephemeral surface water bodies

4.1.3 Data Gaps Identified in the SLERA

The SLERA identified a number of data gaps, where additional information was needed to improve the reliability and accuracy of the risk assessment and recommended data collection activities that could be implemented at the Site to minimize uncertainty in the baseline risk assessment. These recommendations were considered in the development of the 2007 field investigation to support ecological risk assessment at the Site (USEPA and USACE 2007b).

4.2 BASELINE ECOLOGICAL RISK ASSESSMENT

This section summarizes the refined problem formulation step for the BERA, based on the results of the SLERA and the results of the field investigation to support ecological risk assessment at the Site (USEPA and USACE 2007b).

4.2.1 Conceptual Site Model for the Baseline Ecological Risk Assessment

Figure 4-2 presents the CSM for the baseline ecological risk assessment. Because no exposure pathways were eliminated by the SLERA, it is basically the same model that was developed for the SLERA (Figure 4-1), except that exposure to water and sediment from permanent and ephemeral water bodies were divided into separate pathways to account for differences in exposure frequency.

The following sections discuss the main elements of the CSM and the exposure pathways selected for quantitative evaluation in the BERA.

Aquatic Receptors

As noted in Section 2.3.1 (Surface Water Features), the only permanent surface water body at the Site is Knight's Spring, a small pond located adjacent to Knightsville Road near the Godiva tunnel. Because the pond is small and is not connected to another surface water body, it is not considered likely that this pond contains fish. However, the pond may be suitable habitat for aquatic insects and perhaps other benthic invertebrates (UDWR 2007c). For aquatic receptors, the exposure pathways of chief concern are direct contact with surface water and sediment. Based on the type of aquatic organisms present at the pond, ingestion of aquatic food items (aquatic insects, plants, etc.) is not thought to be a complete exposure pathway.

Ephemeral surface water bodies at the Site (sedimentation ponds, Eureka Gulch) are unlikely to be suitable habitat for fish and benthic invertebrates, but might be suitable for some types of aquatic insects if standing water is present in these water bodies for sufficient length of time to support the insect's life cycle. These intermittent surface water bodies were monitored during May – September 2007 for the presence of surface water. Even though this time period was characterized by relatively typical rainfall (see Table 3-4), standing water was not observed at any time in the Sedimentation Ponds or in Eureka Gulch, with the exception of one event in September at Station W4. However, based on post-rainfall observations during the 2007 monitoring period, it is believed that water was present at W4 for only a brief period. Based on these observations, it is concluded that, under normal conditions, exposure of aquatic receptors to ephemeral surface water bodies in the sedimentation ponds and Eureka Gulch is likely to be an incomplete exposure pathway. Therefore, this pathway was not evaluated in the BERA.

Plants and Soil Invertebrates

The primary exposure pathway for both terrestrial plants and soil invertebrates is direct contact with contaminated soil (both surface (0 – 6" bgs) and subsurface (6-18" bgs) soil). This pathway was evaluated quantitatively in the BERA for both receptors.

For terrestrial plants, exposure may also occur due to deposition of dust on foliar (leaf) surfaces, but this pathway is believed to be of minor concern compared to root exposures in surface soil and subsurface soils, and so this pathway was not evaluated in the BERA.

Birds and Mammals

Birds and mammals may be exposed to Site -related contaminants by four main pathways: 1) ingestion of contaminants in or on prey items, 2) incidental ingestion of surface soil while feeding, 3) ingestion of contaminated water, and 4) incidental ingestion of sediment while drinking. All four of these pathways were evaluated quantitatively in the BERA. The exposure to surface water and sediment pathways were quantitatively evaluated at permanent (and not ephemeral) surface water bodies.

Birds and mammals may also be exposed by direct contact (i.e., dermal exposure) and inhalation exposure to airborne dusts in some cases, but these exposure pathways are usually considered to be minor in comparison to exposures from ingestion (USEPA, 2003), and were not evaluated quantitatively.

4.2.2 Study Area

As discussed in Section 2.1.1, the boundaries of ecological concern have not been established. However, for the purposes of collecting samples to support the baseline ecological risk assessment, a study area for ecological exposure was established based on a consideration of potential transport of contaminants from the Site by wind and/or surface water runoff (USEPA and USACE 2007b). The extent of this study area is shown in Figure 2-3 and was selected to approximately encompass all areas that have been potentially impacted by the release of site-related contaminants.

Within the study area, a total of 8 exposure areas of potential concern and 2 reference areas were identified. These areas are shown in Figure 3-3. The 8 exposure areas were selected in order to divide the Site into approximate equal areas, taking into account topography and areas of known mining/milling activities. In addition, the boundaries of the exposure areas were also selected to encompass naturally occurring drainages. The 2 reference areas were established, based on consideration of geology, soil type, elevation, and the absence of visible impacts from mining/milling activities.

These exposure and reference areas were used to group and present the various lines of evidence available for evaluating potential risks to ecological receptors.

4.3 MANAGEMENT GOALS

Management goals are descriptions of the basic objectives which the risk manager at a site wishes to achieve. The overall management goal identified for ecological health at the Eureka Mills Superfund Site is as follows:

> *Ensure adequate protection of ecological systems and receptor populations within and in the vicinity of the Site by protecting them from the deleterious effects of acute and chronic exposures to Site -related contaminants.*

"Adequate protection" is generally defined as protection of growth, reproduction, and survival of local populations. That is, the focus is on ensuring sustainability of the local population, rather than on protection of every individual in the population.

4.4 ASSESSMENT AND MEASUREMENT ENDPOINTS

4.4.1 Assessment Endpoints

Assessment endpoints are explicit statements of the characteristics of the ecological system that are to be protected. In accordance with the general management goals identified above, the assessment endpoints selected for this Site are:

- Adequate protection of aquatic receptors from adverse effects related to exposure to chemicals in surface water and sediment.

- Adequate protection of plants and soil invertebrates from adverse effects related to exposure to chemicals in surface and subsurface soil.

- Adequate protection of birds and mammals from adverse effects to growth, reproduction, or survival related to exposure to chemicals in surface water, sediment, surface soil, and food items.

4.4.2 Measurement Endpoints

Measurement endpoints represent quantifiable ecological characteristics that can be measured, interpreted, and related to the valued ecological components chosen as the assessment endpoints (USEPA, 1992; 1997). The measurement endpoints for each assessment endpoint are summarized in Table 4-2.

As seen, the measurement endpoints can be divided into three basic categories, as follows:

- Predicted Risks (Hazard Quotients)
- Site-specific toxicity tests
- Observations of population and community demographics

These three basic types of measurement endpoints are described in more detail below.

Predicted Risks (Hazard Quotients)

A Hazard Quotient (HQ) is the ratio of the estimated exposure of a receptor at a site to a "benchmark" exposure that is believed to be without significant risk of unacceptable adverse effect:

HQ = Exposure / Benchmark

Exposure may be expressed in a variety of ways, including:

- Concentration in an environmental medium (water, sediment, soil, diet)
- Concentration in the tissues of an exposed receptor
- Amount of chemical ingested by a receptor

In all cases, the benchmark toxicity value must be of the same type as the exposure estimate.

When a receptor is exposed to a chemical by more than one pathway, HQs for that chemical for each exposure pathway may be added across pathways resulting in a “Total HQ” (HQ_t) for each chemical. In accordance with USEPA guidance, HQ_ts for different chemicals are not added unless reliable data are available to indicate that the two (or more) chemicals act on the same target tissue by the same mode of action. At this Site, total HQ values for each chemical were not added across different chemicals.

If the value of an HQ is less than or equal to 1, risks to exposed organisms are thought to be minimal. If the HQ exceeds 1, the risk of adverse effects in exposed organisms may be of potential concern, with the probability and/or severity of adverse effect tending to increase as the value of the HQ increases.

In addition, HQ results may also be interpreted by comparing HQ values at the site to HQ values at a reference location (either the site itself before the impact occurred, or some similar site that has not been impacted). HQ values at the site that are greater in frequency and magnitude than

HQ values at background locations, suggest that the site HQ values may be attributed to exposure to chemicals associated with the site. In contrast, HQ values that are similar in magnitude and frequency to HQ values at background locations suggest that the HQ may not be site-related, but instead attributed to exposure to naturally occurring or anthropogenic concentrations of a chemical that are present at the site.

When interpreting HQ results for non-threatened or endangered receptors, it is important to remember that the assessment endpoint is usually based on the sustainability of exposed populations, and risks to some individuals in a population may occur, while the population is expected to remain healthy and stable. In these cases, population risk is best characterized by quantifying the fraction of all individuals that have HQ values greater than 1, and by the magnitude of the exceedences. The fraction of the population that must have HQ values below a value of 1 in order for the population to remain stable depends on the species being evaluated and on the toxicological endpoint underlying the toxicity benchmark. Consequently, reliable characterization of the impact of a chemical stressor on an exposed population risks requires knowledge of population size, birth rates, and death rates, as well as immigration and emigration rates. Because this type of detailed knowledge of population dynamics is generally not available on a site-specific basis, extrapolation from a distribution of individual risks to a characterization of population-level risks is generally uncertain. However, if all or nearly all of the HQs for individuals in a population of receptors are below 1, it is very unlikely that adverse, population-level effects will occur in the exposed population. Conversely, if many or all of the individual receptors have HQs that are above 1, then adverse effects on the exposed population are likely, especially if the HQ values are large. If only a small portion of the exposed population has HQ values that exceed 1, some individuals may be impacted, but population-level effects are not likely to occur. As the fraction of the population with HQ values above 1 increases, and as the magnitude of the exceedences increases, risk that a population-level effect will occur also increases. This concept is illustrated schematically in Figure 4-3.

In interpreting HQ values and distributions of HQ values, it is always important to bear in mind that the values are estimates, based on predictive models, and are subject to the uncertainties that are inherent in both the estimates of exposure and the estimates of toxicity benchmarks. Therefore, HQ values should be interpreted as estimates rather than highly precise values, and should be viewed as part of the weight-of-evidence along with the results of site-specific toxicity testing and direct observations on the structure and function of the receptor community (see below).

Site-Specific Toxicity Tests

Site-specific toxicity tests measure the response of receptors that are exposed to site media and media collected from reference locations (either the site itself before the impact occurred, or some similar site that has not been impacted). Tests of this type may be done either in the field or in the laboratory using media collected on the site. The chief advantage of this approach is that site-specific conditions which can influence toxicity are usually accounted for. A potential disadvantage is that, if toxic effects are observed to occur when test organisms are exposed to a site medium, it is usually not possible to specify which chemical or combination of chemicals is responsible for the effect. Rather, the results of the toxicity testing reflect the combined effect of the mixture of chemicals present in the site medium. In addition, it is often difficult to test the full range of environmental conditions which may occur at the site across time and space, either in the field or in the laboratory, so these studies are not always adequate to identify the boundary between exposures that are acceptable and those that are not.

In addition, comparing the observed toxicity of test organisms from exposure to site medium to the observed toxicity of test organisms exposed to reference area medium may be a useful tool for interpreting toxicity test results, in evaluating whether or not any observed toxicity may be site-related.

Population and Community Demographic Observations

A third approach for evaluating impacts of environmental contamination on ecological receptors is to make direct observations on the receptors in the field, seeking to determine whether any receptor population has unusual numbers of individuals (either lower or higher than expected), or whether the diversity (number of different species) of a particular category of receptors (e.g., plants, benthic organisms, small mammals, birds) is different than expected. The chief advantage of this approach is that direct observation of community status does not require making the numerous assumptions and estimates needed in the HQ approach. However, there are also a number of important limitations to this approach. The most important of these is that both the abundance and diversity of an ecological population depend on many site-specific factors (habitat suitability, availability of food, predator pressure, natural population cycles, meteorological conditions, etc.), and it is often difficult to know what the expected (non-impacted) abundance and diversity of an ecological population should be in a particular area. This problem is generally approached by seeking an appropriate "reference area" (either the site itself before the impact occurred, or some similar site that has not been impacted), and comparing the observed abundance and diversity in the reference area to that for the site. However, it is sometimes quite difficult to locate reference areas that are truly a good match for all of the important habitat variables at the site, so comparisons based on this approach do not always establish firm cause-and-effect conclusions regarding the impact of environmental contamination on a receptor population.

Weight of Evidence Evaluation

As noted above, each of the measurement endpoints has advantages but also has limitations. For this reason, conclusions based on only one method of evaluation may be misleading. Therefore, the best approach for deriving reliable conclusions is to combine the findings across all of the methods for which data are available, taking the relative strengths and weaknesses of each method into account. If the methods all yield similar conclusions, confidence in the conclusion is greatly increased. If different methods yield different conclusions, then a careful review must be performed to identify the basis of the discrepancy, and to decide which approach provides the most reliable information.

5.0 RISK EVALUATION FOR AQUATIC RECEPTORS

As discussed in Section 3, Site-related contaminants may be of concern to aquatic receptors (benthic macroinvertebrates and aquatic insects) in Knight's Pond. Aquatic receptors living in Knight's Pond may be exposed to Site-related contaminants through several potential pathways. As shown in the Site conceptual model (Figure 4-2), the following exposure pathways were selected for quantitative evaluation.

- Direct contact with chemicals in surface water. This pathway is applicable to aquatic insects and benthic organisms that reside in the uppermost portion of the sediment substrate or the water column.
- Direct contact with chemicals in sediment. This pathway is most applicable to benthic invertebrate species that live within the sediment substrate.

Sections 5.1 and 5.2, present the weight-of-evidence evaluation of risks to aquatic receptors from exposure to surface water and sediment, respectively, using the assessment and measurement endpoints described in Section 4.4.

5.1 EVALUATION OF RISKS FROM SURFACE WATER

5.1.1 Predicted Risks Approach (HQ)

Chemicals of Potential Concern

Approach

Figure 5-1 summarizes the sequence of steps used to identify chemicals of potential concern in surface water. The steps in the screening process used to identify chemicals of potential concern (COPC) are briefly described below.

First, available toxicity data are reviewed to determine if the chemical has an appropriate benchmark value. If a chemical lacks a benchmark value, then is not possible to quantitatively evaluate the chemical further and the chemical is identified as a source of uncertainty.

Next, the detection frequency of the chemical in Site media was reviewed. Chemicals were excluded if they were never detected in any Site sample. However, if the analytical detection limit for a chemical that was never detected was sufficiently high that the chemical would not have been detected even if it were present at a level of concern, that chemical was identified as a source of uncertainty.

Lastly, a maximum HQ (HQ_{max}) was calculated, as follows:

$$HQ_{max} = (C_{max}) / (\text{Benchmark})$$

where:

C_{max}	=	The maximum detected concentration (ug/L) in the dissolved fraction.
Benchmark	=	The minimum benchmark value of the acute and chronic benchmarks (ug/L)

If the HQ_{max} exceeded 1, then the chemical was retained for quantitative evaluation. Conversely, if the HQ_{max} did not exceed 1, then it was excluded from further consideration.

Data

As described in Section 3.1.2, a total of 6 surface water samples were collected at Knight's Spring during May – July 2007. Samples were collected from 2 stations (K1 and K2) and analyzed for TAL Metals in both the dissolved (that which passes through a fine-pore filter) and total recoverable fractions.

There is general consensus that toxicity to aquatic receptors is dominated by the level of dissolved chemicals (Prothro 1993), since chemicals that are adsorbed onto particulate matter may be less toxic than the dissolved forms. Therefore, the initial screen to identify chemicals of potential concern to aquatic receptors was performed using the dissolved concentrations measured in surface water from Knight's Spring.

Benchmark Values

Toxicity benchmark values for the protection of aquatic life from direct contact with chemicals in surface water are available from several sources. Each of the sources evaluated in deriving surface water toxicity benchmarks are described in Appendix C. This Appendix also describes the hierarchy used to identify the most relevant and reliable toxicity benchmark value when more than one value was available. In brief, USEPA acute and chronic National Ambient Water Quality Criteria (NAWQC) values for the protection of aquatic communities (USEPA 2002a) were used, preferentially. If NAWQC values were not available, then the Oak Ridge National Laboratory (ORNL) Tier II secondary acute values (SAVs) and secondary chronic values (SCVs) derived in Suter and Tsao (1996) were used. For chemicals without NAWQC or Tier II values (magnesium, potassium and sodium), ORNL lowest chronic values (LCVs) for fish, daphnids, non-daphnid invertebrates (Suter and Tsao, 1996) were used.

Because water hardness can affect metal toxicity (higher hardness tends to decrease bioavailability and hence toxicity), hardness-dependant benchmarks were calculated. The hardness at the pond ranges from 403 – 567 mg/L. In cases where water hardness exceeds 400 mg/L as $CaCO_3$, USEPA (2002a) recommends that a hardness of 400 mg/L be used in deriving hardness-dependant AWQC. This is because most equations are based on data in the 50-400 mg/L range, and extrapolation outside of the observed range is not recommended. Thus, in accord with USEPA (2002a), a hardness value of 400 mg/L was used to derive hardness-dependant benchmarks for use in the BERA.

The acute and chronic toxicity benchmark values selected for evaluation of risks from direct contact with surface water are shown in Appendix C, Table C-1. For the initial screen, the lowest benchmark value for a chemical (chronic benchmark) was used to select chemicals of potential concern.

Results

The results of the initial screen for exposure of aquatic receptors to chemicals in surface water are presented in Table 5-1. As seen, concentrations of most chemicals were below a level of concern and were eliminated from further evaluation. The following 5 chemicals were retained for quantitative evaluation in the baseline risk assessment: aluminum, cadmium, calcium, manganese, and zinc.

Data for HQ Calculations

The same data set used in the identification of chemicals of potential concern in surface water was used to calculate HQs for aquatic receptors at the pond. In brief, surface water samples were collected monthly during May – July 2007 from 2 stations at the pond (K1 and K2) and analyzed for dissolved and total metals. The dissolved concentrations of metals in surface water were used to evaluate risks to aquatic receptors at the pond, as toxicity is thought to be dominated by the dissolved fraction of metals (Prothro 1993).

Exposure Assessment

For aquatic receptors (benthic macroinvertebrates, aquatic insects), each sample of water may be viewed as representing an environmental exposure location in which one or more organisms may be exposed. Thus, HQ values were calculated on a sample-by-sample basis, for all available samples. In accord with USEPA guidance, non-detects were evaluated at one-half the detection limit.

Toxicity Assessment

The sources evaluated in deriving surface water toxicity benchmarks for use in the BERA are presented in Appendix C. This appendix also described the hierarchy used to identify the most relevant and reliable toxicity benchmark value when more than one value was available. Two benchmarks were selected for each chemical: acute and chronic toxicity values. The acute and chronic toxicity benchmark values selected for evaluation of risks from direct contact with surface water are shown in Table 5-2 and also in Appendix C (Tables C-1a and C-1b). As described above, hardness dependant toxicity values were derived using a hardness of 400 mg/L, in accordance with USEPA (2002a).

Risk Characterization Results

Detailed HQ calculations for exposure of aquatic receptors to surface water at Knight's Spring are provided in Appendix D. Table 5-3 summarizes the frequency and magnitude of HQ exceedences for both the acute and chronic benchmark values for each COPC. Appendix D also presents scatter plots of the HQ values for each COPC. Example HQ scatter plots are shown in Figures 5-2 and 5-3 for cadmium and zinc, respectively. Inspection of Table 5-3 and the graphs in Appendix D reveal the following main conclusions:

- At both sample locations, concentrations of each of the 5 COPCs in surface water result in chronic HQ values above 1 in one or more samples. The chemicals with chronic HQ values that most frequently exceed 1 are aluminum, calcium and manganese. The magnitude of the HQ exceedences for most of these chemicals are generally between 1.0 – 2.0, with the exception of cadmium where chronic HQ values are slightly higher (HQ 2.3 – 3.6).
- Concentrations of zinc result in acute HQ values above 1 at both sample locations. Additionally, concentrations of zinc in both the dissolved and total fractions result in acute HQ values above 1 at both sample locations.

These results suggest the potential for chronic risks to aquatic receptors at the pond due to the concentrations of several metals in water. Acute risks may also be of potential concern due to concentrations of zinc.

Uncertainties

Uncertainties in Measured Concentration Values

Surface water data were available from multiple locations at Knight's Spring and multiple measurements were collected over time. Concentrations appear to be similar between the two stations, so the spatial variability of measured concentrations is judged to be low. However, concentrations of some, but not all, chemicals appear to be variable over time. For example, concentrations of cadmium and zinc decreased in surface water during the 3 month sample period. The reason for the decrease in concentrations is not known. Based on this, temporal variation is a source of uncertainty in the concentrations of metals in surface water. The available data are not sufficient to fully understand the variation in concentrations over time to characterize the magnitude of this uncertainty in surface water concentrations.

Uncertainty in Toxicity Values

Benchmark values used to predict risk to aquatic receptors from contaminants in surface water are based on National Ambient Water Quality Criteria, or ORNL Tier II values. These benchmarks are based on multiple toxicity studies and are intended to be protective of most aquatic species for which reliable toxicity data are available. However, the set of organisms for which there are data may not include the organisms most likely to be present in the Site waters. In addition, these benchmarks are based on studies performed in laboratory waters, and may not account for Site-specific factors that influence toxicity of metals. Because of this, risk predictions based on these benchmarks may either overestimate or underestimate risks to Site species.

5.1.2 Site-Specific Surface Water Toxicity Tests

Toxicity testing of surface water at Knight's Spring has not been conducted. The BTAG and risk managers decided during a March 17, 2007 teleconference that following collection and analysis of surface water from Knight's Spring, the BTAG would review these data and determine what additional data collection activities were needed to support risk management decisions. During the March 24, 2009 teleconference, the BTAG determined that additional data collection activities were not needed to support decision-making for aquatic receptors.

5.1.3 Site-Specific Aquatic Community Surveys

Information on the aquatic communities present at Knight's Spring has not been collected.

The BTAG and risk managers decided during a March 17, 2007 teleconference that, following collection and analysis of surface water and sediment data from Knight's Spring, the BTAG would review these data and determine what additional data collection activities were needed to support risk management decisions, including the collection of information on the aquatic communities at Knight's Spring. During the March 24, 2009 teleconference, the BTAG determined that additional data collection activities were not needed to support decision-making for aquatic receptors.

5.1.4 Weight of Evidence Evaluation for Surface Water

Table 5-4 (upper panel) summarizes the weight-of-evidence evaluation of risks to aquatic receptors from surface water in Knight's Spring. As seen, the Predicted Risk (HQ) approach is the only line of evidence available for evaluating potential risks to aquatic receptors at Knight's Spring. HQ values are above 1 for a few chemicals and in most cases the HQ exceedences range from 1-2. These results indicate that surface water may cause adverse effects in aquatic receptors. However, this conclusion is uncertain due to lack of knowledge regarding the species and relative sensitivity of organisms that may reside in the pond, and the lack of information from other lines of evidence.

5.2 EVALUATION OF RISKS FROM SEDIMENT

5.2.1 Predicted Risks Approach (HQ)

Chemicals of Potential Concern

Chemicals of potential concern (COPCs) for quantitative evaluation were selected using the procedure shown in Figure 5-1.

Data

As described in Section 3.1.2, a total of 10 sediment samples were collected at Knight's Spring during May – July 2007. This included the collection of 6 shallow sediment samples from 2 stations (K1 and K2), over a 3 month period and a total 4 bottom sediment samples. All sediment samples were analyzed for TAL Metals.

Benchmark Values

Toxicity benchmark values for the protection of benthic invertebrates from direct contact with sediment are available from several sources. Each of the sources evaluated in deriving sediment toxicity benchmarks is described briefly in Appendix C. This Appendix also describes the hierarchy used to identify the most relevant and reliable toxicity benchmark value when more than one value was available. In brief, Consensus-Based Sediment Quality Guidelines, threshold effect concentrations (TECs) and a probable effect concentration (PECs) (MacDonald et al., 2000) were used, preferentially. If Consensus-Based Guidelines were not available, then the Threshold Effect Level (TEL) and Probable Effect Level (PEL) values compiled by Ingersoll et al. (1996) were used. Benchmark values for antimony and silver were not available from the above sources and so the NOAA effect range values developed by Long and Morgan (1990) were used.

For each chemical, a threshold effect concentration (TEC) and a probable effect concentration (PEC) were identified. Sediment toxicity should be observed only rarely below the TEC and should be frequently observed above the PEC. The toxicity benchmark value used to select chemicals of potential concern was the lowest benchmark value available for a chemical. These values are shown in Table 5-5.

Results

The results of the initial screen for exposure of aquatic receptors to chemicals in sediment are presented in Table 5-5. The following 10 chemicals were retained for quantitative evaluation in the baseline risk assessment:

Quantitative COPCs	
antimony	mercury
arsenic	nickel
cadmium	silver
copper	zinc
lead	
manganese	

Data for HQ Calculations

The same data set used in the identification of chemicals of potential concern in sediment was used to calculate HQs for aquatic receptors at the pond. A total of 10 sediment samples (6 shallow sediment and 4 bottom sediment) were used in the risk calculations.

Exposure Assessment

For benthic invertebrates, each sample of sediment may be viewed as representing an environmental exposure location in which one or more organisms may be exposed. Thus, HQ values were calculated on a sample-by-sample basis for all available samples. In accord with USEPA guidance, non-detects were evaluated at one-half the detection limit.

Toxicity Assessment

The sources evaluated in deriving sediment toxicity benchmarks for use in the BERA are presented in Appendix C. This appendix also described the hierarchy used to identify the most relevant and reliable toxicity benchmark value when more than one value was available. Two benchmarks were selected for each chemical: a threshold effect concentration (TEC) and a probable effect concentration (PEC) were identified. Sediment toxicity should be observed only rarely below the TEC and should be frequently observed above the PEC. The toxicity benchmark values selected for evaluation of risks from direct contact with sediment are shown in Table 5-6.

Risk Characterization Results

Detailed HQ calculations for exposure of aquatic receptors to surface water at Knight's Spring are provided in Appendix D. The results are presented graphically as scatter plots of the calculated HQ values, grouped by location (station), which allows an assessment of the frequency and magnitude of any HQ values above 1, as well as a comparison of the distribution of HQ values between stations.

Table 5-7 summarizes the frequency and magnitude of HQ exceedences for both the acute and chronic benchmark values for each COPC. Figures 5-4 presents the HQ distributions for lead. Inspection of Table 5-7 and the graphs in Appendix D reveal the following main conclusions:

- Concentrations of cadmium, lead and zinc in sediment result in HQ values above 1 for both TEC- and PEC-based HQs at all locations. The HQ values are often in the 10-100 range.
- Concentrations of arsenic and silver in sediment result in TEC-based HQ values above 1 at almost all locations, with HQ values ranging from 2 – 12. PEC-based HQ values for these chemicals also exceed 1 at several locations, with HQ values ranging from 1.1 – 3.8.

- Concentrations of manganese result in a TEC-based HQ above 1 (HQ = 1.3) and a PEC-based HQ above 1 (HQ = 2.5) at one location.
- Concentrations of antimony, copper, mercury and nickel result in TEC-based HQs that exceed 1 at one or more locations with HQ values ranging from 1.1 – 7.6.

These results suggest the potential for toxicity to benthic organisms that have direct contact with chemicals in sediment, primarily due to concentrations of cadmium, lead, zinc, and to a lesser extent arsenic and silver.

Uncertainties

Uncertainties in Measured Concentration Values

Sediment data were available from multiple locations at Knight's Spring and multiple measurements were collected over time. The density of the samples (n=10) with respect to the size of the pond and the frequency of sampling (monthly for 3 months) is thought to be adequate to characterize the extent of contamination in sediment, spatially. Examination of the data in Appendix D suggest that there is a downward trend in the concentrations of chemicals in shallow sediment over time. This pattern is present in the results for 9 out of 10 chemicals and is consistent with a temporal trends in the concentration values (as opposed to random variation in concentration values). Thus, shallow sediment samples collected over a 3 month period may not be adequate to fully characterize the temporal variation in concentrations present at the pond. Based on this, uncertainty due to sampling error is judged to be low-moderate.

Uncertainty in Toxicity Values

Sediment toxicity benchmarks for benthic invertebrates used in the HQ calculations are based on studies in which multiple contaminants were present and assumes all of the observed toxicity was due to the contaminant of interest, even though other contaminants in the sediment may be associated with observed toxicity. Therefore, there is moderately high uncertainty that exceedence of the benchmark for a particular chemical will actually cause toxicity in benthic organisms. In addition, there may be a wide variety of differences between sediments at Knight's Spring Pond and those used to establish the toxicity benchmarks, which could influence the relative toxicity of chemicals in the sediments. Because of these limitations in bulk sediment benchmarks, HQ values based on the benchmarks should be considered uncertain, and more likely to overestimate than underestimate risks.

Uncertainties in Chemicals Not Evaluated

The initial screen in Table 5-4 identified 10 chemicals without toxicity values that could not be evaluated quantitatively by the risk assessment. These chemicals include: barium, beryllium, calcium, cobalt, magnesium, potassium, selenium, sodium, thallium and vanadium. This omission may tend to underestimate risk, although the magnitude of the underestimation can not be stated.

5.2.2 Site-Specific Sediment Toxicity Tests

Toxicity testing of sediment at Knight's Spring has not been conducted. The BTAG and risk managers decided during a March 17, 2007 teleconference that following collection and analysis of surface water and sediment data from Knight's Spring, the BTAG would review these data and determine what additional data collection activities were needed to support risk management decisions. During the March 24, 2009 teleconference, the BTAG determined that additional data collection activities were not needed to support decision-making for aquatic receptors.

5.2.3 Site-Specific BMI Community Surveys

Information on the nature and diversity of any benthic macroinvertebrate communities present at Knight's Spring has not been collected. The BTAG and risk managers decided during a March 17, 2007 teleconference that following collection and analysis of surface water and sediment data from Knight's Spring, the BTAG would review these data and determine what additional data collection activities were needed to support risk management decisions. During the March 24, 2009 teleconference, the BTAG determined that additional data collection activities were not needed to support decision-making for aquatic receptors.

5.2.4 Weight of Evidence Evaluation for Sediment

Table 5-4 (lower panel) summarizes the evidence available regarding risks to benthic organisms in sediment in Knight's Spring. Predicted risks (HQ Approach) are the only line of evidence that is available. Based on this one line of evidence, benthic macroinvertebrates may be at risk of adverse effects from direct contact with several metals in sediment in Knight's Spring. However, this conclusion is uncertain because of the low confidence in the benchmarks used to compute HQ values, and the lack of information from other lines of evidence.

6.0 RISK EVALUATION FOR PLANTS AND SOIL INVERTEBRATES

The plant and soil invertebrate communities are important components of any ecosystem. Primary producers (or foundation species) such as simple celled plants or complex plants capture energy and provide nutrient and energy input into terrestrial systems as well as providing habitat and forage for a variety of wildlife species. Terrestrial plants and soil invertebrates are good indicators of soil condition because they reside directly in the soil and are not mobile.

Sections 6.1 and 6.2, present the weight-of-evidence evaluation of risks to plants and soil invertebrates, respectively, from direct contact with surface and subsurface soil using the assessment and measurement endpoints described in Section 4.4.

6.1 EVALUATION OF RISKS TO PLANTS

6.1.1 Predicted Risks Approach (HQ)

Chemicals of Potential Concern

The sequence of steps used to identify chemicals of potential concern to plants is the same process used to identify chemicals of potential concern to aquatic receptors. This generalized model for selecting COPCs is shown in Figure 5-1.

Data

All surface soil (0-6” bgs) and subsurface soil (6” to 18” bgs) data collected at the Site that are representative of post-remedy conditions at the Site were utilized to identify COPCs for plants (see Section 3.1.1, Section 3.4, Figure 3-7, and Tables 3-6 through 3-7). In this risk assessment, soil samples that are representative of post-remedy are soil data that were collected outside of boundaries of the remedial action structures shown in Figure 2-2.

Benchmark Values

Screening-level toxicity benchmarks for the protection of plants from chemicals in surface soils are available from several sources. Each of the sources evaluated in deriving soil toxicity benchmarks is described briefly in Appendix C-3, along with a hierarchy for identifying the most relevant and reliable benchmark value when more than one value is available. The soil toxicity benchmarks for plants for all chemicals analyzed in soil are shown in Table C-3 of Appendix C and the values used in the initial screen are shown in Table 6-1. Because Ecological Soil Screening Levels (EcoSSLs) are the most current, USEPA recommended, benchmark values, these values were used, preferentially. If an EcoSSL was not available for a chemical, then Oak Ridge National Laboratory (ORNL) Benchmark values were used (Efroymson et al. 1997a).

Results

The results of the initial screen for exposure of plants to chemicals in soil are presented in Table 6-2. As seen, 15 chemicals were retained for quantitative evaluation in the baseline risk assessment:

Quantitative COPCs	
antimony	copper
arsenic	mercury
barium	nickel
cadmium	selenium
chromium	thallium
cobalt	vanadium
lead	zinc
manganese	

One additional parameter of potential concern in soil for plants is pH. Both low pH (from the oxidation of sulfides in ore) or high pH (from the solubilization of bicarbonate materials in ore) may inhibit plant growth. Data on pH in Site soils are available for 105 samples collected during 2 investigations (URS 2001 and USEPA and USACE 2007a). In all samples but one, the pH values ranged from 6.7 to 8.3, suggesting that abnormal pH is not generally of concern for soil. In one sample, collected at a depth of 6-12 inches at the Bullion Beck/Gemini remedial action area (see Figure 2-2), the pH was 10, which is sufficiently basic that adverse effects on plants would be considered likely. However, because this sample is from a location that is primarily mine waste rather than native soil, it is not considered likely that alkaline soils are a wide-spread issue at the Site.

Data for HQ Calculations

The same data set used in the identification of chemicals of potential concern in soil was used in the initial screen for COPCs (see Section 3.2.1 and Tables 3-6 and 3-7 for summary statistics).

Exposure Assessment

For sessile species such as plants, each soil sample may be viewed as representing an environmental exposure location. Thus, HQs were calculated on a sample-by-sample basis for all available samples.

In accord with USEPA guidance, non-detects were evaluated at one-half the detection limit.

Toxicity Assessment

Toxicity benchmarks used in the HQ calculations are the same soil benchmarks used in the initial screen and are summarized in Table 6-1.

Note that there are different type of benchmark values available (NOAEL, LOAEL, etc.). Proper interpretation of HQ values requires an understanding of the basis for each benchmark value. Appendix C-3 provides additional information on the source of the benchmark values used to evaluate potential risks to terrestrial plants.

Risk Characterization Results

Detailed HQ calculations for exposure of plants to COPCs in soil are provided in Appendix E. The results are presented graphically as scatter plots of the calculated HQ values, grouped by the eight exposure areas (EA1 through EA8) and the two reference areas (Cole Canyon (RC) and Gardner Canyon (RG)) shown in Figure 3-3 that were identified by the ecological risk assessment field investigation (USEPA and USACE 2007b). The scatter plots allow an assessment of the frequency and magnitude of any HQ values above 1, shown by the number of data points above or below the horizontal line (where HQ = 1). The scatter plots also allow a comparison of the distribution of HQ values between exposure areas and reference areas within the study area. The HQ results are summarized in Table 6-3.

Inspection of Table 6-3 and scatter plots in Appendix E indicate the following main conclusions:

- A number of chemicals have a high frequency and/or magnitude of HQ exceedences in soil, including antimony, arsenic, chromium, copper, lead, manganese, mercury, selenium, thallium, vanadium, and zinc. For some of these chemicals, the magnitude of the HQ exceedences often exceeds a value of 10 and in some cases even exceeds a value of 100 (see Tables 6-4 and 6-5).
- Chromium, manganese, selenium, and vanadium also have a high frequency and/or magnitude of HQ exceedences in reference soils, suggesting that the elevation of HQs for these chemicals in Site soils should be interpreted with caution, since high HQs in reference areas is not usually expected.
- Barium, cadmium, cobalt, nickel and selenium have a low frequency and magnitude of HQ exceedences, suggesting that they are likely to contribute only minor toxicity to plants.

Appendix E (see Appendix E-1) presents the spatial distribution of HQ values for each chemical of concern for plants (see upper panels). An example of the spatial distribution of HQs is provided in Figure 6-1 for lead. As seen in Appendix E (Tables E.2-1 through E.2-15), the locations of samples with HQ exceedences for plants are widespread throughout the Site, with the highest magnitude of HQ exceedences generally occurring at exposure areas with known mining/mill sources (EA2, EA5, EA6, EA7) or exposure areas located downgradient of historic mining/milling activities (EA8).

These HQ results indicate that Site soils may be toxic to plants. Based on the frequency and magnitude of HQ values above 1, In some locations, the toxicity is predicted to result in significant population-level effects on the plant community.

Uncertainties in HQ Values

Uncertainties in Measured Concentration Values

Historical investigations at the Site had collected surface soil samples primarily at and in the vicinity of source areas. Additional surface soil samples were collected in 2007 from locations outside of source areas where ecological exposures are likely to occur. Thus, there is good spatial representativeness of the data used in the HQ calculations.

Some of the soil samples collected in historical investigations were composite samples. While compositing surface soil samples across a sample grid may potentially overestimate or underestimate concentrations of chemicals at individual locations within the grid (areas where sessile species, such as plants, may be exposed), it strengthens the estimate of concentrations over larger areas by diminishing the variability between samples. Because of the high density of the placement of composite samples (see Figure 3-1), the use of these data in the BERA is not thought to be a significant source of uncertainty in soil concentration values.

Overall, uncertainty due to sampling error of chemical concentrations in soil is low.

Uncertainties in Soil Benchmarks

The toxicity benchmarks used in HQ calculations for plants and soil organisms are usually based on laboratory studies in which soluble forms of test metals are added to test soils. Thus, these values do not account for occurrence of metals in mineral forms that are largely insoluble and do not contribute as much toxicity as soluble forms. In addition, the values do not account for variations in soil factors such as pH and total organic carbon content which may influence the toxicity of metals in soils to terrestrial plants and invertebrates. Finally, the laboratory toxicity tests may not utilize species that are likely to occur in Site soils. Based on these considerations, confidence in the soil benchmark values and hence in the HQ values is low.

Uncertainties from Chemicals without Soil Benchmarks

Soil benchmark values were not available for 6 chemicals (calcium, cyanide, iron, manganese, potassium and sodium). For most of these chemicals, concentrations observed in Site soils were higher than those observed in reference soils. The majority of chemicals without benchmarks are considered essential nutrients, with the exception of cyanide, and are required by plants and soil organisms for normal functioning. Nevertheless, elevated levels of these chemicals could be toxic to plants, so absence of soil benchmarks for these chemicals could result in an underestimate of risks to plants.

6.1.2 Site-Specific Phytotoxicity Tests

Overview

One way to help reduce the uncertainty associated with risk predictions based on the HQ approach is to perform direct toxicity testing using Site-specific media. Phytotoxicity testing of surface soils from the Site were performed by Fort Labs in Stillwater, Oklahoma. The 28-day soil toxicity tests were performed in accordance with ASTM Standard E-1963-02 (ASTM 2003). Both germination and growth (root length and shoot length) endpoints were evaluated in three plant species, including one grass (switchgrass, *Panicum virgatum*), one forb (tailcup lupine, *Lupinus caudatus*), and one shrub (big sagebrush, *Artemesia tridentata*). The forb and shrub test species are thought to be representative of plant species present at the Site. The grass species is a good lab plant and may be similar to some of the grasses present at the Site. Each species was evaluated for germination, emergence and root and shoot elongation. A total of ten soils were evaluated, including eight site soils (one from each exposure area, EA1-EA8) and two reference soils (samples from each reference area, RC and RG). Sampling locations were selected so that they were co-located with the plant community survey Relevé plots, and were approximately equally divided between areas that appeared to be visibly disturbed/impacted by mining or milling activities at the site and area that appeared to be not visibly impacted by mining or milling. The location of the test soils are shown in Figure 3-3. Details on the chemical characteristics of the test soils, the plant habitat type and their "disturbance classification" (visibly impacted/not visibly impacted) are presented in Table 6-6.

The results for each endpoint were evaluated by comparison to the results for three reference soils, including one laboratory control soil and two Site-specific reference soils (Cole Canyon (RC) and Gardner Canyon (RG)). Greatest emphasis was placed on comparisons to the two site-specific reference soils (RC and RG), since these soils are assumed to be similar to site soils with regard to parameters such as nutrient levels, organic carbon content and type, and water holding capacity, while the laboratory control soil may be quite different (usually much richer). Thus, comparison of results to the laboratory control soil is generally less informative in evaluating the Site-related impacts.

Germination and Emergence Results

Table 6-7 presents the results for the germination and emergence endpoints. As seen, no significant differences in the emergence or germination by the three test species were observed in any of the soil samples collected from Site exposure areas (EA1 – EA8), with respect to the two soil samples from reference areas (RC and RC). These results suggest that the concentration of metals in Site soils are not likely to result in reduced germination or emergence in plants growing in Site soils.

Root and Shoot Length Results

Table 6-8 presents the results for the root/shoot length endpoints for the 3 test species. The results for each test species are discussed in the following sections.

For Switchgrass, Table 6-8 (upper panel) shows that at almost all locations, the shoot length and root length of seedlings grown in surface soil from the site exposure areas (EA1-EA8) were not significantly different from those of seedlings grown in the surface soil from the two reference areas. At one location (EA3), root length was significantly reduced with respect to the Cole Canyon reference soil, but not with respect to the Gardner canyon reference soil (or the laboratory control soil). Because the results were not significantly different from the laboratory control (which would be expected), the significance of this effect is questionable.

For Tailcup lupine (Table 6-8, middle panel), the results for each sample of Site soil do not indicate a significant effect on plant growth, with the exception of the soil samples from EA6 and EA8. The length of roots and shoots of seedlings grown in the EA8 soil sample were significantly less than those grown in soil samples from both reference areas (RC and RG). Similar results were observed for seedlings grown in test soil EA6. Because the effects observed in the soil of these samples are significant with respect to the soil samples from both reference areas and because the effect is observed in more than one endpoint, these data suggest that soils from these two areas may be phytotoxic for this test species.

For Sagebrush, Table 6-8 (lower panel) shows no significant differences in root growth between seedlings grown in Site soils with respect to both reference soils. Shoot length data were not available for statistical comparison as shoots did not emerge in any test soil, including the laboratory control. The lack of shoot emergence is not thought to be a phytotoxic effect, but instead, a trait that is not uncommon to sage brush (Fort Lab 2007).

Correlation with Soil Concentrations

A correlation analysis was conducted to examine the relationship between the concentrations of chemicals, nutrients, and pH in test soils with the observed reductions in root length and shoot length. A pairwise correlation analysis was conducted using Spearman's rank order test. The results are summarized in Table 6-9. As seen, for tailcup lupine, several metals and pH had a significant, negative correlation with shoot length. Three of these metals also had a significant, negative correlation with root length. This suggests that pH and the concentration of several metals in soil could be contributing to the reduced shoot length and root length observed for the tailcup lupine test species at EA6 and EA8. For switchgrass, no significant correlations between soil concentrations and root length were observed, suggesting that factors other than concentrations in soil may be influencing the reduced root length that was observed for this test species.

Summary of Site-Specific Phytotoxicity Results

Of the 8 EAs evaluated, phytotoxic effects (reduced growth) were observed in 2 EAs (EA6 and EA8). These effects were restricted to the forb test species, tailcup lupine (*Lupinus caudatus*). This suggests that this species, and other plant species that are as sensitive as tailcup lupine, may have reduced growth within EA6 and EA8 from direct contact with Site soils.

On a Site-wide basis, only 4% of the observations presented in Tables 6-5 and 6-6 were statistically significant for decreased growth in plants, with respect to the reference areas. Because the effects were restricted to 1 of 3 test species, and were only observed in 2 of 8 EAs, phytotoxicity is thought to be a species- and location- specific effect, as opposed to a Site-wide effect.

Uncertainties in Site-Specific Toxicity Tests

As noted above, there are a number of potential uncertainties associated with Site-specific phytotoxicity tests. First, tests are performed on only a limited set of samples from the Site, so the samples may not capture the full range of variability over space. Next, all tests are based on a comparison of plants grown in Site soils and reference soils, and any differences that are observed may be due to either the effect of chemical contaminants or other factors such as organic content, plant nutrients, etc. Thus, absence of an effect is usually good evidence that the soils are not phytotoxic, but presence of an effect is not certain evidence that chemical contamination is the cause of the effect.

6.1.3 Site-Specific Community Surveys

Data

Plant community observations were collected from eight exposure areas and two reference areas during late May – early June 2007. At each exposure or reference area, different plant community types present were identified (e.g., sagebrush grassland, juniper-piyon upland, disturbed/mined area) and approximately 2-3 community surveys were collected within each community type using the Relevé Method (see Section 3.2.1 for details). Number of species, dominant species, percent cover, and vigor of species were recorded at each survey location. Vigor classifications were assigned based on professional judgment, using the following 5-point scale:

Vigor Class	Vigor	Comments
5	Excellent	Above average health relative to the species, high success of reproduction.
4	Good	Average to slightly above average health relative to the species, some success in reproduction.
3	Fair	Slightly below average health, little to no signs of reproduction.
2	Poor	Far below average health, under some stress, no reproduction; merely "hanging on."
1	Dying	Under extreme stress, dying, and may not continue to persist at the site.

The data from the 2-3 surveys of each community type in each exposure area were combined to calculate a community-wide measure of diversity (number of species), identify the dominant species, and estimate the percent cover and vigor of the dominant species. The results are shown in Table 6-10, grouped by exposure/reference area.

Metrics for Evaluation

The following two metrics were used in the risk assessment to evaluate the plant community data for the Site:

<u>Vigor</u>. The species vigor estimate provides information on both the health and reproductive success of the species. Numeric scores of 3 or less suggest that the overall health of the species and reproductive success is impaired, while values of 4 or higher indicate the species is in good

condition and is reproducing successfully. This metric was given the highest weight in evaluating community status in each exposure area.

Site Area/Reference Area Comparisons. Conceptually, the observations for each community type would be compared to the observations for the same community type at an appropriate reference location in order to identify any Site-related impacts to the plant community. However, of the 9 distinct community types observed at the Site, only 3 were present in the reference areas. Thus, Site-reference comparisons could not be made for all community types. Therefore, in cases where reference data were not available, plant community data were compared qualitatively across exposure units to see if any observable differences or clear spatial patterns were present.

Results

Inspection of the plant vigor data presented in Table 6-10 reveals the following:

- The average vigor of dominant species ranges from 4-5 (good to excellent) at most locations, suggesting that the overall health of the dominant plant species at the Site is fair or better.
- There are a few locations where vigor scores for a dominant species were 3 to 3.5 (fair), indicating community health between fair and good. In EA3, EA5, and EA8, only one dominant species had a score of 3.5 (fair) and all others were 4.0 (good) or above. This suggests that effects in these areas are of minor concern. In EA7, in the Pinyon-Juniper habitat, all three dominant species scored 3-3.5 (fair) for vigor, suggesting this area might be slightly phytotoxic to a range of plants.

Table 6-11 presents the vigor data for each exposure/reference area, grouped by community/ habitat type. The purpose of this table is to allow qualitative comparisons of similar community types between different areas. As seen there are 5 habitat types where plant community observations were collected at more than one exposure and/or reference area. Inspection of the data presented in this table suggest the following:

- The Mountain shrub habitats observed at 5 exposure areas at the Site do not appear to be different from one another with respect to the number of species and the vigor of the dominant species, with vigor scores ranging from 4-5 (good to excellent).
- At the Pinyon-Juniper habitat, the number of species appears similar between exposure areas EA6 and EA7, but appear to be slightly lower than at the reference area (RC).

Vigor scores of dominant species at EA6 appear to be similar to those at the reference area, whereas the vigor scores of dominant species at EA7 are lower than those at the reference area.

- In the Sagebrush habitats, the vigor scores of the dominant species do not appear to be different from the dominant species at the reference area or between exposure areas, with vigor scores ranging from 4-5 (good to excellent) at all areas. The number of species at Site exposure areas appears to be slightly lower than at the reference area, with the number of species ranging from 7-13 as opposed to 21 species at the reference area.
- The Mixed Shrub habitats at EA2, EA3 and EA5 generally appear to be similar to one another in terms of number of species and the vigor of the dominant species, with one exception. The number of species at EA5 appears to be lower than the number of species observed at the two other exposure areas at the Site.
- At the Mountain Drainage habitats, the vigor of dominant species at exposure areas 4 and 5 do not appear to be different from the reference area, with vigors scores of 5 for all species. The number of species at exposure area 4, appears to be slightly lower than reference and lower than the number of species observed at EA5 (3 species at EA4 vs. 9-10 species at RG and EA5).

Correlation with Soil Concentrations

Because the locations of the relevé plots were determined in the field, community data are not co-located with soil data (see Figures 3-6 and 3-7 for sample locations). However, some of the soil samples were collected in the vicinity (from 50 to 200 feet) of the relevé plots, and these data were utilized to examine the correlation between the concentrations of chemicals, nutrients, and pH in test soils with vigor and species diversity.

A pairwise correlation analysis was conducted using Spearman's rank order test on the vigor data. The results are summarized in Table 6-12. As seen, vigor was not significantly correlated with concentrations of chemicals in soil, pH or soil nutrient levels. This suggests that Site-related contaminants in to surface soil are not the primary determinants of plant health at the Site.

For species diversity data, (number of species) this correlation analysis must be conducted using data grouped by habitat type. However, a habitat-level evaluation would result in only 3-5 species diversity observations for the correlation analysis, which is too small a number to provide reliable results. Thus, a correlation analysis of diversity and concentrations of chemicals and nutrient levels was not conducted.

Summary of Plant Community Results

The results presented in Tables 6-9 and 6-10 indicate that decreases in vigor and/or plant diversity were observed in 5 of 8 EAs for the Sagebrush, Pinyon-Juniper, Mixed Shrub and Mountain Drainage habitat types. This is consistent with the hypothesis that Site-related contamination could be impacting plant communities in some locations at the Site.

Uncertainties in Plant Community Studies

As noted above, measures of community status are inherently variable over space and time, and hence a substantial database of observations must be accumulated before effects of chemical exposure can be clearly observed and demonstrated. At this Site, the data for plant communities are based on only one round of observations, so these data must be used with caution in making comparisons between locations and drawing inferences regarding the effects of chemical toxicity.

6.1.4 Weight of Evidence Evaluation for Plants

Summary of the Lines of Evidence

Table 6-13 presents a summary of the overall level of risk to terrestrial plants at each exposure area, based on the three lines of evidence (HQ Approach, Toxicity Testing, Community Survey) available. In general, the levels of risks presented in Table 6-13 were assigned based on a consideration of the frequency and magnitude of adverse effects to the plant community. For the HQ Approach, the level of risk was assigned using the concepts described in Section 4.4.2 and illustrated in Figure 4-3. For the phytotoxicity testing and the plant community survey lines of evidence, the following criteria were used:

LEVEL OF RISK	GENERAL CRITERIA	
	TOXICITY TESTING	COMMUNITY SURVEY
NONE	No significant reductions in any endpoint, in any test species.	No apparent impacts observed
LOW	Significant reduction in 1 endpoint, in 1 test species.	Low frequency and/or magnitude of impacts observed
MEDIUM	Significant reduction in 1 or 2 endpoints, in 1 or 2 test species.	Medium frequency and/or magnitude of impacts observed
HIGH	Significant reduction in more than 2 endpoints in more than 2 test species	High frequency and/or magnitude of impacts observed

Evaluation of the Lines of Evidence

Table 6-14 summarizes the weight of evidence available for evaluating risks to plants. As seen, three different lines of evidence are available to support an evaluation of risks to plants at the Site. The HQ approach predicts a high frequency of risk to plants within all EAs at the Site, the magnitude of which is high at some locations (HQs 40- 300). Site-specific phytotoxicity tests indicated a low frequency of adverse effects in plants, suggesting that phytotoxic effects are not widespread across the Site, but instead are restricted to a few locations (within EA6 and EA8) to selected species (*Lupinus caudatus*, and other species that are as sensitive as this species). The plant community survey results also indicate that the overall health and reproduction of the plant community is fair or better at most locations, with only 2 locations where the health of individual species is slightly below fair. These locations (within EA3 and EA8) were also identified in toxicity testing as areas where reduced plant growth was observed. Further, plant community survey results indicate that the diversity of species observed at some locations (within EA2, EA4, EA6, EA7 and EA8) appears to be slightly lower than the diversity observed at reference areas. Two of these locations (within EA6 and EA8) were also identified in toxicity testing as areas where reduced plant growth was observed.

Taken together, the weight of evidence supports the conclusion that the concentrations of metals in Site soil are generally not of concern in most areas, but may cause reduction in growth and diversity to individual plant species at locations within EA6 and EA8.

6.2 RISKS TO SOIL INVERTEBRATES

6.2.1 Predicted Risks Approach (HQ)

Chemicals of Potential Concern (COPCs)

Figure 5-1 summarizes the sequence of steps used to identify chemicals of potential concern to soil invertebrates.

Data

All surface soil (0-6” bgs) and subsurface soil (6” - 18” bgs) data collected at the Site that are representative of post-remedy conditions at the Site were utilized to identify COPCs for soil invertebrates (see Section 3.1.1, Section 3.4, Figure 3-7, and Tables 3-6 through 3-7). In this risk assessment, soil samples that are representative of post-remedy are soil data that were collected outside of boundaries of the remedial action structures shown in Figure 2-2.

Benchmark Values

Toxicity benchmarks for the protection of soil invertebrates from chemicals in surface soils are available from several sources. Each of the sources evaluated in deriving soil toxicity benchmarks is described briefly in Appendix C-3, along with a hierarchy for identifying the most relevant and reliable benchmark value when more than one value is available. The soil toxicity benchmarks for soil invertebrates for all chemicals analyzed in soil are shown in Table C-3 of Appendix C and the values used in the initial screen are shown in Table 6-15. Because EcoSSLs are the most current, USEPA recommended benchmark values for use in screening assessments, these values were used, preferentially. If an EcoSSL was not available for a chemical, then Oak Ridge National Laboratory Benchmark values were used (Efroymson et al. 1997b).

Results

The results of the initial screen for exposure of soil invertebrates to chemicals in soil are presented in Table 6-16. As seen, 9 chemicals were retained for quantitative evaluation in the baseline risk assessment:

Quantitative COPCs	
antimony	lead
arsenic	manganese
barium	mercury
chromium	zinc
copper	

Data for HQ Calculations

The same data set used in the identification of chemicals of potential concern in soil was used in the initial screen for COPCs (see Section 3.1.1, Section 3.4, and Tables 3-6 and 3-7).

Exposure Assessment

For sessile species such as soil invertebrates, each soil sample may be viewed as representing an environmental exposure location. Thus, HQs were calculated on a sample-by-sample basis for all available samples. In accord with USEPA guidance, non-detects were evaluated at one-half the detection limit.

Toxicity Assessment

Toxicity benchmarks used in the HQ calculations for soil invertebrates are the same as used in the initial screen, and are summarized in Table 6-15.

Note that there are different type of benchmark values available (NOAEL, LOAEL, etc.). Proper interpretation of HQ values requires a detailed understanding of the basis for each benchmark value. See Appendix C-3 for additional information on the source of the benchmark values used to evaluate potential risks to soil invertebrates.

Risk Characterization Results

Detailed HQ calculations for exposure of soil invertebrates to COPCs in soil are provided in Appendix E. The results are presented as scatter plots of the calculated HQ values, grouped by the 8 exposure areas (EA1 through EA8) and the 2 reference areas (Cole Canyon (RC) and Gardner Canyon (RG)). These scatter plots allow an assessment of the frequency and magnitude of any HQ values above 1, shown by the number of data points above or below the horizontal line (where HQ = 1). The scatter plots also allow a comparison of the distribution of HQ values between exposure areas and reference areas within the study area. These results are summarized in Table 6-17.

Inspection of Table 6-17 and the scatter plots in Appendix E indicate the following main conclusions:

- There are a number of chemicals in soil with a high frequency and/or magnitude of HQ values for soil invertebrates above 1, including arsenic, chromium, copper, lead, manganese, mercury and zinc. For some of these chemicals, the magnitude of the HQ exceedences often exceeds a value of 10 and in some cases even exceeds a value of 100 (see Tables 6-18 and 6-19).
- Of these, chromium also has a high frequency and/or magnitude of HQ exceedences in reference soils, suggesting that the elevation of HQs for this chemical should be interpreted with caution, since high HQs in reference areas are not usually expected.
- Barium and antimony have a low frequency and magnitude of HQ exceedences, suggesting that they are likely to contribute only minor toxicity to soil invertebrates.

Appendix E presents the spatial distribution of HQ values for each chemical of concern by exposure area and reference areas. Figure 6-2 presents the spatial pattern of HQ exceedences for zinc.

As seen in Appendix E and Figure 6-2, the locations of samples with HQ exceedences for soil invertebrates are widespread throughout the Site, with a trend toward increasing magnitudes in the HQ exceedences at exposure areas with known source areas.

These HQ results predict toxicity to soil invertebrates from direct contact with several metals in soil at the Site. Based on the frequency and magnitude of HQ values above 1, these results suggest effects on soil invertebrates might be severe, resulting in significant, population-level effects in a number of locations.

Uncertainties

Uncertainties in Soil Concentrations

Historical soil sampling activities at the Site focused mainly on known source areas. Additional surface soil samples were collected in 2007 from locations outside of source areas where ecological exposures are likely to occur. Thus, the spatial representativeness of the data used in the HQ calculations is considered to be good.

Some of the soil samples collected in historical investigations were composite samples. While compositing surface soil samples across a sample grid may potentially overestimate or underestimate concentrations of chemicals at individual locations within the grid (areas where sessile species, such as plants, may be exposed), it strengthens the estimate of concentrations over larger areas by diminishing the variability between samples. Because the high density of the placement of composite samples (see Figure 3-1), the use of these data in the BERA is not thought to be a significant source of uncertainty in soil concentration values.

Soil samples that were collected from mine/mill areas and waste areas that have been remediated or that are scheduled to be remediated were excluded from evaluation in the risk assessment. Although it is not expected that mine waste areas will provide suitable habitat for soil invertebrates some of the remedial areas may also contain soil that could be habitat for these organisms. Thus, excluding samples collected from these areas may tend to underestimate exposure and thus risks to soil invertebrates. However, soil that is capped by remedial action will preclude the infiltration of water, nutrients and oxygen into the underlying soil and thus is not likely to provide a favorable habitat for soil invertebrates. Based on this, the magnitude of the underestimation of risks to soil invertebrates from the exclusion of data collected from remedial action areas is likely to be low.

Similarly, soil samples collected from residences in the town of Eureka were also excluded from evaluation in the risk assessment. However, cleanup actions based on human health (lead cleanup goal of 231 mg/kg lead) should be adequate for the protection of soil invertebrates (soil benchmark for lead of 1,700 mg/kg). Based on this, the exclusion of soil samples collected from residential properties in Eureka from the risk assessment is not likely to underestimate exposure and risk to soil invertebrates.

Overall, uncertainty due to sampling error of chemical concentrations in soil is low.

Uncertainties in Soil Benchmarks

The toxicity benchmarks used in HQ calculations for soil invertebrates are usually based on laboratory studies in which soluble forms of test metals are added to test soils. Thus, these values do not account for occurrence of metals in mineral forms that are largely insoluble and do not contribute as much toxicity as soluble forms. In addition, the values do not account for variations in soil factors such as pH and total organic carbon content which may influence the toxicity of metals in soils to invertebrates. Finally, the laboratory toxicity tests may not utilize species that are likely to occur in Site soils. Based on these considerations, confidence in the soil benchmark values and hence in the HQ values for soil invertebrates is low.

Uncertainties from Chemicals without Soil Benchmarks

Soil benchmark values for soil invertebrates were not available for 10 chemicals (calcium, cobalt, cyanide, iron, manganese, potassium, silver, sodium, thallium and vanadium). For most of these chemical, concentrations observed in Site soils appear to be similar to those observed in reference soils, suggesting that a Site-related release has not occurred for these chemicals. In addition, many of these chemicals (calcium, iron, manganese, potassium, and sodium) are considered essential nutrients, and are required by soil organisms for normal functioning. Thus, the absence of a toxicity benchmark for these chemicals is not likely to result in an underestimation of risk from Site-related releases. However, for a few chemicals (cyanide, silver, and thallium), concentrations in Site soils are higher than those observed in reference soils and thus, the absence of a soil benchmark for these chemicals could result in the underestimation of risk to soil invertebrates from Site-related releases.

6.2.2 Site-Specific Earthworm Toxicity Tests

One way to help reduce the uncertainty associated with risk predictions based on the HQ approach is to perform direct toxicity testing using Site-specific media. Toxicity testing of surface soils from the Site to soil invertebrates were performed by Fort Labs in Stillwater, Oklahoma, in accordance with ASTM Standard E-1676-04 (ASTM 2004). The tests evaluated the mortality and growth of redworms (*Eisenia fetida*) exposed to soil samples from Site exposure areas and reference areas for 28 days. A total of ten soils were evaluated, including eight soils from exposure areas at the Site (one from each exposure area, EA1-EA8) and two from the reference areas (one from each reference area, RC and RG). Soil samples from exposure areas were selected so that an approximately equally number of samples were collected from areas that appeared to be visibly disturbed/impacted by mining/milling activities at the Site and areas that appeared to be not visibly impacted by mining or milling. The sampling locations are shown in Figure 3-3. Details on the chemical characteristics of the soil samples, the plant habitat type and their "disturbance classification" (visibly impacted/not visibly impacted) are presented in Table 6-6. The results of the 28-day test are presented in Table 6-20.

As described above, the results for each endpoint were evaluated by comparison to the results for three reference soils, including one laboratory control soil and two Site-specific reference soils (Cole Canyon (RC) and Gardner Canyon (RG)). Greatest emphasis was placed on comparisons to the two site-specific reference soils (RC and RG), since these soils are assumed to be similar to site soils with regard to parameters such as nutrient levels, organic carbon content and type, and water holding capacity, while the laboratory control soil may be quite different (usually much richer). Thus, comparison of results to the laboratory control soil is generally less informative in evaluating the Site-related impacts.

Mortality Results

As seen in Table 6-20, no significant differences in worm mortality were observed in any of the Site exposure area samples (EA1 – EA8) with respect to the two reference area samples (RC and RG). These results suggest that the concentration of metals in Site soil are not likely to adversely affect the survival of soil invertebrates.

Growth Results

Table 6-20 shows that most of the soil samples from exposure areas did not cause a significant reduction in net body weight, with the exception of soil samples collected from EA2 and EA7. The mean body weight of worms exposed to these test soils were significantly less than the body weights of worms from both reference area soil samples (RC and RG).

Correlation with Soil Concentrations

A correlation analysis was conducted to examine the relationship between the concentrations of chemicals, nutrients, and pH in test soils with the observed reductions in body weight. A pairwise correlation analysis was conducted using Spearman's rank order test. The results are summarized in Table 6-21. As seen, there were no significant correlations of metal concentrations and body weight. However, nitrogen, total organic carbon and potassium had significant, positive correlations with body weight. These data suggest that factors other than concentrations in soil may be influencing the reduced growth in earthworms observed for the test soils from EA2 and EA7.

Uncertainties in Site-Specific Toxicity Tests

There are a number or potential uncertainties associated with Site-specific toxicity tests. First, tests are performed on only a limited set of samples from the Site, so the samples may not capture the full range of variability over space. Next, all tests are based on a comparison of responses by invertebrates exposed to soils from exposure areas and soils from reference areas, and any differences that are observed may be due either to the effect of chemical contaminants or to other soil factors. Thus, absence of an effect is usually good evidence the soils are not toxic, but presence of an effect is not certain evidence that chemical contamination is the cause of the effect.

6.2.3 Site-Specific Community Surveys

Information on the nature and diversity of soil invertebrates at the Site has not been collected.

6.2.4 Weight of Evidence Evaluation for Soil Invertebrates

Summary of the Lines of Evidence

Table 6-22 presents a summary of the overall level of risk to soil invertebrates at each exposure area, based on the two lines of evidence (HQ Approach and Toxicity Testing) available. In general, the overall levels of risks presented in Table 6-22 were assigned based on a consideration of the frequency and magnitude of adverse effects. For the HQ Approach, the level of risk was assigned using the concepts described in Section 4.4.2 and illustrated in Figure 4-3. For the toxicity testing line of evidence, the following criteria were used:

LEVEL OF RISK	GENERAL CRITERIA
	TOXICITY TESTING
NONE	No significant reduction in mortality No significant reduction in growth
LOW	No significant reduction in mortality Slight reduction in growth
MEDIUM	No significant reduction in mortality Moderate reduction in growth
HIGH	Significant reduction in mortality

Evaluation of the Lines of Evidence

Table 6-23 summarizes the weight of evidence available for evaluating risks to soil invertebrates. As seen, two different lines of evidence are available to support an evaluation of risks to soil invertebrates at the Site. The HQ approach predicts a high frequency of risk to soil invertebrates at most exposure areas at the Site, the magnitude of which is very high at some locations (HQs of 20- 800). The Site-specific toxicity tests do not support this conclusion, indicating that mortality does not occur at any location, and that growth reductions occur at only a few locations (within EA2 and EA7). Further, the magnitude of the HQ exceedences within EA2 and EA7 are similar to the magnitude of HQ exceedences observed within other EAs, suggesting that the HQ calculations may not be a good indicator of invertebrate toxicity. In considering these two lines of evidence, greater confidence is placed on the Site-specific toxicity tests than the HQ predictions. This is because the HQ predictions rely on uncertain benchmark values that are likely to be overly conservative, while Site-specific toxicity testing offers a direct measure of effect on receptors of concern. Based on this, it is concluded that the concentrations of metals in Site soil are present at levels that may cause some reduction in soil invertebrate growth at some locations, but that the overall survival of soil invertebrates at the Site is not likely to be adversely impacted.

7.0 EVALUATION OF RISKS TO BIRDS AND MAMMALS

7.1 Predicted Risks Approach (HQ)

7.1.1 Chemicals of Potential Concern

Figure 7-1 summarizes the sequence of steps used to identify COPC to birds or mammals. The steps in the screening process are briefly described below.

First, for each chemical, data were reviewed to determine if the chemical has an appropriate dose-based toxicity reference value (TRV) for birds and/or mammals. If a chemical lacks a TRV value, then is not possible to quantitatively evaluate the chemical further and the chemical is identified as a source of uncertainty.

Next, a maximum HQ (HQ_{max}) was calculated for each medium, for each class of receptors (e.g., birds, mammals) as follows:

$$HQ\max(i) = \frac{C\max(i) \cdot IR\max(i)}{TRV_{NOAEL}}$$

where:

HQ_{max} (i)	=	the maximum possible HQ for exposure to a chemical in medium i
C_{max}	=	the maximum concentration in medium i
IR_{max}	=	the maximum intake rate of medium i for any representative species in each receptor class (e.g., IR_{max} (birds) or IR_{max} (mammals))
TRV_{NOAEL}	=	The No Observed Adverse Effect Level (NOAEL) TRV for chemical i for each receptor class (e.g., NOAEL TRV (birds) or NOAEL TRV (mammals))

Finally, an HQ_{max}(total) was calculated, as follows:

$$HQ\max(total) = \sum_{i=a}^{i=g} HQ\max(i)$$

where:

a = soil
b = sediment
c = plant tissue
d = insect tissue
e = earthworm tissue
f = small mammal tissue
g = surface water

If HQ_{max}(total) is less than or equal to 1, there is strong evidence that that chemical is not of concern to any receptor in the group (birds or mammals), and the chemical is eliminated as a COPC for that group. If the value of HQ_{max}(total) exceeds 1, then the chemical is retained as a COPC for that group for all media.

Data

All surface soil data (0-6" bgs) collected at the Site that are representative of post-remedy conditions at the Site were utilized to identify COPCs for in surface soil (see Section 3.1.1, Section 3.4, Figure 3-7, and Tables 3-6 through 3-7). In this risk assessment, soil samples that are representative of post-remedy are soil data that were collected outside of boundaries of the remedial action structures shown in Figure 2-2.The shallow sediment data collected from Knight's Spring (Stations K1 and K2) were used to identify chemicals of potential concern in sediment. The levels of contaminants in surface water (total fraction) from Knight's Spring and the Dam were used to identify chemicals of potential concern in surface water. All plant tissue, insect tissue, and earthworm tissue data described in Section 3.2 were utilized to identify COPCs in each of these food items.

Because data on the concentration of metals in small mammal tissue were not measured, these levels were estimated from the concentration of metals in soil using the bioaccumulation models developed by Oak Ridge National Laboratory (Sample et al. 1998) (see Appendix G for equations and details). The maximum estimated tissue concentration for a chemical across all trophic groups was used to identify COPCs in small mammal tissue. Because uptake equations were not available for antimony or beryllium, the maximum soil concentration was conservatively assumed for the model.

Toxicity Reference Values

Appendix C-4 describes the TRV selection process for birds and mammals, as well as the sources from which the TRVs originate. In general, the wildlife TRVs were selected to represent relevant toxicity endpoints for population sustainability (growth, reproduction, mortality). Two types of TRVs were identified: those based on a NOAEL, and those based on the lowest observed adverse effect level (LOAEL). The values selected for use in the baseline risk assessment are shown in Table 7-1.

For the initial screen, the NOAEL-based TRVs shown in Table 7-1 were used.

Results

The results of the initial screen for COPCs in Site media are presented in Table 7-2. Table 7-3 summarizes the COPCs that were retained for quantitative evaluation of risks to birds and mammals.

7.1.2 HQ Calculations

The basic equation used for calculation of an HQ value for exposure of a wildlife receptor to a chemical by ingestion of an environmental medium is:

$$HQ_{i,j,r} = \frac{C_{i,j} \cdot (IR_{j,r} / BW_r) \cdot AUF_r}{TRV_{i,r} / RBA_{i,j,r}}$$

where:

$HQ_{i,j,r}$	=	HQ for exposure of receptor "r" to chemical "i" in medium "j"
$C_{i,j}$	=	Concentration of chemical "i" in medium "j" (e.g., mg/kg)
$IR_{j,r}$	=	Intake rate of medium "j" by receptor "r" (e.g., kg/day)
BW_r	=	Body weight of receptor "r" (kg)
$RBA_{i,j,r}$	=	Relative bioavailability of chemical "i" in medium "j" by receptor "r"
$TRV_{i,r}$	=	Oral toxicity reference value for chemical "i" in receptor "r" (mg/kg-d)
AUF_r	=	Area Use Factor of receptor “r”. (Site area/home range area of receptor “r”). If the calculated AUF is greater than 1, a value of 1 is used.

Because all receptors are exposed to more than one environmental medium, the total hazard quotient (HQ_t) to a receptor from a specific chemical is calculated as the sum of HQs across all media:

$$HQ_{t\ i,j,r} = \sum HQ_{i,j,r}$$

where:

HQ_t = Total Hazard Quotient of receptor "r" to chemical "i" in all media (e.g., soil, sediment, surface water, food items, etc.)

$HQ_{i,j,r}$ = HQ for exposure of receptor "r" to chemical "i" in medium "j"

If each pathway-specific HQ and the HQ_t is below 1 based on the NOAEL TRV, it is believed that potential risks are minimal. If any pathway-specific HQ or the HQ_t is above 1 based on the LOAEL TRV, it is considered likely that some adverse effects will occur. If any pathway-specific HQ or the HQ_t is above 1 based on the NOAEL but is below 1 based on the LOAEL, it is considered that adverse effects are possible, but they are likely to be minor in extent and/or severity.

7.1.3 Exposure Assessment

Selection of Representative Indicator Species

It is not feasible to evaluate exposures and risks for each avian and mammalian species potentially present at a Site. For this reason, a number of avian and mammalian feeding guilds that might occur at the Site were identified (see Section 2.3.3), and one species was identified to serve as a representative for each of those feeding guilds. Selection criteria for representative species for each of the feeding guilds included trophic level, feeding habits, and the availability of life history information. The species selected to serve as guild representatives include:

Feeding Guild	Dietary Food Item(s)	Avian Representative	Mammalian Representative
Terrestrial Insectivore	Terrestrial Invertebrates	Northern Flicker	Masked Shrew
Terrestrial Herbivore	Plants	Greater Sage-Grouse	Mule Deer
Terrestrial Omnivore	Plants and Terrestrial Invertebrates	American Robin	Deer Mouse
Terrestrial Carnivore	Small Mammals	Red-tailed Hawk	Red Fox
Aerial Insectivore	Aerial Insects	Cliff Swallow	Big Brown Bat

Exposure Factors

Exposure parameters and dietary intake factors for each representative species were derived from the Wildlife Exposure Factors Handbook (USEPA, 1993), as well as a variety of other sources. The exposure parameters selected for each wildlife receptor are detailed in Appendix F, and are summarized in Table 7-4. Wildlife exposure factors were selected to represent average year-round adult exposures. In some cases, no quantitative data could be located, so professional judgment was used in selecting exposure parameters.

Exposure Units

Wildlife receptors are generally mobile, and hence may be exposed to a range of different concentration values in water, soil, and food web items as they move throughout their home range. As seen in Table 7-4, the home range size of the surrogate receptors are variable, ranging from as small as 0.08 hectares (ha) to as large as 11,100 ha. For the baseline risk assessment, three categories of exposure units (EUs) were selected for evaluation of exposure of avian and mammalian receptors: small home range, medium home range and large home range. Each surrogate was assigned to one of these groups, based on a consideration of the home range size (Appendix F), as follows:

Representative Species	Home Range (Ha)	Exposure Unit Type
Deer Mouse	0.08	Small
Masked Shrew	0.39	
American Robin	0.48	
Northern Flicker	45	Medium
Mule Deer	285	Large
Red-Tailed Hawk	859	
Cliff Swallow	1,000	
Red Fox	1,038	
Greater Sage-Grouse	1,942	
Big Brown Bat	11,100	

Exposure Point Concentrations

General Approach

When exposure occurs over a geographic area, risk from a chemical is related to the arithmetic mean concentration averaged over the entire exposure area. Since the true arithmetic mean concentration cannot be calculated with certainty from a limited number of measurements, the USEPA recommends that the upper 95th percentile confidence limit (UCL) of the arithmetic mean of the chemical concentrations be used to estimate exposure (USEPA, 1992). If the 95% UCL exceeded the highest detected concentration, then the highest detected concentration was used instead (USEPA, 1989).

The approach for computing the 95% UCL of a data set depends on a number of factors, including the number of data points available, the shape of the distribution of the concentrations, and the degree of censoring (USEPA, 2002b). In accord with current USEPA guidance (USEPA 2002b), UCL values were derived using ProUCL v4.0 (USEPA 2007). This software calculates UCLs for a data set using several different strategies, evaluating non-detects using regression on order statistics (ROS). The software evaluates the alternative calculations and recommends which UCL is considered preferable based on the properties of the data set. This approach was followed for all exposure areas with 4 or more samples. Because reliable UCLs can generally not be calculated when the data set is small, if fewer than 4 samples were available, the maximum concentration was used as the exposure point concentration (EPC).

Small Home Range EPCs

Small home range exposure units were assumed to be represented by one sample. For soil, because only one sample is available for each exposure point (sample location), a 95th UCL could not be calculated and the EPC was simply taken to be the concentration in each sample. Because not all media are available at each location where a soil sample was collected, the following assumptions were made in assigning EPCs for other media to each soil sample location:

- Plant Tissue. Plant tissue samples consist of composite samples from plants within a distinct habitat type at an exposure area. Thus, the EPC for plant tissue at a soil sample location is based on the location of the soil sample (both the exposure area and the plant community type).
- Insect Tissue. Insect tissue samples consist of composite samples representing each exposure area or reference area. Thus, the EPC for insect tissue is based on the location (exposure area or reference area) of the soil sample.
- Earthworm Tissue . Only 1 earthworm tissue sample is available for each exposure area or reference area. Thus, the EPC for insect tissue was assigned based on the location (exposure area) of the soil sample.
- Sediment. Knight's Spring is the only source of sediment at the Site and is located within Exposure Area 2 (EA2). Although exposure to sediment at Knight's Spring is likely to occur only to receptors living in the immediate vicinity of spring, exposure to sediment was conservatively assumed to apply to all soil sample locations within EA2. The sediment EPC was calculated from the shallow sediment samples and is equal to the 95^{th} UCL of the mean or the maximum concentration, whichever is lower.

Medium Home Range EPCs

For medium home range receptors, exposure was assumed to be equivalent to one of the eight exposure areas (EAs) at the Site or one of the two reference areas. Therefore, for each EA or reference area, the EPC for each chemical in each medium was the UCL or the maximum value observed in that EA or reference area. Incidental ingestion of sediment from the Knight's Spring was assumed to only apply to receptors at EA2, the EA where the water body is located.

Large Home Range EPCs

Large home range receptors are assumed to be exposed at random over the entire Site, so the EPC for each medium was based on the UCL or maximum detected value for all samples from the Site. This approach was followed for soil, surface water, sediment, plant tissue, insect tissue, and earthworm tissue.

For small mammal tissue, no Site-specific data are available, so tissue concentrations in small mammals were estimated using media-specific uptake equations and factors located in the literature. These bioaccumulation models are presented in Appendix G.

Summary of Exposure Point Concentrations

Exposure point concentrations for COPCs in all media at small, medium and large home range exposure units are presented in Appendix G.

7.1.4 Toxicity Assessment

Ideally, TRVs used in the HQ calculations would be selected for each individual feeding guild that is evaluated. However, because TRVs are usually not available for each feeding guild, this assessment uses more generic TRVs that are based on all birds or all mammals. HQ values were computed using both the NOAEL-based and LOAEL-based TRVs (see Appendix C and Table 7-1).

As seen in Table 7-1, two TRVs are available for mercury: one for the inorganic form and one for the organic form of the metal. For quantifying risks to wildlife, the inorganic TRV was used to quantify risks from soil, sediment and surface water, since inorganic complexes are thought to be the dominant form of the metal in these media (ATSDR, 1999). The chemical form of mercury in plant, insect, earthworm, small mammal tissue is not known. For these media, the organic mercury TRV was conservatively used to quantify risks to wildlife from the ingestion of these media.

7.1.5 HQ-Based Risk Characterization

Appendix H provides the detailed pathway-specific and total HQ calculations for each surrogate receptor. Results for small home-range, medium home-range, and large home-range receptors are discussed below.

Small Home-Range Receptors

As discussed above, small home-range receptors are evaluated as if each soil sampling location were a home range, and risks to the exposed populations are evaluated in terms of the magnitude and frequency of HQ_t values above 1 for each COPC. If all or most NOAEL-based HQ_t values for COPC are below 1, it is concluded the risk to the receptor population from that COPC is minimal. If many LOAEL-based HQ_t values are above 1, then it is concluded that risks to the population for that COPC are of potentially significant ecological concern. If a majority of the LOAEL-based HQ_t values are below 1, but a number of NOAEL-based HQ_t values are above 1, then it is concluded that risks to some individuals may be significant, but that the population-level impacts are likely to be minor.

In addition, HQ results may also be interpreted by comparing HQ_t values at the site to HQ_t values at a reference location (either the site itself before the impact occurred, or some similar site that has not been impacted). HQ_t values at the site that are greater in frequency and magnitude than HQ values at reference locations, suggest that the site HQ_t values may be attributed to exposure to chemicals associated with the site. In contrast, HQ_t values that are similar in magnitude and frequency to HQ_t values at reference locations suggest that the HQ_t may not be site-related, but instead attributed to exposure to naturally occurring or anthropogenic concentrations of a chemical that are present at the site.

Detailed HQ calculations for small home range receptors at this Site are presented in Appendix H. Scatter plots of the HQ_t values, grouped by exposure area, are also provided in Appendix H. Table 7-5 summarizes the results for each small home range receptor by presenting the frequency and magnitude of HQ_t values greater than one, for each COPC. The findings are discussed below.

<u>Avian Omnivore (American Robin)</u>. The results are shown in Table 7-5. As seen, there are a number of EAs where HQ_t values exceed 1 based on the NOAEL and/or LOAEL TRVs for several chemicals.

The chemical that appears to contribute the greatest risk is lead, which exceeds both the LOAEL TRV and the NOAEL TRV at almost all locations (sampling stations) within most EAs. The main source of lead exposure is the ingestion of soil, with additional contributions from the ingestion of insect tissue at EA2 and the ingestion of earthworm tissue at EA6. Selenium in insect tissue and mercury in earthworm tissue also result in a high frequency of LOAEL-based and NOAEL-based HQ_ts at 2 of the on-site EAs (EA1 and EA6 for selenium; EA3 and EA6 for mercury).

Other chemicals that exceed both the LOAEL TRV and the NOAEL TRV, but at a lower frequency (<10% of locations) and/or magnitude include arsenic (at EA6), copper (at EA6), mercury (at EA8), and zinc (at EA2 – EA7). These risks are attributed to the ingestion of these chemicals in soil (zinc) or the ingestion of these chemicals in both soil and insect or earthworm tissue (arsenic, copper, and mercury). HQ_t values at the site are greater in frequency and magnitude than HQ values at reference locations, suggesting that the EA HQ_t values may be attributed to exposure to chemicals associated with the site. These results suggest that potentially significant risks to avian omnivores may occur at all of the on-site EAs.

Other chemicals that result in HQ_t values above a level of potential concern (HQ_t >1) based on the NOAEL (but not the LOAEL) TRV include arsenic (at 7 EAs), barium (at 1 EA), cadmium (at 3 EAs), copper (at 7 EAs and 2 reference areas), mercury (at 5 EAs and 2 reference areas), silver (at 1 EA), and zinc (at 2 EAs and 2 reference areas). These risks are attributed to the ingestion of soil, insect tissue and/or earthworm tissue. As seen in Table 7-5, most HQ_t values are greater in frequency and/or magnitude than HQ_t values in the reference areas. This suggests that while naturally occurring levels of these chemicals could be contributing to these risks, the majority of the risks are attributed to the site. These results suggest that risks to avian omnivores may be occurring at some EAs from these chemicals, though they are likely to be low to moderate in extent and/or severity.

There is one chemical that results in HQ_t values above a level of potential concern (HQ_t >1) based on the NOAEL, but for which a LOAEL is not available: vanadium (at 8 EAs and 2 reference areas). The results for chemicals for which a NOAEL TRV/LOAEL TRV pair are not available are difficult to interpret. Based on the magnitude of the NOAEL exceedences (1.1 - 5), it appears that the HQ_t results for vanadium are generally low at most locations, and most likely would not exceed a LOAEL TRV, had one been available. NOAEL-based HQ_t values exceed a level of potential concern (HQ_t >1) in both reference areas, at a magnitude that is similar to the HQ_t values observed at the EAs, suggesting that naturally occurring levels of vanadium may be contributing to risk. This suggests that additional risks from the ingestion of vanadium may be occurring at all of the on-site EAs, but they are likely to be low to moderate in extent and/or severity.

The frequency of HQ_t exceedences for chemicals where risks are attributed to the ingestion of insect tissue and/or earthworm tissue should be interpreted with caution, because the EPC for each of these media at an exposure area/reference area is based on only 1 composite sample that is then applied to all sample locations within the exposure unit. Additionally, the measured values for some chemicals in insect tissue are uncertain due to elevated detection limits for this media (see Section 3.4). The influence of elevated detection limits on the risk estimates presented in Table 7-5 and the risk conclusions described above are discussed in the Uncertainty Section (see Section 7.1.7).

These results suggest that potentially significant risks to avian omnivores may occur from the ingestion of surface soil at almost all exposure areas at the site. The chemical of primary concern is lead in soil, with lower contributions from arsenic, copper, mercury and zinc in soil and/or insect and earthworm tissue. Additional risks to avian omnivores may be occurring at some EAs from several chemicals (arsenic, barium, cadmium, copper, mercury, silver, vanadium and zinc) in soil, insect tissue and/or earthworm tissue though they are likely to be low to moderate in extent and/or severity.

<u>Mammalian Insectivore (Masked Shrew)</u>. The results are shown in Table 7-5. As seen, there are a number of EAs where HQ_t values exceed 1 based on the NOAEL and/or LOAEL TRVs for several chemicals.

The chemicals that appear to contribute the greatest risk are selenium and thallium, which exceed both the LOAEL TRV and the NOAEL TRV at many locations (sampling stations) within 7 out of 8 EAs. The main source of exposure to both chemicals is the ingestion of insect tissue. Note that the HQ_t values for selenium based on both the NOAEL and the LOAEL TRVs are also above a level of potential concern (HQ_t >1) both reference locations. While this suggests that naturally occurring level of metals could be contributing to risk at some EAs, the magnitude of the HQ_t values in many EAs (EA1, EA2, EA6, EA7), are much greater than the HQ_t values in the reference areas suggesting that the majority of the risks are attributed to the site.

Other chemicals that exceed both the LOAEL TRV and the NOAEL TRV, but at a lower frequency and/or magnitude include arsenic (at 7 EAs), cadmium (at 5 EAs), manganese (at 5 EAs), lead (at 7 EAs) and zinc (at 7 EAs). These risks are attributed to the ingestion of these chemicals in soil (arsenic, lead and zinc) or insect tissue (cadmium and manganese). These results suggest that potentially significant risks to mammalian insectivores may occur at all of the on-site EAs.

Chemicals that result in HQ_t values above a level of potential concern (HQ_t >1) based on the NOAEL (but not the LOAEL) TRV include copper (at 8 EAs and 2 reference areas), chromium (at 1 EA), mercury (at 4 EAs and 1 reference area) and nickel (at 7 EAs and 1 reference area), silver (at 3 EAs) and vanadium (at 1 EA). These risks are attributed to the ingestion of insect tissue (copper and nickel), soil (mercury) or the ingestion of both soil and insect tissue (chromium, silver, and vanadium). Note, HQ_t values exceed a level of concern (HQ_t > 1) in the reference areas for copper, mercury and nickel. However, the magnitude and/or frequency of the values are generally similar to the magnitude and frequencies observed in the EAs, suggesting that naturally occurring levels may be contributing to risk. In the case of nickel (at 2 EAs) and copper (at 4 EAs) the magnitude and frequency of the HQ_t values are greater than those observed in the reference areas, suggesting that site-related releases may also be contributing to the risk at these locations. These results suggest that risks to mammalian insectivores may be occurring at some EAs from these chemicals, though they are likely to be low to moderate in extent and/or severity.

Chemicals that result in HQ_t values above a level of potential concern (HQ_t >1) based on the NOAEL, but for which a LOAEL is not available include: antimony (at 8 EAs and 2 reference areas), silver (at 3 EAs), and vanadium (at 1 EA). The results for chemicals for which both a NOAEL and LOAEL pair are not available are difficult to interpret. Based on the magnitude of the NOAEL exceedences, it appears that the HQ_t results for antimony are large enough (11 – 150) that it is plausible that they might also exceed a LOAEL TRV at some locations, had one been available. Although the HQ_t values for antimony also exceed a level of potential concern (HQ_t > 1) in both reference areas, the magnitude and frequency of the HQ_t values in the reference areas are much lower than the magnitude and frequency of HQ_t values in most areas (at 5 EAs) at the site. This suggests that while naturally occurring levels of antimony may be contributing to risk, the majority of the risks are site-related. On the otherhand, the magnitude of the HQ_t exceedences for both silver and vanadium (1 – 1.2) are low enough that it is probable that they would not exceed a LOAEL TRV, had one been available. These results suggest that potentially significant risks to mammalian insectivores may also be occurring at all of the on-site EAs from the ingestion of antimony in insect tissue. Additional risks from the ingestion of silver and vanadium in both soil and insect tissue may also be occurring, though they are likely to be low to moderate in extent and/or severity.

The frequency of HQ_t exceedences for chemicals where risks are attributed to the ingestion of insect tissue should be interpreted with caution, because the EPC for insect tissue at an exposure area/reference area is based on only 1 composite sample that is then applied to all sample locations within the exposure unit. Additionally, the measured values for some chemicals in insect tissue are uncertain due to elevated detection limits for this media (see Section 3.4). The influence of elevated detection limits on the risk estimates presented in Table 7-5 and the risk conclusions described above are discussed in the Uncertainty Section (see Section 7.1.7).

These results suggest that potentially significant risks to mammalian insectivores may occur at all of the on-site EAs. The chemicals of primary concern are antimony, selenium and thallium in insect tissue, with additional contributions from arsenic, lead and zinc in soil and from cadmium and manganese in insect tissue. Additional risks to mammalian insectivores may be occurring at some EAs from several chemicals (antimony, copper, chromium, mercury, nickel, silver, vanadium) in soil and/or insect tissue, though they are likely to be low to moderate in extent and/or severity.

Mammalian Omnivore (Deer Mouse). As seen in Table 7-5, based on the LOAEL TRV, there are no locations (sampling stations) within the exposure areas or reference areas that are of potential concern (HQ_t>1) to a mammalian omnivore. However, based on the NOAEL TRV, there are many locations in each of the exposure and reference areas, that are of potential concern (HQ_t>1) to a mammalian omnivore for several chemicals.

The chemicals that appear to contribute the greatest risk are antimony, copper, lead, selenium, and zinc (70-100% of locations with NOAEL-based HQ_t >1). Selenium and zinc are above a level of potential concern (HQ_t >1) at all locations (100% of locations) within all 8 EAs and both reference areas, whereas lead is above a level of potential concern at many locations (70-100% of locations) within 6 of the 8 EAs. The risks from copper, selenium and zinc are primarily attributed to the ingestion of insect tissue, with additional contributions from zinc in soil at some locations within EA2 - EA8. The risks from lead are attributed to the ingestion of soil, with additional contributions from the ingestion of insect tissue at EA2 and EA8. Note that the HQ_t values exceed a level of concern (HQ_t > 1) in the reference areas for copper, selenium and zinc. The magnitude and/or frequency of the reference area HQ_t values are generally lower than the magnitude and frequencies observed in the EAs for zinc (at all 8 EAs), selenium (at 6 EAs) and copper (at 1EA). This suggests that while naturally occurring levels may be contributing to risk, the majority of the risk from these chemicals is site-related. These results suggest that risks to mammalian omnivores may be occurring at most locations within all EAs, though they are likely to be low to moderate in extent and/or severity.

There is one chemical that results in HQ_t values above a level of potential concern (HQ_t >1) based on the NOAEL, but for which a LOAEL is not available: antimony (at 8 EAs and 2 reference areas). The results for chemicals for which a NOAEL TRV/LOAEL TRV pair are not available are difficult to interpret. Based on the magnitude of the NOAEL exceedences (2.8 – 15), it appears that the HQ_t results for antimony are large enough in some locations that they could potentially also exceed a LOAEL TRV, had one been available. The HQ_t values for antimony exceed a level of concern (HQ_t > 1) in the reference areas at a frequency and magnitude that is less than the frequency and magnitude of HQ_t values observed at most areas of the site. This suggests that while naturally occurring levels of antimony may be contributing to risks that are above a level of concern at some EAs (3 EAs), the majority of the risk from this chemical is site-related (at 5 EAs). This suggests that potentially significant risks to the Deer Mouse may also be occurring at all of the on-site EAs from the ingestion of antimony in insect tissue.

The frequency of HQ_t exceedences for chemicals where risks are attributed to the ingestion of insect tissue should be interpreted with caution, because the EPC for insect tissue at an exposure area/reference area is based on only 1 composite sample (applied to all sample locations within the exposure unit). Additionally, the measured values for some chemicals in insect tissue are uncertain due to elevated detection limits for this media (see Section 3.4). The influence of elevated detection limits on the risk estimates presented in Table 7-5 and the risk conclusions described above are discussed in the Uncertainty Section (see Section 7.1.7).

These results suggest that risks to mammalian omnivores may be occurring at most locations within all EAs from several chemicals (antimony, copper, selenium and zinc) in insect tissue, though the risks are likely to be low to moderate in extent and/or severity.

Medium Home Range Receptors

As discussed above, at this Site, medium home range receptors are evaluated based on the assumption that their home range is approximately the size of an exposure area at the Site or reference area. Only one receptor (the Northern Flicker) had a home range suitable for evaluation in this way. Detailed HQ calculations are presented in Appendix H-4 along with scatter plots of the HQ_t values for each exposure area. Table 7-6 presents the NOAEL-based and LOAEL-based HQ_t values for each COPC for each exposure area and reference area.
The findings from inspection of Tables 7-6 and the tables and figures in Appendix H-4 are discussed below.

Avian Insectivore (Northern Flicker). The results are shown in Table 7-6. As seen, there are a number of EAs where HQ_t values exceed 1 based on the NOAEL and/or LOAEL TRVs for several chemicals.

The chemical which appears to contribute the greatest risk is lead, which results in LOAEL-based HQ_t values above a level of concern (HQ_t >1) at 7 of 8 EAs and NOAEL-based HQ_t values above a level of concern in all 8 EAs. Note, however, that the NOAEL-based HQ_t for lead is also above a level of concern at 1 of the 2 reference areas at a magnitude that is much less than the HQ_t values observed at almost all of the EAs. The main source of lead exposure is the ingestion of soil, with additional contributions from the ingestion of insect tissue, especially at EA2, EA6 and EA8. Selenium and copper also result in HQ_t values that are above a level of concern based on both the LOAEL and NOAEL TRVs at 4 EAs and 1 EA, respectively, due primarily to the ingestion of insect tissue. Although HQ_t values exceed a level of concern (HQ_t > 1) in the reference areas for these chemicals, the magnitude of the HQ_t value is much less than the magnitude observed at the EA, suggesting that while naturally occurring levels may be contributing to risks that are above a level of concern, the majority of the risk from these chemicals is entirely site-related. These results suggest that potentially significant risks to avian insectivores may occur at all EAs.

Other chemicals that result in HQ_t values above a level of concern (HQ_t >1) based on the NOAEL (but not the LOAEL) TRV include arsenic (at 3 EAs), cadmium (at 1 EA), copper (at 8 EAs and 2 reference areas), mercury (at 8 EAs and 2 reference areas), selenium (at 4 EAs and 2 reference areas), vanadium (at 8 EAs and 2 reference areas), and zinc (at 8 EAs and 2 reference areas). These risks are primarily attributed to the ingestion of insect tissue, with additional contributions from the ingestion of soil. The HQ_t exceedences observed in the reference areas suggest that naturally occurring levels may be contributing to risk. However, in the case of selenium and zinc, the magnitude of the HQ_t values is higher than those observed in the reference area, suggesting that some of the risk is site-related. These results suggest that risks to avian insectivores may be occurring at all EAs from these chemicals, though they are likely to be low to moderate in extent and/or severity.

Note that some of the HQ_t values presented in Table 7-6 are influenced by chemicals that were never detected. The influence of these chemicals on risk estimates and risk conclusions are discussed in the Uncertainty Section (see Section 7.1.7).

These results suggest that potentially significant risks to avian insectivores may occur at all of the on-site EAs. The chemical of primary concern is lead in soil, with additional contributions from lead, selenium and/or copper in insect tissue at some EAs. Additional risks to avian insectivores may be occurring at some EAs from several chemicals (arsenic, cadmium, copper, mercury, selenium, vanadium and zinc) in insect tissue and/or soil, though they are likely to be low to moderate in extent and/or severity.

Large Home Range Receptors

As discussed above, large home range receptors are evaluated based on the assumption that they are likely to be exposed at random at many locations around the Site, and results are expressed in terms of the HQ_t for the Site. Detailed HQ calculations are presented in Appendix H.

The results are summarized in Table 7-7, and are discussed below.

Avian Aerial Insectivore (Cliff Swallow). As seen in Table 7-7, based on the LOAEL TRV, HQ_t exceeds a level of concern (HQ_t>1) to an aerial insectivore at the Site due to concentrations of lead in insect tissue. Based on the NOAEL TRV, HQ_t exceeds a level of concern for copper, lead, selenium and zinc, with HQ_t values ranging from 3-10. The exceedences are attributed mainly to the ingestion of these chemicals in insect tissue, with additional contributions from the incidental ingestion of lead in sediment at Knight's Spring.

Although HQ_t exceedences were also observed in the reference areas for copper, the magnitude of the HQ value is less than those observed at the Site, suggesting that naturally occurring levels of these chemicals may be contributing to risk. Site-related levels of these chemicals alone exceed a level of concern.

These results suggest that potentially significant risks to avian aerial insectivores could occur from the ingestion of lead in insects at the Site. Additional risks are possible from the concentrations of other chemicals in insect tissue (copper, selenium and zinc) and also from the ingestion of lead in sediment, although these additional risks are likely to be minor in extent and/or severity.

Avian Herbivore (Greater-Sage Grouse). As seen in Table 7-7, HQ_t values are below a level of concern for all chemicals based on both the NOAEL-based and LOAEL-based TRVs. These results suggest that potential risks to avian herbivores from the ingestion of metals in surface soil, sediment, surface water and plant tissue at the Site are likely to be minimal.

Avian Carnivore (Red-tailed Hawk). As seen in Table 7-7, HQ_t values are below a level of concern for all chemicals based on both the NOAEL-based and LOAEL-based TRVs. These results suggest that potential risks to avian carnivores from the ingestion of metals in surface soil, sediment, surface water and small mammal tissue at the Site are likely to be minimal.

Mammalian Aerial Insectivore (Big Brown Bat). As seen in Table 7-7, HQ_t values are below a level of concern for all chemicals based on both the NOAEL-based and LOAEL-based TRVs. These results suggest that potential risks to mammalian aerial insectivores from the ingestion of metals in surface water, sediment and insect tissue at the Site are likely to be minimal.

Mammalian Carnivore (Red Fox). As seen in Table 7-7, HQ_t values are below a level of concern for all chemicals based on both the NOAEL-based and LOAEL-based TRVs. These results suggest that potential risks to mammalian carnivores from the ingestion of metals in surface soil, surface water, sediment, plant tissue and small mammal tissue at the Site are likely to be minimal.

Mammalian Herbivore (Mule Deer). As seen in Table 7-7, HQ_t values are below a level of concern for all chemicals based on both the NOAEL-based and LOAEL-based TRVs. These results suggest that potential risks to mammalian herbivores from the ingestion of metals in surface soil, surface water, sediment, and plant tissue at the Site are likely to be minimal.

Summary

Table 7-8 presents a summary of the predicted risks to small home range and medium home range receptors by exposure area. Table 7-9 presents a summary of the predicted risks to large home range receptors. Two types of information are presented for each receptor/exposure area pair: (1) the overall level of risk; and (2) the primary contributor(s) of risk (those chemicals/pathways that contribute the highest level of risk, either alone or in combination).

The level of risks in Tables 7-8 and 7-9 were assigned based on the frequency and/or magnitude of HQ exceedences for a chemical. The categories and general criteria for determining the level of risk are described, by home range size, below.

Small Home Range Receptors

For small home receptors, a qualitative determination of the overall level of risk for a receptor population was made by examining the frequency and magnitude plots in Appendix H and assigning one of five qualitative scores, based on the concepts described in Section 4.4.2 (see Predicted Risks heading) and illustrated in Figure 4-3. The qualitative descriptors are as follows:

LEVEL OF RISK	GENERAL CRITERIA
NONE	All HQ_t values <1
MINIMAL	All or nearly all HQ_t values <1 Low magnitude of exceedences (e.g., HQ_t 1-2)
MODERATE	Low frequency of exceedences (10-30%) Magnitude of exceedences is mainly low, with a few as high as 2-5
HIGH	Many HQ_t values >1 (30-75%), with some values as high as 5-10

SEVERE	Almost all HQ_t values >1 Magnitude of exceedences includes many HQ_t values >10

The above criteria were used to assign a qualitative level of concern to both the LOAEL-based HQ_ts and the NOAEL-based HQ_ts. The LOAEL-NOAEL range of potential concern (e.g., Moderate – High) were reported to illustrate the full uncertainty associated with the population-level risks.

Medium and Large Home Range Receptors

For medium and large home range receptors, only two HQ_t values are available for each exposure unit: a LOAEL-based HQ_t and a NOAEL-based HQ_t. Thus, the qualitative descriptors of the overall level of concern for these receptors will be based on the relative magnitude of each HQ_t value. The qualitative descriptors and criteria for medium and large home range receptors are as follows:

LEVEL OF RISK	GENERAL CRITERIA
NONE	LOAEL-based HQ_t <1 NOAEL-based HQ_t <1
MINIMAL	LOAEL-based HQ_t <1 NOAEL-based HQ_t 1-2
MODERATE	LOAEL-based HQ_t 1-2 NOAEL-based HQ_t 2-5
HIGH	LOAEL-based HQ_t >2 NOAEL-based HQ_t >5

Also, note that some of the risks presented in Tables 7-8 and 7-9 are attributable to chemicals that were never detected. These are discussed in Section 7.1.7.

Table 7-10 presents a summary of the population level risks to small, medium and large home range receptors, based on the HQ approach.

7.1.6 Evaluation of Listed Species

As described in Section 2.3.4, there are five State listed species that are known to occur or have the possibility of occurring at the Site. This includes the Ferruginous Hawk, Greater Sage-Grouse, Fringed Myotis, Townsend's Big-eared Bat, and the Eureka Mountainsnail. Ideally, risks would be calculated for each of these species based on species-specific toxicity values and species-specific exposure parameters. However, no species-specific toxicity values were located for any of these species, and only limited species-specific exposure parameters were available for some of the listed species. These exposure data (when available) were used to refine the risk estimates for the appropriate feeding guild (see above) in order to draw conclusions about the species-specific risks.

Ferruginous Hawk. Risks to an avian carnivore were evaluated in the BERA by using a Red-Tailed Hawk as a representative species. The risk assessment concluded that risks were likely to be minimal to an avian carnivore from the ingestion of soil, sediment, water and small mammals at the Site, with HQ_t values <1 based on both the LOAEL and NOAEL TRVs. The only species-specific exposure data located for the Ferruginous Hawk were body weight estimates. These data (Dunning et al. 1993) indicate that the mean body weight of a Ferruginous Hawk (1.15 kg ww) is very similar to the value of the body weight exposure parameter used for the Red-Tailed Hawk (1.13 kg ww). Although information on intake rates are not available for comparison, based on reported body weights, the risk estimates for the Red-Tailed Hawk in the BERA are likely to be representative of risks to the Ferruginous Hawk. Based on this, potential risks to a Ferruginous Hawk from the Site are judged to be low.

Greater Sage-Grouse. This species was specifically evaluated in the BERA as the representative avian herbivore. The BERA concluded that potential risks from the ingestion of metals in surface soil, sediment, and plant tissue at the Site are likely to be minimal, with HQ_t values <0.01 for most chemicals, based on both the LOAEL and the NOAEL TRV. Based on this potential risks to the Greater Sage-Grouse from the Site are judged to be low.

Fringed Myotis. Although this bat species was not evaluated in the BERA, risks to a Big Brown Bat were evaluated and found to be minimal, with HQ_t values of 1 or less, based on both the LOAEL and the NOAEL TRV. Available information on the body weight of the Fringed myotis (*Myotis thysanodes*) (Keinath et al. 2004) and the intake rate of a bat of a species of the same genus as the Fringed myotis (the Little brown bat (*Myotis lucifugus*)) (Nagy et al. 2001), suggest that the food ingestion rate of the Fringed myotis might be higher (0.66 kg ww/kg BW/day) than the food ingestion rate used to quantify risks to the Big brown bat (0.37 kg ww/kg BW/day). The AUF for the Fringed myotis is not known. Based on the limited water sources at the Site, coupled with the low mass of insects observed at the Site during the 2007 field season, it is not thought that a significant portion of insects would be available for consumption at the Site. Thus, the AUF of 0.04 that was assumed for the Big brown bat seems appropriate for the Fringed myotis. Based on the higher food intake rate, estimated risks to the Fringed myotis would be higher than those estimated for the Big brown bat by a factor of about 1.8. However, NOAEL-based HQ_t values would still be less than for all chemicals except selenium, where the NOAEL-based HQ_t would be 2 and the LOAEL-based HQ_t would be 0.1. These results suggest that risks to the fringed myotis would likely be minimal, with only a slight possibility of risk from excess selenium intake.

Townsend's Big-eared Bat. Although this species was not specifically evaluated in the BERA, risks to the Big Brown Bat were evaluated and found to be minimal, with HQ_t values of 1 or less based on both the LOAEL and the NOAEL TRV. Available information on the body weight of the Townsend's big-eared bat (*Corynorhinus townsendii*, previously classified as *Plecotus townsendii*) (Dobkin et al. 1995) and the intake rate of a bat of the Brown long-eared bat (*Plecotus auritus*) (Nagy et al. 2001), suggest that the food ingestion rate of the Townsend's big-eared bat might be higher (0.49 kg ww/kg BW/day) than the food ingestion rate used to quantify risks to the Big Brown Bat (0.37 kg ww/kg BW/day). The AUF for the Townsend's big-eared bat is not known. Based on the limited water sources at the Site, coupled with the low mass of insects observed at the Site during the 2007 field season, it is not thought that a significant portion of insects would be available for consumption at the Site. Thus, the 0.04 AUF assumed for the Big Brown Bat seems appropriate for evaluating risks to the Townsend's big-eared bat. Using the higher food intake rate, estimated risks to the Townsend's big-eared bat result in HQ_t values that are higher by a factor of about 1.3. However, this would not result in any HQ_t values above 1 based on both the LOAEL and the NOAEL TRV. These results suggest that risks to the Townsend's big-eared bat from the Site are likely to be minimal.

Eureka Mountainsnail. This BERA did not evaluate risks to terrestrial gastropods because of lack of toxicity data and exposure data for any representative species in this group. While risks were evaluated for earthworms, it is not considered likely that snails are sufficiently similar to earthworms to justify extrapolation of the risk results. Thus, the potential risks to this species from exposure to media at the Site are unknown.

Based on this, potential risks to State Species of Concern from exposure at the Site are generally thought to be of low concern, with the exception of the Eureka Mountainsnail for which no information is available.

7.1.7 Uncertainties in HQ-Based Risks

Uncertainties in Soil Concentration Values

As noted earlier, sufficient soil samples were collected at the Site to provide a good spatial coverage of all areas of potential concern. Based on this, uncertainty in the concentration of COPCs in soil is judged to be low.

Uncertainties in Food Item Concentration Values

The BERA utilized measured concentrations of metals in plant tissue, insect tissue and earthworm tissue. Measured concentrations in food items are much more reliable than modeled (predicted) levels, so the uncertainty in food item concentrations are generally thought to be low, with one exception. Low masses of insect tissue collected at the Site resulted in the availability of only one sample of insect tissue for each exposure area, and the detection limits for these samples were limited by the low sample size. Thus, uncertainty around metal concentrations in insects is considered to be moderate.

Concentrations of metals in small mammal tissue were estimated from bioaccumulation models. These models do not account for Site-specific conditions at the Eureka Mills Superfund Site that could influence uptake into small mammals, and hence calculated values are uncertain. In general, it is considered likely that the uptake equations tend to overestimate actual tissue levels, mainly because the equations do not account for the occurrence of metals in mineral forms that prevent them from being taken up into biotic and abiotic tissues, nor do they account for elimination and acclimation processes. Consequently, uncertainty in estimated tissue levels of chemicals in small mammals is judged to be moderate to high.

Uncertainties from Chemicals with Elevated Detection Limits

As described in Section 3.4, chemicals that were never detected at an exposure unit were evaluated in the risk assessment by using an exposure point concentration that was equal to one-half of the detection limit. As also noted in Section 3.4, detection limits for some chemicals are sufficiently high that this approach may tend to result in high HQ values based mainly on the non-detected values. To investigate the potential impacts of these chemicals on risk estimates, risks were re-calculated, excluding chemicals with a detection limit where the HQ at ½ of the detection limit was greater than 0.5. The detailed results are presented in Appendix I (Tables I-1 through I-3). A detailed comparison of the difference in the risk calculation results with all non-detects included and the results with elevated non-detects excluded are presented in Appendix I (Tables I-4 through I-13). Important differences (e.g., instances where risk estimates for a chemical change from being above a level of potential concern (HQ_t > 1) for each surrogate receptor are summarized below, stratified according to home range size to being below a level of potential concern (HQ_t < 1)).

Small Home Range Receptors

Avian Omnivore (American Robin). As shown in Table I-4, excluding the elevated non-detected concentrations from the risk calculations results in risk estimates for three chemicals changing from above a level of potential concern (HQ_t >1) to below a level of potential concern (HQ_t <1) at one or more exposure units. These include the LOAEL-based HQ_t results for selenium (at 2 of 8 EAs) and the NOAEL-based HQ_t results for arsenic (at 1 of 8 EAs), mercury (at 3 of 8 EAs and 1 reference area), and selenium (at 5 of 8 EAs and 2 reference areas).

Although these differences suggest that the risk estimates from these chemicals are uncertain, it does not alter the overall conclusion that potentially significant risks (HQ_t >1 based on both the LOAEL TRV and the NOAEL TRV) may occur to avian omnivores at all eight EAs and at both reference areas, since HQ_t values from other chemicals are substantially above 1 for other chemicals at these EAs that are not attributable to non-detects.

Mammalian Insectivores (Masked Shrew). As shown in Table I-5, excluding the elevated non-detected concentrations from the risk calculations results in risk estimates for eight chemicals changing from above a level of potential concern (HQ_t >1) to below a level of potential concern (HQ_t <1) at one or more exposure units. These include the LOAEL-based HQ_t results for cadmium (1 EA), selenium (6 EAs, and 2 reference areas) and thallium (at 7 EAs). These also include the NOAEL-based HQ_t results for antimony (at 1 reference area), arsenic (at 1EA and 1 reference area), cadmium (at 1EA), mercury (at 2EAs and 1 reference area), nickel (at 6 EAs and 1 reference area), selenium (at 1 EA and 2 reference areas), and thallium (at 6 EAs and 2 reference areas).

Although these differences suggest that the risk estimates from these chemicals are uncertain, it does not alter the overall conclusion that potentially significant risks (HQ_t >1, based on both the LOAEL TRV and the NOAEL TRV) may occur to mammalian insectivores at EA2 through EA8, since HQ_t values from other chemicals are substantially above 1 for other chemicals at these EAs that are not attributable to non-detects. However, at EA1 and both reference areas (RC and RG), the overall risk conclusion would change from concluding that potentially significant risks to mammalian insectivores may occur at this EA and at the reference areas (HQ_t >1, based on both the LOAEL TRV and the NOAEL TRV) to concluding that low to moderate risks (HQ_t >1 based on the NOAEL TRV, but not the LOAEL TRV) to mammalian insectivores may be occurring at locations within this EA.

Mammalian Omnivore (Deer Mouse). As shown in Table I-6, excluding the elevated non-detected concentrations from the risk calculations results in risk estimates for three chemicals changing from above a level of potential concern (HQ_t >1) to below a level of potential concern (HQ_t <1) at one or more exposure units. These include the LOAEL-based HQ_t results for antimony (at 3 of 8 EAs), selenium (at 7 of 8 EAs and 2 reference areas) and thallium (at 4 of 8 EAs).

Although these differences suggest that the risk estimates from these chemicals are uncertain, it does not alter the overall conclusion that low to moderate risks (HQ_t >1 based on the NOAEL TRV, but not the LOAEL TRV) may occur to mammalian omnivores at all eight EAs and at both reference areas, since HQ_t values from other chemicals are substantially above 1 for other chemicals at these EAs that are not attributable to non-detects.

Medium Home Range Receptors

Avian Insectivore (Northern Flicker). As shown in Table I-7, excluding the elevated non-detected concentrations from the risk calculations results in risk estimates for three chemicals changing from above a level of potential concern (HQ_t >1) to below a level of concern (HQ_t <1) at one or more exposure units. These include the HQ_t results for mercury (at all 8 EAs and 2 reference areas), selenium (at 7 of 8 EAs and 2 reference areas) and vanadium (at 3 of 8 EAs).

Although these differences suggest that the risk estimates from these chemicals are uncertain, it does not alter the overall conclusion that potentially significant risks (HQ_t >1, based on both the LOAEL TRV and the NOAEL TRV) may occur to avian insectivores at EA2 through EA8, since HQ values from other chemicals are substantially above 1 for other chemicals at these EAs that are not attributable to non-detects. However, at EA1 the overall risk conclusion would change from concluding that potentially significant risks to avian insectivores may occur at this EA (HQ_t >1, based on both the LOAEL TRV and the NOAEL TRV) to concluding that low to moderate risks (HQ_t >1 based on the NOAEL TRV, but not the LOAEL TRV) to avian insectivores may be occurring at this EA.

Large Home Range Receptors

As shown in Tables I-8 through I-13, excluding the elevated non-detected concentrations from the risk calculations does not result any instances of risk estimates changing from above a level of potential concern (HQ_t >1) to below a level of potential concern (HQ_t <1) for any chemical, for all large home range receptors. This suggests that the uncertainties in risk estimates for large home range receptors that are attributed to elevated non-detects are minimal.

Summary

Based on the evaluation described above, the uncertainties from chemicals with elevated detection limits are moderate.

Uncertainties in Estimating Intake of Soil

Data on soil intake by wildlife species are generally limited, so the soil intake rates used in these calculations are uncertain. Further, it was assumed that the relative bioavailability (RBA) of chemicals in soil is 100%. However, in many cases the absorption of metals in soil is not as high as from food or water, so this approach will often tend to overestimate risks from soil ingestion. Thus, uncertainties in estimating soil intake is thought to be moderate.

Uncertainties in Toxicity Reference Values

The dose-based TRVs used to evaluate risks to wildlife were not specific to each wildlife or avian surrogate species. Instead, TRVs for broad receptor groups (mammals, birds) were used. These TRVs are thought to be conservative, and are in many cases based on the lowest TRV for a bird or mammal species. Thus, use of these values is more likely to overestimate than underestimate risks to specific feeding guilds. The uncertainties in TRVs is thought to be moderate.

Uncertainties in Chemicals Not Evaluated

Chemicals for which no TRV was available are presented below:

Receptor	Chemicals without TRVs	
Birds	antimony beryllium calcium iron magnesium	potassium sodium thallium cyanide
Mammals	calcium iron magnesium	potassium sodium

As seen, many of the chemicals without TRVs (calcium, iron, sodium, potassium, magnesium) are essential nutrients for all living organisms, including birds and mammals. Because of this, higher organisms like birds and mammals have evolved homeostatic mechanisms that control the absorption, retention and excretion of these chemicals, so variations in exposure and intake from environmental sources is very unlikely to cause any adverse effects. On this basis, the lack of TRVs for all of the essential nutrients is not likely to be a significant source of uncertainty. However, the absence of TRVs for non-essential chemicals (antimony, beryllium, cyanide, and thallium) result in an underestimation of the total risk to birds and/or mammals from Site media. Thus, the omission of these chemicals from the risk estimates may underestimate the total risk to birds and mammals at the Site. Uncertainties associated with chemicals not evaluated are judged to be low.

7.2 Site-Specific Toxicity Tests

No Site-specific toxicity testing has been conducted to evaluate risks to avian or mammalian species from Site media (soil, water, sediment, food items).

7.3 Site-Specific Community Surveys

No Site-specific data were located on the density or diversity of avian or mammalian receptors at the Site.

7.4 Weight of Evidence Evaluation for Wildlife

Only one line of evidence (the HQ approach) was available for evaluating risks to wildlife receptors from contaminants in environmental media at the Site. Tables 7-11 and 7-12 summarize the predictions based on this approach for small- and medium- home range receptors and for large home range receptors, respectively. As seen in Table 7-11, potentially significant population-level risks are predicted for small- and medium-home range avian and mammalian insectivores and avian omnivores due to ingestion of surface soil and/or insects at the Site. As seen in Table 7-12 , risks to birds and mammals with large home ranges are predicted to be minimal and/or occurring at a level that does not impact the overall stability of the population. However, potentially significant, population-level risks may occur for avian aerial insectivores due to the ingestion of insects. Because only one line of evidence is available for evaluating risks to birds and mammals, risk conclusions based only the HQ approach must be recognized as uncertain, and additional studies would be needed to determine if the HQ predictions are accurate.

8.0 REFERENCES

Agency of Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological Profile for Mercury. U.S. Department of Health and Human Services. March.

ASTM. 2003. Standard Guide for Conducting Terrestrial Plant Toxicity Tests. E 1963-02. April.

ASTM. 2004. Standard Guide for Conducting Laboratory Soil Toxicity or Bioaccumulation Test with the Lumbricid Earthworm *Eisenia fetida* and the Enchytraeid Potworm *Enchytraeus albidus*.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial Plant Ecology, Chapter 9: Method of sampling the plant community. Benjamin/Cummings Publishing Co.: Menlo Park, CA.

Butler et al. 1920. The Ore Deposits of Utah: USGS Professional Paper 111, 672 p. (as cited in UDEQ 2000).

Dobkin et al. 1995. Springtime movements, roost use, and foraging activity of Townsend's big-eared bat (*Plecotus townsendii*) in central Oregon. 55(4): 315-321.

Dunning et al. 1993. CRC Handbook of Avian Body Masses. CRC Press. Boca Raton, Florida.

Environmental Quality Management (EQM). 2002. Sampling and Analysis Plan for Characterization of Soil Contamination at the Eureka Mills Site. Eureka, Utah. August 19.

Efroymson et al. 1997a. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. ES/ER/TM-85/R3.

Efroymson et al. 1997b. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and litter Invertebrates and Heterotrophic Process: 1997 Revision. ES/ER/TM-126/R2.

Keinath et al. 2004. Fringed Myotis, a Technical Conservation Assessment. Prepared for the USDA Forest Service, Rocky Mountain Region.

Fort Environmental Laboratories, Inc. (Fort Labs). 2007. Redworm and Plant Toxicity Testing, Eureka, Utah. September 10.

HDR. 2007. Potentially Present Bird and Mammal Species and description of the ecological Site setting. Prepared by ecologists (R.Black and T. Toler) in support of the ecological risk assessment for the Eureka Mills Site. Personal Communication. October 15.

HDR. 2008. March 18, 2008 Meeting Notes. Submitted to Mary Darling (USACE) and Paula Schmittdiel (USEPA) by Joe Shields (HDR).

Ingersoll et al. 1996. Calculation and Evaluation of Sediment Effect Concentrations for the Amphipod *Hyalella azteca* and the Midge *Chironomus riparius*. Great Lakes Res. 23(3):602-623.

Long, ER and LG Morgan. 1990. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. National Oceanic and Atmospheric Administration Publication. Technical Memorandum NOS OMA 52. March 1990.

MacDonald, DD, CG Ingersoll and TA Berger. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology 39:20-31.

Mueller-Dombois, D., and H. Ellenburg. 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons. New York, NY. 547 p.

Nagy. 2001. Food Requirements of wild animals: Predictive equations for free-living mammals, reptiles, and birds. Nutrition Abstracts and Reviews. Series B: Livestock Feeds and Feeding. 71(10): 1R-12R. October.

Project Resources, Inc. (PRI). 2003. Surface Soil Investigation Report, Source Areas and Open Areas Operable Units 00-03. Eureka Mills Superfund Site. Eureka, Utah. January.

Prothro, M. 1993. Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria. Memorandum to Water Management Division Directors and Environmental Services Directors, USEPA Regions I-X. October 1, 1993.

Sample, B.E., J.J. Beauchamp, R.A. Efroymson, and G.W. Suter, II. 1998. Development and Validation of Bioaccumulation Models for Small Mammals. Prepared for the US Dept of Energy by Oak Ridge National Laboratory. Report ES/ER/TM-219.

Suter II, GW and CL Tsao. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. Oak Ridge National Laboratory. Document # ES/ER/TM-96/R2. June 1996.

UDEQ. 2000. Site Inspection Work Plan of the Eureka Mills, UT0002240158: Utah Department of Environmental Quality, Division of Environmental Response and Remediation.

UDEQ/DERR. 1999. Quality Assurance Project Plan for Environmental Data Operations: Salt Lake City, Utah, Utah Department of Environmental Quality.

UDWR. 2006a. County Lists of Utah Federally Listed Threatened (T), Endangered (E), and Candidate (C) Species. September 25.

UDWR. 2006b. Utah State Listed Species by County. October 20.

UDWR. 2007a. E-mail correspondence with Kimberly Asmus, Sensitive Species Biologist. Utah Division of Wildlife Resources, Central Region. January.

UDWR. 2007b. E-mail correspondence with Ashely Green, Habitat Manager. Utah Division of Wildlife Resources, Central Region. October.

URS. 2000. Sampling and Analysis Plan, Eureka Mills Outside. Eureka, Utah. November 11. Contract No. 68-W-00-118.

URS. 2001. Eureka Outside Preliminary Removal Assessment Report. Eureka, Utah. January 22. Contract No. 68-W-00-118.

USEPA. 1989. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual (Part A). EPA Document EPA/540/1-89/002.

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

USEPA. 1993. Wildlife Exposure Factors Handbook, Volumes 1 and II. U.S. Environmental Protection Agency. EPA/600/R-93/187a and b.

USEPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final. U.S. Environmental Protection Agency, Environmental Response Team (Edison, NJ). June 5, 1997.

USEPA. 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/002F. April, 1998.

USEPA. 2002a. National Recommended Water Quality Criteria: 2002. United States Environmental Protection Agency, Office of Water, Office of Science and Technology. November. EPA-822-R-02-047.

USEPA. 2002b. Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER 9285.6-10. December 2002.

USEPA. 2003. Guidance for Deriving Ecological Soil Screening Levels (Eco-SSLs). Draft. Office of Solid Waste and Emergency Response. February 2003.

USEPA. 2004. USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review. Final. October. EPA 540-R-04-004.

USEPA. 2006. USEPA Region 8 Superfund Webpage for the Eureka Mills Superfund Site. http://www.epa.gov/region8/superfund/ut/eureka/index.html. Accessed October 2006.

USEPA. 2007. ProUCL Version 4.0. User Guide. EPA/600/R-07/038. April.

USEPA and UDEQ. 2001. Community Involvement Plan. Eureka Mills Site. Eureka, Utah. October.

USEPA and USACE. 2007a. Final Screening Level Ecological Risk Assessment for the Eureka Mills Site. Eureka, Utah. November.

USEPA and USACE. 2007b. Quality Assurance Project Plan and Sampling and Analysis Plan to Support Ecological Risk Assessment at the Eureka Mills Superfund Site. Eureka, Utah. June.

USFWS. 2008. Breeding Bird Survey for Eureka Mills Superfund Site. Eureka, Utah. Prepared by U.S. Fish and Wildlife Service, Utah Field Office. West Valley City, Utah. June.

Washington Group International (WGI). 2002. Remedial Investigation Report for Operable Units 1-4 at the Eureka Mills Site. Eureka, Utah. July 23.

Western Regional Climate Center (WRCC). 2007. Western United States Climate Historical Summaries. Eureka, Utah. Climatological Data Summary 1948 – 1984. http://www.wrcc.dri.edu/cgi-bin/cliRECtM.pl?ut2625. Accessed October 2007.