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DRAFT-FINAL

Engineering Evaluation / Cost Analysis
Mahoney Mine, Alaska

PREPARED FOR THE
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE,
ALASKA REGION

07 July 2006

EXECUTIVE SUMMARY

Project Background

The U.S. Department of Agriculture - Forest Service, Alaska Region (FS) tasked the U.S. Army Corps of Engineers, Alaska District to complete a Phase II Engineering Evaluation / Cost Analysis (EE/CA) document for the Mahoney Mine and mill site. The EE/CA follows the guidance document *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (U.S. Environmental Protection Agency 1993). This EE/CA will be used to guide the second removal action implemented at the site.

The Mahoney Mine is an abandoned mine site located on Revillagigedo Island, approximately nine miles northeast of Ketchikan on the west shore of George Inlet. The site covers approximately 1 acre, and lies 250 feet north of the mouth of the small lagoon at Mahoney Lake Creek. The site is on lands administered by the FS, but this parcel is surrounded by lands owned by Cape Fox Corporation, the Native Village Corporation based in Saxman. The surrounding uplands environment is characterized by steep hillsides, bedrock, and dense forest. The inter-tidal beach areas are classified as estuarine inter-tidal. A scenic viewshed has been designated around Mahoney Lake. Mahoney Lake Creek is an anadromous fish stream and Mahoney Lake provides suitable sockeye salmon habitat.

George Inlet is a popular recreational site with Ketchikan area residents and the Mahoney Mine site is frequently visited. Future land use is expected to remain as recreational. A gravel road developed by Cape Fox Corporation traverses uphill (within 250 feet) from the site and connects to Mahoney Lake. The FS is considering a land exchange with Cape Fox Corporation to address this inholding, however the outcome of this exchange is not integral to the preferred removal action alternative selected in this report.

Past Investigations and Removal Actions

Environmental investigations and removal actions at the Mahoney Mine site have been conducted since 1996. The Bureau of Land Management conducted an inventory level evaluation of physical and chemical hazards at the mine in 1996 and a Removal Preliminary

Assessment in 1997. In 2000, URS/Dames and Moore completed a field investigation in support of an EE/CA. The EE/CA, issued in 2001, presented four removal alternatives:

- Alternative 1 – No Action
- Alternative 2 – Administrative Site Controls
- Alternative 3 – Material Consolidation
- Alternative 4 – Onsite Treatment and Placement

The URS/Dames and Moore 2003 Addendum to the EE/CA presented a fifth alternative as discussed below.

Alternative 5 – Offsite Disposal

Based on the EE/CA, Alternative 5 was selected as the preferred remedial action. In August 2003, Jacobs Engineering Group performed a Non-Time Critical Removal Action. Approximately 90 cubic yards (cy) of contaminated material (characterized as hazardous waste) was removed and transported offsite for disposal. During the removal action, it was determined that the full extent of contaminated material far exceeded the original volume estimates. There was no practical way to complete the removal with this new knowledge during the August mobilization so characterization samples were collected to further delineate the nature and extent of remaining contamination. It was estimated that 450 to 500 cy of contaminated tailings/soils remain at the site. Toxicity Characteristic Leaching Procedure (TCLP) tests demonstrated that the uplands tailings are considered hazardous waste for disposal purposes. Inter-tidal tailings met TCLP criteria and were classified as non-hazardous for disposal purposes.

As part of this Phase II EE/CA, high grade samples of upland tailings were collected and sent to two vendors to perform a bench-scale treatability study to determine if state-of-the-art metals stabilization techniques could be successfully applied to the tailings. This data will be used to decide whether pretreatment is a viable option prior to implementing one of the several proposed removal options.

Risk Assessment

A risk assessment was conducted as part of this Phase II EE/CA. The cumulative risk for the recreational land use scenario is below the established Alaska Department of Environmental Conservation (ADEC) human health risk management level of hazard index (HI) = 1. The cumulative risk for a residential land use scenario is 6, exceeding the ADEC risk management level.

For ecological receptors, the HI for the majority of the individual indicator species exceeds the ADEC risk management level of 1. However, there is no potential for significant adverse effects on *species* abundance along the adjacent shores of George Inlet. The entire populations of flora and fauna communities found in the affected areas are predicted to be minimally exposed to site contaminants. No threatened or endangered species are recognized within target distance limits established around the project area.

Remedial Action Objectives

Remedial action objectives (RAOs) were developed for the Mahoney Mine site based on the overall objective of protecting human health and the environment in accordance with state and federal statutes and regulations. This includes maintaining surface water quality standards in Mahoney Lake Creek and ensuring a diverse and healthy population of invertebrate species along the adjacent shores of George Inlet.

Qualitative RAOs:

- Control potential human contact (dermal and ingestion) and ecological contact with contaminated material.
- Reduce the mobility of contaminants through associated groundwater and surface water pathways.

Quantitative RAOs:

- Prevent future site users from directly contacting soil having constituents which would result in exceedances of the human-health cancer and non-cancer risk management standards of $1x10^{-5}$ (cancer) and 1 (non-cancer).

- Reduce the toxicity characteristic of lead in the tailings to below the Resource Conservation Recovery Act (RCRA) hazardous waste criteria of 5 milligrams per liter.

Table ES-1
Chemicals of Potential Concern and Proposed Cleanup Levels

Chemical – Media	Cleanup Level
Lead – Soil	1,000
Cadmium – Soil	83
Lead – Sediment	450
Cadmium – Sediment	9.6

Note: Units are in milligrams per kilogram.

Removal Alternatives

This Phase II EE/CA expanded, modified, eliminated, and re-named alternatives described in the 2003 EE/CA Addendum. Alternative 2 – Administrative Site Controls was eliminated from consideration in this Phase II EE/CA. The remaining alternatives, described in this EE/CA, have been expanded, modified, and re-named and are summarized below.

Alternative 1 – No Action

Evaluation of the no action alternative is required by the National Contingency Plan. No material would be removed or treated.

Alternative 2 – Offsite Disposal

Alternative 2 involves excavating the contaminated material and transporting the material to either a licensed Subtitle C RCRA hazardous waste disposal facility or a licensed Subtitle D RCRA non-hazardous waste disposal facility, depending on TCLP results.

Alternative 3 – Onsite Treatment and Offsite Disposal

Alternative 3 has similar excavation and transportation actions as Alternative 2. Alternative 3 includes the onsite treatment of the contaminated material with a metals stabilization agent that eliminates its hazardous characteristics. All of the material could then be disposed of in a licensed Subtitle D RCRA non-hazardous waste disposal facility.

Alternative 4 – Onsite Treatment and Onsite Disposal

Alternative 4 involves treating the material onsite to eliminate its hazardous characteristics and consolidating the contaminated material within an onsite repository.

- Sub-option 4A – Consolidate treated material into a monofill, and conduct long-term monitoring.
- Sub-option 4B – Backfill the treated material into underground mine openings, seal the openings, and monitor water discharge and competency of the seal.

Alternative 5 – In-Place Treatment

Alternative 5 includes metals stabilization treatment of the contaminated tailings/soils described in Alternatives 3 and 4. In this alternative, the material is treated in place. A waste rock cap would be placed over the treated material and long-term monitoring would be conducted.

Evaluation of Alternatives

Each alternative is evaluated independently and then compared to the other alternatives using the criteria of effectiveness, implementability and cost, defined in the Comprehensive Environmental Response, Compensation, and Liability Act process.

Protection of Human Health and the Environment

Alternative 1 does not offer protection of human health and the environment because no action is taken. Alternatives 2 and 3 provide the greatest degree of protection because the material is removed from the site. Alternatives 4 and 5 provide significant protection because the material is treated to eliminate the toxic characteristics and then either covered with waste rock to prevent direct exposure or placed into underground mine openings that are subsequently made inaccessible.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

Alternatives 1 will not meet the ARARs because no action is taken. Alternative 2 and 3 are expected to comply with chemical-specific ARARs and meet the RAOs. Alternatives 4 and 5 may not meet all the applicable chemical-specific ARARs as the treated soil will not be removed, but its toxicity will be reduced. The tailings will then be covered or otherwise capped to prevent direct contact. Alternatives 2 through 5 are expected to comply with all location-specific and action-specific ARARs.

Long-Term Effectiveness and Permanence

Alternative 1 does not provide long-term effectiveness and permanence because it is a no action alternative. Alternatives 2 and 3 offer long-term effectiveness and permanence because the material is removed from the site and disposed in a regulated facility. Alternatives 4 and 5 also provide long-term effectiveness and permanence. A monitoring program could be implemented to document the integrity of the cover material, the stability of the chemical stabilization process, and the integrity of the adit closure.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 does not provide reduction of toxicity, mobility, or volume because it is a no action alternative. Alternative 2 provides no treatment. Alternatives 3, 4, and 5 provide equal reduction of toxicity and mobility by treating the material with a metal stabilization process.

Short-Term Effectiveness

Short-term effectiveness is best achieved by minimizing additional risks to workers, the environment, and the local community during the removal action. This category is not applicable to Alternative 1. Implementation of Alternatives 2 through 5 may present a low, short-term risk to workers during the excavation and treatment activities. However, any potential risks to workers are mitigated by using proper personal protective equipment to reduce exposure to inhalation and ingestion of fugitive dust generated during the activity.

Implementability

Alternative 1 is the No Action alternative. The other alternatives are readily implementable because they use similar, commonly used, and available technologies and resources.

Alternatives 2 and 3 each have three sub-options. The implementability varies within the sub-options due primarily to logistical considerations. Sub-options A and C use a heavy-lift helicopter to move the material from the site to a barge or road for transshipment to Ketchikan, whereas the B sub-options transport the material over land from the site to a barge in George Inlet. Sub-options A and C of these two alternatives are highly implementable because it is a proven technology at this site. However, the large number of Super Sacks required to accommodate the revised volume of contaminated tailings/soil present necessarily will increase the current working footprint at the site at the expense of local biota.

Sub-options 4A, 4B, and 5 each propose treating the waste with the same metals stabilization process and provide onsite disposal. Sub-options 4A and 5 both use a waste rock cap to cover the treated material. Sub-option 4A places the treated material in a centralized monofill, whereas Alternative 5 provides for treatment and capping of the material in place. These options both require administrative site controls to prohibit human occupancy of the site and also to restrict Sub-option 4B places the material into the mine workings. Backfilling abandoned underground mine workings is considered a common mine reclamation technique. The integrity of the underground workings is suitable to allow serious consideration of this option. Additional preparation of the material to create a slurry paste that facilitates pumping and underground placement may be required. Oversize rocks will necessarily have to be segregated from the slurry.

Costs

The 30 year present worth cost of Alternatives 2 through 5 ranges from $235,000 to $618,000. There is no cost for Alternative 1.

Preferred Alternative

The preferred removal action alternative for the Mahoney Mine site is to treat the tailings with a metals stabilizing agent and consolidate the upland and intertidal tailings into an onsite monofill adjacent to the main waste rock piles. The monofill will encompass a surface area of nearly 40 by 60 feet and tailings will be piled at a 4:1 slope to a height of 6 feet to conform to local topography. A composite geotextile membrane will be placed over the tailings to shed meteoric water. A toe drain will be constructed around the downgradient side of the monofill to collect surface runoff from the pile and direct it away from Mahoney Lake Creek. Waste rock from the site will be placed over the geotextile membrane to fabricate a 2-foot thick cap over the tailings.

Portals to the underground workings will be backfilled with waste rock to prevent individuals from entering these potentially hazardous areas. An open stope to the surface within the underground workings will be covered with cable mesh to mitigate this final safety concern.

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APPENDICES

ACRONYMS AND ABBREVIATIONS

AAC	Alaska Administrative Code
ACL	alternative cleanup level
ASC	Administrative Site Controls
ADEC	Alaska Department of Environmental Conservation
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
BLM	U. S. Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
COC	contaminant of concern
cy	cubic yard
EE/CA	Engineering Evaluation / Cost Analysis
EM	Engineering Manual
EPA	U.S. Environmental Protection Agency
ERM	effects-range medium
FS	U.S. Department of Agriculture - Forest Service, Alaska Region
HI	hazard index
HQ	hazard quotient
IEUBK	Integrated Exposure Uptake Biokinetic Model
IRIS	Integrated Risk Information System
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NCP	National Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NTCRA	Non-Time Critical Removal Action
PRG	preliminary remediation goal
RAO	removal action objective
RBSL	risk-based screening level
RCRA	Resource Conservation and Recovery Act
SRE	streamlined risk evaluation

ACRONYMS AND ABBREVIATIONS
(continued)

TBC	to be considered
TCLP	Toxicity Characteristic Leaching Procedure
USACE	U.S. Army Corps of Engineers, Alaska District
USDAFS	U.S. Department of Agriculture Forest Service
XRF	X-ray fluorescence
°F	degrees Fahrenheit
µg/kg	micrograms per kilogram

1.0 INTRODUCTION

The U.S. Department of Agriculture - Forest Service, Alaska Region (FS) tasked the U.S. Army Corps of Engineers, Alaska District (USACE) to complete a Phase II Engineering Evaluation / Cost Analysis (EE/CA) document for the Mahoney Mine site. The site is located in the Ketchikan Ranger District of the Tongass National Forest, Alaska (Figure 1-1). The project was completed in accordance with the Statement of Work issued by the FS, and the 2003 Work Plan.

The EE/CA reflects the directions outlined in U.S. Environmental Protection Agency (EPA) guidance document entitled *"Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (EPA 1993). The document states:

> *"The EE/CA is a flexible document tailored to the scope, goals, and objectives of the non-time critical removal action. It should contain only those data necessary to support the selection of a response alternative . . . "*

The term "removal action" is defined in the National Contingency Plan (NCP), section 300.415, and may include a variety of activities ranging from implementing administrative site controls to pre-treatment and physical removal/disposal of contaminated wastes at a site. These options are intended to reduce the threat to human health and the environment.

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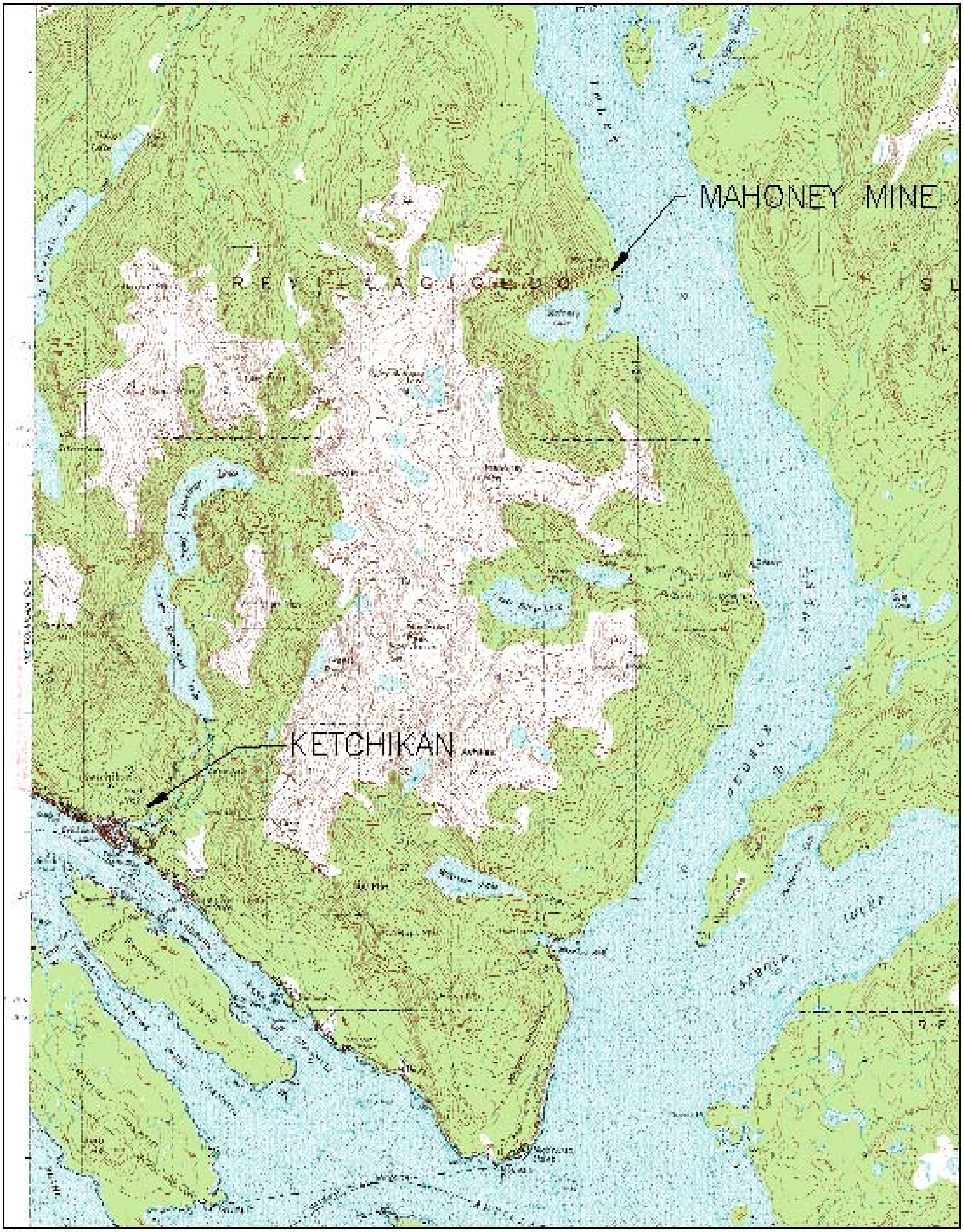

NOTES
1. ADAPTED FROM U.S. GEOLOGICAL SURVEY MAP "KETCHIKAN (B-5)" DATED 1955, 1:63,360

FIGURE 1-1
SITE LOCATION MAP
MAHONEY MINE, KETCHIKAN, AK
U.S. FOREST SERVICE.

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2.0 SITE CHARACTERIZATION AND BACKGROUND

This report is third EE/CA document prepared for the Mahoney Mine site and will be referred to as the Phase II EE/CA report. The first EE/CA was completed in March 2001 and presented in the *Final Report, Engineering Evaluation / Cost Analysis (EE/CA) For Mahoney Mine* (USACE 2001). The second part was the January 2003, *Addendum to the Final Engineering Evaluation/Cost Analysis (EE/CA) For Mahoney Mine / Tongass National Forest, Alaska* (U.S. Department of Agriculture Forest Service [USDAFS] 2003). An interim removal action was completed in the summer of 2003 based on these EE/CA documents. The information in the subsections that follow was taken from those documents. Information was also obtained from the August 2004, *Non-Time Critical Interim Removal Action Report and Site Characterization Plan. Mahoney Mine, Alaska* (USACE 2004).

2.1 SITE DESCRIPTION AND BACKGROUND

2.1.1 Site Location and Access

The Mahoney Mine and millsite are located on Revillagigedo Island, approximately 9 miles northeast of Ketchikan on the west shore of George Inlet. The site is located approximately 250 feet north of the mouth of the small lagoon where Mahoney Lake Creek empties into George Inlet. The coordinates for the site are latitude 55° 25' 39" north and longitude 131° 30' 28" west on the Ketchikan B-5 NW [northwest] USGS [U.S. Geologic Survey] quadrangle. The site is located within Township 74 South, Range 91 East, Section 25, Copper River Meridian.

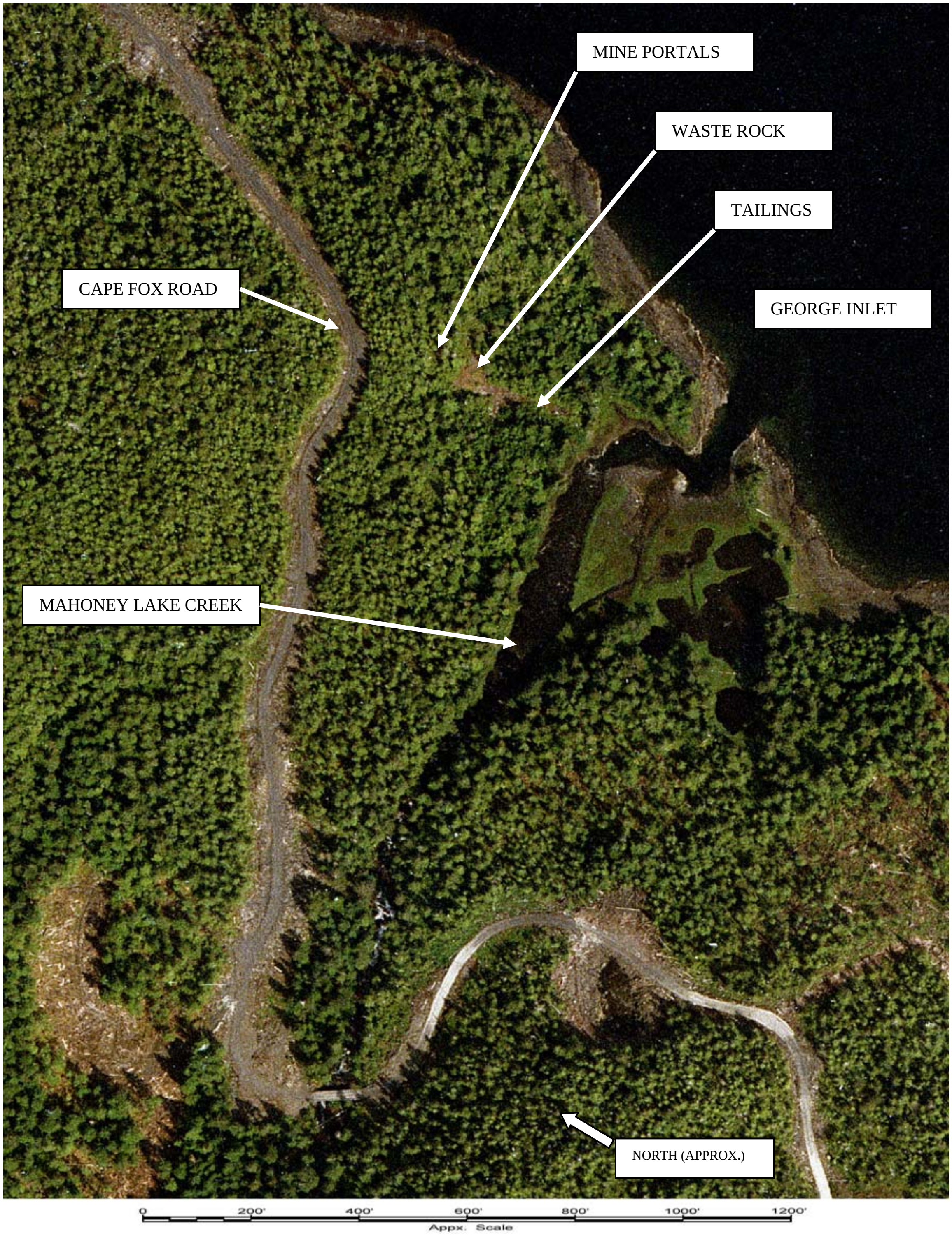
The mine is directly accessible only by boat or floatplane. A private road administered by the Cape Fox Corporation can provide limited access to the site. The road passes within 250 feet north of the site. An extremely steep, heavily forested slope separates the road from the site.

2.1.2 Facility Description

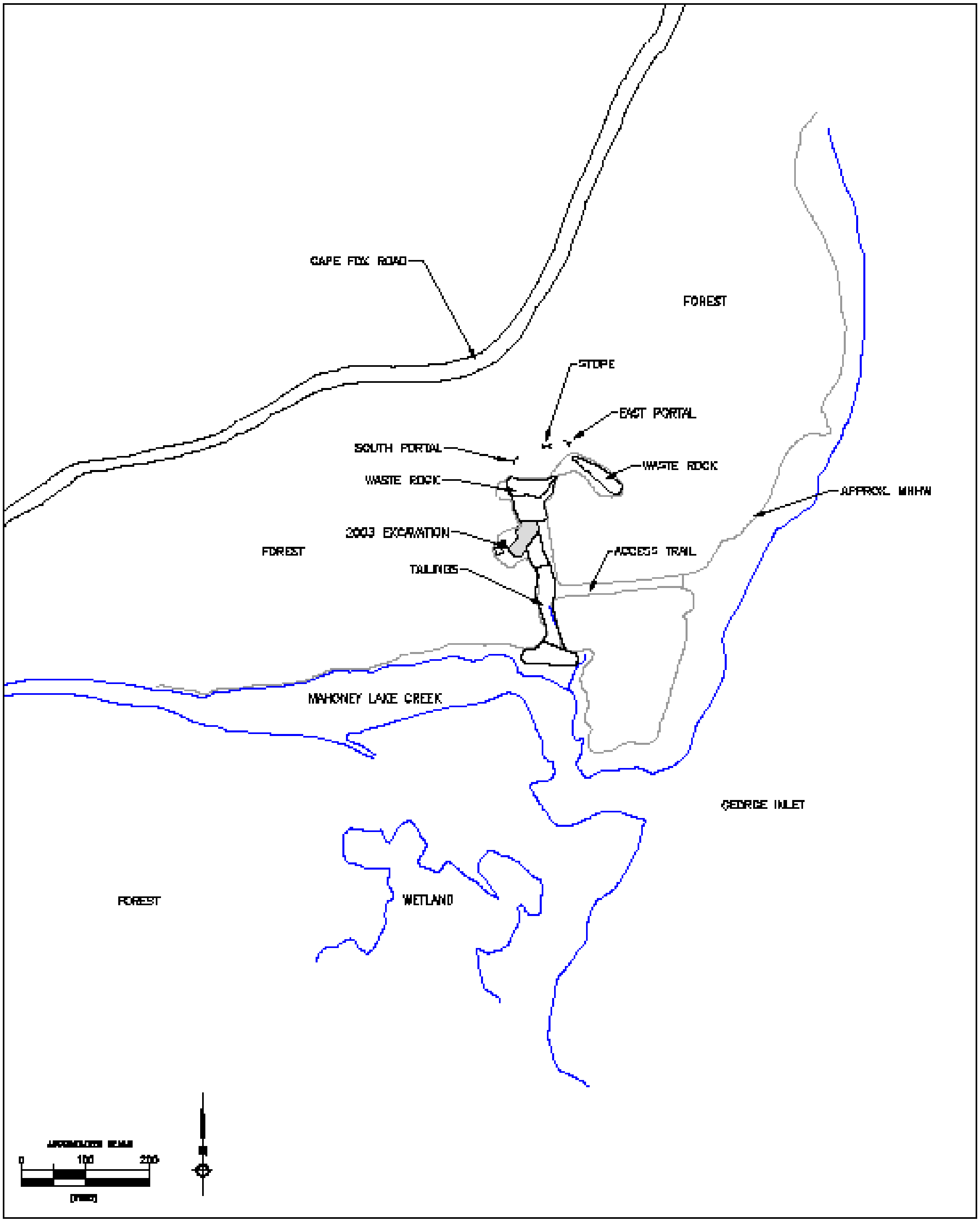
The site is considered an abandoned mine site. The Mahoney Mine was the first zinc producing mine in Alaska. Claims were first staked prior to 1900. Intermittent exploration and mining activities were conducted at the site between 1900 and 1949. The mine workings consist of one adit with two portal entrances, a single stope to the surface, and several trenches advanced along the hillside west of the adit portal. Additional stopes are also present in the underground workings of the mine. The onsite flotation mill processed the Mahoney ore and generated tailings which are deposited within the former mill foundation and extend to Mahoney Lake Creek, a distance of 160 feet (Figure 2-1). Photograph 1 shows the site from the waste rock pile at the adit portal looking down gradient and south towards Mahoney Lake Creek and George Inlet.

Photograph 2 is an annotated aerial view of the site.

Photograph 1 - Mahoney Mine site



Photograph 2 - Aerial photograph of Mahoney Mine site (August 2001).



NOTES
1. LOCATIONS ARE APPROXIMATE; NOT BASED ON SURVEY. LOCATIONS BASED ON AERIAL PHOTOGRAPHS, PRIOR REPORT FIGURES, AND BRIEF SITE VISIT.

FIGURE 2-1
SITE LAYOUT MAP
MAHONEY MINE, KETCHIKAN, AK
U.S. FOREST SERVICE

2.1.3 Physical Setting and Ecology

The Mahoney Mine site covers approximately 1 acre. The site is located in an uplands environment characterized by steep hillsides, bedrock, and dense forest. Site vegetation includes spruce, cedar, hemlock, and alder trees, intermixed with abundant berry bushes and devil's club. The inter-tidal beach areas are classified as estuarine inter-tidal, emergent, consistent with a tidal regime that is irregularly flooded. Mahoney Lake Creek is classified as a riverine lower-upper perennial wetland with an unconsolidated shore that is permanently flooded.

Areas to the north and south of the site are heavily wooded. A scenic viewshed has been designated around Mahoney Lake. Mahoney Lake Creek is an anadromous fish stream and Mahoney Lake provides suitable sockeye salmon habitat. The inter-tidal area located south of the mouth of Mahoney Lake Creek contains a diverse assemblage of marine invertebrates and seaweeds.

2.1.4 Surface Hydrology

Mahoney Lake Creek flows from Mahoney Lake, south of the mine site, and empties into George Inlet. The creek flow has been estimated at rates between 50 and 150 cubic feet per second (cfs). An inter-tidal zone located south of the creek encompasses less than 2 acres, and is covered by beach grasses and boulders. Small tide pools are also present. At high tide, waters from George Inlet cover the inter-tidal area, advancing some 300 feet up the creek. Advancing salt water covers the southern fringe of the mine tailings. At low tide, a few intermittent seeps converge with the main creek east of these tailings. Flow rates for these small seeps were estimated at less than 0.1 cfs during site visits. Another small seep emerges from the main tailings pile, but has low flow that percolates into the inter-tidal zone before discharging to Mahoney Lake Creek.

2.1.5 Geology

The Mahoney area is underlain by black phyllite and argillite that was subsequently intruded by felsic dikes and garnet-rich biotite diorite. These metasedimentary rocks were hornfelsed by a large gabbroic pluton that comprises much of nearby Deer Mountain. Euhedral pyrite cubes are ubiquitous in the argillite and phyllite. Mineralization at the mine consists of a massive sulfide vein of sphalerite and galena, with minor quantities of chalcopyrite. Gangue rock in the vein consists of quartz and crushed, pyritic country rock.

2.1.6 Soils

The soils surrounding the main workings at the Mahoney Mine have been predominantly classified as McGilvery soils developed on steep slopes with grades between 60 to 100 percent. These soils occur within rugged mountain topography with frequently dissected, heterogeneous mountain slopes. The soils are generally well drained and permeable, and are characterized to a 15-inch depth as being comprised of a 1- to 11-inch layer of very dusky red and black peat, overlying a 4-inch layer of dark gray gravelly silt loam.

2.1.7 Climate

Annual precipitation in this area of southeast Alaska varies from approximately 110 to 150 inches, with the rainy season in fall and early winter. Average annual temperatures range from the low 30 degrees Fahrenheit (°F) range in January to the mid 60 °F range in July and August.

2.1.8 Land Use

George Inlet is a popular recreational site with Ketchikan area residents and the Mahoney Mine site is commonly visited. The nearest public access boat ramp is located south of Ketchikan, near Mountain Point, about 9 miles from the site. It is expected that the land use will remain as recreational into the future; however, the FS is considering a land exchange with Cape Fox Corporation to divest itself of this small in-holding within a large block of Native Corporation land. However, the outcome of this exchange is not integral to the preferred removal action alternative selected in this report.

2.1.9 Archeology

Previous site work included an archaeological survey in accordance with Section 106 of the National Historic Preservation Act, 36 CFR [Code of Federal Regulations] 800, and the Forest

Service Handbook 2309.24 (USDAFS 2000). The purpose of the archeological research was to inventory the mine site and to evaluate mining features present for potential eligibility to the National Register of Historic Places. The four criteria for National Register significance concern are: 1) association with significant events, 2) association the significant people, 3) representativeness of culture or technology, and 4) potential for yielding important information about the human past.

The Mahoney Mine site is significant under Criterion A as the first producing zinc mine in Alaska, but its integrity is not sufficient to warrant National Register eligibility. Under Criterion D, however, the Joe Mahoney cabin site, located about 80 feet east of the tailings pile, is potentially significant, and is eligible to the National Register as a site having archaeological potential for yielding information about the life of a subsistence miner-prospector in Southeast Alaska between 1905 and 1940 (USDAFS 2001).

Federal actions taken to reduce public hazards at historic mines must adhere to provisions of the National Historic Preservation Act of 1966. These results are incorporated into the consideration of ARARs evaluating removal action alternatives in this EE/CA.

2.2 PREVIOUS INVESTIGATIONS AND REMOVAL ACTIONS

Environmental investigations and removal actions at the Mahoney Mine site have been conducted since 1996. As the investigations progressed, three zones of mine tailings and potentially contaminated soil and sediment were identified. The three zones are Zone A - the tailings on the slope below the former mill; Zone B - the tailings deposited in the inter-tidal zone of Mahoney Lake Creek; and Zone C - the tailings associated with the log foundation for the former mill. Zone A is similar in nature to Zone C and, therefore, are discussed together. The following subsections summarize the investigations and the removal action. The results are summarized in Section 2.3.

2.2.1 1996 Inventory Inspection

In 1996, the Bureau of Land Management (BLM) performed an inventory-level evaluation of physical and chemical hazards at the mine. Several samples of tailings and surface water were collected and submitted for laboratory analysis. These samples included the following:

- One composite tailings sample was collected from Zone A and analyzed for total metals.
- A background unfiltered surface water sample was collected from an unnamed seep approximately 500 feet west of the site and analyzed for 13 priority pollutant metals.
- An unfiltered surface water sample was collected from one of the intermittent seeps described previously and analyzed for priority pollutant metals.

2.2.2 1997 Removal Preliminary Assessment

In 1997, BLM performed a preliminary assessment/site inspection to determine if hazardous contamination onsite warranted removal under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Additional samples of tailings, soil, sediment, and surface water were collected during this preliminary assessment. The following types of samples were collected:

- One background soil sample was collected and analyzed for priority pollutant metals.
- Four composite tailings samples were collected from both Zone A and Zone B and analyzed for total metals. One of the tailings samples from Zone B was also analyzed for toxicity characteristic leaching procedure (TCLP) metals.
- Two composite sediment samples were collected and analyzed for pollutant priority metals.
- A filtered surface water sample was collected from a seep and analyzed for priority pollutant metals.
- A surface water sample was collected from Mahoney Lake Creek downstream of the mine area and analyzed for priority pollutant metals. The results of this sample indicated that a low concentration of zinc was present in the creek water.

2.2.3 2000 Engineering Evaluation/Cost Analysis

In 2000, Dames and Moore performed a field investigation in support of an EE/CA to fill data gaps identified in the previously collected data. The following samples were collected in order to fill identified data gaps:

- One Zone A tailings sample was collected and submitted for TCLP metals analysis.

- A background sediment sample was collected (near Zone B) and analyzed for priority pollutant metals.
- A sediment sample from Zone B was collected from an area due south of the mine area and analyzed for priority pollutant metals.
- Zone C tailings were identified within the mill foundation during the 2000 EE/CA investigation. Two samples from Zone C tailings were collected and submitted for metals analyses.

As part of the 2001 EE/CA final report, a streamlined risk evaluation (SRE) was completed in order to assess the potential risks and hazards to human health and the environment associated with exposure to site-related contaminants of potential concern (COPC) in various media at the Mahoney Mine site. In general, site data were compared to background data and risk-based screening levels (RBSLs) to select contaminants of concern (COC) for the 2003 Non-Time Critical Removal Action (NTCRA).

Conservative RBSLs were developed on a medium-specific basis by comparing several Applicable or Relevant and Appropriate Requirements (ARAR) and To Be Considered guidance documents including the Alaska Department of Environmental Conservation (ADEC) Method Two soil cleanup criteria, ADEC drinking water maximum contaminant levels, ADEC water quality standards, EPA Region IX Preliminary Remediation Goals (PRGs), EPA ambient water quality criteria, Oak Ridge National Laboratory PRGs, and National Oceanic and Atmospheric Administration (NOAA) sediment benchmarks. Screening levels that were conservative and protective of human health and the environment were chosen for each medium.

In addition to the RBSLs for each medium, exposure pathways were also studied to determine which exposure routes presented the greatest potential to impact human health and the environment. The results of this evaluation were that the primary COCs and exposure routes for the Mahoney Mine site were ingestion of cadmium, lead, mercury, and zinc from soil.

The 2001 EE/CA presented four removal alternatives:

<u>Alternative 1 – No Action</u>

No material removal or treatment would be performed at the site.

Alternative 2 – Administrative Site Controls

Under this alternative, several Administrative Site Controls (ASC) would be implemented at the site to minimize contact of receptors with the identified physical and chemical hazards.

Alternative 3 – Material Consolidation

Alternative 3 involves excavating the tailings from each of the zones, and consolidating the material in Zone C. ASC would also be implemented.

Alternative 4 – Onsite Treatment and Placement

Alternative 4 involves excavating the tailings from each of the zones, processing the material with solidifying agents using onsite treatment equipment, and stockpiling the treated material in a centrally located portion of the site. Appropriate ASC would also be implemented.

2.2.4 2003 Engineering Evaluation/Cost Analysis Addendum

The 2003 Addendum to the EE/CA presented a fifth alternative:

Alternative 5 – Offsite Disposal

Alternative 5 involves excavating the tailings from Zones A, B, and C, and disposing of them in a licensed disposal facility. No long-term monitoring and maintenance would be required at the site.

2.2.5 2003 Non-Time Critical Removal Action

Based on the EE/CA documentation, Alternative 5 was selected as the preferred remedial action. In August 2003, Jacobs Engineering Group performed a NTCRA. This action intended to remove a combined 100 cubic yards (cy) of contaminated hazardous and non-hazardous waste. At the northern edge of Zone C, material was excavated from a 20 foot by 27 foot area. Excavation ceased between 2.5 to 3.5 feet below ground surface (bgs). An area west of the site measuring 20 foot by 25 foot was subsequently excavated to approximately 1-1½ feet bgs. Approximately 90 cy of lead and petroleum-contaminated material was removed and transported offsite for disposal.

During the removal action, it was determined that the full extent of contaminated material far exceeded the original estimates. As part of the NTCRA, characterization samples were taken to more fully characterize the extent of contamination at the site.

Twenty samples (including three duplicates) were collected as identified below:

- Nine confirmation samples were collected from Zone A (including two duplicates)
- Seven samples (including one duplicate sample) were collected from Zone B
- Four samples were collected from Zone C

Samples were analyzed for metals. Five samples were analyzed by TCLP tests to characterize waste streams.

2.2.6 2004 Site Visit

As part of this Phase II EE/CA project, a site visit was conducted by the USACE. The primary purpose of the visit was to confirm site conditions and to obtain site-specific measurements to be used in the evaluation of removal alternatives. During this visit, samples of potentially contaminated material were collected from each of the three Zones A, B, and C.

Six samples were collected. Four samples were collected from Zone A, one from Zone B, and one from Zone C. Each sample was analyzed for total lead. The sample with the highest lead concentration was further analyzed for lead using TCLP.

The sample with the highest lead content was sent to two vendors to perform a bench-scale treatability study to determine if state-of-the-art metals stabilization techniques could be successfully applied to the Mahoney tailings. Both vendors supply a lead treatment product that reduces the leachability of lead, rendering a potentially hazardous waste as non-hazardous. The results of the treatability studies are presented in Appendix A.

A composite sample of waste rock was obtained to determine its acid-producing character. An Acid Base Accounting Procedure (Sobek method) was performed on this material to determine the neutralization potential of the material, and to calculate the acid potential of the material.

2.3 NATURE AND EXTENT OF CONTAMINATION

The nature and extent of contamination at the Mahoney site is based on samples collected from investigations discussed in Section 2.2. Figure 2-2 shows the site zones, available sampling results and the current estimated extent of contaminated material.

2.3.1 Contaminants of Concern

The COCs were initially selected after completing a SRE, performed as part of the 2001 EE/CA. The 2000 SRE determined that lead, cadmium, mercury, and zinc were the COCs in Zones A and C; and cadmium, lead, and zinc were the COCs in Zone B. The sections below summarize the analytical data leading to the selection of the initial selection of COCs. The site risks were re-evaluated as part of this Phase II EE/CA. The revised human health and ecological risk assessments are presented in Section 3.0.

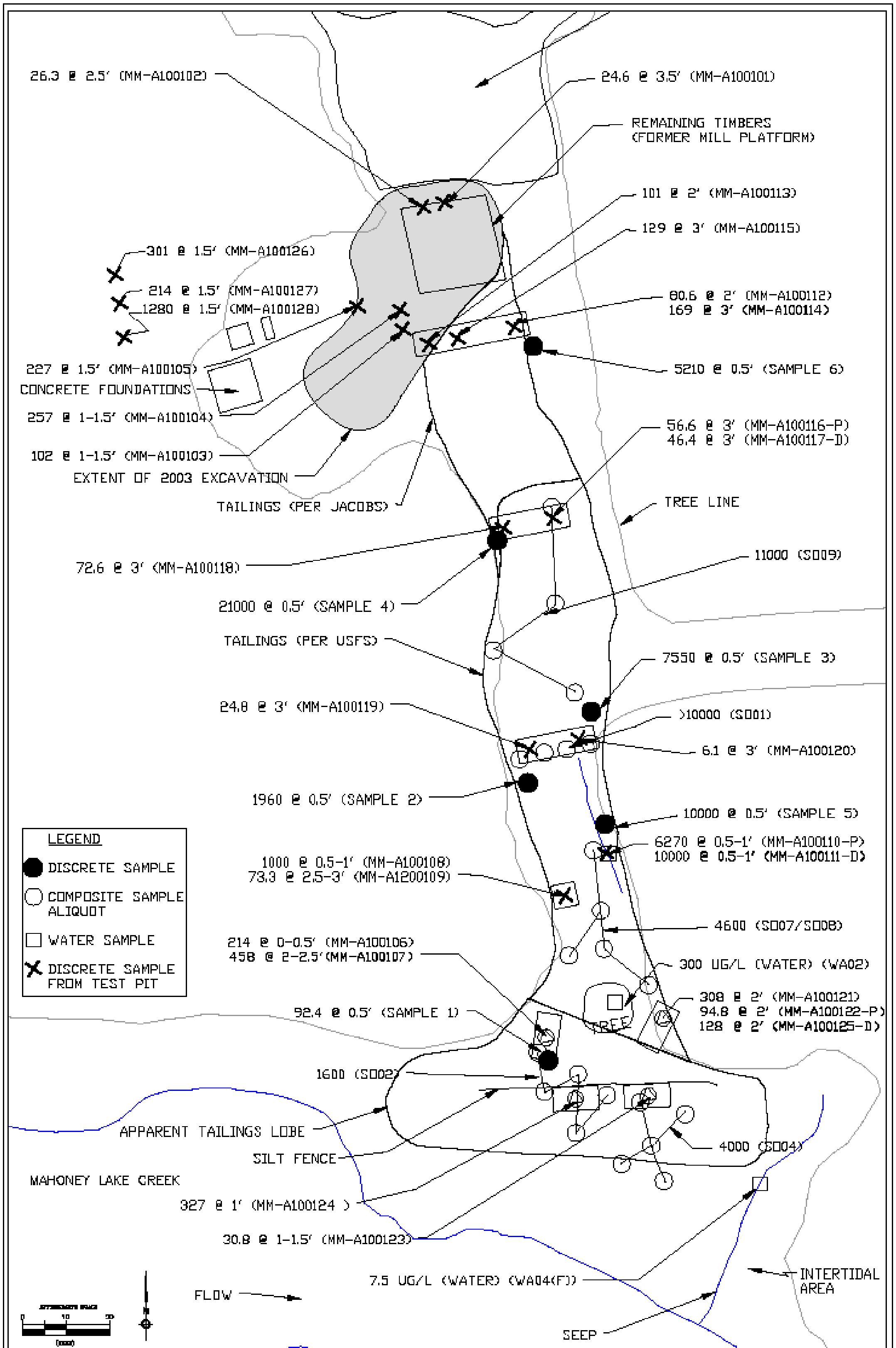
Background Data

One soil and one sediment background sample were collected in 1997 and 2000, respectively. Four background soil samples, including one duplicate sample were collected during the 2003 NTCRA.

Table 2-1
Background Soil / Sediment Results

Data Source	1997 Removal Preliminary Assessment	2003 NTCRA			2001 EE/CA
Sample ID	SO06	MM-A1001-26	MM-A1001-27	MM-A1001-28	MMSED #2
Media	Soil				Sediment
Analyte					
Cadmium	0.06	1.4	2.5	4.2	ND
Lead	0.33	301	214	1280	ND
Mercury	0.04	0.13	0.13	0.32	NA
Zinc	2	73.1	142	445	44.4

Notes:
NA = not analyzed
ND = not detected
Units are in milligrams per kilogram.



NOTES:
1. LOCATIONS ARE APPROXIMATE; NOT BASED ON SURVEY. LOCATIONS BASED ON AERIAL PHOTOGRAPHS, PRIOR REPORT FIGURES AND FIELD NOTES, AND BRIEF SITE VISIT.
2. ALL CONCENTRATIONS SHOWN ARE LEAD IN SOIL IN MG/KG, UNLESS INDICATED OTHERWISE. SAMPLE IDs ARE SHOWN IN PARENTHESIS.
3. ALL DEPTHS ARE BELOW GROUND SURFACE IN FEET.

FIGURE 2-2
DATA SUMMARY MAP
MAHONEY MINE, KETCHIKAN, AK
U.S. FOREST SERVICE.

Zones A and C

Data from the investigations are summarized in Tables 2-2 and 2-3. In general, unsaturated tailings from Zones A and C contain elevated metals concentrations.

Table 2-2
Zone A Soil Results

Source Data	**1996 Inventory Inspection**	**1997 Removal Preliminary Assessment**		**2003 NTCRA**									**2004 Site Visit**			
Sample ID	SO01	SO07/08	SO09	MM-A1001-08	MM-A1001-09	MM-A1001-10	MM-A1001-11	MM-A1001-16	MM-A1001-17	MM-A1001-18	MM-A1001-19	MM-A1001-20	2	3	4	5
Media	Soil															
Analyte						Duplicate		Duplicate								
Cadmium	88	65	150	24.8	0.27	62.8	72.3	0.41	0.32	0.41	2.7	0.77	--	--	--	--
Lead	10,000	4,500	11,000	1,000	73.3	6,720	10,000	56.6	46.4	72.6	24.8	6.1	1,960	7,550	21,.000	10,000
Mercury	0.6	0.22	1.0	ND	0.032	0.38	0.33	0.024	0.033	0.022	0.015	0.0065	--	--	--	--
Zinc	9,950	6500	15,000	1750	87.7	5030	5270	220	198	236	389	130	--	--	--	--

Notes:

ND = not detected
Units are in milligrams per kilogram.

Table 2-3
Zone C Soil Results

Data Source	2002 EE/CA		2003 NTCRA				2004 Site Visit
Sample ID	MM-SS 1	MM-SS 2	MM-A1001-12	MM-A1001-13	MM-A1001-14	MM-A1001-15	6
Media	Soil						
Analyte			Duplicate				
Cadmium	234	165	2.1	2.5	1.4	0.64	--
Lead	28,000	12,600	80.6	101	169	129	5,210
Mercury	17.1	19	0.027	0.027	0.026	0.024	--
Zinc	29,400	19,100	329	440	463	344	--

Note: Units are in milligrams per kilogram.

Zone B

Samples from the inter-tidal zone are presented below. In general, the unsaturated tailings from Zones A and C indicate markedly higher metals concentrations than those from inter-tidal Zone B.

Table 2-4
Zone B Sediment Results

Data Source	1997 Removal Preliminary Assessment				2001 EE/CA	2003 NTCRA							2004 Site Visit
Sample ID	SO02	SO03	SO04	SO05	MM SED 1	MM-A 1001-06	MM-A1001-07	MM-A1001-21	MM-A1001-22	MM-A1001-25	MM-A1001-23	MM-A1001-24	1
Media	Sediment												
Analyte									Duplicate				
Cadmium	2.8	0.21	59	0.5	0.49	0.73	2.2	2.1	3.9	4.7	1.7	3.3	
Lead	1,600	39	4,000	36	28	214	458	308	94.8	128	30.8	327	92.4
Zinc	410	61	5,500	274	163	114	293	328	1310	1,790	259	849	

Note: Units are in milligrams per kilogram.

Surface Water

During the 1996 investigation, one surface water seep and one background surface water seep were sampled. Unfiltered water samples were collected from the tailings pile seep (WA02), and from an unnamed background seep located on the steep slopes uphill and approximately 500 feet west of the site (WA01).

During the 1997 investigation, two additional surface water samples were collected. One sample was collected at a seep that converges with Mahoney Lake Creek east of the tailings area (WA04) and one sample Mahoney Lake Creek downstream of the mine (WA03).

All samples were analyzed for priority pollutant metals. No metals were detected above analytical detection limits in the background sample. Several metals were detected in site samples WA02 and WA04, including cadmium, lead, and zinc. The 1996 samples were analyzed as total unfiltered samples whereas the 1997 samples were filtered and analyzed for dissolved metals. The downstream sample did not reveal any surface water exceedances relative to aquatic life criteria.

No additional seeps or mine water were observed or samples during the 2000 field investigation, the 2003 NTCRA, or the 2004 site visit.

Table 2-5
Surface Water/ Seeps - Results

Data Source	**1996 Inventory Inspection**		**1997 Removal Preliminary Assessment**	
Sample ID	WA 01	WA 02	WA 03	WA 04
Media	Water			
Analyte	Background (Unfiltered)	Seep at Mill Site (Unfiltered)	Mahoney Lake Creek Downstream from Tailing (Filtered)	Seep East of Tailings (Filtered)
Cadmium	ND	0.012	ND	0.0021
Lead	ND	0.3	ND	0.0075
Zinc	ND	2.1	0.01	0.59

Notes:
ND = not detected
Units are in milligrams per kilogram.

2.3.2 Volume of Contaminated Material

The 2001 EE/CA concluded there were approximately 100 cy of contaminated material combined from Zones A, B, and C. During the 2003 NTCRA, the extent of contamination was discovered to be greater than the original estimate. It is now estimated that 400 to 500 cy of contaminated material remains within the three zones.

The current estimated area of contamination in Zones A and C is approximately 5,750 square feet. Assuming an average depth of 1.5 feet, approximately 320 cy of lead-contaminated material remains in Zones A and C.

Sediment characterization data indicate that residual lead contamination remains in Zone B, and encompasses the majority of the cleared area. The current estimated area with residual contamination in Zone B is approximately 1,250 square feet. Assuming an average depth of 3.0 feet, approximately 130 cy of lead-contaminated sediment remains in Zone B. Ultimately, the volume of contaminated material removed will be guided by x-ray fluorescence (XRF) field screening and corresponding laboratory confirmation sampling. Another factor contributing to the volume removed will be the approval of alternate sediment cleanup levels for the inter-tidal area.

2.3.3 Waste Characterization

Throughout the Mahoney Mine environmental reports, the material of potential concern is referred to as *mine tailings, soil, sediment,* or by the generic term *contaminated material*. The potentially contaminated material may include a combination of:

- *Waste rock* - development rock that has been removed during mining
- *Mine tailings* - refuse or dross remaining after ore from a mining operation has been processed
- *Native soil and sediment* that has increased metals concentrations as a result of contact with mine tailing

Mine Tailing / Waste Rock as Solid Waste

Mine tailings generally are solid wastes and thus, regulated by Alaska Solid Waste Regulations. Waste rock, however, is exempt from the requirements by 18 AAC [Alaska Administrative Code] 60:005 (c), 8, unless it is determined to have the potential to generate acid rock drainage. It is not expected that the Mahoney Mine site will produce acid drainage. Acid Base Accounting tests were performed on the waste rock using the including standard Sobek procedures. The results indicate that the material will not produce acid mine drainage.

Waste rock may be a material of concern if intermixed with tailings or other contaminants and cannot be easily separated. The various removal alternatives described in this EE/CA suggest using the waste rock as a capping material.

Alternatives that include treatment of the mine tailings may be managed under 18 AAC 60.005(e), as “inert waste” if 1) the waste is treated so that the potential for a release of hazardous constituents is eliminated, and 2) the treated waste will not present a threat to the public health, safety, or welfare, or to the environment. The applicable solid waste regulations for “inert waste” would be 18 AAC 60.460. Several of the removal alternatives described in this report introduce a stabilization agent that when added to the tailings converts a potentially hazardous waste into a non-hazardous waste.

Resource Conservation and Recovery Act Hazardous Wastes

Wastes from the extraction and beneficiation of minerals are excluded from Resource Conservation and Recovery Act (RCRA) Subtitle C hazardous waste requirements under the Bevill Amendment and EPA’s subsequent regulatory determination. Based upon available information, the mine tailings from the Mahoney Mine meet the RCRA exemption and would not be regulated as a hazardous waste. Although potentially exempt, the FS is not inclined to take advantage of this exemption.

Characterization by the Toxicity Characteristic Leaching Procedure

In each of the previous investigations, at least one sample of contaminated material was analyzed by the TCLP Method for RCRA metals. The TCLP results indicate that the material in Zones A and C fails the test and not withstanding any exemption, would be classified as hazardous for RCRA disposal purposes (40 CFR 264). The TCLP data from Zone B samples is below the applicable criteria (likely due to the continued tidal flushing of this material). The contaminated material that exceeds the toxicity levels by TCLP, may be exempt as a RCRA waste, but the material must be handled and disposed in a manner that would not be detrimental to human health or the environment.

Table 2-6
Contaminated Material TCLP Data

Data Source	1997 BLM Removal Preliminary Assessment	2001 EE/CA	2003 NTCRA					2004 Site Visit
Sample ID	SO02	MMTP 1	MM-A1001-03	MM-A1001-08	MM-A1001-10	MM-A1001-13	MM-A1001-16	SL-04
Zone	B	A	C	A	A	C	A	C
Analyte								
Lead	1,600	28,000	102	1,000	6,720	101	56.6	21,000
TCLP Lead (criteria for lead 5 mg/L)	ND	**17.70**	0.37	0.30	**10.50**	0.12	0.05	**25.40**

Notes:
ND = not detected
Units are in milligrams per liter (mg/L)
Bold = above the TCLP criteria for lead of 5 mg/L

3.0 RISK EVALUATION SUMMARY

The purpose of the risk evaluation is to determine whether contaminants are present in site media at concentrations that have the potential to cause unacceptable human health and ecological risks via complete exposure pathways. The full risk evaluation is found in Appendix C.

3.1 HUMAN HEALTH RISK EVALUATION

A risk assessment or risk evaluation includes four main steps:

- Data Collection and Data Evaluation
- Toxicity Assessment
- Exposure Assessment
- Risk Characterization

3.1.1 Data Collection and Data Evaluation

Data collection reviewed four reports from prior investigations:

- Bureau of Land Management, Juneau Field Office, *Final Report Removal Preliminary Assessment, Mahoney Mine*, April 1998 (BLM 1998)
- *Final Report Engineering Evaluation/Cost Analysis (EE/CA) For Mahoney Mine*, March 2001 (USDAFS 2001)
- *Non-time Critical Removal Action Report, Mahoney Mine, Alaska*, August 2004 (USACE 2004)
- USACE, *Mahoney Mine Pb Sample Results*, email dated 31 March 2004 (USACE 2004)

Data evaluation included evaluation of duplicate samples, detection limits, sample collection, comparison with naturally occurring background concentrations, and screening level comparisons. The screening level comparison brings concentration and toxicity into the data evaluation step. This is the concentration-toxicity screen referenced in EPA's "Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)," (1989). The results are the following human health and environmental COPCs and their exposure point concentrations.

Table 3-1
Human Health COPC

Soil COPC	Exposure Point Concentration (mg/kg)	Statistical Measure
Antimony	12.3	Maximum
Cadmium	35	95UCL Bootstrap
Chromium	120	Maximum
Copper	350	Maximum
Iron	47,900	Maximum
Lead	4,500	95UCL Bootstrap
Mercury	0.39	95UCL H-UCL
Residual-range organics	1,100	Maximum
Zinc	3,590	95UCL Bootstrap
Sediment COPC	**Exposure Point Concentration (mg/kg)**	**Statistical Measure**
Chromium	273	Maximum
Lead	255	95UCL Student-t
Surface Water COPC	**Exposure Point Concentration (µg/L)**	**Statistical Measure**
Cadmium	12	Maximum
Lead	300	Maximum
Zinc	2,100	Maximum

Notes:
mg/kg = milligram per kilogram
UCL = upper confidence limit
µg/L = microgram per liter

3.1.2 Toxicity Assessment

Toxicity assessment included toxicity data from the:

- EPA's Integrated Risk Information System (IRIS) http://www.epa.gov/IRIS/index.html
- EPA Region 9 Preliminary Remediation Goals Table http://www.epa.gov/region09/waste/sfund/prg/index.htm
- Agency for Toxic Substances and Disease Registry Toxicological Profiles http://www.atsdr.cdc.gov/toxprofiles/

Table 3-2
Human Health Toxicity Values

COPC	RfDo	RfDo Source
Antimony	4E-4	IRIS
Cadmium	5E-4	IRIS
Chromium	1.5E+0	IRIS
Copper	4E-2	R9 (HEAST)
Iron	3E-1	R9 (NCEA)
Mercury	2E-4	See Appendix C
Zinc	3E-1	IRIS

Notes:
HEAST = Health Effects Assessment Summary Tables
NCEA = National Center of Environmental Assessment
RfDo = Reference Dose Oral

3.1.3 Exposure Assessment

The exposure assessment included assumptions on the visitor frequency to the Mahoney Mine area and standard EPA and ADEC parameters. The human health evaluation examined the child receptor. The child receptor is more conservative and protective than the adult receptor. The current scenario evaluation assumed the same child would visit the site 1 weekend a month for 6 months per year (12 days per year). The residential scenario assumed full-time residence onsite and used the ADEC parameter of 350 days per year. Exposure pathways evaluated are:

- Ingestion of surface water
- Dermal contact with surface water
- Ingestion of soil
- Dermal contact with soil
- Ingestion of sediment
- Dermal contact with sediment

3.1.4 Risk Characterization

The cumulative risk for the recreational scenario is below the established ADEC risk management level of hazard index (HI) = 1[(1)]. The cumulative risk for a residential scenario is 6, which is over the ADEC risk management level.

(1) The noncancer hazard quotient (HQ) assumes that there is a level of exposure (i.e., reference dose (RfD)) below which it is unlikely for even sensitive populations to experience adverse health effects. If the exposure level (E) exceeds this threshold (i.e., if

Because of the unique characteristics of the toxicological properties for lead, lead risks were not included in the cumulative risk calculations, but were evaluated separately with the Integrated Exposure Uptake Biokinetic Model (IEUBK). Under the recreational visitor scenario, lead does not pose a risk. Under the residential scenario, lead may lead to elevated lead blood levels in children. In accordance with ADEC protocol, the risk due to residual-range organics was also not included in the cumulative risk calculation.

Table 3-3
Human Health Cumulative Risk Calculation

	Recreational Visitor	Full Time Resident
$HI_{ingest\ SW}$	0.1	3
$HI_{dermal\ SW}$	0.04	0.08
$HI_{ingest\ Soil}$	0.07	2
$HI_{dermal\ Soil}$	0.08	0.9
$HI_{ingest\ Sed}$	0.00004	0.00008
$HI_{dermal\ Sed}$	0.0003	0.0006
HI_{TOTAL}	**0.3**	**6**

3.2 ECOLOGICAL RISK EVALUATION

The ecological risk evaluation follows the general guidance provided by EPA (1993, 2001) for implementing a risk-based approach in support of an EE/CA, and the specific guidance provided by ADEC (2000) for conducting screening risk evaluations. A risk evaluation provides information to determine whether cleanup actions may be necessary, what exposures need to be addressed by the action, and define the appropriate cleanup levels in some cases. This ecological risk evaluation is divided into two tiers. In Tier 1, available ecotoxicity benchmarks for soil, water, and sediment are identified. These benchmarks are based on the most sensitive receptors known from the available literature. The benchmarks are then compared with maximum contaminant concentrations (that are above background levels) to determine whether there is any basis for ecological concern. Many of the COPC have more than one benchmark value. In these cases the range of values are examined. In Tier 2, contaminants that exceed ecological benchmark values are further evaluated by considering site-specific factors such as:

E/RfD exceeds unity), there may be concern for potential noncancer effects. As a rule, the greater the value of HQ (= E/RfD) above unity, the greater the level of concern. However, HQ is not a statistical probability. A HQ of 0.001 does not mean that there is a one in one thousand chance of the effect occurring. The level of concern does not increase linearly as the HQ approaches and exceeds one because HQs (and RfDs) do not have equal accuracy or precision and are not based on the same severity of toxic effects. (A hazard index is the sum of two or more hazard quotients.)

- Receptor species: Ecological receptors identified by ADEC that may actually occur at the site and which are useful in making site management decisions
- Exposure: Estimates of average exposure concentrations and evaluation of the area used by receptors
- Effects: Ecotoxicity thresholds, contaminant bioavailability, and uptake that may be different than the benchmark values used in Tier 1

Table 3-4
Ecological COPC

Soil COPC	Exposure Point Concentration (mg/kg)	Statistical Measure
Antimony	12.3	Maximum
Cadmium	35	95UCL Bootstrap
Chromium	120	Maximum
Copper	350	Maximum
Diesel-range organics	210	Maximum
Iron	47,900	Maximum
Lead	4,500	95UCL Bootstrap
Mercury	0.39	95UCL H-UCL
Nickel	42	Maximum
Residual-range organics	1,100	Maximum
Selenium	3.96	Maximum
Silver	18.1	Maximum
Zinc	3,590	95UCL Bootstrap
Sediment COPC	**Exposure Point Concentration (mg/kg)**	**Statistical Measure**
Chromium	273	Maximum
Cobalt	51	Maximum
Copper	82	Maximum
Lead	255	95UCL Student-t
Molybdenum	13	Maximum
Zinc	1,370	95UCL Chebyshev
Surface Water COPC	**Exposure Point Concentration (µg/L)**	**Statistical Measure**
Cadmium	12	Maximum
Lead	300	Maximum
Zinc	2,100	Maximum

Notes:
mg/kg = milligrams per kilogram
UCL = upper confidence limit
µg/L = micrograms per liter

Assessment endpoints and indicator species for the environmental risk evaluation relied on the ADEC "User's Guide for Selection and Application of Default Assessment Endpoints and Indicator Species in Alaskan Ecoregions" (ADEC 1999).

The environmental evaluation assessment endpoints, indicator species, and exposure media are in the following table.

Table 3-5
Environmental Assessment Endpoints, Indicator Species, and Exposure Media

Default Assessment Endpoint	Indicator Species	Primary (bold) and Other Exposure Media
Primary Producers (Trophic Level 0)		
The potential for significant adverse effects on terrestrial soil plant species abundance, diversity, and primary production	All plants that obtain nutrients primarily from soil	Surface soil
The potential for significant adverse effects on freshwater semi-aquatic plant species abundance, diversity, and primary production	All plants that obtain nutrients primarily from freshwater sediment	Freshwater sediment Freshwater
Herbivores and Detrivores (Primary Consumers – Trophic Levels 1 and 2)		
The potential for significant adverse effects on freshwater aquatic invertebrate community abundance and diversity	All freshwater aquatic invertebrates	Freshwater
The potential for significant adverse effects on freshwater benthic invertebrate community abundance and diversity	All freshwater benthic invertebrates	Freshwater sediment Freshwater
The potential for significant adverse effects on soil invertebrate community abundance and diversity	All terrestrial invertebrates	Surface soil
The potential for significant adverse effects on freshwater fish detritivore abundance and diversity	All freshwater fish	Freshwater
The potential for significant adverse effects on freshwater semi-aquatic avian herbivore abundance and diversity	Mallard	Freshwater sediments Freshwater
The potential for significant adverse effects on terrestrial avian herbivore abundance and diversity	Dark-eyed junco	Surface soil Freshwater
The potential for significant adverse-effects on freshwater semi-aquatic mammalian herbivore abundance and diversity	Northern bog lemming	Freshwater sediment Freshwater
The potential for significant adverse effects on terrestrial mammalian herbivore abundance and diversity	Long-tailed vole	Surface soil Freshwater
Secondary Consumers (Trophic Level 3)		
The potential for significant adverse effects on freshwater avian invertevore abundance and diversity	American dipper	Freshwater
The potential for significant adverse effects of freshwater semi-aquatic avian invertevore abundance and diversity	Common snipe	Freshwater sediment
The potential for significant adverse effects on terrestrial avian invertevore abundance and diversity	American robin	Surface soil
The potential for significant adverse effects on freshwater fish invertevore abundance and diversity	All freshwater fish	Freshwater

Default Assessment Endpoint	Indicator Species	Primary (bold) and Other Exposure Media
The potential for significant adverse effects on terrestrial mammalian invertevore abundance and diversity	Masked shrew	Surface soil Freshwater
Tertiary Consumers (Trophic Level 4)		
The potential for significant adverse effects on freshwater avian piscivore abundance and diversity	Belted kingfisher	Freshwater
The potential for significant adverse effects on terrestrial avian carnivore abundance and diversity	Northern shrike	Surface soil
The potential for significant adverse effects on terrestrial mammalian carnivore abundance and diversity	Shorttail weasel	Surface soil
The potential for significant adverse effects on freshwater semi-aquatic mammalian carnivore abundance and diversity	Mink	Freshwater Sediment Surface soil
The potential for significant adverse effects on freshwater mammalian piscivore abundance and diversity	River otter	Freshwater
The potential for significant adverse effects on freshwater fish piscivore abundance and diversity	All freshwater fish	Freshwater

The default assessment endpoints are the species abundance, diversity, and primary production in the various ecological niches. Indicator species are given in order to evaluate each niche.

To evaluate the ecological risks, a semi-quantative approach was undertaken. This approach examined several issues. These are:

- Background ranges of the COPC (evaluated as part of Tier 1)
- The toxicity of the COPC to the various assessment endpoints
- The size of the contaminated area
- The home range of the indicator species
- The population density of the indicator species
- The bioaccumulation potential of the COPC

The sediments and soils on the site have elevated concentrations of contaminants. Although the compounds are originally from the site (ore and waste rock), they have become more accessible to contact and leaching through the mine and processing activities. Contaminant concentrations in the sediments across Mahoney Lake Creek from the site may be naturally occurring or may have leached from the adjacent mine. Toxicity values for all the COPCs and all the assessment endpoints were not always available. When toxicity values were not available, nutrient minimums were examined. If there was no toxicity information available for the receptor species (e.g., Dark-eyed junco), a related species from the same trophic level was used as a surrogate (e.g., chicken).

The contamination at the site covers a relatively small area. The upland forest area of contaminated soil (mine tailings) covers approximately 1/3 of an acre. The coastline/estuary area includes about 1 acre of sediment and 400 to 500 lineal feet of creek. This is important when evaluating the impacts of the COPCs on the various indictor species in conjunction with the home ranges and population densities. A large home range indicates that the animal would only spend a limited amount of time in the contaminated area and potential intake of a contaminant would be a small fraction of total intake. The potential impact on a particular animal would be lessened due to a limited amount of contaminant ingested. The contaminated area would have a much smaller impact on a species with a large population density. For instance, if an animal's home range exactly coincided with the contaminated area (the 1/3 acre of uplands, or the 1 acre of semi-aquatic) the impact may be measurable for that particular animal, but would not affect the adjacent members of that species. Another factor in this evaluation is the available, adjacent habitat. Revillagigedo Island is about 717,000 acres (about the size of Rhode Island) as compared to the 1/3 acre of uplands on the site and 1 acre of semi-aquatic habitat. Revillagigedo Island has over 90 creeks running to marine waters and over 340 miles of coastline.

Although the HI for the majority of the indicator species is over the risk management level of 1, this index is based on the impacts to an individual plant or animal. There is no potential for significant adverse effects on *species* abundance, diversity, and primary production in the various ecological niches. The primary reason for this is the minimal exposure of the COPC to the species or flora and fauna communities and the available adjacent high quality habitat on the island.

3.3 ALTERNATE CLEANUP LEVELS

3.3.1 Current Scenario Alternate Cleanup Levels

The concentrations of contaminants onsite do not pose an unacceptable risk to either human health or the environment under various exposure scenarios.

The cleanup levels for soil and groundwater documented in 18 AAC 75, Tables B and C are based on a residential scenario. The risk evaluation demonstrated that under the current and future scenarios of the occasional visitor, there is no risk. This evaluation included human exposure to soils, sediments, and surface water. Therefore, the recommended alternative cleanup levels (ACLs) can be the current site soil, water and sediment concentrations (i.e., no cleanup required). The risk evaluation made assumptions concerning the exposure frequency of the visitor. It assumed that a child (the same child every visit) would visit the site for 1 weekend (2 days) per month, 6 months per year. An added level of conservatism can be incorporated by increasing this exposure frequency. However, even by doubling the visitations, the HI is still within the acceptable risk management range and the concentrations on site are acceptable as ACLs.

The State of Alaska does not currently have prescriptive regulatory cleanup levels in place for ecological receptors. However, the 18 AAC 75 regulations definitively state that cleanup remedies shall be protective of the environment. Although no ecological cleanup values are in place, ADEC published a technical memorandum on Sediment Quality Guidelines in March 2004. This technical memorandum recommends use of the NOAA Screening Quick Reference Tables for upland sediments. However, in doing so ADEC states "The values are Sediment Quality Guidelines (SQGs) and as such, should be used for screening purposes only. They are not meant to be, nor should they be, viewed or utilized as sediment cleanup levels." The risk evaluation demonstrated that there is no ecological risk from the site COPCs. Washington State sediment standards are widely used as screening criteria for marine sediments, in conjunction with Effects Range Lows and Effects Range Mediums promulgated by NOAA.

3.3.2 Residential Scenario Alternate Cleanup Levels

The ACLs for a residential scenario would not consider the groundwater as a drinking water source. Drinking water in the area is largely obtained from surface water and occasional rain catchments. Sampling of Mahoney Lake Creek showed no contamination above 18 AAC 75 groundwater cleanup levels. As seen in the following table, all onsite concentrations are below the 18 AAC 75 cleanup levels except for lead and iron. However, the 18 AAC 75 regulations also require the total HI not to exceed 1.

Table 3-6
18 AAC 75 Cleanup Values

COPC	Onsite Soil Concentration	18 AAC 75 Table B1 Ingestion Cleanup Level
Antimony	12.3	33
Cadmium	35	83
Chromium	120	120,000
Copper	350	3,320
Iron	47,900	24,900
Lead	4,500	400/1000
Mercury	0.39	15.8 (ingest); 13 (inhalation)
Zinc	3,590	25,000

Note: Units are in milligrams per kilogram.

The following residential COPC hazard quotients (HQs) are calculated using the procedure from the "Residential Scenario" section of the risk evaluation.

Table 3-7
Residential COPC Soil HQs

COPC	Site Soil Concentration (mg/kg)	HQ Residential Soil Incidental Ingestion	HQ Residential Soil Dermal Contact
Antimony	12.3	0.2	0.04
Cadmium	35	0.6	0.8
Chromium	120	0.0006	0.001
Copper	350	0.06	0.002
Iron	47,900	1.1	0.03
Lead	4,500		
Mercury	0.39	0.01	0.0004
Zinc	3,590	0.08	0.002
HI_{Soil}		**2**	**0. 9**

Table 3-8
Residential COPC Sediment HQs

COPC	Site Sediment Concentration (mg/kg)	HQ Residential Sediment Incidental Ingestion	HQ Residential Sediment Dermal Contact
Chromium	273	0.00008	0.0006
$HI_{Sediment}$		**0.00008**	**0.0006**

Note: mg/kg = milligrams per kilogram.

In order to meet the 18 AAC 75 regulations, the site COPC concentrations have to be remediated to achieve a HI of 1. This can be done by lowering one or more COPC concentrations. A possible combination is shown below with ACLs for cadmium, iron, and lead. The ACL for lead is based on the IEUBK model and does not impact the HI. See the "Residential Scenario" section of the risk evaluation.

Table 3-9
Possible Residential ACLs

COPC	Site Soil Concentration (mg/kg)	Soil ACL (mg/kg)	HQ Residential Soil Incidental Ingestion at ACL	HQ Residential Soil Dermal Contact at ACL
Antimony	12.3		0.2	0.04
Cadmium	**35**	**12**	**0.2**	**0.3**
Chromium	120		0.0006	0.001
Copper	350		0.06	0.002
Iron	**47,900**	**20,000**	**0.5**	**0.01**
Lead	**4,500**	**750**		
Mercury	0.39		0.01	0.0004
Zinc	3,590		0.08	0.002
HI_{Soil}			**1**	**0. 4**
$HI_{Soil\ Total}$			**1**	

Note: mg/kg = milligrams per kilogram

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4.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND REMOVAL ACTION OBJECTIVES

This section provides the removal action justification, a summary of the regulatory requirements, and the objectives for developing removal alternatives. Section 4.1 outlines the justification for soil removal at the Mahoney Mine site. Section 4.2 discusses the ARARs. Section 4.3 presents the removal action objectives (RAOs), and Section 4.4 presents the development of cleanup levels.

4.1 REMOVAL ACTION JUSTIFICATION

The NCP states that a removal action may be conducted at a site when a threat to human health or welfare or the environment is determined. An appropriate removal action is undertaken to abate, minimize, stabilize, mitigate, or eliminate the release or the threat of release at a site. Section 300.415 of the NCP outlines eight factors to be considered when determining the appropriateness of a removal action, such as actual or potential exposure to nearby human populations, animals or the food chain from hazardous substances, pollutants or contaminants, high concentrations of hazardous substances, pollutants, or contaminants in soil, largely at or near the surface that may migrate, and weather conditions that may cause hazardous substances to migrate or be released.

Once it is decided that a removal action is appropriate, an endangerment determination is made and the lead agency decides whether the removal action is classified as an "emergency", "time-critical", or "non-time critical" removal. "Emergencies" are those removals in which the release is ongoing and an immediate response is warranted. The FS has not been delegated lead agency authority to conduct this type of removal action. Rather, the FS has delegated authority to conduct "time-critical" removal actions where, based on a site evaluation, it is determined there are less than 6 months available before onsite response activities must begin. "Non-time critical" removals are those for which it is determined there is more than a 6 month planning period available before removal actions must begin.

The Mahoney Mine release was determined appropriate for a NTCRA based on identification of COCs that may present an ecological and/or human health risk.

4.2 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

ARARs are Federal and State environmental requirements or facility citing laws used to: 1) evaluate the appropriate extent of site cleanup; 2) scope and formulate alternatives; and 3) guide the implementation and operation of a selected action. NCP Section 300.415(I) establishes that removal actions are required to attain "to the extent practicable, considering the exigencies of the situation, all state as well as federal ARARs." To determine whether compliance with ARARs is practicable, factors such as the urgency and scope of the removal action should be considered, as well as site characteristics and location. Scope relates to the special nature of removals in that they may be used to minimize and mitigate potential harm rather than totally eliminate it. Therefore, even though a particular standard may be an ARAR for a particular medium, it may be outside the scope of the removal action when such cleanup is not necessary for stabilization of the site.

Under CERCLA § 121 (e), federal, state, or local permits are not required for response actions conducted entirely onsite. This permit exemption applies to administrative permit requirements (e.g., National Environmental Policy Act documentation, record keeping, and enforcement). However, compliance with the substantive requirements of applicable regulations must be achieved.

The NCP defines three categories of potential requirements in the hazardous substance response process: 1) applicable requirements, 2) relevant and appropriate requirements, and 3) information to be considered (TBC) guidance. These definitions are discussed in the following paragraphs.

Chemical-specific ARARs are usually human health- or ecological risk-based standards that limit concentrations of chemicals found in or, discharged to the environment. These ARARs govern the extent of site remediation by providing either actual clean-up levels or the basis for calculating such levels.

Location-specific ARARs pertain to special locations (i.e., wetlands, floodplains, sensitive ecosystems, or places of historical or archeological significance). These ARARs generally place restrictions on the concentration of hazardous substances or the conduct of activities solely based on the site's particular characteristics or location, such as areas of critical environmental concern or habitats for endangered species or significant archeological features.

Action-specific ARARs are technology- or activity-based limitations that direct how response actions are conducted. The applicability of this set of requirements is directly related to the particular activities selected for the sites. Evaluation of action-specific ARARs is one criterion for assessing the feasibility and effectiveness of remedial alternatives, and is discussed in Section 4.0.

TBC Guidance are advisories or guidance issued be federal or state government that are not legally binding and do not have the status of potential ARARs. They are considered in the absence of federal or state ARARs, or when such ARARs are not sufficiently protective.

The selected removal action will comply with the ARARs identified for the site as a threshold consideration. A summary of potential ARARs for the Mahoney Mine site is provided in Appendix B. This is a preliminary list of ARARs that may apply to the site or potential removal actions. The final list of ARARs will be developed through consultation with state and federal agencies and included in the Non Time Critical Action Memorandum produced by the FS.

4.3 REMOVAL ACTION OBJECTIVES

The NCP specifies that RAOs be developed which address: 1) contaminants of concern, 2) media of concern, 3) potential exposure pathways, and 4) preliminary remediation levels. The development of these goals involves ARARs and the results of the SRE for the Mahoney Mine site.

RAOs were developed based on the overall objective of protecting human health and the environment in accordance with state and federal statutes and regulations. The RAOs for the Mahoney Mine site are summarized as follows:

Qualitative RAOs

Based on the above factors, the following qualitative remedial action objectives were developed:

- Control potential human contact (dermal and ingestion) and ecological contact with contaminated material
- Reduce the mobility of contaminants through associated groundwater and surface water pathways

Quantitative RAOs

Based on the qualitative remedial action objective, the following quantitative RAOs were developed:

- Prevent future site users from directly contacting soil having constituents which would result in exceedances of the human-health cancer risk management standard of $1x10^{-5}$, and the non-cancer risk standard, of 1, set forth in 18 AAC 75.325
- Reduce the toxicity of the contaminants to below RCRA hazardous waste criteria for lead 5 milligrams per liter by the TCLP

The RAOs identify responses that are necessary to adequately address human-health and ecological risks, as well the potential groundwater impact posed by contaminated material. Based on the results of the risk assessment and information collected during the field investigation, site-specific RAOs were developed for contaminated material in Zones A and C and in Zone B.

In Section 5.0, removal action alternatives are evaluated by their ability to meet the RAOs. Based on data comparisons and other considerations discussed in the risk assessment, metals detected in site surface water and sediment do not appear to present a significant risk to human or ecological receptors.

Zones A and C

Representative samples of material from Zones A and C indicate elevated concentrations of lead. These zones also exhibit elevated levels of mercury, zinc, antimony, cadmium, chromium, silver, and selenium. The risk assessment summarizes which constituents were retained as either chemicals of human concern based on ADEC migration-to-drinking water RBSLs, or chemicals of ecological concern based on conservative ecological benchmarks. Based on the general magnitude of exceedances, the lack of sensitive terrestrial receptors in the area, and the TCLP results that show only lead present above RCRA regulatory limits, the RAOs developed for soil pertains to lead and cadmium. Lead cleanup levels must be determined on a site-specific basis, based on land use. For residential land use, the soil cleanup level is 400 milligrams per kilogram (mg/kg) and ACL of 750 mg/kg was also calculated for a residential land use scenario. For commercial or industrial land use, as applied in 18 AAC 75.340(e)(3), the soil cleanup level is 1,000 mg/kg. For residential land use, the ingestion pathway soil cleanup level for cadmium is 83 mg/kg and an ACL of 12 mg/kg was also calculated for a residential land use scenario.

Zone B

Representative samples of sediment from Zone B indicate that lead and cadmium are the primary constituents of concern relative to exposure pathways to human and ecological receptors in the inter-tidal zone. Sediment effects-range medium (ERM) benchmarks established by NOAA were chosen as the cleanup levels for lead and zinc in Zone B. Also considered were the Washington State marine sediment standards where lead cleanup levels of 450 mg/kg have been applied.

Table 4-1 presents the selected COCs and corresponding cleanup levels.

Table 4-1
Chemicals of Potential Concern and Proposed Cleanup Levels

Chemical - Media	Basis of Selection	Cleanup Level (mg/kg)	Comments
Lead - Soil	ADEC	1,000	1,000 m/kg is ADEC industrial / commercial cleanup level
Cadmium - Soil	ADEC	83	The ACL calculated (12) was lower than the ADEC cleanup level
Lead - Sediment	Washington State Sediment Standard	450	Non-regulatory guideline values
Cadmium - Sediment	NOAA – ERM Benchmark	9.6	Non-regulatory guideline value

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5.0 IDENTIFICATION AND ANALYSIS OF REMOVAL ACTION ALTERNATIVES

5.1 IDENTIFICATION OF REMOVAL ACTION ALTERNATIVES

In the 2001 EE/CA technologies and associated process options having the highest potential for success at the Mahoney Mine site were identified for preliminary screening evaluation. Process options that passed the screening process were assembled into removal action alternatives for further analysis of their effectiveness, implementability, and cost. A range of removal alternatives were developed that offered protection from the chemical hazards to human health and the environment. The five alternatives presented in the 2001 EE/CA and the 2003 EE/CA addendum are listed below:

- Alternative 1 – No Action
- Alternative 2 – Administrative Site Controls
- Alternative 3 – Material Consolidation
- Alternative 4 – Onsite Treatment and Placement
- Alternative 5 – Offsite Disposal

The 2003 NTCRA implemented Alternative 5 – Offsite Disposal. Based on the increased volume of tailings identified during the 2003 NTCRA and the logistical constraints offered by the site location, additional removal options were more fully developed in this EE/CA. This Phase II EE/CA expanded, modified, eliminated, and re-named alternatives described in the 2003 EE/CA Addendum. Alternative 2 – Administrative Site Controls was eliminated from consideration in this Phase II EE/CA. The remaining alternatives, described in this EE/CA, have been expanded, modified, and re-named and are summarized below. In addition, the remaining alternatives also contain sub-options that pertain mainly to engineering and logistical considerations; for example, transporting soil from the site to a barge via helicopter versus a temporary road. Alternative 1 – No Action alternative was retained for comparison purposes.

5.1.1 Alternative 1 – No Action

The no action alternative is part of the evaluation as required by the NCP. This is a default alternative used as a baseline against which the other alternatives are compared. With this alternative, the contaminated material would remain in place, with no ASC or monitoring. No material would be removed or treated.

5.1.2 Alternative 2 – Offsite Disposal

This alternative involves excavating the contaminated material and transporting the material to a licensed Subtitle C RCRA hazardous waste disposal facility. Separation of the material based on waste characterization results is possible. An evaluation of the potential cost saving of the different disposal costs compared to the time and costs required to perform the segregation would be required. A reduction in waste volume may also be accomplished by mechanical screening of oversized material from the waste stream. The tailings contain a large percentage of oversized rocks up to boulder size that are amenable to mechanical screening, and could be used to cap the resulting excavated area. This size separation would be viable only if the oversized rocks could be easily separated and relatively free of adhering contaminated material.

Approximately 450 cy of contaminated material (tailings, soils, and sediments) would be excavated and disposed. The excavation work would be performed using a conventional excavator and front-end loader. As the excavation progressed, infield XRF analysis and laboratory confirmatory samples would be collected to ensure RAOs are achieved in the excavated areas. The area would then be regraded and shaped using available waste rock, if needed, to ensure positive drainage and minimize erosion. The disturbed areas would be reclaimed and revegetated in accordance with FS requirements.

The excavated material would be transported to Ketchikan, Alaska and loaded onto a commercial shipping vessel for transport to Seattle, Washington. Both U.S. and Canadian manifests would need to accompany the waste during transport through International and Canadian waters on route to Seattle, Washington.

From Seattle, the material would then be transported by rail or truck to a suitable landfill. Suitable landfills identified during the previous EE/CA include the US Ecology Services of Idaho facility, located in Grand View, Idaho, and Waste Management, Inc. facility located in Arlington, Oregon. If segregation of hazardous versus non-hazardous waste was found to be cost effective, the non-hazardous material would be disposed at the Rabanco facility in Seattle, Washington. Individual containers would be sampled and evaluated to address this criterion.

The sub-options for this alternative involve the method in which the contaminated material is transported from the mine site.

Sub-option 2A – In this sub-option the material would be placed in 2,200 pound (0.66 cy) Super Sacks and airlifted by helicopter to a barge stationed in George Inlet. This method was used during the 2003 NTCRA. A composite TCLP sample would be taken on a routine basis.

Sub-option 2B – In this sub-option the material would be driven in bulk directly to the barge via the recently pioneered, 250 foot temporary access trail used in the 2003 NTCRA. The material would be placed in thirty, 20-foot shipping containers by the bucket of a front-end loader. Using this approach, over 100 round trips would be required, average turnaround time would be nearly 4 minutes. For this sub-option, improvements to the existing trail would be needed. Because of numerous trips along the access trail by heavy equipment, road improvements may include placing a separation geotextile and geogrid, and placing waste rock atop the geogrid. Waste rock can be obtained from the large dumps outside the east portal of the mine adit. Alternatively, the containers could be moved from the barge by forklift and staged on the uplands for loading, and then reloaded onto the barge when full. Individual containers would be sampled for TCLP analysis in this scenario.

Sub-option 2C – In this sub-option the material would be placed in 0.66 cy Super Sacks and airlifted by helicopter to trucks on Cape Fox Road directly north of the mine site. The sacks could be staged on the Cape Fox Road and moved onto trucks by excavator, as availability allowed.

5.1.3 Alternative 3 – Onsite Treatment and Offsite Disposal

Alternative 3 has similar excavation and transportation actions as described in Alternative 2. Alternative 3 includes the onsite treatment of the contaminated material with a method that eliminates its hazardous characteristics. All of the material could then be disposal in a licensed Subtitle D RCRA non-hazardous waste disposal facility.

Two potential stabilization products are envisioned for use at the Mahoney Mine site, ECOBOND™ Pb, developed by Metals Treatment Technologies, LLC and MAECTITE™ developed by Sevenson Environmental Services, Inc. Both companies performed treatability studies on tailings samples from Mahoney Mine; both have found their treatment reduces leachability of lead to below RCRA criteria.

ECOBOND™ Pb is supplied as a granular product with a unit weight of approximately one ton per cubic yard. Application of the product generally involves excavating the tailings and placing them in a mixing unit such as a pugmill. ECOBOND™ Pb product is then added to the tailings and mixed. Water is added, followed by additional mixing to facilitate thorough contact between the product and tailings particles. Sampling to verify reduced leachability is generally conducted about 12 hours after application. In-place application is also feasible provided that thorough mixing/contact of the granular product can be achieved throughout the tailings. Amendment rates used in the ECOBOND™ Pb treatability study ranged from 1.0 to 2.5 percent by weight. Although all amendment rates used in the study reduced leachability to below RCRA criteria, Metals Treatment Technologies recommended a 2.0 percent amendment rate for the Mahoney Mine site.

MAECTITE™ is supplied as a liquid product in drums. Product application can be accomplished by excavating the tailings, placing them in a pugmill, spraying or otherwise applying the liquid product, and mixing the product into the tailings. Alternatively, mixing can be conducted in a stockpile using an excavator or loader. In-place treatment can be accomplished by pulling back tailings with an excavator bucket, spraying on MAECTITE™ product, and folding the tailings back to facilitate mixing of the product throughout the tailings. Both in-place and ex-situ methods have been used successfully in the past. Sevenson has conducted in-place treatment down to 4 feet deep. Amendment rates for MAECTITE™ are commonly 3 gallons of product per ton of tailings. The treatability study conducted by Sevenson showed that application of MAECTITE™ will reduce leachability of lead in Mahoney Mine tailings to below RCRA criteria.

The data from the treatability studies are provided bin Table 5-1. The treatability study reports are provided in Appendix B. Figure 5-1 shows a conceptual layout of Alternative 3.

Table 5-1
Treatability Studies Data Summary

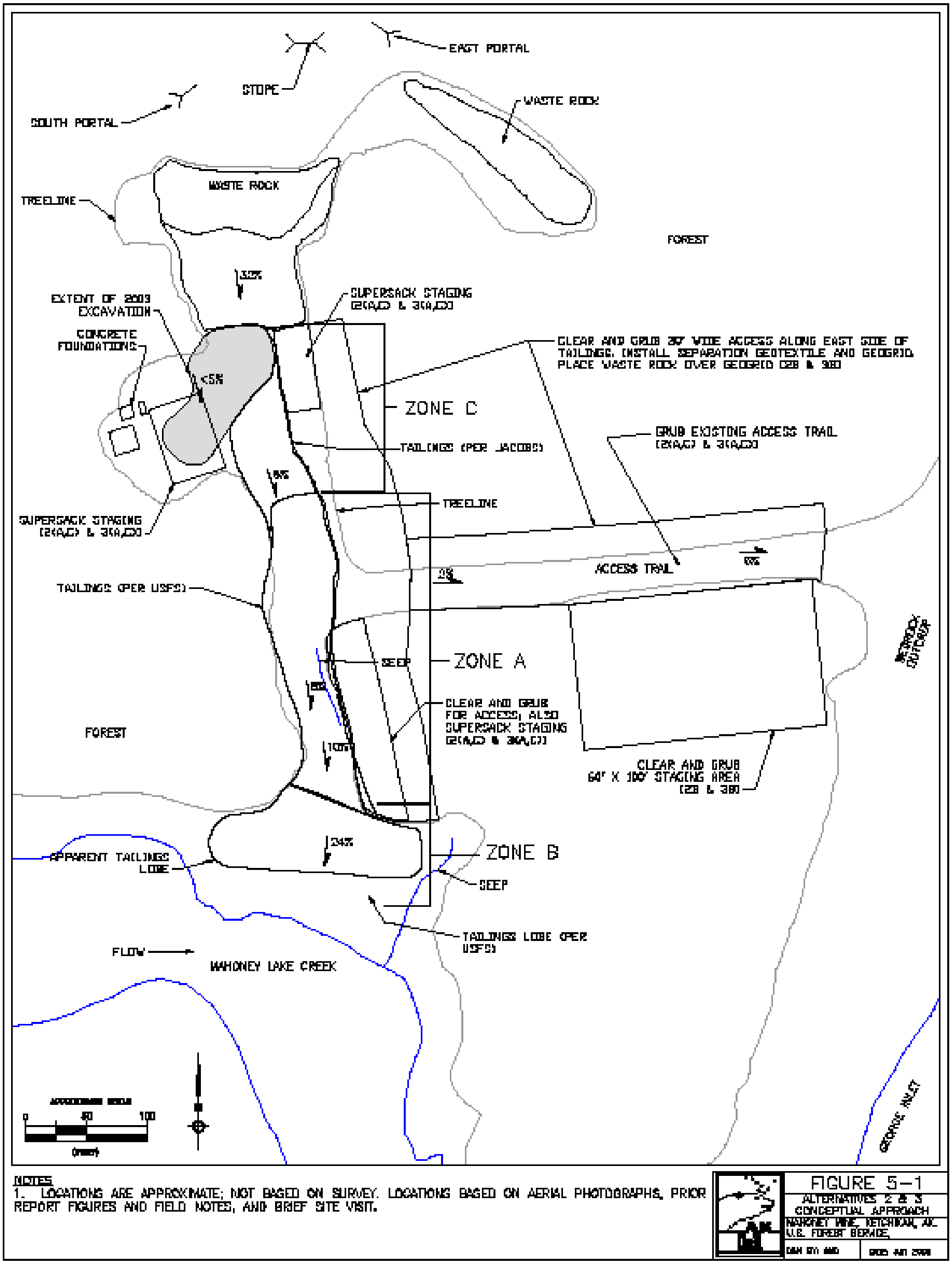
	USACE Analysis	Sevenson Environmental Services, Inc. (Maectitie)	Metals Treatment Technologies, LLC (Ecobond)
Pretreatment			
Lead (mg/kg)	21,000	18,700	6,170 (1)
TCLP Lead (mg/L)	25.4	11.2	11.2
Post Treatment by Vendors			
TCLP Lead (mg/L)		0.38 – 1.21	1 - 3.4
Post Treatment Confirmation (2)			
Lead (mg/kg)		15,900	14,500
TCLP Lead (mg/L)		0.323	0.716
TCLP Lead (mg/L)		0.948	

Notes:
Lead analysis performed by Method 6010 except (1)
(1) performed by X-ray Defraction
(2) Analysis performed by USACE
mg/kg = milligrams per kilogram
mg/L = milligrams per liter

The sub-options for this alternative describe the methods in which the contaminated material is transported from the mine site.

Sub-option 3A – In this sub-option the material would be placed in 0.66 cy Super Sacks and airlifted by helicopter to a barge stationed in George Inlet. This method was used during the 2003 NTCRA.

Sub-option 3B – In this sub-option the material would be driven in bulk directly to the barge via the recently pioneered, 250 foot temporary access trail used in the 2003 NTCRA. The material would be placed in thirty, 20-foot shipping containers by the bucket of a front-end loader. Using this approach, over 100 round trips would be required, average turnaround time would be nearly 4 minutes. For this sub-option, improvements to the existing trail would be needed. Because of numerous trips along the access trail by heavy equipment, road improvements may include



EAST PORTAL
STOPE
SOUTH PORTAL
WASTE ROCK
WASTE ROCK
TREELINE
FOREST
32%
EXTENT OF 2003 EXCAVATION
SUPERSACK STAGING (2(A,C) & 3(A,C))
CONCRETE FOUNDATIONS
CLEAR AND GRUB 30' WIDE ACCESS ALONG EAST SIDE OF TAILINGS. INSTALL SEPARATION GEOTEXTILE AND GEOGRID. PLACE WASTE ROCK OVER GEOGRID (2B & 3B)
<5%
ZONE C
GRUB EXISTING ACCESS TRAIL (2(A,C) & 3(A,C))
TAILINGS (PER JACOBS)
8%
TREELINE
SUPERSACK STAGING (2(A,C) & 3(A,C))
ACCESS TRAIL
0%
3%
TAILINGS (PER USFS)
SEEP
ZONE A
CLEAR AND GRUB FOR ACCESS; ALSO SUPERSACK STAGING (2(A,C) & 3(A,C))
FOREST
10%
CLEAR AND GRUB 60' X 100' STAGING AREA (2B & 3B)
24%
ZONE B
APPARENT TAILINGS LOBE
SEEP
TAILINGS LOBE (PER USFS)
FLOW
MAHONEY LAKE CREEK
0 50 100
(FEET)
GEORGE INLET
NOTES
1. LOCATIONS ARE APPROXIMATE; NOT BASED ON SURVEY. LOCATIONS BASED ON AERIAL PHOTOGRAPHS, PRIOR REPORT FIGURES AND FIELD NOTES, AND BRIEF SITE VISIT.
FIGURE 5-1
ALTERNATIVES 2 & 3
CONCEPTUAL APPROACH
MAHONEY MINE, KETCHIKAN, AK.
U.S. FOREST SERVICE

placing a separation geotextile and geogrid, and placing waste rock atop the geogrid. Waste rock can be obtained from the large dumps outside the east portal of the mine adit. Alternatively, the containers could be moved from the barge by forklift and staged on the uplands for loading, and then reloaded onto the barge when full.

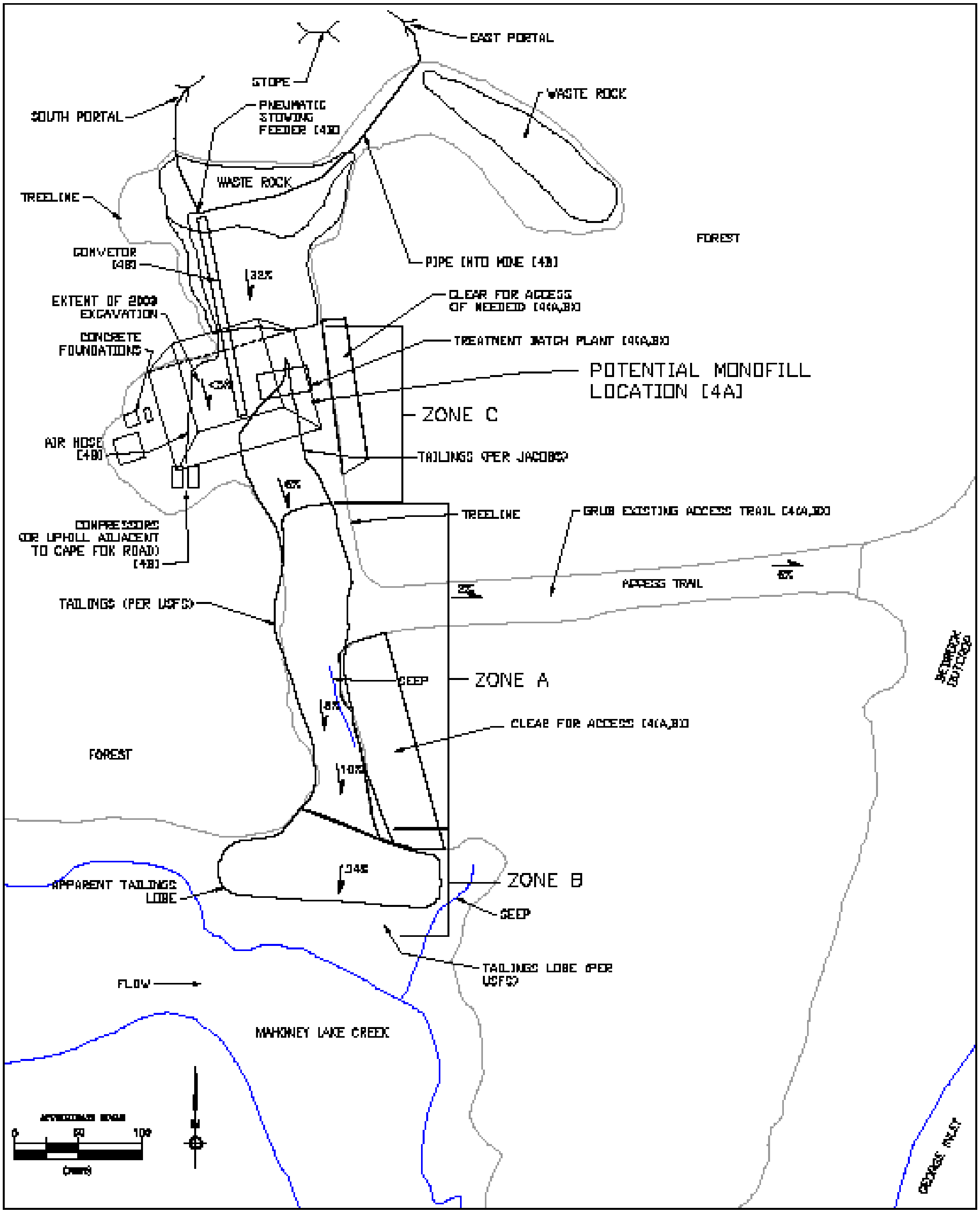
Sub-option 3C – In this suboption the material would be place in 0.66 cy Super Sacks and airlifted by helicopter to trucks on Cape Fox Road directly north of the mine site. The helicopter would be mobilized numerous times throughout the excavation work because of the limited capacity of trucks. Alternatively, all of the sacks could be staged on the Cape Fox Road and moved on to trucks as availability allowed.

5.1.4 Alternative 4 – Onsite Treatment and Onsite Disposal

Alternative 4 involves treating the material onsite to eliminate its hazardous characteristic (as described in Alternative 3) and consolidating the contaminated material within an onsite repository. The material is placed on site by one of two methods. Figure 5-2 shows a conceptual layout of Alternative 4.

Sub-option 4A – In this sub-option the treated material would be consolidated into a monofill near the northern edge of Zone C (away from the Mahoney Lake Creek and the tidal zone).

The monofill footprint in Zone C would be excavated to 3 feet bgs (similar depth to the previous excavation completed in this zone during the 2003 NTCRA); segregating contaminated from non-contaminated materials. This footprint would be 40 by 59 feet (2,360 square feet). Treated material would be placed in this excavation up to the former ground surface. Additional treated materials would then be placed atop the initial footprint. These inert materials would extend up along the 32 percent waste rock slope north of Zone C. Monofill side-slopes on the west, south, and east would be constructed at a ratio of 4 (horizontal) to 1 (vertical). The monofill would be constructed up to 3 feet above the adjacent ground surface; total thickness of stabilized material in the central area would be 6 feet. A composite geotextile membrane would be placed over the tailings and beneath the waste rock capping maerial. A 1- to 2-foot thick waste rock cover would be placed atop the stabilized material. A toe drain would be installed to the west to direct runoff away from the George Inlet. Note that the thickness of the monofill could be altered to account



NOTES:
1. LOCATIONS ARE APPROXIMATE; NOT BASED ON SURVEY. LOCATIONS BASED ON AERIAL PHOTOGRAPHS, PRIOR REPORT FIGURES AND FIELD NOTES, AND BRIEF SITE VISIT.

FIGURE 5-2
ALTERNATIVE 4
CONCEPTUAL APPROACH
MAHONEY MINE, KETCHIKAN, AK.
U.S. FOREST SERVICE

for more or less material. At 6 feet thickness, there is ample room in the cleared area for approximately 524 cubic yards of material. At 8 feet thickness, there is room for approximately 700 cubic yards of material. The final slopes would conform as best as possible to the surrounding topography.

Post disposal monitoring of groundwater and or surface seeps may be required with this alternative. ASCs in the form of a deed restriction would be placed on the property as a mechanism to prevent disturbance of the monofill. No maintenance of the final rock cover is expected but periodic inspections would likely be a part of this alternative.

Sub-option 4B – In this sub-option the treated material would be backfilled into the mine workings with a pneumatic stowing technique or similar technology. A preliminary investigation of the mine void space indicated that there are at least 600 feet of accessible underground workings in the Mahoney adit. The adit dimensions are at a minimum 7 feet wide and 6 feet tall. There are several small stoped out areas that may also be used. A more complete investigation, including a determination that the current workings are safe and meet the Occupational Safety and Health Administration standards for confined space occupancy would be needed.

The waste rock slope immediately north of Zone C is approximately 30 feet high at a slope of 32 percent. Transporting tailings via a low-ground-pressure dump-truck style vehicle would require clearing and grubbing a new trail. This trail would probably extend east from Zone C in a curve to lengthen the route and reduce the grade. At least a 300-foot length would be needed to reduce the slope to the 10 percent maximum stipulated in USACE Engineering Manual (EM) EM385-1-1 Part 21.I.07b. Obtaining a waiver of this EM is not desired for this project. Geogrid and waste rock fill would likely need to be applied to the trail.

Another option would be to use a conveyor to move materials up the waste rock slope to the adit portal. This approach would require less impact to existing vegetation than cutting a new trail. Alternatively, the material may be pumped up the slope using a pneumatic/hydraulic pipe feeder system.

The adit openings would be sealed with polyurethane foam or backfilled with waste rock after backfilling of tailings is complete.

Post disposal inspections would not be required, but monitoring of groundwater and or surface seeps may be needed. No ASC would be placed on the property.

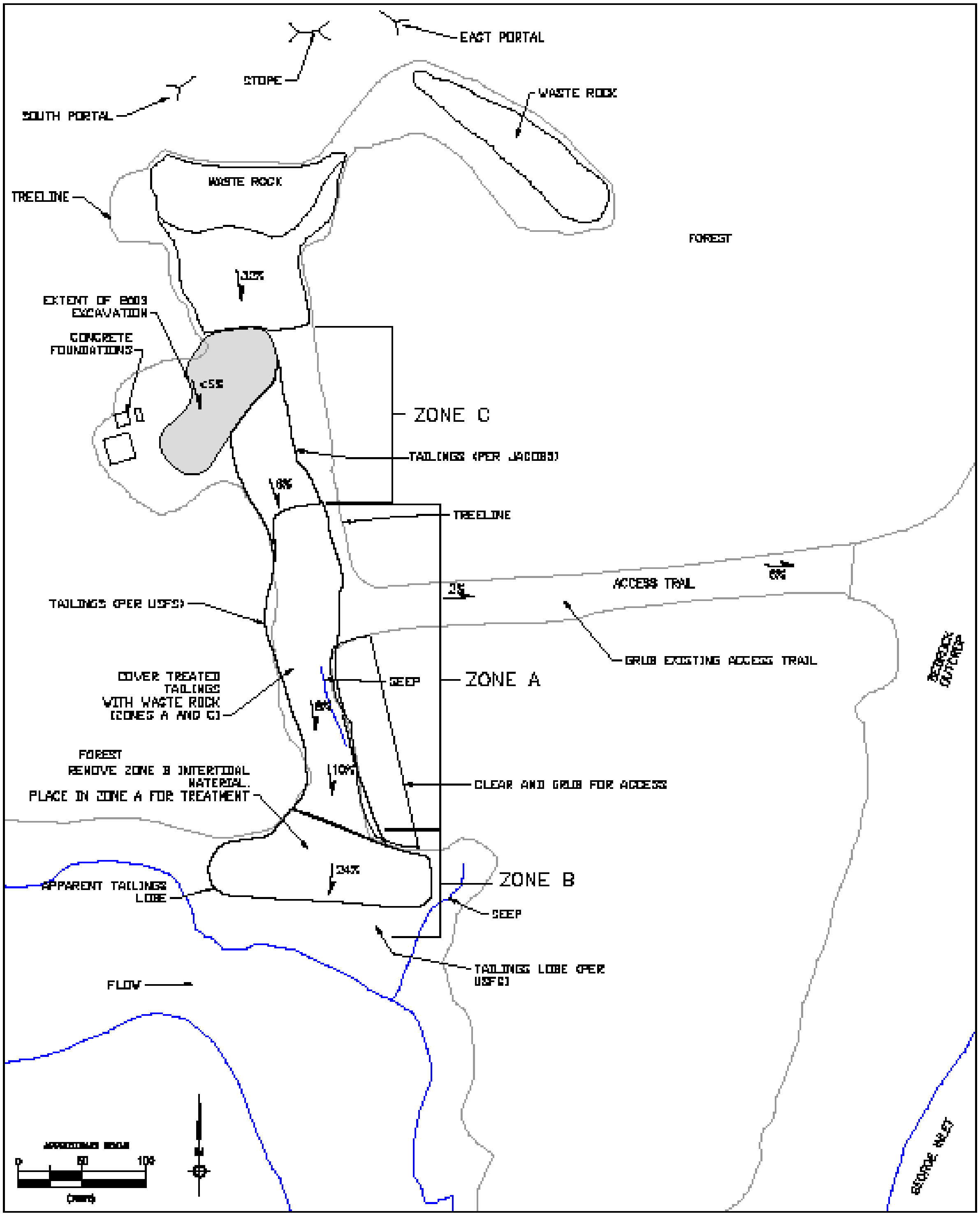
5.1.5 Alternative 5 – In-Place Treatment

Alternative 5 includes the aforementioned treatment of the contaminated material described in Alternative 4. However, the method is slightly different. In this alternative the material is treated in-place, without consolidating onsite or offsite removal. The contaminated material would be mixed with the treatment material by tilling or similar mixing action. Waste rock would be placed over the treated tailings to prevent direct contact (dermal or ingestion pathways) with the treated material (drainage would not be improved unless crowning or other contouring is performed.

Post disposal monitoring of groundwater and/or surface seeps may be required with this alternative. ASC in the form of a deed restriction would be placed on the property as a mechanism to prevent disturbance of the treated material. No maintenance of the final rock cover is expected but periodic inspections would likely be a part of this alternative. Figure 5-3 shows a conceptual layout of Alternative 5.

5.2 ANALYSIS OF REMOVAL ACTION ALTERNATIVES

The removal alternatives were evaluated using criteria established in the EPA EE/CA guidance. This section provides a description of these criteria and the evaluation of each removal alternative. The removal alternatives are evaluated with respect to their expected effectiveness, implementability, and cost.



NOTES
1. LOCATIONS ARE APPROXIMATE; NOT BASED ON SURVEY. LOCATIONS BASED ON AERIAL PHOTOGRAPHS, PRIOR REPORT FIGURES AND FIELD NOTES, AND BRIEF SITE VISIT.

FIGURE 5-3
ALTERNATIVE 6
CONCEPTUAL APPROACH
MAHONEY MINE, KETCHIKAN, AK.
U.S. FOREST SERVICE

Effectiveness

Effectiveness includes several evaluation factors that are described below:

- Protection of Human Health and the Environment: This criterion assesses the ability of the alternative to be protective of humans under present and future land use conditions. Furthermore, protection of ecological receptors would be evaluated.
- Compliance with ARARs: Identifies whether or not implementation of the alternative would comply with all chemical-specific, action-specific, and location-specific ARARs.
- Long-Term Effectiveness: This criterion addresses the magnitude of residual risk remaining at the conclusion of removal activities. It addresses the adequacy and reliability of controls established by a removal action alternative to maintain reliable protection of human health and the environment over time.
- Reduction of Toxicity, Mobility, and Volume Through Treatment: Identifies whether or not implementation of the alternative would reduce contaminant toxicity, mobility (e.g., preventing leaching into groundwater) or volume.
- Short-Term Effectiveness: This criterion addresses the effects of an alternative during the construction and implementation phase until RAOs are met. This criterion includes the speed with which the remedy achieves protectiveness and potential to create adverse impacts on human health and the environment during construction and implementation.

Implementability

Implementability is evaluated in accordance with the following criteria:

- Technical Feasibility: The evaluation of construction and operational considerations, as well as demonstrated performance/useful life.
- Administrative Feasibility: Including permitting requirements, easements/rights of way, and impact on adjoining property are evaluated.
- Availability of Services and Materials: The availability of qualified contractors to conduct site preparation, design, excavation, and transportation. The availability of disposal facilities, which are licensed to accept soil, classified as hazardous and non-hazardous waste.
- State Acceptance: The concurrence of the State of Alaska and ADEC with the proposed alternatives.
- Community Acceptance: The acceptance of the proposed alternatives by other stakeholders.

Cost

The cost estimate contains the initial project costs and operations and maintenance costs. The cost estimate for each component of the proposed alternative is based on assumptions provided in Appendix D. In addition, the present worth is calculated using the discount rate of 3.1 percent.

Table 5-2
Alternative Cost Summary

Alternative	Alternative Name	Cost
1	**No Action**	$0
2	**Offsite Disposal**	
Sub-option 2A	Airlifted to Barge	$600,000
Sub-option 2B	Driven to Barge	438,000
Sub-option 2C	Airlifted to Trucks	$618,000
3	**Onsite Treatment and Offsite Disposal**	
Sub-option 3A	Airlifted to Barge	$531,000
Sub-option 3B	Driven to Barge	376,000
Sub-option 3C	Airlifted to Trucks	548,000
4	**Onsite Treatment and Onsite Disposal**	
Sub-option 4A	Placed in Monofill	$304,000
Sub-option 4B	Placed in Mine Workings	$245,000
5	**In-Place Treatment**	$235,000

5.2.1 Alternative 1 – No Action

Effectiveness

Effectiveness includes several evaluation factors that are described below:

- Overall Protection of Human Health and the Environment: This is a no action alternative; therefore, there would be no protection of human health and the environment by implementing this alternative.
- Compliance with ARARs/TBC Guidance: Implementation of this alternative will not comply with the chemical-specific ARARs. This alternative will not achieve the RAO of removing COCs above site-specific, risk-based levels. Implementation of this alternative does not require compliance with location-specific ARARs. There are no action-specific ARARs for the no action alternative.
- Long-Term Effectiveness and Permanence: Because this is a no action alternative, this alternative does not offer a long-term permanent and effective solution.
- Reduction of Toxicity, Mobility, or Volume Through Treatment: This alternative does not include a treatment component; therefore, evaluation of this criterion is not applicable.
- Short-Term Effectiveness: There is no short-term effectiveness associated with the no action alternative.

Implementability

There are no technical or administrative implementability concerns associated with the No Action alternative. The No Action alternative requires no services or materials. The state and community would not support the No Action alternative.

Cost

The 30 year net present worth is $0.

5.2.2 Alternative 2 – Offsite Disposal

Effectiveness

Effectiveness includes several evaluation factors that are described below:

- Protection of Human Health and Environment: This alternative provides protection to human health and the environment by achieving RAOs. Material exceeding site cleanup levels would be excavated and disposed of in accordance with applicable federal and state transportation and disposal regulations.
- Compliance with ARARs and TBC Guidance: Implementing this alternative will comply with all chemical-specific ARARs and RAOs for COCs that have specific risk-based cleanup levels.
- Location Specific ARARs: Implementation of this alternative will comply with the location-specific ARARs. There are no species deemed endangered, threatened or of special concern. The archeological areas of concern are not within the proposed work zone.
- Action Specific ARARs: Implementation of Alternative 2 will comply with all action-specific ARARs listed in Appendix B.
- Reduction of Toxicity, Mobility, and Volume through Treatment: Toxicity would not be reduced in the excavated soil. All material contaminated with COCs above cleanup levels would be permanently removed to a secure disposal facility, therefore, reducing mobility.
- Long-Term Effectiveness and Permanence: Excavation and off-site disposal would be an effective and permanent alternative. All material contaminated with COCs above cleanup levels will be removed and disposed of in accordance with applicable regulations.
- Short-Term Effectiveness: Excavation and disposal requires that materials be excavated, staged, characterized for disposal purposes, and transported on waterways, public roadways and/or rail lines, to the appropriate disposal facilities. Risks to site workers would be controlled by appropriate use of protective clothing and good construction practices.

Additional risks associated with the transportation of contaminated soils would include the potential for highway and waterway accidents and spills of contaminated materials. Following appropriate Department of Transportation, state, and local shipping requirements for all transportation-related activities would minimize the risks associated with waste transportation.

The site has been disturbed from the original mining operations and from the recent removal actions. Implementation of this alternative could significantly disrupt biota at the site as large footprints would have to be created to store and move Super Sacks or containers during the actual removal activities. Appropriate sediment control measures would be implemented to reduce potential impact to Mahoney Lake Creek or George Inlet.

Implementability

Implementability is evaluated in accordance with the following criteria:

- Technical Feasibility: The sub-options of this alternative involve procedures that can easily be implemented. Labor, equipment, and materials required for this alternative are conventional and readily available. The sub-options vary in their implementability with respect to the expected difficulties associated with transporting the soil offsite. Sub-option 2A is considered the base line sub-option because this method was used in the previous removal action and there is documented success with this method. Sub-option 2B requires additional roadwork and installation of a temporary bulkhead on the beach to accommodate the increased heavy equipment travel from the site to the barge. Sub-option 2C uses similar helicopter approach as in Sub-option 2A, but delivers the sacks to waiting trucks or stages the material on the road. In either case these considerations decrease the implementability from that of Sub-option 2A.
- Administrative Feasibility: Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Sub-option 2C uses a private road and will require additional coordination with the Cape Fox Corporation and potentially increase permitting requirements. The Cape Fox Corporation may also require road maintenance to mitigate the wear and tear associated with moving the tailings over the existing gravel road.
- Availability of Services and Materials: Contractors are available to conduct site preparation, design, excavation, and transportation. Several facilities are licensed to accept material classified as hazardous and non-hazardous waste.
- State Acceptance: State acceptance will be addressed through the regulatory agency and public review aspect of this EE/CA.
- Community Acceptance: Community acceptance will be addressed during public review of this EE/CA.

Cost

The 30 year net present worth of the three Alternative 2 sub-options range from $438,000 to $618,000. There are no monitoring or maintenance costs associated with these options. Appendix D provides cost components for Alternative 2. Costs are based on assumptions for each component presented in Appendix D.

5.2.3 Alternative 3 – Onsite Treatment and Offsite Disposal

Effectiveness

Effectiveness includes several evaluation factors that are described below:

- Protection of Human Health and Environment: This alternative provides protection to human health and the environment by achieving RAOs. Soil exceeding site cleanup levels would be excavated and disposed of in accordance with applicable federal and state transportation and disposal regulations.
- Compliance with ARARs and TBC Guidance: Implementing this alternative will comply with all chemical-specific ARARs and RAOs for COCs that have specific risk-based cleanup levels.
- Location-Specific ARARs: Implementation of this alternative will comply with the location-specific ARARs. There are no species deemed endangered, threatened or of special concern. The archeological areas of concern are not within the proposed work zone.
- Action-Specific ARARs: Implementation of Alternative 2 will comply with all action-specific ARARs listed in Appendix B.
- Reduction of Toxicity, Mobility, and Volume through Treatment: All material contaminated with COCs above cleanup levels would be permanently removed to a secure disposal facility, therefore, reducing mobility. Toxicity would be reduced in the excavated material prior to transportation from the site. A small volume increase would occur because of the addition of stabilization agents.
- Long-Term Effectiveness and Permanence: Excavation and offsite disposal would be an effective and permanent alternative. All material contaminated with COCs above cleanup levels will be removed and disposed of in accordance with applicable regulations.
- Short-Term Effectiveness: Excavation and disposal requires that materials be excavated, staged, characterized for disposal purposes, and transported on waterways, public roadways and or rail lines, to the appropriate disposal facilities. Risks to site workers would be controlled by appropriate use of protective clothing and good construction practices.

Additional risks associated with the transportation of contaminated soils would include the potential for highway and waterway accidents and spills of contaminated materials. Following appropriate Department of Transportation, state, and local shipping requirements for all transportation-related activities would minimize the risks associated with waste transportation.

The site has been disturbed from the original mining operations and from the recent removal actions. Implementation of this alternative could significantly disrupt biota at the site as large footprints would have to be created to store and move Super Sacks or containers during the actual removal activities. Appropriate sediment control measures would be implemented to reduce potential impact to Mahoney Lake Creek or George Inlet.

Implementability

Implementability is evaluated in accordance with the following criteria:

- Technical Feasibility: The sub-options of this alternative involve procedures that can easily be implemented. Labor, equipment, and materials required for this alternative are conventional and readily available. The sub-options vary in their implementability with respect to the expected difficulties associated with transporting the material off the site. Sub-option 3A is considered the base line because this method was used in the previous removal action. Sub-option 3B requires installation of a temporary bulkhead on the beach and roadwork to accommodate the increased heavy equipment travel from the site to the barge. Sub-option 3C uses a similar helicopter approach as in Sub-option 3A, but delivers the sacks to waiting trucks or stages the material on the road. In either case these considerations decrease the implementability from Sub-option 3A. The Cape Fox Corporation may also require road maintenance to mitigate the wear and tear associated with moving the tailing over the existing gravel road
- Administrative Feasibility: Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Sub-option 3C uses a private road and will require additional coordination with the Cape Fox Corporation and potentially increase permitting requirements.
- Availability of Services and Materials: Contractors are available to conduct site preparation, design, excavation, and transportation. Several facilities are licensed to accept material classified as non-hazardous waste.
- State Acceptance: State acceptance will be addressed through the regulatory agency and public review aspect of this EE/CA.
- Community Acceptance: Community acceptance will be addressed during public review of this EE/CA.

Cost

The 30 year net present worth of three Alternative 3 sub-options range from $376,000 to $548,000. There are no monitoring or maintenance costs associated with these options. Appendix D provides cost components for Alternative 3. Costs are based on assumptions for each component presented in Appendix D.

5.2.4 Alternative 4 – Onsite Treatment and Onsite Disposal

Effectiveness

Effectiveness includes several evaluation factors that are described below:

- Protection of Human Health and Environment: This alternative provides protection to human health and the environment by achieving RAOs. Material exceeding site cleanup levels would be excavated, treated to eliminate the hazardous properties of the material, and consolidated in an engineered monofill or backfilled into the abandoned underground mine workings. This alternative would eliminate the toxic property of the material and eliminate the direct contact exposure pathway.
- Compliance with ARARs and TBC Guidance: Implementing this alternative will comply with all chemical-specific ARARs and RAOs for COCs that have specific risk-based cleanup levels.
- Location-Specific ARARs: Implementation of this alternative will comply with the location-specific ARARs. There are no species deemed endangered, threatened, or of special concern. The archeological areas of concern are not within the proposed work zone.
- Action-Specific ARARs: Implementation of Alternative 4 will comply with all action-specific ARARs listed in Appendix B.
- Reduction of Toxicity, Mobility, and Volume through Treatment: All material contaminated with COCs above cleanup levels would be treated, reducing the toxicity. The treatment process is such that the leachability is reduced so that the mobility will also be reduced. The treated material would be placed in an engineered monofill or in the abandoned underground mine workings; both options would also decrease the mobility of the constituents. A small volume increase would occur because of the treatment process.
- Long-Term Effectiveness and Permanence: Excavation, treatment, and onsite disposal would be an effective and permanent alternative. The treatment process is a permanent chemical reaction that will not reverse or produce leachable metal compounds. In either placement scenario the material will be segregated from human receptors thus eliminating the direct exposure pathway. The monofill will require periodic inspections. It is expected that the in-mine placement would require no maintenance, although the adit closures would have to be monitored to ensure integrity.

- Short-Term Effectiveness: Excavation, treatment and onsite disposal requires that the materials be excavated, staged, sampled for TCLP, and handled during final onsite placement. Risks to site workers would be controlled by appropriate use of protective clothing and good construction practices.

The site has been disturbed from the original mining operations and from the recent removal actions. Implementation of this alternative would not be significantly disruptive for biota at the site during the actual removal activities.

Implementability

Implementability is evaluated in accordance with the following criteria:

- Technical Feasibility: Sub-options 4A and 4B both treat the soil using the same process, although in a slightly different manner, and then provides for final disposal on-site. Both of these sub-options involve procedures that can easily be implemented. Although mine stowing technology (4B) is not common in Alaska the technique has been well documented. The issues with this option relates to the integrity of the underground workings and their suitability as a confined space workplace because of the potential to compromise the atmosphere in the underground workings when carbon dioxide producing pumps. Sub-option 4A uses a monofill approach. Labor, equipment, and materials required for these sub-options are conventional and available.
- Administrative Feasibility: Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. With Sub-option 4A, deed restrictions will be required.
- Availability of Services and Materials: Contractors are available to conduct site preparation, design, excavation, treatment, and final onsite placement.
- State Acceptance: State acceptance will be addressed following regulatory agency and public review of this EE/CA.
- Community Acceptance: Community acceptance will be addressed following regulatory agency and public review of this EE/CA.

Cost

The 30 year net present worth of Sub-option 4A is approximately $304,000, with first year monitoring costs of $12,000 and a 30 year monitoring cost of $90,000. Sub-option 4B cost is $245,000 with no long-term monitoring. Appendix D provides cost components for Alternative 4. Costs are based on assumptions for each component presented in Appendix D.

5.2.5 Alternative 5 – In-Place Treatment

Effectiveness

Effectiveness includes several evaluation factors that are described below:

- Protection of Human Health and Environment: This alternative provides protection to human health and the environment by achieving RAOs. Material exceeding the toxicity characteristics (exceeding TCLP for lead) would be treated to eliminate the hazardous property. This alternative also includes covering the treated material with waste rock, eliminating the direct contact exposure pathway. In essence, this alternative is similar to the monofill approach without material consolidation.
- Compliance with ARARs and TBC Guidance: Implementing this alternative will comply with all chemical-specific ARARs and RAOs for COCs that have specific risk-based cleanup levels.
- Location-Specific ARARs: Implementation of this alternative will comply with the location-specific ARARs. There are no species deemed endangered, threatened, or of special concern. The archeological areas of concern are not within the proposed work zone.
- Action-Specific ARARs: Implementation of Alternative 5 will comply with all action-specific ARARs listed in Appendix B.
- Reduction of Toxicity, Mobility, and Volume through Treatment: All material characterized as hazardous would be treated, reducing the toxicity. The treatment process is such that the leachability is reduced so that the mobility of hazardous constituents will be reduced. The treated material would be covered with waste rock, a capping technique that also contributes to the decrease in mobility. A small volume increase would occur because of stabilization agents added during the treatment process.
- Long-Term Effectiveness and Permanence: In-place treatment would be an effective and permanent alternative. The treatment process is a permanent chemical reaction that will not reverse or produce leachable metal compounds. The material will be physically separated from any receptor, thus eliminating the direct exposure pathway. It is expected that no maintenance would be required; however, periodic inspection of the cap is recommended.
- Short-Term Effectiveness: Treatment requires that materials be partially excavated and handled for application of the agents and sampling for TCLP characterization prior to final onsite placement and capping. Risks to site workers would be controlled by appropriate use of protective clothing and good construction practices.

The site has been disturbed from the original mining operations and from the recent removal actions. Implementation of this alternative would not be significantly disruptive for biota at the site during the actual treatment activities as no new footprint has to be created. Appropriate sediment control measures would be implemented to reduce potential impact to Mahoney Lake Creek or George Inlet.

Implementability

Implementability is evaluated in accordance with the following criteria:

- Technical Feasibility: This alternative involves procedures that can easily be implemented. This option involves the treating of the material as in Alternatives 3 and 4 followed by capping with waste rock. Labor, equipment, and materials required for this alternative are conventional and readily available.
- Administrative Feasibility: Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. This alternative will require deed restrictions.
- Availability of Services and Materials: Contractors are available to conduct site preparation, design, excavation, treatment, and final onsite placement.
- State Acceptance: State acceptance will be addressed following regulatory agency and public review of this EE/CA.
- Community Acceptance: Community acceptance will be addressed following regulatory agency and public review of this EE/CA.

Cost

The 30 year net present worth of Alternative 5 is approximately $235,000, with first year monitoring cost of $12,000 and a 30 year monitoring cost of $90,000. Appendix D provides cost components for Alternative 5. Costs are based on assumptions for each component presented in Appendix D.

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6.0 COMPARATIVE ANALYSIS OF REMOVAL ACTIONS ALTERNATIVES

This section provides a comparative analysis of the alternatives presented in Section 5.1. In Section 5.2, each alternative was analyzed independently without consideration of other alternatives. In this section, a comparative analysis is completed to identify the advantages and disadvantages of each alternative relative to one another so that the key tradeoffs can be identified. Table 6-1 presents a qualitative summary comparison of the alternatives.

Table 6-1
Comparative Analysis of Removal Action Alternatives

Alterrnatives	Alternative 1 No Action	Alternative 2 Offsite Disposal			Alternative 3 Onsite Treatment and Offsite Disposal			Alternative 4 Onsite Treatment and Onsite Disposal		Alternative 5 In-Place Treatment
Criteria										
Effectiveness										
Overall Effectiveness	Poor	Excellent			Excellent			Good		Good
Protection of Human Health	Poor	Excellent			Excellent			Good		Good
Protection of the Environment	Poor	Excellent			Excellent			Good		Good
Compliance with ARARS	No	Yes			Yes			Yes		Yes
Long-Term Effectiveness	Poor	Excellent			Excellent			Good		Good
Short-Term Effectiveness	Poor	Excellent			Excellent			Excellent		Excellent
Reduction of Toxicity, Mobility, or Volume	Poor	Excellent			Excellent			Excellent		Excellent
Alterrnatives	**1**	**2A**	**2B**	**2C**	**3A**	**3B**	**3C**	**4A**	**4B**	**5**
Implementablility										
Overall Implementablity	Poor	Excellent	Good	Good	Excellent	Good	Good	Good	Good	Good
Technical Feasibility	Excellent	Excellent	Good	Excellent	Excellent	Good	Excellent	Excellent	Good	Excellent
Availability of Services & Materials	Not Applicable	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Administrative Feasibility	Excellent	Excellent	Excellent	Good	Excellent	Excellent	Good	Good	Good	Good
Regulatory Acceptability *	Poor	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Good	Good
Community Acceptablility *	Poor	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Fair	Good	Fair
Cost										
Overall Cost	None	High	Moderate	High	Moderate	Low	High	Low	Low	Low
Capital Cost	None	High	Moderate	High	Moderate	Low	High	Low	Low	Low
Operations Monitoring and Maintenance Cost	None	None	None	None	None	None	None	Low	Low	Low

Notes:
* = anticipated response
Qualitative Criteria Range: Excellent, Good, Fair, Poor
Cost Range: High, Moderate, Low, None.

6.1 EFFECTIVENESS

6.1.1 Protection of Human Health and the Environment

Alternative 1 does not offer protection of human health and the environment because no action is taken. Alternatives 2 and 3 provide the greatest degree of protection because the material is removed from the site. Alternatives 4 and 5 provide significant protection because the material is treated to eliminate the toxic characteristic and then covered with waste rock to prevent direct exposure (Sub-option 4A and Alternative 5) or placed into the abandoned underground mine openings that are sealed shut after placement (Sub-option 4B). Deed restrictions (Sub-option 4A and Alternative 5) preventing certain land uses would further mitigate exposure pathways to humans; however, the land use restriction would not prevent exposure to ecological receptors. Periodic sampling of surface seeps or groundwater, if required, does not provide protection to human health and the environment; however, it will alert regulatory agencies that a contingency remedy may require implementation. Alternatives 2 and 3 provide the greatest level of protection to humans and ecological receptors.

6.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

Alternative 1 will not meet the ARARs because no action is taken. Alternatives 2 and 3 are expected to comply with chemical-specific ARARs and met RAOs which include removing COCs to below their respective cleanup levels and by providing disposal. Alternatives 4 and 5 may not meet all the applicable chemical specific ARAR in that the treated soil will not be removed, but its toxicity will be reduced and then covered or otherwise capped to prevent against direct contact. Alternatives 2 through 5 are expected to comply with all location-specific and action-specific ARARs.

6.1.3 Long-Term Effectiveness and Permanence

Alternative 1 does not provide long-term effectiveness and permanence because it is a no action alternative. Alternatives 2 and 3 offer long-term effectiveness and permanence because the material is removed and disposed in a regulated facility. Alternative 4 and 5 also provide long-term effectiveness and permanence. In each of these two alternatives, the material is treated with a nonreversible chemical process that eliminates the hazardous characteristic of the material and is then covered with waste rock or otherwise placed to prevent direct exposure to potential receptors. A monitoring program could be implemented to document the integrity of the cover material, and the stability of the chemical stabilization process. Alternatives 2 and 3 provide the highest degree of long-term effectiveness and permanence because these two methods consist of physically removing contaminated soil from the site to a regulated, out-of-state disposal facility.

6.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 does not provide reduction of toxicity, mobility, or volume because it is a no action alternative. Alternative 2 provides no treatment, but the mobility is reduced by placing the material in an offsite, engineered facility. Alternatives 3, 4, and 5 provide equal reduction of toxicity, and mobility by treating the material with a metal stabilization process. Additional reduction in mobility results from covering the treated material with waste rock or placing the material in the mine voids. A slight volume increase may occur due to the treatment process.

6.1.5 Short-Term Effectiveness

Short-term effectiveness is best achieved by minimizing additional risks to workers, the environment, and the local community during the removal action. The principal threat to human health is contact with contaminants once they have been extracted or removed or during the treatment and consolidation process.

As no action is taken under Alternative 1, this category is not applicable to this alternative. Implementation of Alternatives 2 through 5 may present a low, short-term risk to workers during the excavation and treatment activities. However, any potential risks would be mitigated by using proper personal protective equipment. Because of the limited access to the site, there is no risk to the public from implementation of these alternatives.

6.2 IMPLEMENTABILITY

The implementabilty discussion below considers the technical feasibility, the administrative feasibility, and the availability of services and materials.

Alternative 1 is a no action alternative. The other alternatives are readily implementable because they use similar and commonly used and available technologies and resources. There are, however, some differences between alternative and among sub-options.

Alternatives 2 and 3 each have three sub-options. The implementability varies within the sub-options due primarily to logistical considerations. Sub-option A (both 2A and 3A) use the helicopter approach to move the material from the site to a barge for transshipment to Ketchikan. This alternative is highly implementable largely because this procedure was used in the previous removal action and there is documented success in using this method. However, because of the large number of Super Sacks required to accommodate the revised volumes present, the current footprint at the site will have to be increased at the expense of local biota.

Sub-option B (both 2B and 3B) also utilize a helicopter to sling load material; however, the material is delivered to trucks on the nearby Cape Fox Road. If permission were granted by the Cape Fox Corporation to allow temporary staging of material on the road, these sub-options would become more implementable. The involvement of the Cape Fox Corporation and the additional permitting that may be needed decreases the implementability on an administrative level. The Cape Fox Corporation may also require road maintenance after the hauling is completed.

Sub-option C (both 2C and 3C) transport the material in bulk, either on a large front-end loader or in bulk containers, directly to a barge. This sub-option is highly implementable, although difficulties may develop in providing a sufficiently firm temporary road base from the site to the barge landing. Other technical implementabilty issues may arise regarding the staging and loading of the barge through the tide cycles. A temporary jersey-barrier type bulkhead may have to be developed on the beach to facilitate barge loading/unloading.

All of the above six sub-options (2A, 2B, 2C, 3A, 3B, and 3C) would likely be equally accepted by the state and the community because the contaminated material is removed from the site.

Sub-options 4A and 4B and Alternative 5 each treat the waste with the same metals stabilization process and provide onsite disposal. Alternatives 4A and 5 both cover the treated material with waste rock. Sub-option 4A consolidates the tailings into a monofill whereas Alternative 5 provides a waste rock cap over the treated, in-place material. The monofill option and the in-place sub-option are both technically feasible. The administrative feasibility decreases slightly for Sub-option 4A and Alternative 5. These options both require ASC and deed restrictions to prohibit human occupancy on the site and protect against future contact with the material.

Sub-option 4B renders the tailings non-hazardous before backfilling the material into the underground mine workings. Backfilling underground mine workings is considered a common mine reclamation technique. The integrity of the underground workings plays a large role in the implementability of this option. It is expected that only the piping equipment will be in the mine during the mine filling. Because of the distance from the mine opening that the material will need to be placed, this alternative may not be practicable. Additional implementability concerns may be not having the experienced personnel or appropriate equipment available in a convenient or timely manner. Additional preparation of the material such as separating large rock may be required. These factors lower the implementability, but the alternative is still considered viable.

Options that leave wastes onsite, in any form, often receive less support from the state regulatory agencies and the community.

6.3 COST

Detailed cost estimates were prepared for the nine alternatives and sub-options. The estimates and assumptions used in developing the estimates are presented in Appendix D. The 30 year present worth cost of Alternatives 2 through 5 range from $231,500 for Alternative 5 to $618,000 for Sub-option 2C. The cost estimate contains the capital cost and operations and maintenance costs. The present worth is calculated using the 2006 discount rate of 3.1 percent. There is no cost for Alternative 1 – No Action alternative.

Table 6-2
Alternative Cost Summary

Alternative	Alternative Name	Cost
1	**No Action**	$0
2	**Offsite Disposal**	
Sub-option 2A	Airlifted to Barge	$600,000
Sub-option 2B	Driven to Barge	438,000
Sub-option 2C	Airlifted to Trucks	$618,000
3	**Onsite Treatment and Offsite Disposal**	
Sub-option 3A	Airlifted to Barge	$531,000
Sub-option 3B	Driven to Barge	376,000
Sub-option 3C	Airlifted to Trucks	548,000
4	**Onsite Treatment and Onsite Disposal**	
Sub-option 4A	Placed in Monofill	$304,000
Sub-option 4B	Placed in Mine Workings	$245,000
5	**In-Place Treatment**	$235,000

Alternatives 2 and 3 each have three sub-options pertaining to the different methods used to transport material from the site (helicopter to barge, bulk containers to barge, and helicopter to truck). Within these two alternatives, the Sub-option B, bulk loading of soil from the site to a barge, was estimated to be 30 to 40 percent less than Sub-options A and C, both involving helicopter transportation.

The cost difference between similar sub-options in Alternatives 2 and 3 is approximately 10 percent. For example, the cost of Sub-option 2A is estimated at $600,000 whereas Sub-option 3A is $531,000. The substantive difference in the alternatives is that Alternative 2 disposes the material offsite as hazardous waste and Alternative 3 treats the material onsite and disposes Sub-options 4A and 4B, both which include onsite treatment and onsite placement, are substantially lower than the offsite disposal alternatives. The estimated cost for Sub-option 4A is $304,000 and for Sub-option 4B is $245,000.

Alternative 5 has the lowest estimated cost at $235,000.

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7.0 SELECTION OF PREFERRED ALTERNATIVE

The preferred removal action alternative for the Mahoney Mine site is to treat the tailings with a metals stabilizing agent and consolidate the upland and intertidal tailings into an onsite monofill adjacent to the main waste rock piles. The monofill will encompass a surface area of nearly 40 by 60 feet and tailings will be piled at a 4:1 slope to a height of 6 feet to conform to local topography. A composite geotextile membrane will be placed over the tailings to shed meteoric water. A toe drain will be constructed around the downgradient side of the monofill to collect surface runoff from the pile and direct it away from Mahoney Lake Creek. Waste rock from the site will be placed over the geotextile membrane to fabricate a nearly 2-foot thick cap over the tailings. Portals to the underground workings will be backfilled with waste rock to prevent individuals from entering these potentially hazardous areas. An open stope to the surface within the underground workings will be covered with cable mesh to mitigate this final safety concern.

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8.0 REFERENCES

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APPENDIX A

Treatability Studies

MAHONEY MINE
USACE
Elmendorf Air Force Base, Alaska

TREATABILITY REPORT

T. E. Moody, Ph.D
Metals Treatment Technologies, LLC
April 29, 2004

1.0 OBJECTIVE

The objective of this report is to present the findings of a laboratory treatability study conducted by Metals Treatment Technologies ($MT^{2)}$ designed to determine the Resource Conservation and Recovery Act (RCRA) leachable lead (Pb) concentrations from untreated and ECOBOND® Pb treated soil.

2.0 SAMPLE DESCRIPTION AND CHARACTERIZATION

The sample of Pb contaminated soil was delivered to MT^2 sample receiving by Todd Fickel, U.S Army Corps of Engineers, Alaska District, at Elmendorf Air Force Base, Alaska. The sample type/consistency is a wet muck soil. The sample was sent in one plastic bag that weighed 2 kilograms. The sample arrived at the MT^2 treatability laboratory on 5 April 2004. A description of the sample and chemical analysis is presented in Table 1. X-ray fluorescence (XRF) analysis was done in house using a Niton model XL 700 multi-element XRF spectrophotometer.

Table 1
Sample Description and Characterization

MT^2 Sample No.	Description	Total Pb XRF Analysis	Fe XRF Analysis	Mn XRF Analysis	Cu XRF Analysis
137-1	The sample was very wet; dark brown in color; high in organic matter	6,170	6,420	812	153

Note: All units are in milligrams per kilogram.

The soil was then tested for hazardous Pb by using the U.S. Environmental Protection Agency's (EPA) SW-846 Method No. 1311 "Toxicity Characteristic Leaching Procedure" (TCLP). The TCLP extraction fluids were then filtered and analyzed by atomic absorption spectrophotometry. The results of the subsequent analysis are presented in Table 2.

Table 2
Pre-Treatment TCLP Results

MT^2 Sample #	MT^2 Test #	pH of the Soil	TCLP Pb (mg/L)
137-1	Control	5.53	19.7
RCRA Criteria			**5.0**

The untreated TCLP Pb extraction value of 19.3 milligrams per liter (mg/L) indicates that sample MT^2 137-1 is above the RCRA criteria for non-leachable Pb (sample analysis > 5.0 mg/L).

3.0 TREATMENT STUDIES

Sample MT^2 137-1 was used for treatment studies. Each ECOBOND® Pb treatment was implemented using 100 grams (g) of the contaminated soil. As with the untreated data, the treated soil was examined for irregularities and none was discovered. ECOBOND® Pb formula was applied and mixed with the sample in increasing amounts. Because of the high percent of moisture inherent in the soil, water was not added with ECOBOND® Pb. After weighing measurements and complete mixing with the treatment materials, the sample and treatment materials were allowed to incubate and stabilize overnight. The following day, samples were taken and extracted for Pb implementing EPA's SW-846 Method No. 1311 "Toxicity Characteristic Leaching Procedure." The TCLP extraction fluids were then filtered and analyzed by atomic absorption spectrophotometry. The results of the ECOBOND® Pb treatment tests are presented in Table 3.

Table 3
ECOBOND® Pb TCLP Data

MT² Test #	MT² I.D. #	Sample Weight	ECOBOND® Pb Formulation	H_2O Addition	pH of the Soil	TCLP Pb Untreated (mg/L)	TCLP Pb Treated (mg/L)
12-54-1	137-1	100g	1.0%	0.0%	4.95	19.7	3.4
12-54-2	137-1	100g	1.5%	0.0%	4.66	19.7	2.0
12-54-3	137-1	100g	2.0%	0.0%	4.45	19.7	1.6
12-54-4	137-1	100g	2.5%	0.0%	4.54	19.7	1.0
RCRA Criteria							**5.0**

4.0 CONCLUSIONS

The addition of ECOBOND® Pb to the soil to stabilize and reduce leachable Pb to non-hazardous RCRA levels was successful from 1.0 percent to 2.5 percent by weight amendment levels.

5.0 RECOMMENDATION

MT² recommends a 2.0 percent addition of ECOBOND® Pb to the soil for stabilizing the Pb to below the RCRA non-hazardous level. Although 1.0 and 1.5 percent ECOBOND® Pb additions provide TCLP values less than 5.0 mg/L, below the RCRA hazardous level, a 2.0 percent addition addresses field variability and incorporates a buffer for stabilizing hot spots.

APPENDIX B

Applicable or Relevant and Appropriate Requirements

Action Specific ARARs

Authority	Citation	Description	Type	Rationale
Hazardous Materials Transportation Act	49 CFR Parts 10, 171 through 177	Standards Applicable to Transport of Hazardous Wastes	ARAR	Regulates transportation of hazardous materials including mining wastes that are not exempt under the Bevill Amendment.
Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR Part 257	Establishes criteria for use in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health or the environment and, thereby, prohibits open dumps	ARAR	Applies to solid wastes at the site
Solid Waste and Hazardous Waste Regulations	40 CFR 239 -299 18 AAC 60 and 18 AAC 62	Defines solids wastes that are regulated as hazardous wastes and how those waste are handled, treated and disposed.	ARAR	Not applicable to mine waste or tailings currently onsite, exempt from hazardous waste regulations per the Bevill Amendment. Congress enacted the "Bevill Amendment" in 1980, exempting temporarily from hazardous waste regulation "solid waste from the extraction, beneficiation, and processing of ores and minerals." 42 U.S.C. § 6921(b)(3)(A)(ii). Mine wastes may not be exempt under Bevill if they independently exhibit the characteristics of hazardous materials or if the agency determines they "may present an imminent and substantial endangerment to health and the environment." 42 U.S.C. § 6973(a).
Clean Water Act	40 CFR Part 122-125	National Pollutant Discharge Elimination System,, establishes a program for controlling discharges from inactive mine sites.	ARAR	Applicable to the inactive mine site and potentially to the work area during removal actions
Alaska Solid Waste Management	18 AAC60	These regulations govern waste disposal facilities, storage limitations, land spreading restrictions and requirements for special waste disposal. Permitting standards and monitoring requirements are also within these regulations.	ARAR	Solid waste regulations are applicable to the construction of monofills.

Location Specific ARARs

Authority	Citation	Description	Type	Rationale
Coastal Zone Management Act	33 CFR Part 320	Provides for the use, management, restoration and enhancement of coastal environments.	ARAR	The site is with the Coastal Zone Management Act (CZMA) jurisdiction. Federal sites are exempt from the CZMA but must comply with Alaska coastal zone regulations.
Alaska Coastal Management	06 AAC 80	These regulations contains the standards of the Alaska Coastal Management Program for the management of land and water uses in Alaska's coastal zone.	ARAR	These regulations are applicable if removal actions, such as a barge landing, affect the coastal environment.
National Historic Preservation Act	32 CFR Part 229, 36 CFR Part 800	Provides for the preservation of historical and archeological data that would be lost due to alterations of the terrain.	ARAR	The Mahoney cabin site may be eligible for inclusion on the National Register.
Endangered Species Act	50 CFR Part 17, 222, 227	Provides for the protection and conservations of listed wildlife and their habitats	TBC	No endangered species were initially identified at the site.
Fish and Wildlife Coordination Act	40 CFR Part 6	Consultation with the Fish and Wildlife Service is required to evaluate Federal project effects to Fish and Wildlife Resources	ARAR	Applicable to the action in streams and tidelands or involving dredge or fill activities in streams or wetlands. Certain mitigation may be appropriate, such as timing of remedial actions to avoid impacts to fish and wildlife
Management of federal Lands	13 USC 1700	Establishes requirements concerning utilization of public lands.	ARAR	Applicable dependent on land type and feature present at the site.

Chemical Specific ARARs

Authority	Citation	Description	Type	Rationale
Alaska Solid Waste Management	18 AAC60	These regulations govern waste disposal facilities, storage limitations, land spreading restrictions and requirements for special waste disposal. Permitting standards and monitoring requirements are also within these regulations.	ARAR	Solid waste regulations are applicable to the storage and disposal of solid waste such as mining tailing and contaminated soil.
Alaska Hazardous Waste	18 AAC62	These regulations defines wastes that are hazardous wastes; establishes standards for generators, transporters and disposal facilities.	ARAR	The contaminated soil that exceed the lead TCLP criteria will be considered a hazardous waste.
Alaska Water Quality Standards	18 AAC 70	Water quality standards identify uses for water and establishes in-stream criteria for pollutants.	ARAR	The water quality standards may be applicable to the on-site water (seeps) and the adjacent Mahoney Lake Creek.
Alaska Oil and Other Hazardous Substance Pollution Control	18 AAC75	These regulations govern the release of oil and other hazardous substances and related cleanup requirements.	ARAR	Soil and water cleanup levels in these regulations are applicable to the onsite soil and water.
Alaska Drinking Water	18 AAC 80	The regulations establish standards for drinking water	ARAR	The regulations establish all groundwater as a potential drinking water source unless specifically classified otherwise. Although no contaminated groundwater has been identified at the site, any potential action must not cause the groundwater to become contaminated.

Federal Water Quality Criteria	40 CFR Part 131	Sets standards for surface water to protect aquatic organisms and human health.	ARAR	Provides comparative criteria for surface water standards.
National Primary Drinking Water Standards	40 CFR Part 141	Sets standards for drinking water systems and specifies Maximum Contaminant Levels (MCLs)	ARAR	MCL are valid because all groundwater is considered a potential drinking water by Alaska regulations. NCP also require that MCLs be ARARs for groundwater.
National Secondary Drinking Water Standards	40 CFR Part 143	Sets aesthetic standards for drinking water systems and specifies Secondary Maximum Contaminant Levels (SMCLs).	TBC	May be are valid depending on type of contamination present. Zinc in drinking water in a SMCL.
Resources Conservation and Recovery Act	40 CFR Part 261	Regulations that address the identification, treatment and disposal of hazardous wastes.	ARAR	The contaminated soil that exceed the lead TCLP criteria will be considered a hazardous waste.
Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities	OSWER Directive No. 9355.4-12	Describes methods for developing site specific preliminary remediation goals and media specific cleanup standards for lead	TBC	The primary contaminant at the site is lead
Alaska Risk Assessment Procedures Manual - June 8, 2000	Adopted by reference in 18 AAC 75	Provides guidance in the preparation of human health and ecological risk assessments.	TBC	Human and ecological receptors are currently in contact with the contaminated material.

Alaska Determining Background Concentrations in Soil - June 13, 2003		Provides guidance on the calculations of background concentrations	TBC	Site specific background concentrations of some metals may be above cleanup levels.

APPENDIX C

Risk Assessment, Supporting Documents and Calculations

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FIGURES

1.0 HUMAN HEALTH RISK EVALUATION

The purpose of the risk evaluation is to determine whether contaminants are present in site media at concentrations that have the potential to cause unacceptable human health risks via complete exposure pathways.

A risk assessment or risk evaluation includes four main steps.

- Data Collection and Data Evaluation
- Toxicity Assessment
- Exposure Assessment
- Risk Characterization

The following pages document these four steps. Supporting information and calculations follow the risk evaluation reference section.

1.1 DATA COLLECTION AND DATA EVALUATION

1.1.1 Data Evaluation and Summary

Samples were collected from surface soil (0 – 3.5 feet), surface water, and sediments from July 1996 through August 2003. All data were validated or assessed for quality assurance/quality control (QA/QC) purposes by verifying that appropriate analytical methods were used and by evaluating the quality of the data with respect to quantification limits, qualifiers and codes, and blanks. All data quality objectives were achieved and the quality of the chemical data supports the decisions that were made at the site. Samples included in the SRE were analyzed according to the U.S. Environmental Protection Agency (EPA) - or Alaska Department of Environmental Conservation (ADEC)-approved analytical methods that are appropriate for risk evaluation purposes, as follows:

- EPA 13 Priority Pollutant Metals (EPA 272.2, 206.2, 210.2, 213.2, 218.1, 220.2, 245.1, 249.2, 239.2, 204.2, 270.2, 279.2, 289.1)
- EPA Method 6000/7000 series for metals
- ADEC Methods AK 102/103 for DRO and RRO

A summary of all analytical data is provided in Tables 6-11, 6-12 and 6-13.

1.1.2 Preliminary Chemicals of Potential Concern

The preliminary COPC list was compiled from the list of all detected analytes onsite. This list was then reduced by retaining analytes that exceeded the CERCLA observed release concentration (ORC). ORC is defined as: 1) organic chemicals detected above reporting limits, and 2) metals detected above three times background. The ORC is employed by EPA as part of the hazard ranking system to establish whether an observed release of hazardous substances should be addressed under CERCLA. According to EPA guidance (EPA 1989), "Information on background chemicals may [be] obtained by the collection of site-specific background samples and/or from other sources (e.g., County Soil Conservation Service surveys, United States Geological Survey [USGS] reports). . . . [A] comparison of sample concentrations with background concentrations e.g., using the geometric mean concentrations of the two data sets) is useful for identifying the non-site-related chemicals that are found at or near the site."

Three background samples were collected at the site. One background water sample was collected from a small seep 500 feet uphill and west of the site. One background soil sample was taken from a steep hillside above the uppermost mine workings at an elevation of 300 feet. This was a composite sample from four holes dug through a layer of humus, duff and twigs to a thin soil layer. Results from this sample are not indicative of a mineral soil[1]. One background sediment sample was taken from a creek about three-quarters of a mile south of the site.

Due to the limited number of site-specific background samples, two regional background reports were also used in determining background concentrations. The US Geological Survey (USGS) report, "Element Concentrations in Soils and Other Surficial Materials of Alaska," (1988) summarizes the mean concentrations and range for 35 elements in soil and sediment throughout Alaska. This USGS report gives the mean arithmetic mean and the range of

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[1] Background results for the elements were non-detect for six of the 13 elements, and below any regional background concentrations for four of the 13, and at the low end of regional background for three of the 13.

values for each element. Since the study encompassed the entire state of Alaska, the lowest value from the range of concentrations was conservatively used as a background comparison level. A second report by the USGS, "Results from the analysis of 723 stream-sediment samples from the Stikine Geophysical Survey area within the Petersburg, Sumdum, Bradfield Canal, and Sitka quadrangles, southeastern Alaska" (1998), focused on an area adjacent to the Ketchikan area. Since this study area included the Mahoney Mine location, the mean concentrations were used as background comparison levels. The selected background concentrations and a summary of the Tier 1 COPCs are presented in Tables 6-11 and 6-12.

Analytes that are considered within background are as follows.

Analytes Within Background Ranges

Soil	Sediment	
Aluminum	Aluminum	Nickel
Arsenic	Arsenic	Niobium
Barium	Barium	Potassium
Beryllium	Beryllium	Selenium
Manganese	Cadmium	Silver
Molybdenum	Calcium	Sodium
Potassium	Gallium	Strontium
Scandium	Iron	Thallium
Sodium	Lanthanum	Vanadium
Strontium	Lithium	Yttrium
Titanium	Magnesium	
Vanadium	Manganese	

1.1.3 Concentration-Toxicity Screening

EPA guidance states, "[c]arrying a large number of chemicals through a quantitative risk assessment may be complex, and it may consume significant amounts of time and resources. The resulting risk assessment report, with its large, unwieldy tables and text, may be difficult to read and understand, and it may distract from the dominant risks presented by the site. In these cases, the procedures discussed in this section – using chemical classes, frequency of detection, essential nutrient information, and a concentration-toxicity screen – may be used to further reduce the number of chemicals of potential concern in each medium." (EPA 1989). This concentration-toxicity screening compares maximum concentrations of COPC to risk-based screening criteria based on a residential exposure scenario. This screening is based on the most conservative assumptions, regardless of the exposure scenarios that actually exist or are likely to occur in the future. The objectives of this approach are to ensure that COPCs are not prematurely eliminated from further evaluation, and to reduce the number of constituents carried through to the risk characterization step.

The maximum concentrations of COPCs reported for soil, surface water, and sediment samples were also evaluated for cumulative risk. The concentration-toxicity screening yielded a final list of COPCs for human health that was carried into the risk characterization. The following sections describe the selection of risk-based screening levels, compare site concentrations to the screening levels, and present a characterization of cumulative risk due to multiple COPCs.

1.1.4 Development of Risk-Based Screening Levels

The primary risk-based levels employed in the concentration-toxicity screening were one-tenth of the soil and groundwater cleanup levels promulgated by the State of Alaska in regulations 18 AAC 75, Tables B1, B2, and C. The ADEC soil cleanup levels are based on residential exposure scenarios and were derived using default EPA and ADEC assumptions. The Table B1 and Table B2 soil cleanup levels are separated by rainfall zone and exposure pathway. Ketchikan experiences a mean annual precipitation of greater than 40 inches, based on the NOAA Western Research Climate Center website (http://www.wrcc.dri.edu/summary/climsmak.html). Therefore, the selected screening levels were based on the Over 40 Inch Zone, and the lesser of the Ingestion or Inhalation pathway. The ADEC soil cleanup levels that are protective of the migration to groundwater pathway were not selected as screening levels as this pathway is not complete at the Mahoney Mine site.

ADEC developed the Table C groundwater cleanup levels using federally promulgated drinking water standards, maximum contaminant levels (MCLs), or risk-based levels. Risk-based levels are based on toxicological data and risk to human health. The concentration-toxicity screening only selected levels that are risk-based. If the 18 AAC 75 Table C cleanup level was not risk-based, a risk-based level was calculated. This insures correct values in calculation of the cumulative risk.

If 18 AAC 75 cleanup levels were unavailable for a particular COPC, the ADEC Tech Memo 01-007 (Additional Cleanup Values) was used. If 18 AAC 75 and Tech Memo 01-007 had no cleanup levels, the ADEC Web-based calculator was used to obtain the risk-based level (http://www.dec.state.ak.us/spar/cs/webcalc/).

In consideration of the ADEC cleanup regulations, COPCs with concentrations exceeding the screening level (one-tenth of the ADEC cleanup levels) were included in the risk characterization. Lead, DRO (diesel range organics), and RRO (residual range organics) were not included in the quantitative characterization because of the unique approaches for assessing risks associated with those contaminants. Lead, DRO and RRO were evaluated separately from the other COPCs.

COPCs with concentrations below risk-based screening levels do not pose an unacceptable risk to human health and were eliminated from further evaluation.

1.1.5 Concentration-Toxicity Screening

The concentration-toxicity cumulative risk calculations are shown in Table 1-1. Based on the conceptual site model (CSM) (see Figure 6-1), the current scenario media of potential concern for human health is surface water for the recreation user. The CSM future scenario also includes 'mine claimant.' Since mining is an occupational activity that is inherently associated with hazardous materials (minerals), the health and safety plan would cover potential exposures/risks due to ore extraction and waste handling activities. Therefore, this possible future scenario will not be evaluated. The screening is conservative in order not to prematurely exclude potential risks. Therefore, for the purposes of the concentration-toxicity screening the residential scenario is evaluated. Also, in addition to the surface water media, soil and sediment are also evaluated.

Soil

A total of 30 analytes were detected in the site soils. These included 27 metals, 1 non-metal (selenium), and two petroleum fractions (DRO, RRO). The concentration-toxicity screening narrowed the final COPC list to the following nine analytes:

- Antimony
- Cadmium
- Chromium
- Copper
- Iron
- Lead
- Mercury
- RRO
- Zinc

Surface Water

Five metals (cadmium, copper, lead, silver and zinc) were identified as preliminary COPCs in surface water (Table 6-13). Copper and silver dropped out during the concentration-toxicity screening. Thus the final Tier 1 COPC list included:

- Cadmium
- Lead
- Zinc

Seafood

Ingestion of seafood was not evaluated as the only significant surface water sampling results were from two small seeps originating from the tailing piles. Seafood harvesting cannot occur from these seeps due to their low and intermittent flows and shallow water. The seafood ingestion pathway is considered incomplete at this site.

Sediment

A total of 30 analytes (all metals) were detected in the site sediments (Table 6-12). The concentration-toxicity screening narrowed the final COPC list to:

- Chromium
- Lead

1.1.6 Concentration-Toxicity Screening Cumulative Risk

Cumulative risk is defined as the sum of excess cancer or noncancer risks resulting from exposure to multiple chemicals and exposure pathways. According to ADEC regulations, the cumulative cancer risk remaining at a site must be equal to or less than 1 in 100,000 ($1x10^{-5}$), and the cumulative noncarcinogenic hazard index (HI)[2] must be equal to or less than 1. As a conservative measure under the concentration-toxicity screening step, cumulative risk was calculated assuming residential exposures. The exposure pathways evaluated include ingestion of soil, sediments, and surface water. Dermal exposures were not quantified in this screening because the risk-based screening levels for ingestion of soil and water are considered protective of the dermal route. Ingestion of fish and seafood was not quantified because the seeps are too small to contain fish or seafood and the Mahoney Lake Creek contained no analytes above screening levels. The concentration-toxicity screening did not evaluate the soil and sediment concentrations separately, but evaluated the highest concentration regardless of which media contained the contaminant. No carcinogenic compounds above concentration-toxicity screening levels were detected at the site. Table 1-1 presents the calculations used for determining cumulative (non-cancer) risks that may be associated with potentially complete exposure pathways and COPCs exceeding risk-based screening levels.

Cumulative risk was calculated by dividing the maximum detected concentration of each COPC by the applicable risk-based concentration and then multiplying by 1 for noncarcinogens. The hazard quotients are then summed across all COPCs and exposure pathways to yield a total HI for the site. The these calculations used the following equations:

[2] The noncancer hazard quotient (HQ) assumes that there is a level of exposure (i.e., reference dose (RfD)) below which it is unlikely for even sensitive populations to experience adverse health effects. If the exposure level (E) exceeds this threshold (i.e., if E/RfD exceeds unity), there may be concern for potential noncancer effects. As a rule, the greater the value of HQ (= E/RfD) above unity, the greater the level of concern. However, HQ is not a statistical probability. A HQ of 0.001 does not mean that there is a one in one thousand chance of the effect occurring. The level of concern does not increase linearly as the HQ approaches and exceeds one because HQs (and RfDs) do not have equal accuracy or precision and are not based on the same severity of toxic effects. (A hazard index is the sum of two or more hazard quotients.)

$$HI = \Sigma [(Max. Conc. / RBC) \times 1] \quad \text{Eq. 1}$$

Petroleum hydrocarbons (RRO) were not included in the cumulative risk evaluation, because ADEC considers the risk due to the petroleum fractions characterized by the constituents (BTEX and PAHs). Lead is also not included in cumulative risk calculations. Due to its particular toxic effect, lead is evaluated with the Integrated Exposure Uptake Biokinetic Model (IEUBK).

The total HI across all exposure pathways is 7 (Table 1-1), which is above the ADEC risk management level of 1. The total HI is driven by ingestion of iron and cadmium in soils.

The cumulative risks summarized in this section should be considered preliminary. These potential risks are based on a residential exposure scenario, which is unlikely for the Mahoney Mine site. Exposure to sediments, in particular, is likely to be much lower than that assumed for a residential scenario.

Table 1-1
Screening Cumulative Risk Calculations

Analytes	Maximum Concentration	/	Risk-Based Concentration	=	Hazard Quotient (HQ)
SOIL (mg/kg)					
antimony	12.3	/	33	=	0.4
cadmium	165	/	83	=	2
chromium	default to sediment concentration				
copper	350	/	3,320	=	0.1
iron	47,900	/	24,900	=	2
mercury	1.69	/	15.8	=	0.1
zinc	19,100	/	25,000	=	0.8
SEDIMENT (mg/kg)					
chromium	273	/	250	=	1
WATER (ug/L)					
cadmium	12	/	18	=	0.7
zinc	2,100	/	11,000	=	0.2
Hazard Index (HI)					**7**

1.1.7 Data Collection and Data Evaluation Summary

The purpose of the data collection and data evaluation was to acquire reliable chemical release and exposure data for quantitative human health risk evaluation and to focus the evaluation on the chemicals that pose the greatest risk.

The following COPCs were identified in soil for protection of human health:

- Antimony
- Cadmium
- Chromium
- Copper
- Iron
- Lead
- Mercury
- RRO
- Zinc

The following final COPCs were identified in surface water for protection of human health:

- Cadmium
- Lead
- Zinc

The following final COPC were identified in sediment for protection of human health:

- Chromium

Petroleum hydrocarbons (RRO) was not included in the cumulative risk evaluation, because ADEC considers the risk due to the BTEX and PAH constituents as adequately characterizing the petroleum risk. Lead was retained for the risk characterization due to the use of the IEUBK model.

The cumulative risk calculated in concentration-toxicity screening exceeded the ADEC risk management level of 1. The total HI across all COPCs and exposure pathways was 7. Since the cumulative risk results exceed ADEC risk management levels, the COPCs were evaluated further in the risk characterization.

1.2 EXPOSURE ASSESSMENT

The exposure assessment examines the potential receptors and routes of exposure. Current scenarios and future scenarios are considered In addition, the 95 percent upper confidence limit (UCL95) on the mean was used where appropriate to represent the exposure concentration (EC) for each COPC, rather than the maximum detected concentration. UCL95 values are an upper bound[3] estimate of the mean and; therefore, provide a more realistic indication of the actual exposure that could be experienced by a receptor of concern. These methodologies are consistent with standard EPA risk assessment practices and ADEC cleanup regulations and guidance (ADEC 2000).

1.2.1 Calculation of Exposure Concentrations

Data sets for each COPC were used to derive an exposure concentration that was used to calculate risks. The EC is defined as an estimate of the arithmetic mean concentration that is contacted by a receptor over the exposure period. This definition assumes that an individual moves randomly across an exposure area (in this case, the entire site) and the likelihood of contacting any one-exposure point (sampling location, data point) is equally probable. The mean concentration is most representative of the concentration that would be contacted over time within the exposure area (EPA 1992). To reduce the uncertainty associated with estimating the true mean, the UCL95 on the arithmetic mean was calculated.

The UCL95 for each COPCs was calculated using ProUCL software[4], which allows routine statistical analyses of environmental data. ProUCL calculates UCL95s using the H statistic for lognormally distributed data sets and the Student-t statistic for normally distributed data sets, consistent with ADEC guidance (ADEC 2003). There are also five different methods of calculating an UCL95 for nonparametric distributions. The UCL95s were calculated

[3] On repeated sampling, there is only a 5 percent probability that the true sample mean would be outside of the 95 percent confidence limits.
[4] ProUCL Version 2.1 (EPA 2003)

according to the data distribution for each data set (i.e., normal, lognormal, or nonparametric), as determined by ProUCL. For each data set, the highest field duplicates result and one-half the reported detection limit for non-detect results were included. The UCL95 was not calculated for data sets with fewer than ten data points. In these cases the maximum concentration was conservatively retained as the exposure concentration.

The distribution of mercury in soil qualified as lognormal; and the distribution of lead in sediment qualified as normal, so the ECs for these COPCs are based on UCL95s.

The distributions of cadmium, lead, and zinc in soil neither qualified as normal nor lognormal, so the UCL95 was determined based on nonparametric methods. ProUCL provides five nonparametric approaches for determining the nonparametric UCL95: CLT, Jackknife, Standard Bootstrap, Bootstrap t, and Chebyshev. The other COPC had less than 10 data points so the highest concentration was used as the exposure concentration.

Table 1-2
Human Health COPC Exposure Point Concentrations

Soil COPC	**Exposure Point Concentration (mg/kg)**	**Statistical Measure**
Antimony	12.3	Maximum
Cadmium	35	95UCL Bootstrap
Chromium	120	Maximum
Copper	350	Maximum
Iron	47,900	Maximum
Lead	4,500	95UCL Bootstrap
Mercury	0.39	95UCL H-UCL
RRO	1,100	Maximum
Zinc	3,590	95UCL Bootstrap
Sediment COPC	**Exposure Point Concentration (mg/kg)**	**Statistical Measure**
Chromium	273	Maximum
Lead	255	95UCL Student-t
Surface Water COPC	**Exposure Point Concentration (ug/L)**	**Statistical Measure**
Cadmium	12	Maximum
Lead	300	Maximum
Zinc	2,100	Maximum

1.2.2 Exposure Pathways

The CSM (Figure 6-1) shows a completed pathway for the future scenario of 'mine claimant.' Mining activities inherently include exposure to ore and processing waste, and the existing waste (mine tailings) are no different from those produced by future mining. This type of industrial activity will also have safety plans for worker safety. Therefore, this future scenario is not included in the evaluation.

The only other completed pathways in the CSM are ingestion of surface water, dermal contact with surface water, and ingestion of fish and seafood by the recreation user (current and future). The most probable future scenario for this site (part of the Tongass National Forest) is the recreation user. Seeps located onsite are not suitable habitat for fish and seafood and the samples from Mahoney Lake Creek do not contain contaminates. Therefore the ingestion of fish and seafood is not included in the evaluation. Although the CSM classifies contact with soils and sediments as insignificant, these pathways will be included in the evaluation since campers onsite may contact these media.

The exposure assessment examines the recreational user considering the following exposure pathways:

- Ingestion of surface water
- Dermal contact with surface water
- Ingestion of soil
- Dermal contact with soil
- Ingestion of sediment
- Dermal contact with sediment

The recreational receptor was assumed to visit the site one weekend per month (2 days) from May through October (6 months). This equals 12 days per year and is based on site observations and information from the Forest Service (USACE 2004). A child receptor was evaluated. The child receptor is more conservative and is protective of the adult receptor. The standard input parameters are shown in the following table.

Table 1-3
Exposure Assessment – Child Receptor

Child Receptor			
	Input	**Units**	**Source**
Soil ingestion rate	200	mg/day	EPA 1989
Body weight	15	kg	EPA 1996
Exposure duration	6	years	EPA 1996
Water ingestion rate	2	liters/day	EPA 1989
Exposure frequency	12	days/year	USACE 2004
Skin surface area soil water	 2,800 6,600	cm^2	EPA 2001
Soil adherence factor	3.3	mg/cm^2-event	EPA 2001

Soil and sediment exposure is divided evenly between soil and sediment. Assuming children playing half the time on the shore and half the time inland.

Dermal contact under the recreational scenario was evaluated according to EPA guidance (http://www.epa.gov/superfund/programs/risk/ragse/index.htm). For most COPCs, oral toxicity values were used to evaluate the dermal pathway in accordance with EPA guidance. The oral reference doses for antimony, cadmium, and chromium were adjusted to derive an absorbed reference dose in accordance with EPA guidance.

The exposure assumptions and calculations are provided in the "Support Information and Calculations" paragraph. Lead is evaluated in the "Risk Calculations for Lead in Soil and Water" paragraph below. Following ADEC guidance, petroleum hydrocarbons (RRO) were not included in the cumulative risk evaluation. ADEC considers the risk due to the BTEX and PAH constituents as adequately characterizing the petroleum risk.

1.3 TOXICITY ASSESSMENT

Toxicity assessment included toxicity data from the:

- U. S. Environmental Protection Agency's (EPA) Integrated Risk Information System (IRIS) http://www.epa.gov/IRIS/index.html
- EPA Region 9 Preliminary Remediation Goals Table http://www.epa.gov/region09/waste/sfund/prg/index.htm

- Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles http://www.atsdr.cdc.gov/toxprofiles/

Table 1-4
Human Health Toxicity Values

COPC	CS	RfDo	RfDo Source
Antimony	12.3	4E-4	IRIS
Cadmium	35	5E-4	IRIS
Chromium	120	1.5E+0	IRIS
Copper	350	4E-2	R9 (HEAST)
Iron	47900	3E-1	R9 (NCEA)
Mercury	0.39	2E-4	See Support Calculations
Zinc	3590	3E-1	IRIS

1.4 RISK CHARACTERIZATION

The total noncancer risk for the recreational scenario is (see Support Information and Calculations):

$$
\begin{aligned}
HI_{ingest\ SW} &= 0.1 \\
HI_{dermal\ SW} &= 0.04 \\
HI_{ingest\ Soil} &= 0.07 \\
HI_{dermal\ Soil} &= 0.08 \\
HI_{ingest\ Sed} &= 0.00004 \\
HI_{dermal\ Sed} &= 0.0003 \\
\mathbf{HI_{TOTAL}} &= \mathbf{0.3}
\end{aligned}
$$

This cumulative risk, or hazard index, is below the ADEC and EPA risk management level of 1.

1.4.1 Risk Calculations for Lead in Soil and Water

A screening level of 400 mg/kg was used to evaluate lead concentrations in soil and is designed to be a departure point for determining the need for further risk assessment. This screening value is based on EPA’s interim soil lead guidance (EPA 1994). The residential lead screening level was calculated based on an updated version of the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) model using conservative default parameters for early childhood lead exposures.

“The IEUBK Model is designed to evaluate relatively stable exposure situations, rather than rapidly varying exposures. The model does not report each iterative calculation; rather, it reports one-year average blood lead concentrations. Because the IEUBK Model allows changes in exposure to environmental lead concentrations only at one year intervals, and provides output at only one year age intervals, changes in exposure are smoothed over one year. The model cannot be used to predict the effects of short term exposure episodes, such as exposure over a few days or weeks to lead dust and airborne particles that may be generated during lead paint abatement. The IEUBK Model should provide reasonable accuracy for blood lead concentration prediction as long as the changes in these environmental lead concentrations can be approximated by annual average values.” (EPA 1994). While the exposure at the Mahoney Mine site is short-term, it is not a one-time exposure such as exposure during lead paint abatement. It is a recurring exposure over several months per year for several years.

Variables in the IEUBK model can be modified based on site-specific data. Only two were modified for this evaluation. The other variables were kept at their default values. The variable of lead concentration in soil was changed from 200 mg/kg to 270 mg/kg. The variable of lead concentration in water was changed from 3.85 ug/L to 7.11 ug/L. These values were obtained as explained below.

The average annual exposure (to lead in soil) for a recreational visitor to the site can be approximated by summing the relative exposure to a given concentration based on duration of site use. The default annual average concentration of lead in environmental media (soil) in the IEUBK model is 200 mg/kg. The average concentration of lead in soil at the site is 2,340 my/kg. A recreational visitor is expected/assumed to spend 12 days per year at the site, and 353 days elsewhere. Therefore, the annual average concentration of lead that a recreational visitor could be exposed to can be calculated using Equation 2 (see below). The resulting annual average exposure concentration for a recreational visitor is 270 mg/kg.

$$\frac{(2340 \text{ mg/kg})(12 \text{ days/year}) + (200 \text{ mg/kg})(353 \text{ days/year})}{365 \text{ days/year}} = 270 \text{ mg/kg} \qquad \text{Eq.2}$$

The average annual exposure (to lead in drinking water) for a recreational visitor to the site can also be approximated as shown in Equation 3 (see below). The site average lead concentration from all surface water sources is 103 ug/L (this includes the two seeps onsite). The default value for the IEUBK drinking water is 3.85 ug/L. Averaging the 103 ug/L over the exposure frequency of 12 days per year and the 3.85 ug/L over the 353 days per year gives,

$$\frac{(103\ \text{ug/L})\ (12\ \text{days/year})\ +\ (3.85\ \text{ug/L})\ (353\ \text{days/year})}{365\ \text{days/year}} = 7.11\ \text{ug/L} \qquad \text{Eq. 3}$$

Using the site-specific annual average concentration of lead in soil and water, and the default values for all other parameters in the IEUBK model, the calculated blood-lead levels are all below the EPA risk management level of 10 ug/dL.

Year (ug/dL)	Blood level
0.5-1	4.6
1-2	5.2
2-3	4.9
3-4	4.6
4-5	3.9
5-6	3.5
6-7	3.1

The blood lead levels are below the EPA risk management level of 10 ug/dL for all years. Therefore, the lead levels at the site do not contribute to any unacceptable risks.

Note: ug/dL = micrograms per deciliter.

1.4.2 Residential Scenario

The Mahoney Mine site is part of the Tongass National Forest. As indicated previously, the current exposure and future exposure scenario is the occasional recreational visitor. Calculations for the residential scenario are completed here as a benchmark for unrestricted future use and a tool for comparison with other risk evaluations in the region.

The only parameter that changes between the occasional recreational visitor and the permanent year-round resident is the exposure frequency (EF). Instead of a visitor recreating at the site for one weekend a month for six months of the year, the individual is living on the site full time.

Thus, for the ingestion of surface water the exposure frequency (EF) changes from 12 days per year to 350 days per year. The value 12 is based on the one weekend a month (2 days) and six months per year. The 350 days per year is based on the resident living full time on the site and obtaining their drinking water from the surface water onsite.

The dermal contact with surface water EF changes from 12 to 24 days /year. Even though the child is living full time onsite, it is assumed he or she will only be playing in the surface water four days per month for six months per year.

The incidental ingestion of soil EF changes from 12 days per year to 330 days per year. The 330 is an ADEC default that accounts for some snow cover and cold weather.

The dermal contact with soil EF changes from 12 days per year to 130 days per year. This is assuming the child onsite will be playing in the soil for 5 days per week and 26 weeks per year.

The ingestion of sediment EF changes from 12 to 24 days per year. This is the same EF as used for the dermal contact with surface water.

The dermal contact with sediment EF likewise changes from 12 to 24 days per year.

In calculation of the hazard quotients (HQ) and hazard indexes (HI), the exposure frequency is in direct proportion to the HQ and HI. The recalculation of the site risks (HIs) for a residential scenario can be accomplished by using these proportions, or ratios, as follows.

Table 1-5
Residential Cumulative Risk Calculation

		Recreational **Visitor**	**x**	**Ratio**	**=**	Full-Time **Resident**
$HI_{ingest\ SW}$	=	**0.1**	**x**	**350/12**	**=**	**3**
$HI_{dermal\ SW}$	**=**	**0.04**	**x**	**24/12**	**=**	**0.08**
$HI_{ingest\ Soil}$	**=**	**0.07**	**x**	**330/12**	**=**	**2**
$HI_{dermal\ Soil}$	**=**	**0.08**	**x**	**130/12**	**=**	**0.9**

$HI_{ingest\ Sed}$	=	0.00004	x	24/12	=	0.00008
$HI_{dermal\ Sed}$	=	0.0003	x	24/12	=	0.0006
HI_{TOTAL}	=	0.3		6		

The IEUBK model was used to predict blood lead levels in children under the residential scenario. The predicted blood lead levels are above the EPA risk management level of 10 ug/dL for all years at an average soil concentration of 2,340 mg/kg. At a potential lead alternate cleanup level (ACL) of 750 mg/kg, the predicted blood lead levels are below 10 ug/dL for all years.

	Blood Lead Levels (ug/dL)	
Year	Soil Level at 2,340 mg/kg	Soil Level at 750 mg/kg
0.5-1	17.8	8.5
1-2	20.6	9.7
2-3	19.5	9.1
3-4	19.1	8.7
4-5	16.4	7.3
5-6	14.1	6.2
6-7	12.6	5.5

All input parameters for the model were kept at their default values, except for the outdoor soil lead concentration. The outdoor lead in soil was changed to a site-specific average value of 2,340 mg/kg. Surface water was not included in these calculations as it is assumed the resident will have a developed water source and not be using the seeps.

1.5 HUMAN HEALTH RISK EVALUATION CONCLUSIONS

The cumulative risk for the recreational scenario is all below the established ADEC risk management levels. The cumulative risk for a residential scenario is 6, which is over the ADEC risk management level.

Because of the unique characteristics of the toxicological properties for lead, lead risks were not included in the cumulative risk calculations, but were evaluated separately with the IEUBK model. In accordance with ADEC protocol, the risk due to RRO was also not included in the cumulative risk calculation.

As a result of the human health risk evaluation, all the COPC were eliminated under the current recreational scenario. All current site risks are below the ADEC risk management levels. If the area use were to change to residential, site risks would be over the regulatory levels.

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2.0 ECOLOGICAL RISK EVALUATION

The ecological risk evaluation follows the general guidance provided by EPA (1993, 2001) for implementing a risk-based approach in support of an EE/CA, and the specific guidance provided by ADEC (2000) for conducting screening risk evaluations. A risk evaluation provides information to determine whether cleanup actions may be necessary, what exposures need to be addressed by the action, and define the appropriate cleanup levels in some cases. This ecological SRE is divided into two tiers. In Tier 1, available ecotoxicity benchmarks for soil, water, and sediment are identified. These benchmarks are based on the most sensitive receptors known from the available literature. The benchmarks are then compared with maximum contaminant concentrations (that are above background levels) to determine whether there is any basis for ecological concern. Many of the COPC have more than one benchmark value. In these cases the range of values are examined. In Tier 2, contaminants that exceed ecological benchmark values are further evaluated by considering site-specific factors such as:

- Receptor species – Ecological receptors identified by ADEC that may actually occur at the site and which are useful in making site management decisions;
- Exposure – Estimates of average exposure concentrations and evaluation of the area used by receptors
- Effects – Ecotoxicity thresholds, contaminant bioavailability, and uptake that may be different than the benchmark values used in Tier 1

2.1 TIER 1 – ECOTOXICITY AND POTENTIAL RECEPTORS

In the Tier 1 screening level evaluation, indicator species are selected that are representative of potential exposure to broad assemblages or communities of organisms. Conservative media-specific screening levels that represent a lower threshold of risk are used to determine whether contaminants can be eliminated or should be retained for further evaluation. Exceeding a screening value does not necessarily mean there is a risk, but a risk is possible. Screening values for a particular media may vary considerably due to the test methods, species, and intake. For instance, the media-specific screening values for lead in soil range from 3.19 mg/kg for wildlife at a no observed effect level to 1,700 mg/kg for an invertebrate.

The Tier 1 risk calculations include a range of screening values. This yields a range of conservative risk estimates for each COPC.

Media-specific screening values used for this evaluation are summarized in Table 6-11 for soils, Table 6-12 for sediments, and Table 6-13 for surface water.

2.1.1 Soil Screening

The media-specific screening values for soils are based on a comprehensive review of toxicological data compiled from many studies on a wide range of species that have undergone extensive evaluation and peer review and include the following:

- Oak Ridge National Laboratory (ORNL) 1996
- EPA 2002
- EPA 2004
- BLM 1996

Many of the toxicological benchmarks and screening values are based on species that may not be found in Southeast Alaska. Nevertheless, the species selected for the development of toxicological benchmarks and screening values are representative of assemblages of organisms that are endemic to the Southeast Alaska ecoregion. Furthermore, the ORNL and EPA screening levels are broadly applicable because they were derived from very conservative exposure assumptions for:

- Foraging Area – Assumes foraging occurs exclusively within the site
- Habitat Homogeneity – Assumes that 100 percent of the habitat is suitable for foraging
- Diet Uniformity – Assumes that the receptors diet consists of a single prey or forage type
- Chemical Bioavailability – Assumes 100 percent absorption and uptake for all COPCs
- Seasonality – Assumes all receptors reside and are active within the site for the entire year

Consequently, the values that are presented in Table 6-11 are inherently conservative, relevant to the Southeast Alaska ecoregion, and form an adequate basis for the initial screening.

2.1.2 Surface Water Screening

The media-specific screening values for fresh and estuarine surface water (Table 6-13) were derived from a variety of sources including:

- Screening Benchmarks for Ecological Risk Assessment (ORNL 1996)
- Alaska Water Quality Criteria Manual (ADEC 2003)
- Risk Management Criteria for Metals at BLM Mining Sites (BLM 1996)
- ECOTOX database (EPA 2004)
- "Screening Quick Reference Tables," (SquiRT, 1999) (NOAA 1999)

The selected screening level was the lowest of the available, relevant published values from each reference.

2.1.3 Sediment Screening

Screening values for intertidal sediments (Table 6-12) were compiled from published sediment quality values including:

- "Screening Quick Reference Tables," (SquiRT) (NOAA 1999)
- Risk Management Criteria for Metals at BLM Mining Sites (BLM 1996)
- Washington State Administrative Code 173-420, Sediment Quality Standards (WAC 2004)

The selected screening level was the lowest of the available published values from each reference. Since sediments at the site include freshwater and brackish, both fresh and marine sediment-screening values were considered.

2.2 TIER 1 COMPARISONS WITH SCREENING LEVEL BENCHMARKS

The onsite concentrations of chemicals/contaminants are compared to screening level benchmarks. This comparison uses the hazard quotient (HQ) method. The HQ compares the exposure estimate (dose) to the ecological risk-based value. Compounds that exceed a HQ>1 are retained for further evaluation in Tier 2. Quotient calculations include:

$$HQ = \frac{Dose}{Benchmark} \quad \text{or} \quad HQ = \frac{EEC}{Benchmark}$$

where:

HQ	=	hazard quotient (no units)
Dose	=	estimated contaminant intake as determined in the exposure estimate (mg/kg-day)
EEC	=	estimated environmental concentration (for example, mg/kg)
Benchmark	=	toxicity reference value, an approved risk based concentration or a NOAEL (units to match Dose or EEC)

A HQ > 1 for a compound is interpreted as a level at which a *potential* adverse ecological effect *may* occur. Cumulative risks across multiple compounds and pathways are additive and expressed as a hazard index (HI).

HI = Σ HQ with similar toxicological endpoints

2.2.1 Soil Screening

Soil screening values were available for all contaminants except calcium, magnesium, DRO and RRO. These COPCs were carried into the Tier 2 screening. Soil screening values are compared with maximum detected contaminant concentrations for soils in Table 6-11. Antimony, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, silver, and zinc exceeded the minimum Tier 1 screening values, which are based on wildlife and plant community exposure.

$$HI = HQ_{Sb} + HQ_{Cd} + HQ_{Cr} + HQ_{Cu} + HQ_{Fe} + HQ_{Pb} + HQ_{Hg} + HQ_{Ni} + HQ_{Se} + HQ_{Ag} + HQ_{Zn}$$

Compound	**Dose or EEC / Benchmark(s)**	=	**HQ**
Antimony	[12.3 mg/kg / (0.248 to 78 mg/kg)]	=	0.2 to 50
Cadmium	[35 mg/kg / (0.001 to 140 mg/kg)]	=	0.2 to 40,000
Chromium	[120 mg/kg / (0.4 to 10,020 mg/kg)]	=	0.01 to 300
Copper	[350 mg/kg / (1.84 to 100 mg/kg)]	=	4 to 200
Iron	[47,900 mg/kg / (200 mg/kg)]	=	200
Lead	[4,500 mg/kg / (3.19 to 1,700 mg/kg)]	=	3 to 1,000
Mercury	[0.39 mg/kg / (0.1 to 30 mg/kg)]	=	0.01 to 4
Nickel	[42 mg/kg / (15.1 to 200 mg/kg)]	=	0.2 to 3
Selenium	[3.96 mg/kg / (0.414 to 100 mg/kg)]	=	0.04 to 10
Silver	[18.1 mg/kg / (2 to 50 mg/kg)]	=	0.4 to 9
Zinc	[3,590 mg/kg / (3.9 to 200 mg/kg)]	=	18 to 900
TOTAL	**HI**	=	**200 to 40,000**

2.2.2 Surface Water Screening

Surface water screening values are compared with maximum detected chemical concentrations for stream and seep samples in Table 6-13. Cadmium, copper, lead, silver, and zinc exceeded the minimum Tier 1 screening values, which are based on wildlife and plant community exposure.

$$HI = HQ_{Cd} + HQ_{Cu} + HQ_{Pb} + HQ_{Ag} + HQ_{Zn}$$

Compound	**Dose or EEC / Benchmark(s)**	=	**HQ**
Cadmium	[12 ug/L / (0.094 to 4,132 ug/L)]	=	0.003 to 100
Copper	[6.9 ug/L / (0.205 to 65,200 ug/L)]	=	0.0001 to 34
Lead	[300 ug/L / (0.35 to 16,540 ug/L)]	=	0.02 to 900
Silver	[0.97 ug/L / (0.12 to 0.37 ug/L)]	=	0.0006 to 3
Zinc	[2,100 ug/L / (0.34 to 62,300 ug/L)]	=	0.03 to 6,000
TOTAL	**HI**	=	**0.05 to 7,000**

2.2.3 Sediment Screening

Sediment screening values were available for all COPC except for molybdenum as indicated in Table 6-12. Sediment screening values are compared with maximum detected chemical concentrations for freshwater and marine intertidal sediments. Substances that exceeded screening levels for sediments were chromium, cobalt, copper, lead, and zinc.

Compound	**Dose or EEC / Benchmark(s)**	=	**HQ**
Chromium	[273 mg/kg / (36.3 to 370 mg/kg)]	=	0.7 to 8
Cobalt	[51 mg/kg / (10 mg/kg)	=	5
Copper	[82 mg/kg / (18.7 to 390 mg/kg)]	=	0.2 to 4
Lead	[255 mg/kg / (30 to 530 mg/kg)]	=	0.5 to 8
Zinc	[1,370 mg/kg / (98 to 960 mg/kg)]	=	1 to 14
TOTAL	**HI**	=	**7 to 40**

2.3 TIER 1 SUMMARY

Ecological risk was evaluated for COPCs depending on the availability of published screening values and comparison to background levels.

Screening values were not available for calcium, magnesium, DRO and RRO in soils; and molybdenum in sediments. Calcium was eliminated as a COPC because it is a naturally occurring substance in plants and animals. The one calcium detection in soil is within an order of magnitude of the human recommended daily intake (RDI). It is also within background concentrations for calcium across the State of Alaska. The "Element Concentrations in Soils and Other Surficial Materials of Alaska," (USGS 1988) gives the arithmetic mean calcium concentration within Alaska as 20,000 mg/kg with concentrations ranging from 400 to 100,000 mg/kg. The one sample at the Mahoney Mine had 5,700 mg/kg. Magnesium was also eliminated as a COPC for similar reasons. The one detection in soil is ten times the human RDI. It is also within background concentrations for magnesium across the State of Alaska. USGS 1988 gives the arithmetic mean magnesium concentration within Alaska as 12,000 mg/kg with concentrations ranging from 1,300 to 74,000 mg/kg. The one sample at Mahoney Mine had 4,000 mg/kg.

The Tier 1 evaluation indicated that some substances and compound categories could be eliminated as COPCs. The COPCs that were retained for evaluation in Tier 2 are listed in Table 2-1 (Ecological COPC Exposure Point Concentrations).

Table 2-1
Ecological COPC Exposure Point Concentrations

Soil COPC	Exposure Point Concentration (mg/kg)	Statistical Measure
Antimony	12.3	Maximum
Cadmium	35	95UCL Bootstrap
Chromium	120	Maximum
Copper	350	Maximum
DRO & RRO	1,100	Maximum
Iron	47,900	Maximum
Lead	4,500	95UCL Bootstrap
Mercury	0.39	95UCL H-UCL
Nickel	42	Maximum
Selenium	3.96	Maximum
Silver	18.1	Maximum
Zinc	3,590	95UCL Bootstrap

Sediment COPC	Exposure Point Concentration (mg/kg)	Statistical Measure
Chromium	273	Maximum
Cobalt	51	Maximum
Copper	82	Maximum
Lead	255	95UCL Student-t
Molybdenum	13	Maximum
Zinc	1,370	95UCL Chebyshev
Surface Water COPC	**Exposure Point Concentration (ug/L)**	**Statistical Measure**
Cadmium	12	Maximum
Lead	300	Maximum
Zinc	2,100	Maximum

2.4 TIER 2 EVALUATION

The purpose of the Tier 2 risk evaluation is to refine the exposure assumptions of the Tier 1 evaluation, allowing for a more site-specific ecological risk characterization. The Tier 1 evaluation resulted in the COPCs in Table 2-1. Parameters that were further evaluated to more accurately estimate ecological risk included contaminant concentration, default receptor selection and toxicity, area use factors by default receptors, and chemical bioavailability and uptake.

2.4.1 Contaminant Exposure Point Concentrations

UCL95s of the mean were determined for soil and sediment concentrations of Tier 2 contaminants. The UCL95 provides a more accurate estimate of exposure concentrations. The sample results that were 'non-detect' were included in the calculations by assuming one-half of the detection limits. The data were then evaluated to determine whether they were normally or lognormally distributed. Depending on the data distribution[5], a UCL95 value was then calculated with ProUCL software.

2.4.2 Ecoregion, Assessment Endpoints and Indicator Species

The Mahoney Mine site is in the Southeast ecoregion. Ecological sub-regions include the Coastal Western Hemlock-Sitka Spruce Forests and Southeast Coastline/Estuary (ADEC

[5] In some instances, the data did not conform to either a normal or a lognormal distribution, in which case non-parametric methods were used to estimate a UCL95.

1999). The ADEC Default Assessment Endpoints and Primary Indicator Species are as follows (modified after ADEC 1999).

Table 2-2
Assessment Endpoints

Default Assessment Endpoint	Indicator Species	Primary (bold) and Other Exposure Media
Primary Producers (Trophic Level 0)		
The potential for significant adverse effects on terrestrial soil plant species abundance, diversity, and primary production.	All plants that obtain nutrients primarily from soil.	**Surface Soil**
The potential for significant adverse effects on freshwater semi-aquatic plant species abundance, diversity, and primary production.	All plants that obtain nutrients primarily from freshwater sediment.	**Freshwater Sediment** Fresh Water
Herbivores and Detrivores (Primary Consumers – Trophic Levels 1 and 2)		
The potential for significant adverse effects on freshwater aquatic invertebrate community abundance and diversity.	All freshwater aquatic invertebrates.	**Fresh Water**
The potential for significant adverse effects on freshwater benthic invertebrate community abundance and diversity.	All freshwater benthic invertebrates.	**Freshwater Sediment** Fresh Water
The potential for significant adverse effects on soil invertebrate community abundance and diversity.	All terrestrial invertebrates.	**Surface Soil**
The potential for significant adverse effects on freshwater fish detritivore abundance and diversity.	All freshwater fish.	**Fresh Water**
The potential for significant adverse effects on freshwater semi-aquatic avian herbivore abundance and diversity.	Mallard	**Freshwater Sediments** Fresh Water
The potential for significant adverse effects on terrestrial avian herbivore abundance and diversity.	Dark-eyed junco	**Surface Soil** Fresh Water
The potential for significant adverse-effects on freshwater semi-aquatic mammalian herbivore abundance and diversity.	Northern bog lemming	**Freshwater Sediment** Fresh Water
The potential for significant adverse effects on terrestrial mammalian herbivore abundance and diversity	Long-tailed vole	**Surface Soil** Fresh Water
Secondary Consumers (Trophic Level 3)		

Default Assessment Endpoint	Indicator Species	Primary (bold) and Other Exposure Media
The potential for significant adverse effects on freshwater avian invertevore abundance and diversity	American dipper	**Fresh Water**
The potential for significant adverse effects of freshwater semi-aquatic avian invertevore abundance and diversity	Common snipe	**Freshwater Sediment**
The potential for significant adverse effects on terrestrial avian invertevore abundance and diversity	American robin	**Surface Soil**
The potential for significant adverse effects on freshwater fish invertevore abundance and diversity	All freshwater fish	**Fresh Water**
The potential for significant adverse effects on terrestrial mammalian invertevore abundance and diversity	Masked shrew	**Surface Soil** Fresh Water
Tertiary Consumers (Trophic Level 4)		
The potential for significant adverse effects on freshwater avian piscivore abundance and diversity	Belted kingfisher	**Fresh Water**
The potential for significant adverse effects on terrestrial avian carnivore abundance and diversity	Northern shrike	**Surface Soil**
The potential for significant adverse effects on terrestrial mammalian carnivore abundance and diversity	Shorttail weasel	**Surface Soil**
The potential for significant adverse effects on freshwater semi-aquatic mammalian carnivore abundance and diversity	Mink	**Fresh Water** Sediment Surface Soil
The potential for significant adverse effects on freshwater mammalian piscivore abundance and diversity	River otter	**Fresh Water**
The potential for significant adverse effects on freshwater fish piscivore abundance and diversity	All freshwater fish	**Fresh Water**

There are no endangered or threatened species in the Mahoney Mine site area. However, the peregrine falcon is known to pass through the area during migration.

The default assessment endpoints are the species abundance, diversity, and primary production in the various ecological niches. Indicator species are given in order to evaluate each niche.

To evaluate the ecological risks, a semi-quantative approach was undertaken. This approach examined several issues. These are,

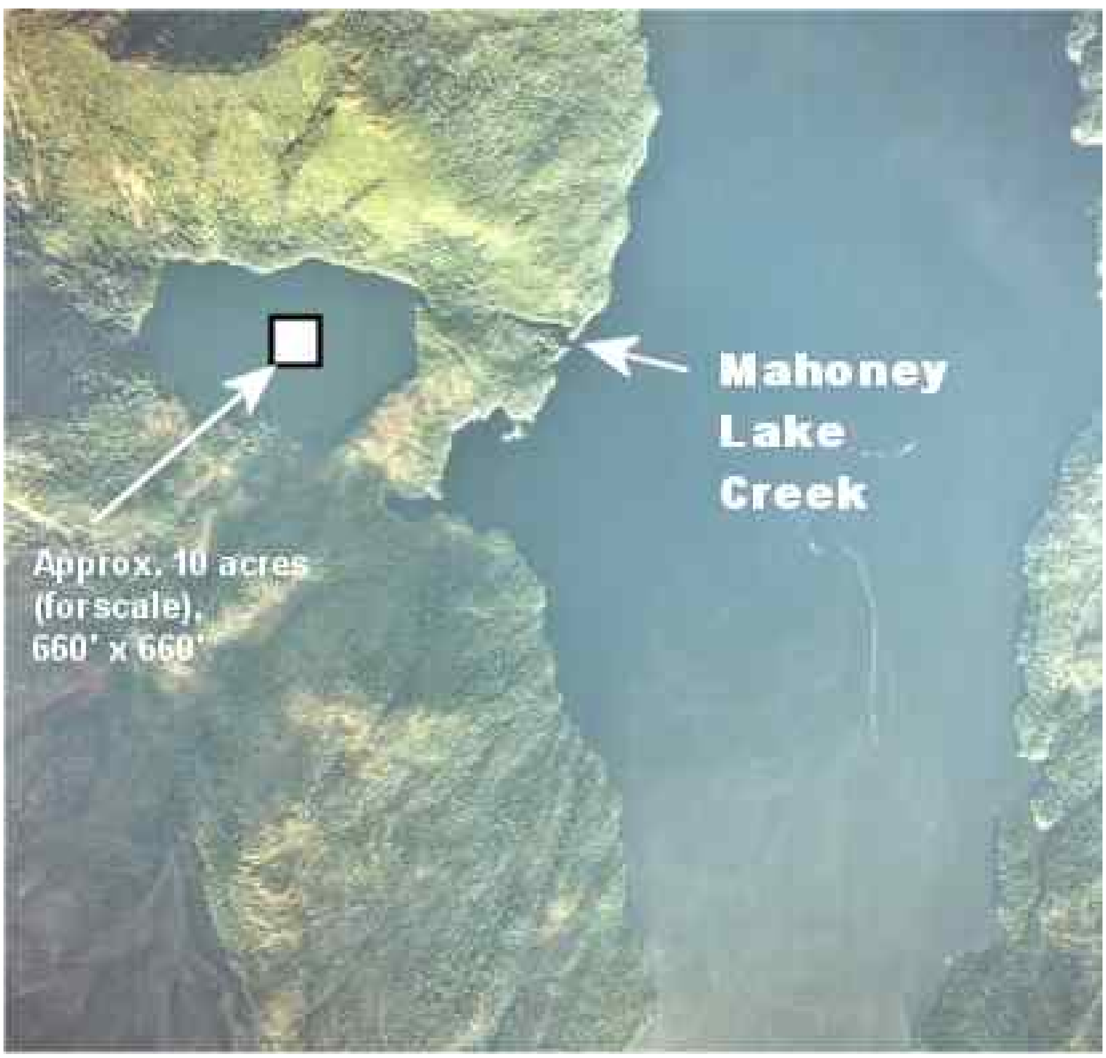
- Background ranges of the COPC (evaluated as part of Tier 1)
- The toxicity of the COPC to the various assessment endpoints
- The size of the contaminated area
- The home range of the indicator species
- The population density of the indicator species
- The bioaccumulation potential of the COPC

The sediments and soils on the site have elevated concentrations of contaminants. Although the compounds are originally from the site (ore and waste rock), they have become more accessible to contact and leaching through the mine activities. Contaminant concentrations in the sediments across Mahoney Lake Creek from the site may be naturally occurring or may have leached from the adjacent mine. Toxicity values for all the COPCs and all the assessment endpoints were not always available. When toxicity values were not available, nutrient minimums were examined. If there was no toxicity information available for the receptor species (e.g., Dark-eyed junco), a related species from the same trophic level was used as a surrogate (e.g., chicken).

The contamination at the site covers a relatively small area. The upland forest area of contaminated soil (mine tailings) covers approximately 1/3 of an acre. The coastline/estuary area includes about 1 acre of sediment and 400 to 500 lineal feet of creek. This is important when evaluating the impacts of the COPCs on the various indictor species in conjunction with the home ranges and population densities. A large home range indicates that the animal would only spend a limited amount of time in the contaminated area and potential intake of a contaminant would be a small fraction of total intake. The potential impact on a particular animal would be lessened due to a limited amount of contaminant ingested. The contaminated area would have a much smaller impact on a species with a large population density. For instance, if an animal's home range exactly coincided with the contaminated area (the 1/3-acre of uplands, or the 1-acre of semi-aquatic) the impact may be measurable for that particular animal, but would not affect the adjacent members of that species. Another factor in this evaluation is the available, adjacent habitat. Revillagigedo Island is about 717,000 acres (about the size of Rhode Island) as compared to the 1/3-acre of uplands on the site and 1-acre of semi-aquatic habitat. Revillagigedo Island has over 90 creeks running to marine waters and over 340 miles of coast.

The bioaccumulation potential of a COPC can also impact higher trophic levels. However, this is related to the density of the prey species in the contaminated area and the home area of the predator.

The issue is if any of the site contaminants are affecting the *species abundance, diversity, and production*.



Photograph 1 - Mahoney Mine Aerial Photo 1980

Photograph 2- Mahoney Mine Aerial Photo August 2001

2.4.3 Primary Producers (Trophic Level 0)

The Tier 1 evaluation indicated a possible adverse effect on the primary producers (plants that obtain their primary nutrients from the soil and those that obtain their primary nutrients from the sediments). The Tier 2 HIs based on plant specific benchmarks are as follows. Due to more than one relevant benchmark in the literature, a range of HIs were calculated (See "Support Information and Calculations").

Terrestrial

The plant HI is 50 to 200. This is still high and above the management level of HI = 1. The risk drivers are lead and zinc.

Table 2-3
Terrestrial Soil Plants Cumulative Risk

Compound	Site Soil Conc. (mg/kg)	HQ
Antimony	12.3	2
Cadmium	35	2 to 4
Chromium	120	0.2 to 0.6
Copper	350	0.9
DRO	210	no data
Iron	47,900	no data
Lead	4,500	22 to 98
Mercury	0.39	1
Nickel	42	0.4 to 7
RRO	1,100	no data
Selenium	3.96	4
Silver	18.1	9
Zinc	3,590	4 to 36
HI =		**50 to 200**

Although the hazard index is above the risk management level of 1, there is no potential for significant adverse effects on terrestrial soil plant abundance, diversity, and primary production or on the *species* abundance, diversity, and primary production. The risk drivers are lead and zinc. These COPC are concentrated in the mine tailings. Mining operations started around 1900 and most operations ceased by about 1950. Visitations to the area indicate that there are no adverse effects on the upland plant species abundance, diversity, and primary production at the site (due to COPCs as opposed to clearing and grubbing of vegetation).

25 March 2004 Site Visit

4 August 2003 Removal Action

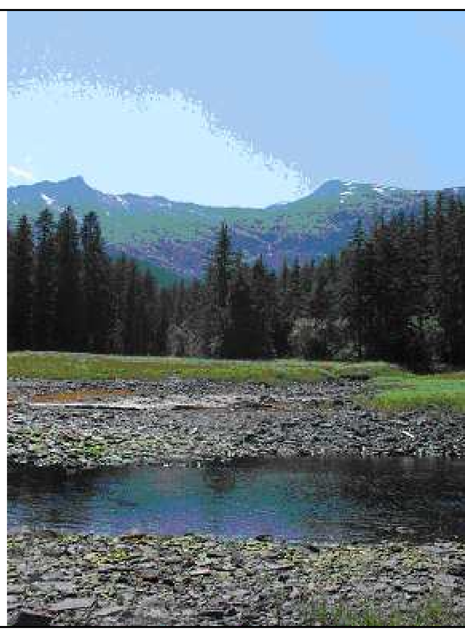
Semi-Aquatic

Toxicity information for semi-aquatic plants considers chemical concentrations in water. Little toxicity data is available for semi-aquatic plants and chemical sediment concentrations. To evaluate the potential impacts on the semi-aquatic plants, the sediment concentrations were compared to terrestrial plant databases. The plant HI is 4 to 30. This is still high and above the management level of HI = 1. The risk drivers are cobalt, lead, and zinc. The site sediment concentrations for cobalt, lead and zinc are slightly over three times the respective arithmetic mean background concentrations. However, all sediment concentrations are within the regional background ranges. It is possible the cobalt, lead, and zinc sediment concentrations represent background concentrations.

Table 2-4
Semi-Aquatic Plants Cumulative Risks

Compound	Site Sediment Conc. (mg/kg)	HQ	SE Alaska Background Sediment Conc. (mean and range) (mg/kg)
Chromium	273	0.3 to 1	50; 3 to 1,040
Cobalt	51	0.1 to 9	16; 3 to 70
Copper	82	0.2	22; 2 to 664
Lead	255	1 to 6	19; 4 to 826
Molybdenum	13	no data	2.4; 2 to 16
Zinc	1,370	2 to 14	105; 30 to 2,120
Zinc (water)	10 ug/L	0.06	
HI =		**4 to 30**	

Although the hazard index is over the risk management level of 1, there is no potential for significant adverse effects on terrestrial soil plant abundance, diversity, and primary production or on the *species* abundance, diversity, and primary production. Mining operations onsite started about 1900 and most operations ceased about 1950. Visitations to the area indicate that there is no adverse effect on the semi-aquatic plant species abundance, diversity, and primary production onsite.



TOP: Bottom of Zone B by Mahoney Lake Creek.

LEFT: At the foot of Zone B looking across Mahoney Lake Creek.

2.4.4 Herbivores and Detrivores - Primary Consumers (Trophic Levels 1 & 2)

The Tier 1 evaluation demonstrated a possible adverse effect on the primary consumers. The primary consumers (and the indicator species) include the:

- Freshwater aquatic invertebrate community
- Freshwater benthic invertebrate community
- Soil invertebrate community
- Freshwater fish detritivore community
- Freshwater semi-aquatic avian herbivore community (Mallard)
- Terrestrial avian herbivore community (Dark-eyed junco)
- Semi-aquatic mammalian community (Northern bog lemming)
- Terrestrial mammalian community (Long-tailed vole)

Semi-Aquatic Invertebrate Communities

The invertebrate HI is 0.4 to 4. The low end is below the ADEC risk management level of HI = 1. The high end is slightly over the management level of HI = 1. All site sediment concentrations are slightly over three times the respective arithmetic mean background concentrations. However, all sediment concentrations are within the regional background ranges. It is possible the sediment concentrations represent background concentrations.

Table 2-4
Freshwater Benthic and Aquatic Invertebrate Communities Cumulative Risk

Compound	Site Sediment Conc. (mg/kg)	Semi-Aquatic HQ	SE Alaska Background Sediment Conc. (mean and range) (mg/kg)
Chromium	273	0.3 to 3	3 to 1,040
Cobalt	51	0.002 to 0.2	3 to 70
Copper	82	0.002 to 0.07	2 to 664
Lead	255	0.006 to 0.03	4 to 826
Molybdenum	13	no data	2 to 16
Zinc	1,370	0.05 to 1	30 to 2,120
Zinc (water)	10 ug/L	0.01 to 0.1	
HI =		**0.4 to 4**	

Although the hazard index is over the risk management level of 1, there is no potential for significant adverse effects on semi-aquatic invertebrate abundance, diversity, and primary production or on species abundance, diversity, and primary production. Mining operations started around 1900 and most operations ceased by about 1950. The semi-aquatic area near the site is largely the approximate 1-acre across Mahoney Lake Creek. Any effect on the invertebrates within this 1-acre will not affect the species abundance, diversity, and primary production on the island due to the low HI and small area of contamination.

Terrestrial Invertebrate Communities

The terrestrial invertebrate HI is 10 to 20. This is above the management level of HI = 1. The risk drivers are cadmium, DRO+RRO, iron, and zinc. The site soil concentration for iron (47,900 mg/kg) is over three times the low end of the background range (5,500 mg/kg) for soils in Alaska. However, the soil iron concentration is only slightly over the arithmetic mean background concentration for Alaska (38,000 mg/kg) and within the Alaskan background range (5,500 to 100,000 mg/kg). It is possible the soil iron concentration represents the background concentration.

Table 2-5
Terrestrial Invertebrate Communities Cumulative Risk

Compound	Site Soil Conc. (mg/kg)	HQ
Antimony	12.3	0.02 to 0.1
Cadmium	35	0.001 to 4
Chromium	120	0.1 to 1
Copper	350	0.009 to 0.3
DRO + RRO	1,310	3
Iron	47,900	10
Lead	4,500	0.1 to 0.4
Mercury	0.39	0.00002 to 0.0002
Nickel	42	0.004 to 0.2
RRO	1,100	see DRO
Selenium	3.96	0.04 to 0.06
Silver	18.1	0.4
Zinc	3,590	0.1 to 3
HI =		**10 to 20**

Mining operations started around 1900 and most operations ceased by about 1950. The relatively low HI, and the small area of the mine tailings (abut 1/3-acre), precludes any adverse effect on the population of invertebrates on the island. Any effect on the invertebrates within the 1/3-acre will not affect the species abundance, diversity, and primary production. These factors indicate that there is little potential for significant adverse effects on terrestrial invertebrate abundance, diversity and primary production; and no effect on the *species* abundance, diversity, and primary production.

<u>Freshwater Fish Detritivores</u>

The freshwater fish detritivore **HI is 0.0004 to 0.02**. This is below the ADEC risk management level of HI = 1. The HI of 1 is based on the contaminant concentrations in the fresh water of Mahoney Lake Creek. Zinc is the only contaminant of concern detected in the water. There is no potential for significant adverse effects on the freshwater fish detritivore species abundance, diversity, and primary production.

<u>Avian Communities</u>

The avian communities are represented by the freshwater semi-aquatic avian herbivore community (Mallard), and the terrestrial avian herbivore community (Dark-eyed junco).

The terrestrial avian herbivore community HI is 20 to 200. This is above the management level of HI = 1. The risk drivers are iron and lead. The site soil concentration for iron (47,900 mg/kg) is over three times the low end of the background range (5,500 mg/kg) for soils in Alaska. However, the soil iron concentration is only slightly over the arithmetic mean background concentration for Alaska (38,000 mg/kg) and within the Alaskan background range (5,500 to 100,000 mg/kg). It is possible the soil iron concentration represents the background concentration.

Table 2-6
Terrestrial Avian Herbivore Communities Cumulative Risk

Compound	Site Soil Conc. (mg/kg)	HQ
Antimony	12.3	no data
Cadmium	35	0.004 to 2
Chromium	120	0.1 to 6
Copper	350	0.9
DRO + RRO	1,310	0.007
Iron	47,900	10

Compound	Site Soil Conc. (mg/kg)	HQ
Lead	4,500	4 to 100
Mercury	0.39	0.0002 to 0.04
Nickel	42	no data
RRO	1,100	included with DRO
Selenium	3.96	0.01
Silver	18.1	no data
Zinc	3,590	0.7
HI =		**20 to 100**

The home range of the Dark-eyed junco has been documented as 2 to 3 acres with up to 6.4 pairs per acre in prime habitat. The contaminated upland area onsite is about 1/3 of an acre. While it is possible that a pair of juncos may have their home range entirely within the upland area, this would not affect the species as a whole on the island. Considering the ranges and densities of the junco, and the fact that only two of the COPC are risk drivers, there is no impact on the species abundance, diversity, and primary production on the island.

The freshwater semi-aquatic avian herbivore community HI is 1 to 20. The high end is above the risk management level of HI = 1. The risk drivers are chromium and lead. The site sediment concentrations for chromium (273 mg/kg) and lead (255 mg/kg) are over three times the arithmetic mean background concentration for the region (50 and 19 mg/kg respectively) but within the regional background ranges (3 to 1,040 mg/kg for chromium and 4 to 826 mg/kg for lead). It is possible the sediment chromium and lead concentrations represent background concentrations.

Table 2-7
Freshwater Semi-Aquatic Avian Herbivore Communities Cumulative Risk

Compound	Site Sediment Conc. (mg/kg)	Semi-Aquatic HQ
Chromium	273	0.3 to 10
Cobalt	51	0.1 to 0.3
Copper	82	0.2
Lead	255	0.2 to 8
Molybdenum	13	0.001 to 0.04
Zinc	1,370	0.3
Zinc (water)	10 ug/L	0.00003
HI =		**1 to 20**

The home range of the mallard varies depending on terrain type. The figures of 100 to 3550 acres have been documented (EPA 1993). Compared to the 1-acre of semi-aquatic terrain onsite, only a very small fraction of the mallard's time would be spent onsite.

Considering the ranges and densities of the mallard, and the fact that only two of the COPC are risk drivers, there is no impact on the species abundance, diversity, and primary production on the island.

Mammalian Communities

The mammalian communities are represented by the freshwater semi-aquatic mammalian herbivore community (northern bog lemming), and the terrestrial mammalian herbivore community (long-tailed vole).

The freshwater semi-aquatic mammalian herbivore community HI is 2 to 6. This is above the risk management level of HI = 1. The risk drivers are lead and zinc. The site sediment concentrations for lead (255 mg/kg) and zinc (1,370 mg/kg) are over three times the arithmetic mean background concentration for the region (19 and 105 mg/kg respectively) but within the regional background ranges (4 to 826 mg/kg for lead and 30 to 2,120 mg/kg for zinc). It is possible the sediment lead and zinc concentrations represent background concentrations.

Table 2-8
Freshwater Semi-Aquatic Mammalian Herbivore Communities Cumulative Risk

Compound	Site Sediment Conc. (mg/kg)	Semi-Aquatic HQ	Background (mg/kg)
Chromium	273	0.4 to 0.8	3 to 1,040 SE
Cobalt	51	0.07 to 0.2	3 to 70 SE
Copper	82	0.1	2 to 664 SE
Lead	255	0.8 to 2	4 to 826 SE
Molybdenum	13	0.001	2 to 16 SE
Zinc	1,370	0.2 to 3	30 to 2,120 SE
Zinc (water)	10 ug/L	0.00003	
HI =		**2 to 6**	

The home range of the bog lemming is under an acre (Idaho Museum of Natural History). Compared to the 1-acre of semi-aquatic terrain onsite, it is possible to have a couple of pairs to half a dozen pairs of lemmings in the contaminated area. Lemmings have fairly dense population densities and can vary up to 36 per acre. Since there is plenty of adjacent habitat available for this species, even if the contaminants had an adverse affect on the animals living onsite, it would not have an adverse effect on the species abundance and diversity. Considering the ranges and population densities of the lemming, and the fact that the risk is only slightly over the benchmark HI of 1, there is no impact on the species abundance, diversity, and primary production on the island.

The terrestrial mammalian herbivore community HI is 20 to 60. This is above the risk management level of HI = 1. The risk drivers are iron, lead and zinc. The site soil concentration for iron (47,900 mg/kg) is over three times the low end of the background range (5,500 mg/kg) for soils in Alaska. However, the soil iron concentration is only slightly over the arithmetic mean background concentration for Alaska (38,000 mg/kg) and within the Alaskan background range (5,500 to 100,000 mg/kg). It is possible the soil iron concentration represents the background concentration.

Table 2-9
Terrestrial Mammalian Herbivore Communities Cumulative Risk

Compound	Site Soil Conc. (mg/kg)	HQ
Antimony	12.3	0.002 to 4
Cadmium	35	0.2 to 3
Chromium	120	0.2 to 0.3
Copper	350	0.5
DRO + RRO	1,310	0.1
Iron	47,900	10
Lead	4,500	10 to 30
Mercury	0.39	0.2
Nickel	42	0.3
RRO	1,100	included with DRO
Selenium	3.96	0.2
Silver	18.1	0.008
Zinc	3,590	0.4 to 9
HI =		**20 to 60**

The home range of the vole varies up to 0.2 acres (EPA 1993). Compared to the 1/3-acre of uplands, it is possible to have a couple of pairs to half a dozen pairs of voles in the contaminated area. This species has fairly dense population densities. The vole can vary from about one to over 200 per acre. Since there is plenty of adjacent habitat available for both these species, even if the contaminants had an adverse affect on the animals living onsite, it would not have an adverse effect on the species abundance and diversity. Considering the ranges and population densities of the vole, there is no impact on the species abundance, diversity, and primary production on the island.

2.4.5 Secondary & Tertiary Consumers (Trophic Levels 3 & 4)

The secondary and tertiary consumer indicator species are listed in the table below along with the primary consumer indicator species.

The evaluation of the primary consumers (trophic levels 1 and 2) indicated that the contamination at the Mahoney Mine does not adversely impact the abundance and diversity of the indicator species at trophic levels 1 and 2. This is due to the low to moderate toxicity of the COPC and the exposure (home ranges and population densities) of the indicator species.

Table 2-10
Primary, Secondary & Tertiary Consumers

Primary Consumers (Trophic Levels 1 & 2)		Secondary Consumers (Trophic Level 3)	Tertiary Consumers (Trophic Level 4)
Indicator Species	**HI**	**Indicator Species**	**Indicator Species**
Mallard	1 to 20	American Dipper	Belted Kingfisher
Dark-eyed Junco	20 to 200	Common Snipe	Northern Shrike
		American Robin	
Northern Bog Lemming	2 to 6		Mink
Long-tailed Vole	20 to 60	Masked Shrew	Short-tailed Weasel
			River Otter
Freshwater fish detritivores	0.0004 to 0.02	Freshwater fish invertevore	Freshwater fish piscivore

The main pathways at trophic levels 1 and 2 include ingestion of soil and sediment. Soil as a proportion of diet is similar for all the above species (1.76% to 4%) except for the snipe (12% based on data for the related species, the woodcock). However, even at this higher ingestion rate, there is no impact on the species abundance, diversity, and primary production due to the small area of contamination.

At the higher trophic levels the additional consideration of bioaccumulation of the contaminants in the prey species is also evaluated.

The COPCs onsite that may pose the greatest potential for bioaccumulation are cadmium, selenium, and to a lesser degree, mercury. These compounds are known to accumulate up the food chain. The sediment concentrations of these three COPC are within background ranges. The soil concentrations of these three COPC are above background. However, the exposure to the higher trophic levels is less than that of the primary consumers (Trophic levels 1 and 2). This is due to the larger home ranges of the higher trophic level predators.

The American Dipper may be either a migrant or a year-round resident. Its home range is about 1000 feet of stream to one-half mile of stream. The Mahoney Mine site has about 400 to 500 feet of stream running through it. It is possible that one (the dippers are solitary except for the breeding season), dipper may inhabit the site. The amount of potential contaminant accumulating through the food chain is minor and not likely to adversely affect the individual dipper let alone adversely impact the species diversity and abundance.

A similar situation exists with the Common Snipe and the Robin. Their home ranges vary from three-quarters of an acre up to 240 acres and 0.37 of an acre up to 2 acres. The site will not impact these two species diversity and abundance on the island.

The home range of the shrew is up to one acre with population densities of about 1 to 5 per acre. While it is possible to have several shrews living in the contaminated area, there is no impact on the species diversity and abundance on the island.

Adverse impacts to the diversity and abundance of freshwater fish invertevores is not an issue due to the small site area, clean water of Mahoney Lake Creek, and large feeding area of fish invertevores.

The home ranges of the tertiary consumers are:

Belted Kingfisher: 0.24 to 1.2 miles of shoreline
Northern Shrike: up to 540 acres in winter
Shorttail Weasel: up to 40 acres
Mink: 640 – 1900 acres

The COPCs do not adversely impact the abundance or diversity of the tertiary consumers.

3.0 ALTERNATE CLEANUP LEVEL

3.1 CURRENT SCENARIO ALTERNATE CLEANUP LEVELS

Under the current scenario for both human health and ecological, cleanup is not required. The concentrations of contaminants onsite do not pose an unacceptable risk to either human health or the environment.

The cleanup levels for soil and groundwater documented in 18 AAC 75, Tables B and C are based on the residential scenario. The risk evaluation demonstrated that under the current and future scenarios of the occasional visitor, there is no risk. This evaluation included human exposure to sediments. Therefore, the recommended ACLs can be the current site soil, water and sediment concentrations (i.e., no cleanup required). The risk evaluation made assumptions concerning the exposure frequency of the visitor. It assumed that a child (the same child every visit) would visit the site for one weekend (2 days) per month, six months per year. An added level of conservatism can be incorporated by increasing this exposure frequency. However, even by doubling the visitations, the hazard index is still within the acceptable risk management range and the concentrations onsite are acceptable as ACLs.

The State of Alaska does not currently have prescriptive regulatory cleanup levels in place for ecological receptors. However, the 18 AAC 75 regulations definitively state that cleanup remedies shall be protective of the environment. Although no ecological cleanup values are in place, ADEC published a technical memorandum on Sediment Quality Guidelines in March 2004. This technical memorandum recommends use of the NOAA Screening Quick Reference Tables (SquiRT). However, in doing so ADEC states "The values are Sediment Quality Guidelines (SQGs) and as such, should be used for screening purposes only. They are not meant to be, nor should they be, viewed or utilized as sediment cleanup levels." The risk evaluation demonstrated that there is no ecological risk from the site compounds.

3.2 RESIDENTIAL SCENARIO ALTERNATE CLEANUP LEVELS

The ACLs for a residential scenario would not consider the groundwater as a drinking water source. Drinking water in the area is largely obtained from surface water and occasional rain catchments. Sampling of Mahoney Lake Creek showed no contamination above 18 AAC 75 groundwater cleanup levels. Since groundwater is not a drinking water source, the 18 AAC 75 regulations allow the migration to groundwater cleanup levels to be increased by a factor of 10. As seen in the following table, all onsite concentrations are below the 18 AAC 75 cleanup levels except for lead and iron. However, the 18 AAC 75 regulations also require the total hazard index not to exceed 1.

Table 3-1
18 AAC 75 Cleanup Values

COPC	Onsite Soil Concentration (mg/kg)	18 AAC 75 Table B1 Ingestion Cleanup Level (mg/kg)	18 AAC 75 Table B1 Migration to GW Cleanup Level x 10 (mg/kg)
Antimony	12.3	33	30
Cadmium	35	83	45
Chromium	120	120,000	>1,000,000
Copper	350	3,320	62,600
Iron	47,900	24,900	
Lead	4,500	400	400
Mercury	0.39	15.8 (ingest); 13 (inhalation)	12.4
Zinc	3,590	25,000	81,000

The following residential COPC HQs are calculated using the procedure from the "Residential Scenario" section.

Table 3-2
Residential COPC Soil HQs

COPC	**Site Soil Conc. (mg/kg)**	**HQ Residential Soil Incidental Ingestion**	**HQ Residential Soil Dermal Contact**
Antimony	12.3	0.2	0.04
Cadmium	35	0.6	0.8
Chromium	120	0.0006	0.001
Copper	350	0.06	0.002
Iron	47,900	1.1	0.03
Lead	4,500		
Mercury	0.39	0.01	0.0004
Zinc	3,590	0.08	0.002
HI_{Soil}		**2**	**0. 9**

Table 3-3
Residential COPC Sediment HQs

COPC	Site Sediment Conc. (mg/kg)	HQ Residential Sediment Incidental Ingestion	HQ Residential Sediment Dermal Contact
Chromium	273	0.00008	0.0006
$HI_{Sediment}$		**0.00008**	**0.0006**

In order to meet the 18 AAC 75 regulations, the site COPC concentrations have to be remediated to achieve a HI of 1. This can be done by lowering one or more COPC concentrations. A possible combination is shown below with ACLs for cadmium, iron, and lead. The ACL for lead is based on the IEUBK model and does not impact the HI. See the "Residential Scenario" section.

Table 3-4
Possible Residential ACLs

COPC	Site Soil Conc. (mg/kg)	Soil ACL (mg/kg)	HQ residential soil incidental ingestion	HQ residential soil dermal contact
Antimony	12.3		0.2	0.04
Cadmium	**35**	**12**	**0.2**	**0.3**
Chromium	120		0.0006	0.001
Copper	350		0.06	0.002
Iron	**47,900**	**20,000**	**0.5**	**0.01**
Lead	**4,500**	**750**		
Mercury	0.39		0.01	0.0004
Zinc	3,590		0.08	0.002
HI_{Soil}			**1**	**0. 4**
$HI_{Soil\ Total}$			**1**	

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4.0 UNCERTAINTY ANALYSIS

EPA guidance states: "There are several categories of uncertainties associated with site risk assessments. One is the initial selection of substances used to characterize exposures and risk on the basis of the sampling data and available toxicity information. Other sources of uncertainty are inherent in the toxicity values for each substance used to characterize risk. Additional uncertainties are inherent in the exposure assessment for individual substances and individual exposures. These uncertainties are usually driven by uncertainty in the chemical monitoring data and the models used to estimate exposure concentrations in the absence of monitoring data, but can also be driven by population intake parameters. Finally, additional uncertainties are incorporated in the risk assessment when exposures to several substances across multiple pathways are summed." (EPA 1989)

The following is a qualitative analysis of the uncertainties of this evaluation. Some uncertainties are applicable to both the human health and environmental evaluation. Some are only applicable to human health or the environment.

	EFFECT ON EVALUATION		
ASSUMPTION	**Potential Magnitude for Over-Estimation of Risk**	**Potential Magnitude for Under-Estimation of Risk**	**Potential Magnitude for Over- or Under Estimation of Risk**
Environmental Sampling and Analysis			
Sufficient samples may not have been taken to characterize the media being evaluated, especially with respect to background concentrations			Moderate
Systematic or random error in the chemical analyses may yield erroneous data.			Low
Exposure Parameter Estimation			
The standard assumptions regarding body weight, period exposed, population characteristics, and lifestyle may not be representative of any actual exposure situation.			Moderate
The amount of media intake is assumed to be constant and representative of the exposed population	Moderate		

	EFFECT ON EVALUATION		
ASSUMPTION	**Potential Magnitude for Over-Estimation of Risk**	**Potential Magnitude for Under-Estimation of Risk**	**Potential Magnitude for Over- or Under Estimation of Risk**
The use of indicator species and surrogate species may misrepresent exposure to other species onsite.			Low
Toxicity Data			
Toxicity data for some of the indicator species and contaminants are not available.		Low to Moderate	
Risk			
The indicator species in the evaluation may not provide an accurate indication of the environmental risks.			Low

The overall conclusion is that the level of risk indicated in the risk evaluation is well within an order of magnitude, which is within EPA and ADEC guidelines.

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6.0 SUPPORT INFORMATION AND CALCULATIONS

6.1 RISKS FOR INGESTION OF SURFACE WATER RECREATIONAL SCENARIO

Intake (mg/kg-day) $= \dfrac{CW \times IR \times EF \times ED}{BW \times AT}$ (EPA 1989, Exhibit 6-11)

$= \dfrac{(CW)(2\ L/day)(12\ days/year)(6\ years)}{(15\ kg)((6\ years)(365\ days/year)}$

$= (CW\ mg/L)(0.0044\ L/kg\text{-}day)$

$Intake_{Cd} = (12\ ug/L)(mg/1000\ ug)(0.0044\ L/kg\text{-}day)$

$= 5.3E\text{-}5\ mg/kg\text{-}day$

$Intake_{Zn} = (2100\ ug/L)(mg/1000\ ug)(0.0044\ L/kg\text{-}day)$

$= 0.0092\ mg/kg\text{-}day$

HQ = Intake / RfD (EPA 1989, p. 8-11)

$HQ_{Cd} = (5.3E\text{-}5\ mg/kg\text{-}day) / (5E\text{-}4\ mg/kg\text{-}day)$

$= 0.1$

$HQ_{Zn} = (0.0092\ mg/kg\text{-}day) / (3E\text{-}1\ mg/kg\text{-}day)$

$= 0.03$

$\mathbf{HI_{ingest\ SW}} = HQ_{Cd} + HQ_{Zn} = 0.1 + 0.03 = \mathbf{0.1}$

Parameter	Value	Reference
CW; chemical concentration in water (ug/L) [Cd = cadmium, Zn = zinc]	12 for Cd 2100 for Zn	Table 1-3
IR; ingestion rate (liters/day)	2	EPA 1989, Exhibit 6-11
EF; exposure frequency (days/year)	12	assuming one weekend per month (2 days) for 6 months/year visit to site
ED; exposure duration (years)	6	childhood exposure
BW; body weight (kilograms)	15	child
AT; averaging time (days)	6 x 365	(ED x 365 days/year) EPA 1989, Exhibit 6-11
RfD (Cadmium), reference dose (mg/kg-day)	5E-4	IRIS (accessed 8 APR 2004)
RfD (Zinc), reference dose (mg/kg-day)	3E-1	IRIS (accessed 8 APR 2004)
HQ, hazard quotient (unitless)		
HI, hazard index (unitless)		

6.2 RISKS FOR DERMAL CONTACT WITH SURFACE WATER RECREATIONAL SCENARIO

DA_{event} (mg/cm^2-event) = Kp x Cw x t_{event} (EPA 2001, Eqn. 3-4)

DA_{event} (Cd) = (1.0E-3 cm/hr)(12 ug/L)(1 hr/event)(L/10^3 cm^3)(mg/10^3 ug)

= 1.2E-8 (mg/cm^2-event)

DA_{event} (Zn) = (6.0E-4 cm/hr)(2100 ug/L)(1 hr/event)(L/10^3 cm^3)(mg/10^3 ug)

= 7.2E-9 (mg/cm^2-event)

DAD (mg/kg-day) = $\frac{DA_{event} \times EV \times ED \times EF \times SA}{BW \times AT}$ (EPA 2001, Eqn. 3.1)

DAD = $\frac{(DA_{event})(2\ events/day)(6\ years)(12\ days/year)(6600\ cm^2)}{(15\ kg)(6 \times 365\ days)}$

DAD = (DA_{event})(29 event-cm^2/kg-day)

DAD (Cd) = (1.2E-8 mg/cm^2-event)(29 event-cm^2/kg-day)

= 3.5E-7 mg/kg-day

DAD (Zn) = (7.2E-9 mg/cm^2-event)(29 event-cm^2/kg-day)

= 2.1E-7 mg/kg-day

RfD_{ABS} (mg/kg-day) = RfDo x ABS_{GI} (EPA 2001, Eqn. 4.3)

RfD_{ABS} (for Cd) = (5E-4 mg/kg-day)(0.025)

= 1E-5 mg/kg-day

RfD_{ABS} (for Zn) = RfDo (for Zn) (EPA 2001, Exhibits 1-2, 4-1) (no multiplier for zinc ABS_{GI})

= 3E-1 mg/kg-day

HQ = $\frac{DAD}{RfD_{ABS}}$ (EPA 2001, Eqn. 5.2)

HQ_{Cd} = (3.5E-7 mg/kg-day) / (1E-5 mg/kg-day)

= 0.04

HQ_{Zn} = (2.1E-7 mg/kg-day) / (3E-1 mg/kg-day)

= 7E-7

$HI_{dermal\ SW}$ = HQ_{Cd} + HQ_{Zn} = 0.04 + 7E-7 = **0.04**

Parameter	Value	Reference
DA_{event}; absorbed dose per event (mg/cm^2-event)		EPA 2001, Eqn. 3-4
Kp; dermal permeability coefficient of compound in water (cm/hr) [Cd = cadmium, Zn = zinc]	1.0E-3 for Cd 6.0E-4 for Zn	EPA 2001, Exhibit B-4
Cw; chemical concentration in water (ug/L)	12 for Cd 2100 for Zn	Table 1-3
t_{event}; event duration (hour/event)	1	EPA 2001, Exhibit 3-2
DAD; dermally absorbed dose (mg/kg-day)		EPA 2001, Eqn. 3.1
EV; event frequency (events/day)	2	assumption
ED; exposure duration (years)	6	EPA 2001, Exhibit 3-2, child
EF; exposure frequency (days/year)	12	assuming one weekend per month (2 days) for 6 months/year visit to site
SA; skin surface area available for contact (cm^2)	6600	EPA 2001, Exhibit 3-2
BW; body weight (kilograms)	15	EPA 2001, Eqn. 3.1
AT; averaging time (days)	6 x 365	(ED x 365 days/year) EPA 20019, Eqn. 3.1
ABS_{GI}; Fraction of contaminant absorbed in gastrointestinal tract (dimensionless)	0.025 for Cd	EPA 2001, Exhibit 4-1 (Zn not adjusted)
RfD_{ABS}; reference dose dermal absorption (mg/kg-day)		EPA 2001, Eqn. 4.3
RfDo (Cadmium), oral reference dose (mg/kg-day)	5E-4	IRIS (accessed 8 APR 2004)
RfDo (Zinc), oral reference dose (mg/kg-day)	3E-1	IRIS (accessed 8 APR 2004)

6.3 RISKS FOR INGESTION OF SOIL RECREATIONAL SCENARIO

$$\text{Intake (mg/kg-day)} = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT} \quad \text{(EPA 1989, Exhibit 6-14)}$$

$$= \frac{\text{(CS mg/kg)(200 mg/day)(1E-6 kg/mg)(0.5)(12 days/yr)(6 yrs)}}{\text{(15 kg) (6 x 365 days)}}$$

= (CS mg/kg)(2.2E-7 /day)

HQ = Intake / RfDo (EPA 1989, p. 8-11)

COPC	CS	Intake	RfDo	RfDo Source	HQ
Antimony	12.3	2.7E-6	4E-4	IRIS	0.007
Cadmium	35	7.7E-6	5E-4	IRIS	0.02

COPC	CS	Intake	RfDo	RfDo Source	HQ
Chromium	120	2.6E-5	1.5E+0	IRIS	0.00002
Copper	350	7.7E-5	4E-2	R9 (HEAST)	0.002
Iron	47900	1.1E-2	3E-1	R9 (NCEA)	0.04
Mercury	0.39	8.6E-8	2E-4	See below	0.0004
Zinc	3590	7.9E-4	3E-1	IRIS	0.003
$HI_{ingest\ Soil}$					**0.07**

Parameter	Value	Reference
CS; chemical concentration in soil (mg/kg)	chemical specific	Table 1-1
IR; ingestion rate (mg soil/day)	200	EPA 1989, Exhibit 6-14, child
CF; conversion factor (kg/mg)	1E-6	
FI; fraction ingested from contaminated source (unitless)	pathway-specific = 0.5	assumption that half of intake is from soil and half from sediment
EF; exposure frequency (days/year)	12	assuming one weekend per month (2 days) for 6 months/year visit to site
ED; exposure duration (years)	6	childhood exposure
BW; body weight (kilograms)	15	child
AT; averaging time (days)	6 x 365	(ED x 365 days/year) EPA 1989, Exhibit 6-11
HQ, hazard quotient (unitless)		
HI, hazard index (unitless)		

RfDo calculation for mercury (Hg).

From the "Toxicological Profile for Mercury," U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, March 1999.

Chronic, NOAEL, oral-rat = 1.9 mg/kg/day
Chronic, LOAEL, oral-rat = 1.9 mg/kg/day

Uncertainty factors:

10 to account for variation in the general population and to protect sensitive subpopulation.

10 for extrapolation from animals to humans, interspecies variability between humans and other mammals.

10 for use of LOAL instead of a NOAEL.

Modifying Factor:

10 due to uncertainty in non-peer reviewed calculation of RfD.

$$RfD = \frac{1.9 \text{ mg/kg-day}}{10 \times 10 \times 10 \times 10} = 0.00019 \text{ mg/kg-day}$$

Ingestion cleanup level (residential scenario) for over 40-inch zone = 15.8 mg/kg (ADEC Web Calculator)

6.4 RISKS FOR DERMAL CONTACT WITH SOIL RECREATIONAL SCENARIO

DA_{event} (mg/cm^2-event) = $CS \times CF \times AF \times ABS_d$ (EPA 2001, Eqn. 3.12)

DA_{event} = (CS mg/kg)(1E-6 kg/mg)(3.3mg/cm^2-event)(0.001)

= (CS mg/kg)(3.3E-9 kg/cm^2-event)

$$DAD\ (mg/kg\text{-}day) = \frac{DA_{event} \times EF \times ED \times EV \times SA}{BW \times AT}$$ (EPA 2001, Eqn. 3.11)

$$DAD = \frac{(DA_{event})(12\ days/year)(6\ years)(1\ events/day)(2800\ cm^2)}{(15\ kg)(6 \times 365\ days)}$$

DAD = (DA_{event})(6 event-cm^2/kg-day)

RFD_{ABS} = RFDo x ABS_{GI} (EPA 2001, Eqn. 4.3)

HQ = DAD / RfD_{ABS} (EPA 2001, Eqn. 5.2)

COPC	CS	DAevent	DAD	RfD_{ABS}	HQ
Antimony	12.3	4.1E-8	2.5E-7	6E-5	0.004
Cadmium	35	1.2E-7	7.2E-7	1E-5	0.07
Chromium	120	4.0E-7	2.4E-6	2E-2	0.0001
Copper	350	1.2E-6	7.2E-6	4E-2	0.0002
Iron	47900	1.6E-4	9.6E-4	3E-1	0.003
Mercury	0.39	1.3E-9	7.8E-9	2E-4	0.00004
Zinc	3590	1.2E-5	7.2E-5	3E-1	0.0002
$HI_{dermal\ Soil}$					**0.08**

Parameter	Value	Reference
DA_{event}; Absorbed dose per event (mg/cm^2-event)		EPA 2001, Eqn. 3.12
DAD; Dermal absorbed dose (mg/kg-day)		EPA 2001, Eqn. 3.11
CS; chemical concentration in soil (mg/kg)	chemical specific	Table 1-1
CF; conversion factor (kg/mg)	1E-6	
AF; Adherence factor of soil to skin (mg/cm^2-event)	3.3	EPA 2001, Exhibit 3-3
ABS_d; Dermal absorption fraction	0.001 for Cd. 0.001 assumed for all others	EPA 2001, Exhibit 3-4
EF; exposure frequency (days/year)	12	assuming one weekend per month (2 days) for 6 months/year visit to site
ED; exposure duration (years)	6	childhood exposure
EV; event frequency (events/day)	1	site specific; assumes one event per day in soil and one per day in sediment.

Parameter	Value	Reference
SA; skin surface area available for contact (cm^2)	2800	EPA 2001, Exhibit 3-5
BW; body weight (kilograms)	15	child
AT; averaging time (days)	6 x 365	(ED x 365 days/year) EPA 2001, Eqn. 3.11
ABS_{GI}; Fraction of contaminant absorbed in gastrointestinal tract (dimensionless)	Sb = 0.15 Cd = 0.025 Cr = 0.013 no adjustment for CU, FE, Hg, and Zn	EPA 2001, Exhibit 4-1
RfD_{ABS}; Absorbed reference dose (mg/kg-day)	RfDo x ABS_{GI} (for Sb, Cd, Cr, Mn, and V); RfDo for others	EPA 2001, Eqn. 4.3
HQ, hazard quotient (unitless)		
HI, hazard index (unitless)		

6.5 RISKS FOR INGESTION OF SEDIMENT RECREATIONAL SCENARIO

$$\text{Intake (mg/kg-day)} = \frac{CS \times IRc \times CF \times FI \times EF \times EDc}{BWc \times AT} \quad \text{(EPA 1989, Exhibit 6-14)}$$

$$= \frac{(CS\ \text{mg/kg})(200\ \text{mg/day})(1E\text{-}6\ \text{kg/mg})(0.5)(12\ \text{days/yr})(6\ \text{yrs})}{(15\ \text{kg})\ (6 \times 365\ \text{days})}$$

$$= (CS\ \text{mg/kg})(2.2E\text{-}7\ /\text{day})$$

$$HQ = \text{Intake} / RfDo \quad \text{(EPA 1989, p. 8-11)}$$

COPC	CS	Intake	RfDo	RfDo Source	HQ
Chromium	273	6.0E-5	1.5E+0	IRIS	0.00004
$HI_{ingest\ Sediment}$					**0.00004**

Parameter	Value	Reference
CS; chemical concentration in sediment (mg/kg)	chemical specific	Table 1-2
IRc; ingestion rate child (mg soil/day)	200	EPA 1989, Exhibit 6-14, child
CF; conversion factor (kg/mg)	1E-6	
FI; fraction ingested from contaminated source (unitless)	pathway-specific = 0.5	assumption that half of intake is from soil and half from sediment
EF; exposure frequency (days/year)	12	assuming one weekend per month (2 days) for 6 months/year visit to site
EDc; exposure duration (years)	6	childhood exposure
BWc; body weight (kilograms)	15	child
AT; averaging time (days)	6 x 365	(ED x 365 days/year) EPA 1989,

Parameter	Value	Reference
		Exhibit 6-14, noncarcinogenic
RFDo, reference dose, oral	1.5 (Cr)	IRIS
HQ, hazard quotient (unitless)		
HI, hazard index (unitless)		

6.6 RISKS FOR DERMAL CONTACT WITH SEDIMENT RECREATIONAL SCENARIO

DA_{event} (mg/cm^2-event) = CS x CF x AF x ABS_d (EPA 2001, Eqn. 3.12)

DA_{event} = (CS mg/kg)(1E-6 kg/mg)(3.3mg/cm^2-event)(0.001)

= (CS mg/kg)(3.3E-9 kg/cm^2-event)

$$DAD\ (mg/kg\text{-}day) = \frac{DA_{event}\ x\ EF\ x\ ED\ x\ EV\ x\ SA}{BW\ x\ AT}$$ (EPA 2001, Eqn. 3.11)

$$DAD = \frac{(DA_{event})(12\ days/year)(6\ years)(1\ events/day)(2800\ cm^2)}{(15\ kg)(6\ x\ 365\ days)}$$

DAD = (DA_{event})(6 event-cm^2/kg-day)

RFD_{ABS} = RFDo x ABS_{GI} (EPA 2001, Eqn. 4.3)

HQ = DAD / RfD_{ABS} (EPA 2001, Eqn. 5.2)

COPC	CS	ABS_d	DAevent	DAD	ABS_{GI}	RfD_{ABS}	HQ
Chromium	273	0.001	9.0E-7	5.4E-6	0.013	2E-2	0.0003
$HI_{dermal\ Sediment}$							**0.0003**

Parameter	Value	Reference
DA_{event}; Absorbed dose per event (mg/cm^2-event)		EPA 2001, Eqn. 3.12
DAD; Dermal absorbed dose (mg/kg-day)		EPA 2001, Eqn. 3.11
CS; chemical concentration in soil (mg/kg)	chemical specific	Table 1-2
CF; conversion factor (kg/mg)	1E-6	
AF; Adherence factor of soil to skin (mg/cm^2-event)	3.3	EPA 2001, Exhibit 3-3
ABS_d; Dermal absorption fraction	0.001 assumed for Cr	EPA 2001, Exhibit 3-4
EF; exposure frequency (days/year)	12	assuming one weekend per month (2 days) for 6 months/year visit to site
ED; exposure duration (years)	6	childhood exposure
EV; event frequency (events/day)	1	site specific; assumes one event per day in soil and one per day in sediment.

Parameter	Value	Reference
SA; skin surface area available for contact (cm^2)	2800	EPA 2001, Exhibit 3-5
BW; body weight (kilograms)	15	child
AT; averaging time (days)	6 x 365	(ED x 365 days/year) EPA 2001, Eqn. 3.11
ABS_{GI}; Fraction of contaminant absorbed in gastrointestinal tract (dimensionless)	0.013 (Cr)	EPA 2001, Exhibit 4-1
RfD_{ABS}; Absorbed reference dose (mg/kg-day)	RfDo x ABS_{GI} (for Cr)	EPA 2001, Eqn. 4.3
HQ, hazard quotient (unitless)		
HI, hazard index (unitless)		

Table 6-1
Total Hazard Index Recreational Scenario

(Cumulative Risk) = Σ HI by Pathway

$HI_{ingest\ SW}$ = **0.1**
$HI_{dermal\ SW}$ = **0.04**
$HI_{ingest\ Soil}$ = **0.07**
$HI_{dermal\ Soil}$ = **0.08**
$HI_{ingest\ Sed}$ = **0.00004**
$HI_{dermal\ Sed}$ = **0.0003**

HI_{TOTAL} = **0.3**

6.7 ECOLOGICAL RISKS

The soil and sediment COPCs are shown below. The only COPC in surface water is zinc at 10 ug/L.

Compound	Site Soil Conc. (mg/kg)
Antimony	12.3
Cadmium	35
Chromium	120
Copper	350
DRO + RRO (sum)	1,310
Iron	47,900
Lead	4,500
Mercury	0.39
Nickel	42
RRO	1,100
Selenium	3.96
Silver	18.1
Zinc	3,590

Compound	Site Sediment Conc. (mg/kg)
Chromium	273
Cobalt	51
Copper	82
Lead	255
Molybdenum	13
Zinc	1,370

6.8 ECOLOGICAL RISKS – PRIMARY PRODUCERS (TROPHIC LEVEL 0)

Assessment endpoints and indicator species for primary producers include:

- The potential for significant adverse effects on terrestrial soil plant species abundance, diversity, and primary production
  - All plants that obtain nutrients primarily from soil
- The potential for significant adverse effects on freshwater semi-aquatic plant species abundance, diversity, and primary production
  - All plants that obtain nutrients primarily from freshwater sediment

Toxicity values are available for terrestrial soil plant species. However, toxicity values for aquatic plants are not available for sediment concentrations. Published toxicity values for aquatic plants are based on compound concentrations dissolved in water. To evaluate the semi-aquatic plant species end-point, terrestrial plant toxicity values are used based on sediment concentrations and water concentrations are used for Mahoney Lake Creek. Concentrations of compounds in the seeps are not evaluated, as the area of the seeps is small and not critical to aquatic plant abundance, diversity and production. The only COPC in Mahoney Lake Creek is zinc at 10 ug/L.

Toxicity values are from the EPA ECOTOX Database unless indicated otherwise.

Due to different study parameters, many of the toxicity studies have more than one toxicity benchmark for the same receptor. These multiple benchmarks are indicated as a range of values for the receptor HQs.

$$HQ = \frac{\text{CS (concentration in soil or sediment)}}{\text{Benchmark}}$$

Plant Species

Antimony

Effect of **Antimony** on Terrestrial Plants
ENDPOINT: Screening Value of 5 mg/kg (ORNL)

$HQ_{Sb\text{-}Soil}$ = 12.3 mg/kg (onsite conc.) = 2

5 mg/kg (screening)

Cadmium

Effect of **Cadmium chloride** on ***Festuca rubra***
ENDPOINT: >=30 day(s) LOEC of 19 mg/kg
Effect of **Cadmium chloride** on ***Lolium perenne*** (**Perennial ryegrass)**
ENDPOINT: >=30 day(s) LOEC of 8, 22 mg/kg
Effect of **Cadmium sulfate** on ***Hordeum vulgare*** (barley)
ENDPOINT: 45 day(s) LOEC/ of 8.33 mg/kg

$$HQ_{cadmium} = \frac{\text{35 mg/kg (onsite conc.)}}{\text{8 mg/kg (LOEC) to 22 mg/kg (LOEC)}} = \text{2 to 4}$$

Chromium

Effect of **Acetic acid, Chromium(3+) salt** on ***Avena sp.*** (oat)
ENDPOINT: 200 day(s) NOEC of 200, 400, 800 mg/kg soil

$$HQ_{Cr\text{-}Soil} = \frac{\text{120 mg/kg (onsite conc.)}}{\text{200 to 800 mg/kg (NOEC)}} = \text{0.2 to 0.6}$$

$$HQ_{Cr\text{-}Sed} = \frac{\text{273 mg/kg (onsite conc.)}}{\text{200 to 800 mg/kg (NOEC)}} = \text{0.3 to 1}$$

Cobalt

Effect of **Cobalt chloride** on ***Hordeum vulgare*** (barley)
ENDPOINT: 18 day(s) EC20 of 37.3 to 471.5 mg/kg soil
Effect of **Cobalt chloride** on ***Medicago sativa*** (alfalfa)
ENDPOINT: 22 day(s) EC20 of 5.8 to 276.3 mg/kg soil
Effect of Cobalt chloride on ***Raphanus sativus*** (**Radish**).
ENDPOINT: 18 day(s) EC20 of 16.3 to 266.7 mg/kg

$$HQ_{Co\text{-}Sed} = \frac{\text{51 mg/kg (onsite conc.)}}{\text{5.8 to 471.5 mg/kg (NOEC)}} = \text{0.1 to 9}$$

Copper

Effect of **Acetic acid, Copper (1+) salt** on ***Avena sp.*** (oat)
ENDPOINT: 200 day(s) NOEC of 200, 400 mg/kg soil

$$HQ_{Cu\text{-}Soil} = \frac{\text{350 mg/kg (onsite conc.)}}{\text{400 mg/kg (NOEC)}} = 0.9$$

$HQ_{Cu\text{-}Sed}$ = <u>82 mg/kg (onsite conc.)</u> = 0.2

400 mg/kg (NOEC)

DRO and RRO

No data

Iron

No data

Lead

Effect of **Acetic acid, Lead(2+) salt** on ***Avena sp.*** (oat)
ENDPOINT: 200 day(s) NOEC of 800 mg/kg soil
Effect of **Lead chloride** on ***Festuca rubra*** **Growth**
ENDPOINT: >=30 day(s) LOEC of 46, 300 mg/kg
Effect of **Lead chloride** on ***Lolium perenne*** (perennial ryegrass)
ENDPOINT: >=30 day(s) LOEC of 560, 2000 mg/kg

$$HQ_{Pb\text{-}Soil} = \frac{4500 \text{ mg/kg (onsite conc.)}}{46 \text{ mg/kg (LOEC) to } 200 \text{ mg/kg (NOEC)}} = 22 \text{ to } 98$$

$$HQ_{Pb\text{-}Sed} = \frac{255 \text{ mg/kg (onsite conc.)}}{46 \text{ mg/kg (LOEC) to } 200 \text{ mg/kg (NOEC)}} = 1 \text{ to } 6$$

Mercury

Effect of **Mercury** on Terrestrial Plants
ENDPOINT: Screening Value of 0.3 mg/kg (ORNL)

$$HQ_{Hg\text{-}Soil} = \frac{0.39 \text{ mg/kg (onsite conc.)}}{0.3 \text{ mg/kg (screening)}} = 1$$

Molybdenum

No data

Nickel

Effect of **Acetic acid, Nickel(2+)salt** on ***Avena sp.*** (oat)
ENDPOINT: 200 day(s) NOEC of 6.25, 25, 100 mg/kg soil

$$HQ_{Ni\text{-}Soil} = \frac{42 \text{ mg/kg (onsite conc.)}}{6.25 \text{ to } 100 \text{ mg/kg (NOEC)}} = 0.4 \text{ to } 7$$

Selenium

Effect of **Selenium** on Terrestrial Plants
ENDPOINT: Screening Value of 1 mg/kg (ORNL)

$$HQ_{Se\text{-}Soil} = \frac{3.96 \text{ mg/kg (onsite conc.)}}{1 \text{ mg/kg (screening)}} = 4$$

Silver

Effect of **Silver** on Terrestrial Plants
ENDPOINT: Screening Value of 2 mg/kg (ORNL)

$$HQ_{Ag\text{-}Soil} = \frac{18.1 \text{ mg/kg (onsite conc.)}}{2 \text{ mg/kg (screening)}} = 9$$

Zinc

Effect of **Zinc acetate** on ***Avena sp.*** (oat)
ENDPOINT: 200 day(s) NOEC of 100, 200, 400, 800 mg/kg soil

Zinc		
Lemna minor Duckweed	NOEC	160 ug/L

$$HQ_{Zn\text{-}Soil} = \frac{3590 \text{ mg/kg (onsite conc.)}}{100 \text{ to } 800 \text{ mg/kg (NOEC)}} = 4 \text{ to } 36$$

$$HQ_{Znc\text{-}Sed} = \frac{1370 \text{ mg/kg (onsite conc.)}}{100 \text{ to } 800 \text{ mg/kg (NOEC)}} = 2 \text{ to } 14$$

$$HQ_{Zn\text{-}SW} = \frac{10 \text{ ug/L (onsite conc.)}}{160 \text{ ug/L (NOEC)}} = 0.06$$

Table 6-2
Primary Producers (Trophic Level 0) Terrestrial HQs

Terrestrial Soil Plants - Cumulative Risk			
Compound	**Site Soil Conc. (mg/kg)**	**HQ**	**Background (mg/kg)**
Antimony	12.3	2	<1 to 8.8 NA
Cadmium	35	2 to 4	0.01 to 22 NA
Chromium	120	0.2 to 0.6	5 to 390 AK
Copper	350	0.9	3 to 810 AK
DRO	210	no data	
Iron	47,900	no data	5,500 to 100,000 AK
Lead	4,500	22 to 98	<4 to 310 AK
Mercury	0.39	1	<0.01 to 4.6 NA
Nickel	42	0.4 to 7	<3 to 320 AK
RRO	1,100	no data	
Selenium	3.96	4	<0.1 to 4.3 AK
Silver	18.1	9	0.13 to 0.77 NA
Zinc	3,590	4 to 36	<20 to 2,700 AK
HI =		**50 to 200**	

Notes:
NA = North American background range
AK = Alaskan background range

Table 6-3
Primary Producers (Trophic Level 0) Semi-Aquatic HQs

Semi-Aquatic Plants - Cumulative Risks			
Compound	**Site Sediment Conc. (mg/kg)**	**HQ**	**Background (mg/kg)**
Chromium	273	0.3 to 1	3 to 1,040 SE
Cobalt	51	0.1 to 9	3 to 70 SE
Copper	82	0.2	2 to 664 SE
Lead	255	1 to 6	4 to 826 SE
Molybdenum	13	no data	2 to 16 SE
Zinc	1,370	2 to 14	30 to 2,120 SE
Zinc (water)	10 ug/L	0.06	
HI =		**4 to 30**	

Note:
SE = Southeast Alaska background range

6.9 ECOLOGICAL RISKS – HERBIVORES AND DETRIVORES (TROPHIC LEVELS 1 AND 2)

Assessment endpoints and indicator species for Herbivores and Detrivores include:

- The potential for significant adverse effects on freshwater aquatic invertebrate community abundance and diversity

- All freshwater aquatic invertebrates
- The potential for significant adverse effects on freshwater benthic invertebrate community abundance and diversity
  - All freshwater benthic invertebrates
- The potential for significant adverse effects on soil invertebrate community abundance and diversity
  - All terrestrial invertebrates
- The potential for significant adverse effects on freshwater fish detritivore abundance and diversity
  - All freshwater fish
- The potential for significant adverse effects on freshwater semi-aquatic avian herbivore abundance and diversity
  - Mallard
- The potential for significant adverse effects on terrestrial avian herbivore abundance and diversity
  - Dark-eyed junco
- The potential for significant adverse-effects on freshwater semi-aquatic mammalian herbivore abundance and diversity
  - Northern bog lemming
- The potential for significant adverse effects on terrestrial mammalian herbivore abundance and diversity
  - Long-tailed vole

Toxicity values are from the EPA ECOTOX Database unless indicated otherwise.

<u>Invertebrate Communities</u>

Toxicity values for freshwater sediment are not readily available for all compounds. In some cases, the toxicity values for terrestrial organisms were substituted. Concentrations of compounds dissolved in the water of the seeps are not evaluated, as the area of the seeps is small and not critical to aquatic invertebrate and benthic organism abundance, diversity and production. The only COPC in Mahoney Lake Creek is zinc at 10 ug/L.

Antimony

Effect of **Antimony sulfate** on ***Eisenia fetida*** **(Earthworm)**
ENDPOINT: 14 day(s) LOEC of 697 mg/kg
Effect of **Antimony sulfate** on ***Enchytraeus crypticus*** **(Earthworm)**
ENDPOINT: 28 day(s) LOEC of 538 mg/kg
Effect of **Antimony sulfate** on ***Folsomia candida*** **(Springtail)**
ENDPOINT: 28 day(s) LOEC of 126 mg/kg

$$HQ_{Sb\text{-}Soil} = \frac{12.3 \text{ mg/kg (Site Conc.)}}{126 \text{ to } 697 \text{ mg/kg}} = 0.02 \text{ to } 0.1$$

Cadmium

Effect of **Cadmium** on ***Eisenia fetida*** **(Earthwrom)**
ENDPOINT: 8 week(s) NOEC 1800 to 18000 mg/kg
ENDPOINT: 8 week(s) NOEC 3500 to 35000 mg/kg

Effect of **Cadmium chloride** on ***Eisenia andrei*** **(Earthworm)**
ENDPOINT: 12 week(s) LOEC of 10 to 305 mg/kg

Effect of **Cadmium chloride** on ***Folsomia candida*** **(Springtail)**
ENDPOINT: 6 week(s) NOEC of 60 to 95 mg/kg
ENDPOINT: 28 day(s) NOEC of 120 to 380 mg/kg

$$HQ_{Cd\text{-}Soil} = \frac{35 \text{ mg/kg (onsite conc.)}}{10 \text{ to } 35000 \text{ mg/kg (NOECs, LOECs)}} = 0.001 \text{ to } 4$$

Chromium

Effect of **Nitric acid, Chromium(3+) salt** on ***Eisenia andrei*** **(Earthworm)**
ENDPOINT: <=6 week(s) LOEC of 1000 mg/kg
ENDPOINT: <=11 week(s) LOEC of 100 mg/kg
ENDPOINT: 6 week(s) LOEL of 973 mg/kg

$$HQ_{Cr\text{-}Soil} = \frac{120 \text{ mg/kg (Site Conc.)}}{100 \text{ to } 1000 \text{ mg/kg}} = 0.1 \text{ to } 1$$

$HQ_{Cr\text{-}Sed}$ = <u>273 mg/kg (Site Conc.)</u> = 0.3 to 3

100 to 1000 mg/kg

Cobalt

Effect of **Cobalt** on ***Eisenia fetida*** **(Earthworm)**
ENDPOINT: 8 week(s) NOEC of 300 to 30000 mg/kg

$$HQ_{Co\text{-}Sed} = \frac{\underline{51\text{ mg/kg (Site Conc.)}}}{300\text{ to }30000\text{ mg/kg}} = 0.002\text{ to }0.2$$

Copper

Effect of **Copper** on ***Eisenia fetida*** **(Earthworm)**
ENDPOINT: NOEC 1100 to 11000 mg/kg
ENDPOINT: NOEC of 22000 mg/kg

Effect of **Copper oxide** on ***Eisenia fetida*** **(Earthworm)**
ENDPOINT: 8 week(s) LOEC of 20000 to 40000 ppm

$$HQ_{Cu\text{-}Soil} = \frac{\underline{350\text{ mg/kg (Site Conc.)}}}{1100\text{ to }40000\text{ mg/kg}} = 0.009\text{ to }0.3$$

$$HQ_{Cu\text{-}Sed} = \frac{\underline{82\text{ mg/kg (Site Conc.)}}}{1100\text{ to }40000\text{ mg/kg}} = 0.002\text{ to }0.07$$

DRO and RRO

Using benzo(a)pyrene and fluorene as surrogates for petroleum:

Effect of **Benzo(a)pyrene** on ***Enchytraeus crypticus*** **(Earthworm)**
ENDPOINT: 30 day(s) LOEC of 400 mg/kg

Effect of **9H-Fluorene** on ***Eisenia fetida*** **(Earthworm)**
ENDPOINT: 8 week(s) NOEC of 500 mg/kg

$$HQ_{DRO\ \&\ RRO\ Soil} = \frac{\underline{210\text{ (DRO)} + 1100\text{ (RRO) mg/kg (onsite conc.)}}}{400\text{ to }500\text{ mg/kg}} = 3$$

Iron

Effect of Iron on Springtails
ENDPOINT: NOAEL of 3515 mg Fe / kg diet (Ecological Soil Screening Levels for Iron Interim Final OSWER Directive 9285.7-69)

$$HQ_{Fe\text{-}Soil} = \frac{47900 \text{ mg/kg (Site Conc.)}}{3515 \text{ mg/kg}} = 10$$

Lead

Effect of **Lead chloride** on ***Eisenia fetida* (Earthworm)**
ENDPOINT: 8 week(s) NOEC of 14000 to 40000 mg/kg

Effect of **Lead oxide** on ***Eisenia fetida* (Earthworm)**
ENDPOINT: 8 week(s) LOEC of 10000 to 20000 mg/kg

Effect of **Lead(II) sulfate** on ***Eisenia fetida* (Earthworm)**
ENDPOINT: 8 week(s) LOEC of 10000 to 16000 mg/kg

$$HQ_{Pb\text{-}Soil} = \frac{4500 \text{ mg/kg (Site Conc.)}}{10000 \text{ to } 40000 \text{ mg/kg}} = 0.1 \text{ to } 0.4$$

$$HQ_{Pb\text{-}Sed} = \frac{255 \text{ mg/kg (Site Conc.)}}{10000 \text{ to } 40000 \text{ mg/kg}} = 0.006 \text{ to } 0.03$$

Mercury

Effect of **Mercury** on ***Eisenia fetida* (Earthworm)**
ENDPOINT: 8 week(s) NOEC of 2400 – 24000 mg/kg

$$HQ_{Hg\text{-}Soil} = \frac{0.39 \text{ mg/kg (Site Conc.)}}{2400 \text{ to } 24000 \text{ mg/kg}} = 0.00002 \text{ to } 0.0002$$

Molybdenum

"Sodium molybdate and other molybdenum compounds in toxic baits . . . Baits containing 1,000 mg/kg Mo/kg were fatal to 99% of the termite Reticulitermes flavipes in 48 days. . . Some other species of insects—including fire ants (Solenopsis sp.) and various species of beetles and cockroaches—were not affected when exposed to baits containing 5,000 mg Mo/kg for 48 days." (USFWS 1989).

Site concentration of Mo in soils is 1 mg/kg. Site concentration in sediments is 13 mg/kg.

Nickel

Effect of **Nickel** on ***Eisenia fetida* (Earthworm)**
ENDPOINT: 8 week(s) NOEC of 1200 to 12000 mg/kg

Effect of **Nickelous chloride** on ***Eisenia fetida* (Earthworm)**
ENDPOINT: 8 week(s) LOEC of 200 ppm

$$HQ_{Ni\text{-}Soil} = \frac{\text{42 mg/kg (Site Conc.)}}{\text{200 to 12000 mg/kg}} = 0.004 \text{ to } 0.2$$

RRO

See DRO

Selenium

Effect of **Selenium** on **Microorganisms**
ENDPOINT: Screening 100 mg/kg (ORNL)
Effect of **Selenium** on **Earthworms**
ENDPOINT: Screening 70 mg/kg (ORNL)

$$HQ_{Se\text{-}Soil} = \frac{\text{3.96 (Site Conc.)}}{\text{70 to 100 mg/kg}} = 0.04 \text{ to } 0.06$$

Silver

Effect of **Silver** on **Microorganisms**
ENDPOINT: Screening 50 mg/kg (ORNL)

$$HQ_{Ag\text{-}Soil} = \frac{\text{18.1 mg/kg (Site Conc.)}}{\text{50 mg/kg}} = 0.4$$

Zinc

Effect of **Zinc** on ***Eisenia fetida* (Earthworm)**
ENDPOINT: 8 week(s) NOEC of 1300 to 26000 mg/kg

Zinc		
Ceriodaphnia reticulata Water flea	LOEC	198 to 618 ug/L
Ceriodaphnia reticulata Water flea	NOEC	101 to 140 ug/L
Daphnia magna Water flea	NOEC	900 ug/L
Dreissena polymorpha Zebra mussel	LOEC	500 ug/L

$$HQ_{Zn\text{-}Soil} = \frac{\text{3590 mg/kg (Site Conc.)}}{\text{1300 to 26000 mg/kg}} = \text{0.1 to 3}$$

$$HQ_{Zn\text{-}Sed} = \frac{\text{1370 mg/kg (Site Conc.)}}{\text{1300 to 26000 mg/kg}} = \text{0.05 to 1}$$

$$HQ_{Zn\text{-}Water} = \frac{\text{10 ug/L (Site Conc.)}}{\text{101 to 900 ug/L}} = \text{0.01 to 0.1}$$

Table 6-4
Freshwater Benthic and Aquatic Invertebrate Communities - Cumulative Risk

Freshwater Benthic and Aquatic Invertebrate Communities - Cumulative Risk			
Compound	**Site Sediment Conc. (mg/kg)**	**Semi-Aquatic HQ**	**Background (mg/kg)**
Chromium	273	0.3 to 3	3 to 1,040 SE
Cobalt	51	0.002 to 0.2	3 to 70 SE
Copper	82	0.002 to 0.07	2 to 664 SE
Lead	255	0.006 to 0.03	4 to 826 SE
Molybdenum	13	no data	2 to 16 SE
Zinc	1,370	0.05 to 1	30 to 2,120 SE
Zinc (water)	10 ug/L	0.01 to 0.1	
HI =		**0.4 to 4**	

Note:
SE = Southeast Alaska background range

Table 6-5
Terrestrial Invertebrate Communities - Cumulative Risk

Terrestrial Invertebrate Communities - Cumulative Risk			
Compound	**Site Soil Conc. (mg/kg)**	**HQ**	**Background (mg/kg)**
Antimony	12.3	0.02 to 0.1	<1 to 8.8 NA
Cadmium	35	0.001 to 4	0.01 to 22 NA
Chromium	120	0.1 to 1	5 to 390 AK
Copper	350	0.009 to 0.3	3 to 810 AK
DRO + RRO	1,310	3	
Iron	47,900	10	5,500 to 100,000 AK
Lead	4,500	0.1 to 0.4	<4 to 310 AK
Mercury	0.39	0.00002 to 0.0002	<0.01 to 4.6 NA
Nickel	42	0.004 to 0.2	<3 to 320 AK
RRO	1,100	see DRO	
Selenium	3.96	0.04 to 0.06	<0.1 to 4.3 AK
Silver	18.1	0.4	0.13 to 0.77 NA
Zinc	3,590	0.1 to 3	<20 to 2,700 AK
HI =		**10 to 20**	

Notes:
NA = North American background range
AK = Alaskan background range

Freshwater Fish Detritivores

Zinc

Danio rerio Zebra danio	LOEC	2000 to 23100 ug/L
Danio rerio Zebra danio	NOEC	1500 to 20000 ug/L

$$HQ_{Zinc} = \frac{10 \text{ ug/L (onsite conc.)}}{1500 \text{ to } 23100 \text{ mg/kg}} = 0.0004 \text{ to } 0.02$$

Table 6-6
Freshwater Fish Detritivore Communities HQs

Compound	**Site Water Conc. (ug/L)**	**HQ**	**Background (ug/L)**
Zinc	10	0.0004 to 0.02	no data

Avian Herbivores (Mallard and Dark-eyed Junco)

Exposure to the site contaminates for the terrestrial and semi-aquatic avian herbivores is primarily through the site soils and sediments with secondary exposure through surface water.

Mallard:

- Body weight: Adult about 1000 to 1225 grams. (EPA 1993)
- Home range: about 40 to 1440 ha (wetlands, river) (EPA 1993) (= 100 to 3550 acres)
- Estimated Percent Soil in Diet (dry weight): <2 (EPA 1993)
- Water ingestion rate: 0.055 to 0.058 g/g-day (EPA 1993)
- Food ingestion rate: 0.23 g/g-day (EC 2004)

Dark-eyed Junco:

- Home range: 2 or 3 acres; (Familiar Birds 2004)
- May exceed 100 pairs per square mile (6.4 pairs / acre) during favorable conditions; (NACBI 2004)

Antimony

- Site soil concentration: 12.3 mg/kg
- Toxicity - no data

Cadmium

Site soil concentration: 35 mg/kg.

"Mammals and birds are comparatively resistant to the biocidal properties of cadmium. . . . Although mallards and chickens tolerated 200 ppm of cadmium in diets for protracted periods, kidney cadmium exceeded 130 ppm fresh weight under this regimen, a concentration considered life-threatening to some organisms." (USFWS 1985) If 2% is used as the percentage of soil to diet, a calculated SSL = 200 mg/kg / 0.02 = 10,000 mg Cd /kg soil. The HQ = 35 mg/kg / 10,000 mg/kg = 0.004.

Cadmium	Avian herbivore (dove)	Eco-SSL (mg/kg dw) (*Soil_j*) (Ecological Soil Screening Levels for Cadmium Interim Final OSWER Directive 9285.7-65)	20

Using the Eco-SSL of 20 mg/kg, the HQ = 35 mg/kg / 20 mg/kg = 2.

<u>Chromium</u>

Site soil concentration: 120 mg/kg; site sediment concentration: 273 mg/kg.

"Adult black ducks fed diets containing 10 or 50 ppm anionic Cr+3, as $CrK(SO_4)_2.12H_2O$, for 5 months were normal in survival, reproduction, and blood chemistry. However, in ducklings from treated groups that were fed Cr-contaminated diets at original parental dosages, growth patterns were altered and survival was reduced (Haseltine et al. 1985). In another study with black ducks, adults were fed diets containing 0, 20, or 100 ppm anionic Cr+3 and ducklings from these pairs were fed the same diets for 7 days; tests of avoidance responses of the ducklings to a fright stimulus showed that the Cr had no significant effect on their behavior (Heinz and Haseltine 1981)." (USFWS 1986)

Chromium III	Eco-SSL Avian Soil Screening Benchmark (ORNL 2004)	21 mg/kg soil
Chromium	Nutrition requirement, chicken (http://www.epa.gov/ecotox/ecossl/pdf/ecossl_attachment_4-3.pdf)	10-20 mg/kg diet

The concentration in the site soils is 120 mg/kg (ppm) and in sediment 273 mg/kg.

If the percentage of soil to diet is 2%, the calculated SSL = 20 mg/kg / 0.02 = 1,000 mg Cr /kg soil. The HQ_{soil} = 120 mg/kg / 1,000 mg/kg = 0.1. The $HQ_{sediment}$ = 273 mg/kg / 1,000 mg/kg = 0.3.

Using the Eco-SSL, the HQ_{soil} = 120mg/kg / 21 mg/kg = 6. The $HQ_{sediment}$ = 273 mg/kg / 21 mg/kg = 10.

Cobalt

Site concentration is 51 mg/kg in sediments.

Cobalt	Nutrition requirement, poultry (http://www.epa.gov/ecotox/ecossl/pdf/ecossl_attachment_4-3.pdf)	3-10 mg/kg diet

Cobalt	Avian herbivore (dove)	Eco-SSL (mg/kg dw) (*Soil*$_j$) (Ecological Soil Screening Levels for Cobalt Interim Final OSWER Directive 9285.7-67)	200

At 2% soil to diet ratio, the calculated SSL = (10 mg Co / kg diet) / (0.02 kg soil / kg diet) = 500 mg Co / kg soil. The HQ = 51 mg/kg / 500 mg/kg = 0.1

Using the Eco-SSL, the HQ = 51 mg/kg / 200 mg/kg = 0.3.

Copper

Site soil concentration is 350 mg/kg. Site sediment concentration is 82 mg/kg.

Copper	Nutrition requirement, chicken, turkey and quail (http://www.epa.gov/ecotox/ecossl/pdf/ecossl_attachment_4-3.pdf)	4-8 mg/kg diet

At a 2% soil to diet ratio, the calculated SSL = (8 mg Cu / kg diet) / 0.02 kg soil / kg diet) = 400 mg/kg.

The HQ_{soil} = 350 mg/kg / 400 mg/kg = 0.9.

The $HQ_{sediment}$ = 82 mg/kg / 400 mg/kg = 0.2.

DRO and RRO

Site soil concentrations are 210 mg/kg for DRO and 1100 mg/kg for RRO (1,310 mg/kg total). Using PAHs as a surrogate for DRO and RRO:

PAHs	Mallard	USFWS 1987, No mortality or visible signs of toxicity were evident during exposure; however, liver weight increased 25% and blood flow to liver increased 30%, when compared to controls. 7-month study. (LOEL)	4000 mg PAHs / kg food

Using a 2% soil to diet ratio, the calculated SSL = (4,000 mg PAHs / kg diet) / (0.02 kg soil / kg diet) = 200,000. The HQ = 1,310 mg/kg / 200,000 mg/kg = 0.007.

Iron

Site soil concentration is 47,900 mg/kg. At 2% soil to diet ratio, a calculated SSL = (80 mg Fe / kg diet) / (0.02 kg soil / kg diet) = 4,000 mg/kg. The HQ = 47,900 mg/kg / 4,000 mg/kg = 10.

Iron	Nutrition requirement, chicken, turkey (http://www.epa.gov/ecotox/ecossl/pdf/ecossl_attachment_4-3.pdf)	40-80 mg/kg diet

Lead

The site soil concentration of lead is 4,500 mg/kg. The sediment concentration is 255 mg/kg.

Lead	Avian herbivore (dove)	Eco-SSL (mg/kg dw) (*Soil$_j$*) (Ecological Soil Screening Levels for Lead Interim Final OSWER Directive 9285.7-70)	33
Lead	Mallard	USFWS 1988, No deaths; no pathology; no significant accumulations of Pb; decrease in blood ALAD activity , and increase in blood Pb levels—both returned to normal within 3 weeks on Pb-free diet. (LOEL)	25 mg Pb / kg food

At a 2% soil to diet ratio, the calculated SSL = (25 mg Pb / kg diet) / (0.02 kg soil / kg diet) = 1,250 mg/kg. The HQ_{soil} = 4,500 mg/kg / 1,250 mg/kg = 4. The $HQ_{sediment}$ = 255 mg/kg / 1,250 mg/kg = 0.2.

Using the Eco-SSL, the HQ_{soil} = 4,500 mg/kg / 33 mg/kg = 100. The $HQ_{sediment}$ = 255 mg/kg / 33 mg/kg = 8.

Mercury

The site mercury soil concentration is 0.39 mg/kg. This is below the ORNL Ecological Benchmark value for avian diet and below the LD0 value quoted in USFWS's work.

Chemical	CASRN	ORNL ECW Avian Diet Screening Benchmark mg/kg
Mercury	7439976	10

Mercury Dietary	Coturnix (Japanese Quail)	USFWS 1987; LD0	32.0 mg Hg / kg diet

Using a 2% soil to diet ratio, the calculated SSL = (32 mg Hg / kg diet) / (0.02 kg soil / kg diet) = 1,600 mg/kg. The HQ = 0.39 mg/kg / 1,600 mg/kg = 0.0002.

Using the ECW SSL, the HQ = 0.39 mg/kg / 10 mg/kg = 0.04.

Molybdenum

Site sediment concentration is 13 mg/kg.

Molybdenum	Poultry	USFWS 1989; Mo dietary requirement	0.2 to 6 mg Mo / kg diet
Molybdenum	Poultry, chicks	USFWS 1989; LOAEL	200 mg Mo / kg diet

Using a 2% soil to diet ratio and the dietary requierment, the calculated SSL = (6 mg Mo / kg diet) / (0.02 kg soil / kg diet) = 300 mg/kg. The HQ = 13 mg/kg / 300 mg/kg = 0.04.

Using a 2% soil to diet ratio and the LOAEL, the calculated SSL = (200 mg Mo / kg diet) / (0.02 kg soil / kg diet) = 10,000 mg/kg. The HQ = 13 mg/kg / 10,000 mg/kg = 0.001.

Nickel

The site soil concentration of nickel is 42 mg/kg. No avian toxicity data available.

Selenium

Site soil concentrations are 3.96 mg/kg. "Among birds, it appears that domestic chickens are extremely sensitive to Se; reduced hatching of eggs was recorded at 7 to 9 ppm Se in feed (Ort and Latshaw 1978). Similar results were observed by El-Bergearmi et al. (1977) in Japanese quail at 6 and 12 ppm dietary selenite. . . .Poor [mallard] egg hatchability was recorded in the 25 ppm selenite group, but not in the 10 ppm selenite group; however, hatching percent was reduced in eggs of adults fed 10 ppm of Se as selenomethionine.” (USFWS 1985).

Using a 2% soil to diet ratio, the calculated SSL = (6 mg Se / kg diet) / (0.02 kg soil / kg diet) = 300 mg/kg. The HQ = 3.96 mg/kg / 300 mg/kg = 0.01.

Silver

Site soil concentration of silver is 18.1 mg/kg. No avian toxicity data.

Zinc

Site soil concentration is 3,590 mg/kg. Site sediment concentration is 1,370 mg/kg. Site surface water concentration is 10 ug/L.

Zinc	Nutrition requirement, chicken, quail, pheasant, fowl (http://www.epa.gov/ecotox/ecossl/pdf/ecossl_attachment_4-3.pdf)	25-100 mg/kg diet

Using a 2% soil to diet ratio, the calculated SSL = (100 mg Zn / kg diet) / (0.02 kg soil / kg diet) = 5,000 mg/kg.

The HQ_{soil} = (3,590 mg Zn / kg soil) / (5,000 mg Zn / kg soil) = 0.7.

The $HQ_{sediment}$ = (1,370 mg Zn / kg soil) / (5,000 mg Zn / kg soil) = 0.3

The Mallard HQ due to surface water ingestion can be calculated by dividing the amount of zinc ingested by the zinc nutritional requirement. The daily zinc ingestion is calculated by multiplying the water ingestion rate (0.058 g/g-day) times the body weight (1,225 g) times the zinc concentration in the water times conversion factors.

Daily zinc ingestion = (0.058 g/g-day) x (1,225 g) x (10ug Zn / L) x (L / 10^3 g) x (g / 10^6 ug)

= .... 7.105E-007 g / day

Nutritional Requirement

$$= (100 \text{ mg Zn / kg diet}) \times (0.23 \text{ g diet / g bw – day}) \times (1{,}225 \text{ g bw}) \times (\text{kg} / 10^6 \text{ mg})$$

= .... 0.028175 g / day

HQ = 7.105E-007 / 0.028175 = 0.00003

Table 6-7
Freshwater Semi-Aquatic Avian Herbivore Communities Cumulative Risk

Compound	Site Sediment Conc. (mg/kg)	Semi-Aquatic HQ	Background (mg/kg)
Chromium	273	0.3 to 10	3 to 1,040 SE
Cobalt	51	0.1 to 0.3	3 to 70 SE
Copper	82	0.2	2 to 664 SE
Lead	255	0.2 to 8	4 to 826 SE
Molybdenum	13	0.001 to 0.04	2 to 16 SE
Zinc	1,370	0.3	30 to 2,120 SE
Zinc (water)	10 ug/L	0.00003	
HI =		**1 to 20**	

Note:
SE = Southeast Alaska background range

Table 6-8
Terrestrial Avian Herbivore Communities - Cumulative Risk

Terrestrial Avian Herbivore Communities - Cumulative Risk			
Compound	**Site Soil Conc. (mg/kg)**	**HQ**	**Background (mg/kg)**
Antimony	12.3	no data	<1 to 8.8 NA
Cadmium	35	0.004 to 2	0.01 to 22 NA
Chromium	120	0.1 to 6	5 to 390 AK
Copper	350	0.9	3 to 810 AK
DRO + RRO	1,310	0.007	
Iron	47,900	10	5,500 to 100,000 AK
Lead	4,500	4 to 100	<4 to 310 AK
Mercury	0.39	0.0002 to 0.04	<0.01 to 4.6 NA
Nickel	42	no data	<3 to 320 AK
RRO	1,100	included with DRO	
Selenium	3.96	0.01	<0.1 to 4.3 AK
Silver	18.1	no data	0.13 to 0.77 NA
Zinc	3,590	0.7	<20 to 2,700 AK
HI =		**20 to 100**	

Notes:
AK = Alaskan background range
NA = North American background range

Mammalian Herbivores (northern bog lemming and long-tailed vole)

Exposure to the site contaminates for the terrestrial and semi-aquatic mammalian herbivores is primarily through the site soils and sediments with secondary exposure through surface water.

Long-tailed vole (similar to the meadow vole) (EPA 1993):

"The long-tailed vole (Microtus longicaudus) (tail 5 to 9 cm) is slightly larger (11 to 14 cm) than the meadow vole. It is found in the western United States and Canada to Alaska and lives along streambanks, in mountain meadows, sometimes in dry situations, and in brushy areas during winter. In addition to grasses and bark, it feeds on bulbs. It nests above ground in winter and burrows in summer."

Meadow Vole statistics:

- Body weight: 17 to 40 grams
- Food ingestion rate: 0.30 – 0.35 g/g-d
- Water ingestion rate: 0.14 to 0.21 g/g-d
- Home Range: 0.0002 to 0.083 ha (= 0.0005 to 0.2 acres)
- Population Density: 2 – 549 /ha (= 0.8 to 222 / acre)
- Estimated % Soil in Diet: 2.4

Northern bog lemming (*Synaptomys borealis*):

"*S. borealis* primarily live in burrows among sedges and grasses (Wilson et al, 1999). They can be found where moisture levels are high and growth of sedges and grasses are sufficient to provide cover as well as act as their food supply (Wilson et al, 1999). During the snow free months this species is active both above and below ground, though most activity at this time occurs below ground to avoid predation by the high diversity of mammalian and avian predators (Wilson et al, 1999). During the winter months this risk of predation is lowered and most activity occurs above ground. Lemmings construct globular nests composed of mosses, grasses, and sedges at ground level just beneath the snow in the winter months and build their nests underground in the summer months

(Banfield, 1974). They remain active year-round." (Nicholas, D. 2001. "Synaptomys borealis" (ADW 2004).

Northern bog lemming statistics:

- Body weight: 23 to 34 grams
- Home Range: < 1 acre
- Population Density: up to 36 per acre (DAI 2004)

The toxicity reference value (TRV) is similar to the reference dose for human risk. Soil screening levels (SSL) are calculated according to the wildlife exposure models and parameters. TRV's are given in mg of contaminant / kg body weight (bw) / day.

$$\text{SSL} = \frac{\text{TRV (mg / kg of bw / day)} \;/\; \text{(1,000 g / kg)}}{\text{Food ingestion rate (g food / g bw – day)} \times \text{Estimated \% soil in diet (g / g)}}$$

SSL =   mg contaminant / kg soil

<u>Antimony</u>

Site soil concentration: 12.3 mg/kg,

ORNL (http://risk.lsd.ornl.gov/cgi-bin/eco/bench_select)		
Chemical	**CASRN**	**Eco-SSL Mammalian Soil Screening Benchmark mg/kg**
Antimony	7440360	21

Ecological Soil Screening Levels for Antimony Interim Final OSWER Directive 9285.7-61		
Mammalian herbivore (vole)	Eco-SSL	3.2 mg/kg dry wt soil
Short-tailed vole (*Microtus agrestis)*	NOAEL; 60 days	60.9(Dose: mg/kg bw -day)
rat, mouse, vole - highest bounded NOAEL below the lowest bounded LOAEL	TRV	0.06 mg antimony/kg bw/day

$$\text{SSL} = \frac{\text{(0.06 mg Sb / 1000 g bw-day)}}{\text{(0.33 g food/g bw-day)} \times \text{(0.024 g soil / g food)}} = \text{0.0076 mg Sb / g soil}$$

$$= \text{7.6 mg Sb / kg soil}$$

$$SSL = \frac{(60.9 \text{ mg Sb} / 1000 \text{ g bw-day})}{(0.33 \text{ g food/g bw-day}) \times (0.024 \text{ g soil} / \text{g food})} = 7.7 \text{ mg Sb} / \text{g soil}$$

$$= 7700 \text{ mg Sb} / \text{kg soil}$$

Depending on the study selected, the HQ can vary by three orders of magnitude.

HQ = (12.3 mg/kg) / (7,700 mg/kg) = 0.002

HQ = (12.3 mg/kg) / (3.2 mg/kg) = 4

Cadmium

Site soil concentration: 35 mg/kg.

Ecological Soil Screening Levels for Cadmium Interim Final OSWER Directive 9285.7-65		
Mammalian herbivore (vole)	Eco-SSL	12 mg/kg dry wt soil
Bank vole (*Clethrionomys glareolus*)	NOAEL	1.5, 1.87, 4.99, 6.29, 10.5, 11.5, 12.6 (Dose: mg/kg -day)
Bank vole (*Clethrionomys glareolus*)	LOAEL	1.87, 4.99, 5, 12.6, 35.3 (Dose: mg/kg -day)
Vole (*Microtus pennsylvanicus*)	NOAEL; 40 days	0.179, 0.478, 0.579 (Dose: mg/kg-day)
Vole - highest NOAEL below the lowest LOAEL	TRV	1.5 mg cadmium/kg bw/day

Using the highest NOAEL (1.5) below the lowest LOAEL (1.87), a SSL can be calculated.

$$SSL = \frac{(1.5 \text{ mg Cd} / 1000 \text{ g bw-day})}{(0.33 \text{ g food/g bw-day}) \times (0.024 \text{ g soil} / \text{g food})} = 0.19 \text{ mg Cd} / \text{g soil}$$

$$= 190 \text{ mg Cd} / \text{kg soil}$$

The calculated HQs can vary an order of magnitude.

$HQ_{Eco\text{-}SSL}$ = (35 mg/kg) / (12 mg/kg) = 3

$HQ_{calc\text{-}SSL}$ = (35 mg/kg) / (190 mg/kg) = 0.2

Chromium

Site soil concentration is 120 mg/kg. Site sediment concentration is 273 mg/kg.

ORNL (http://risk.lsd.ornl.gov/cgi-bin/eco/bench_select)		
Chemical	**CASRN**	**Eco-SSL Mammalian Soil Screening Benchmark mg/kg**
Chromium III	7440473	360

Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs); OSWER Directive 92857-55, Jaunary 2004		
Chemical	**CASRN**	**Nutrition Requirements, mice and rats (mg/kg diet dw)**
Chromium III	7440473	5

Using the nutritional requirement as a RfD a conservative SSL can be calculated.

$$SSL = \frac{(5 \text{ mg Cr} / 1000 \text{ g bw-day})}{(0.33 \text{ g food/g bw-day}) \times (0.024 \text{ g soil / g food})} = 0.63 \text{ mg Cr / g soil}$$

$$= 630 \text{ mg Cr / kg soil}$$

$HQ_{Eco\text{-}SSL\text{-}soil}$ = (120 mg/kg) / (360 mg/kg) = 0.3

$HQ_{calc\text{-}SSL\text{-}soil}$ = (120 mg/kg) / (630 mg/kg) = 0.2

$HQ_{Eco\text{-}SSL\text{-}sediment}$ = (273 mg/kg) / (360 mg/kg) = 0.8

$HQ_{calc\text{-}SSL\text{-}sediment}$ = (273 mg/kg) / (630 mg/kg) = 0.4

Cobalt

Site sediment concentration is 51 mg/kg.

ORNL (http://risk.lsd.ornl.gov/cgi-bin/eco/bench_select)		
Chemical	**CASRN**	**Eco-SSL Mammalian Soil Screening Benchmark mg/kg**
Cobalt	7440484	340

Ecological Soil Screening Levels for Cobalt Interim Final OSWER Directive 9285.7-67		
Mammalian herbivore (vole)	Eco-SSL	720 mg/kg dry wt soil

HQ_{ORNL} = (51 mg/kg) / (340 mg/kg) = 0.2

HQ_{OSWER} = (51 mg/kg) / (720 mg/kg) = 0.07

Copper

Site soil concentration is 350 mg/kg. Site sediment concentration is 82 mg/kg.

"Risk Management Levels for Metals at BLM Mining Sites," Technical Note 390, Dec 1996		
Deer Mouse	Risk Management Level for Metals in Soils	640 mg/kg soil

HQ_{soil} = (350 mg/kg) / (640 mg/kg) = 0.5

$HQ_{sediment}$ = (82 mg/kg) / (640 mg/kg) = 0.1

DRO and RRO

Site soil concentrations are 210 mg/kg for DRO and 1,100 mg/kg for RRO. Total = 1,310 mg/kg.

Petroleum mixtures used as surrogates.

"Development of Fraction Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons (TPH)," Total Petroleum Hydrocarbon Criteria Working Group Series, Vol 4, 1997			
Naphthalene/ methylnaphthalenes	Rats	NOEL LOAEL	<300 mg/kg/day = 300 mg/kg/day
Dearomatized aliphatic; $C_9 – C_{12}$ isoparaffins/n-alkanes/ naphthenes	Rats	LOAEL	500 mg/kg/day
Dearomatized aliphatic; $C_{10} – C_{13}$ isoparaffins/n-alkanes/ naphthenes	Rats	NOAEL	100 mg/kg/day

Using the highest NOAEL below the lowest LOAEL, the calculated SSL is:

$$SSL = \frac{(100 \text{ mg POL} / 1000 \text{ g bw-day})}{(0.33 \text{ g food/g bw-day}) \times (0.024 \text{ g soil / g food})} = 13 \text{ mg POL / g soil}$$

$$= 13{,}000 \text{ mg POL / kg soil}$$

HQ = (1,310 mg/kg) / (13,000 mg/kg) = 0.1

Iron

Site soil concentration for iron is 47,900 mg/kg.

Iron toxicity on mammalian herbivores such as would be found onsite is scarce. Iron nutrient requirements for cattle, pigs and sheep range from 25 to 80 mg Fe per kg of diet.

At 2.4% soil to diet ratio, iron ingestion would be 47,900 mg/kg x 2.4% = 11,500 mg Fe / kg diet. This is three orders of magnitude larger than the nutritional requirement.

Using the nutritional requirement as a RfD a conservative SSL can be calculated.

SSL = (80 mg Fe / kg diet-day) / (0.024 kg soil / kg diet) = 3,300 mg Fe / kg soil

HQ = (47,900 mg/kg) / (3,300 mg/kg) = 10

Lead

Site soil concentration is 4,500 mg/kg. Site sediment concentration is 255 mg/kg.

"Risk Management Levels for Metals at BLM Mining Sites," Technical Note 390, Dec 1996		
Deer Mouse	Risk Management Level for Metals in Soils	142 mg Pb/kg soil

Ecological Soil Screening Levels for Lead Interim Final OSWER Directive 9285.7-70		
Mammalian herbivore (vole)	Eco-SSL	340 mg/kg dry wt soil
Mouse (*Mus musculus*)	NOAEL	3.5, 4.00, 13.7, 16.3, 46.4, 101, 136, 137, 139, 144, 187, 202, 362, 379, 404, 534, 632, 1260 (Dose: mg/kg -day)
Mouse (*Mus musculus*)	LOAEL	2.0, 3.1, 3.39, 3.62, 5.50, 8.00, 16.6, 27.3, 46.4, 78.6, 99.8, 137, 139, 154, 163, 202, 373, 381, 404, 437, 506, 635, 646, 670, 748, 762, 775, 1264, 1360, 1370, 1440, 1990, 2530, 3630 (Dose: mg/kg -day)
Bank vole (*Clethrionomys glareolus*)	NOAEL	1.10, 34.6 (Dose: mg/kg-day)
Bank vole (*Clethrionomys glareolus*)	LOAEL	34.6 (Dose: mg/kg-day)
Mouse, Vole - highest NOAEL below the lowest LOAEL	TRV	1.1 mg lead/kg bw/day

Using the highest NOAEL below the lowest LOAEL, a SSL can be calculated.

$$SSL = \frac{(1.1 \text{ mg Pb} / 1000 \text{ g bw-day})}{(0.33 \text{ g food/g bw-day}) \times (0.024 \text{ g soil} / \text{g food})} = 0.14 \text{ mg Pb} / \text{g soil}$$

$$= 140 \text{ mg Pb} / \text{kg soil}$$

$HQ_{calc\text{-}SSL\text{-}soil}$ = (4,500 mg/kg) / (140 mg/kg) = 30

$HQ_{Eco\text{-}SSL\text{-}soil}$ = (4,500 mg/kg) / (340 mg/kg) = 10

$HQ_{calc\text{-}SSL\text{-}sediment}$ = (255 mg/kg) / (140 mg/kg) = 2

$HQ_{Eco\text{-}SSL\text{-}sediment}$ = (255 mg/kg) / (340 mg/kg) = 0.8

Mercury

The site soil concentration is 0.39 mg/kg.

"Risk Management Levels for Metals at BLM Mining Sites," Technical Note 390, Dec 1996		
Deer Mouse	Risk Management Level for Metals in Soils	2 mg Hg/kg soil

HQ = (0.39 mg/kg) / (2 mg/kg) = 0.2

Molybdenum

The site sediment concentration is 13 mg/kg.

"Molybdenum is beneficial and perhaps essential to adequate mammalian nutrition; moreover, it can protect against poisoning by copper or mercury, and may be useful in controlling cancer. . . Aside from cattle and sheep, all evidence indicates that other mammals are comparatively tolerant of high dietary intakes of Mo, including horses, pigs, small laboratory animals, and mammalian wildlife . . . " (USFWS 1989)

USFWS 1989. " Molybdenum hazards to fish, wildlife, and invertebrates: a synoptic review." US Fish & Wildlife Service, Biological Report 85 (1:19), August 1989.		
Guinea pig, Cavia sp.	LD0	80 mg Mo / kg bw

$$SSL = \frac{(80 \text{ mg Mo} / 1000 \text{ g bw-day})}{(0.33 \text{ g food/g bw-day}) \times (0.024 \text{ g soil / g food})} = 10 \text{ mg Mo / g soil}$$

$$= 10000 \text{ mg Mo / kg soil}$$

HQ = (13 mg/kg) / (10,000 mg/kg) = 0.001

Nickel

The site soil concentration of Ni is 42 mg/kg.

"Draft Toxicological Profile For Nickel," U.S. Department Of Health And Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, September 2003.		
Mouse	NOAEL	1.1, 1.2, 44, 45.3, 80, 90.6 mg/kg/day
Mouse	LOAEL	2.2, 2.5, 20.3, 44, 108 mg/kg/day

Using the highest NOAEL below the lowest LOAEL, the SSL is:

$$SSL = \frac{(1.2 \text{ mg Ni} / 1000 \text{ g bw-day})}{(0.33 \text{ g food/g bw-day}) \times (0.024 \text{ g soil / g food})} = 0.15 \text{ mg Ni / g soil}$$

$$= 150 \text{ mg Ni / kg soil}$$

HQ = (42 mg/kg) / (150 mg/kg) = 0.3

Selenium

The site soil concentration is 3.96 mg/kg.

"Toxicological Profile For Selenium," U.S. Department Of Health And Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, September 2003.		
Mouse	NOAEL	0.17 to 7.17 mg/kg/day
Mouse	LOAEL	0.173 to 9.4 mg/kg/day

Using the highest NOAEL below the lowest LOAEL, the SSL is:

$$SSL = \frac{(0.17 \text{ mg Se} / 1000 \text{ g bw-day})}{(0.33 \text{ g food/g bw-day}) \times (0.024 \text{ g soil / g food})} = 0.02 \text{ mg Se / g soil}$$

$$= 20 \text{ mg Se / kg soil}$$

HQ = (3.96 mg/kg) / (20 mg/kg) = 0.2

Silver

The site soil concentration is 18.1 mg/kg.

"Toxicological Profile For Silver," U.S. Department Of Health And Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, December 1990.		
Mouse	LOAEL	18.1 mg/kg/day

$$SSL = \frac{(18.1 \text{ mg Ag} / 1000 \text{ g bw-day})}{(0.33 \text{ g food/g bw-day}) \times (0.024 \text{ g soil / g food})} = 2.3 \text{ mg Ag / g soil}$$

$$= 2{,}300 \text{ mg Ag / kg soil}$$

HQ = (18.1 mg/kg) / (2,300 mg/kg) = 0.008

Zinc

The site soil concentration is 3,590 mg/kg. The site sediment concentration is 1,370 mg/kg. The site surface water concentration is 10 ug/L.

"Zinc is relatively nontoxic in mammals. A wide margin of safety exists between normal intakes and those producing deleterious effects." (USFWS 1993)

"Risk Management Levels for Metals at BLM Mining Sites," Technical Note 390, Dec 1996		
Deer Mouse	Risk Management Level for Metals in Soils	419 mg Zn/kg soil

USFWS, R. 1993. " Zinc hazards to fish, wildlife, and invertebrates: a synoptic review." US Fish & Wildlife Service, Biological Report 10, April 1993.		
Domestic mouse, Mus sp.	LD0	104 to 109 mg Zn / kg bw

"Draft Toxicological Profile For Zinc," U.S. Department Of Health And Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, September 2003.		
Mouse	NOAEL	6.5, 20.8 to 1110 mg/kg/day
Mouse	LOAEL	68 to 1110 mg/kg/day

Using the lowest LOAEL, which has higher NOAELs, the SSL is:

$$SSL = \frac{(68 \text{ mg Zn} / 1000 \text{ g bw-day})}{(0.33 \text{ g food/g bw-day}) \times (0.024 \text{ g soil / g food})} = 8.6 \text{ mg Zn / g soil}$$

= 8,600 mg Zn / kg soil

$HQ_{calc\text{-}SSL\text{-}soil}$ = (3,590 mg/kg) / (8,600 mg/kg) = 0.4

$HQ_{calc\text{-}SSL\text{-}sediment}$ = (1,370 mg/kg) / (8,600 mg/kg) = 0.2

$HQ_{BLM\text{-}soil}$ = (3,590 mg/kg) / (419 mg/kg) = 9

$HQ_{BLM\text{-}sediment}$ = (1,370 mg/kg) / (419 mg/kg) = 3

The lemming HQ due to surface water ingestion can be calculated by dividing the amount of zinc ingested by the zinc LOAEL times the lemming body weight. The daily zinc ingestion is calculated by multiplying the water ingestion rate (use 0.2 g/g-day) times the body weight (30 g) times the zinc concentration in the water times conversion factors.

Daily zinc ingestion = (0.2 g/g-day) x (30 g) x (10 ug Zn / L) x (L / 10^3 g) x (g / 10^6 ug)

= 6E-008 g / day

$$HQ = \frac{6E\text{-}008\ g/day}{(68\ mg\ Zn / 1000\ g\ bw\text{-}day) \times (30\ g) \times (g / 1{,}000\ mg)}$$

= 0.00003

Table 6-9
Freshwater Semi-Aquatic Mammalian Herbivore Communities - Cumulative Risk

Freshwater Semi-Aquatic Mammalian Herbivore Communities - Cumulative Risk			
Compound	**Site Sediment Conc. (mg/kg)**	**Semi-Aquatic HQ**	**Background (mg/kg)**
Chromium	273	0.4 to 0.8	3 to 1,040 SE
Cobalt	51	0.07 to 0.2	3 to 70 SE
Copper	82	0.1	2 to 664 SE
Lead	255	0.8 to 2	4 to 826 SE
Molybdenum	13	0.001	2 to 16 SE
Zinc	1,370	0.2 to 3	30 to 2,120 SE
Zinc (water)	10 ug/L	0.00003	
HI =		**2 to 6**	

Note:
SE = Southeast Alaska background range

Table 6-10
Terrestrial Mammalian Herbivore Communities - Cumulative Risk

Terrestrial Mammalian Herbivore Communities - Cumulative Risk			
Compound	**Site Soil Conc. (mg/kg)**	**HQ**	**Background (mg/kg)**
Antimony	12.3	0.002 to 4	<1 to 8.8 NA
Cadmium	35	0.2 to 3	0.01 to 22 NA
Chromium	120	0.2 to 0.3	5 to 390 AK
Copper	350	0.5	3 to 810 AK
DRO + RRO	1,310	0.1	
Iron	47,900	10	5,500 to 100,000 AK
Lead	4,500	10 to 30	<4 to 310 AK
Mercury	0.39	0.2	<0.01 to 4.6 NA
Nickel	42	0.3	<3 to 320 AK
RRO	1,100	included with DRO	
Selenium	3.96	0.2	<0.1 to 4.3 AK
Silver	18.1	0.008	0.13 to 0.77 NA
Zinc	3,590	0.4 to 9	<20 to 2,700 AK
HI =		**20 to 60**	

Notes:
AK = Alaskan background range
NA = North American background range

6.10 ECOLOGICAL RISKS – SECONDARY CONSUMERS (TROPHIC LEVEL 3)

Bioaccumulation Factors for COPC

EPA, "Ecological Soil Screening Levels for **Antimony**," Interim Final, OSWER Directive 9285.7-61, November 2003.			
Surrogate Receptor Group	Soil ingestion as a proportion of diet	Soil-to-biota bioaccumulation factor (BAF)	Diet to biota BAF
Mammalian ground insectivore (shrew)	0.03	1	NA
Mammalian carnivore (weasel)	0.04	1	0.001

ATSDR, "Toxicological Profile For **Cadmium**," U.S. Department Of Health And Human Services Public Health Service, Agency for Toxic Substances and Disease Registry, July 1999.	
Invertebrates	113 to 18000
Fresh water aquatic organisms	3 to 4190
Saltwater aquatic organisms	5 to 3160

"The data indicate that cadmium bioaccumulates in all levels of the food chain. Cadmium accumulation has been reported in grasses and food crops, and in earthworms, poultry, cattle, horses, and wildlife (Alloway et al. 1990; Beyer et al. 1987; Gochfeld and Burger 1982; Kalac et al. 1996; Munshower 1977; Ornes and Sajwan 1993; Rutzke et al. 1993; Sileo and Beyer 1985; Vos et al. 1990). The metal burden of a crop depends on uptake by the root system, direct foliar uptake and translocation within the plant, and surface deposition of particulate matter (Nwosu et al. 1995). In general, cadmium accumulates in the leaves of plants and, therefore, is more of a risk in leafy vegetables grown in contaminated soil than in seed or root crops (Alloway et al. 1990). He and Singh (1994) report that, for plants grown in the same soil, accumulation of cadmium decreased in the order: leafy vegetables > root vegetables > grain crops."

ATSDR, "Toxicological Profile For **Chromium**," U.S. Department Of Health And Human Services Public Health Service, Agency for Toxic Substances and Disease Registry, September 2000.
The bioconcentration factor (BCF) for chromium(VI) in rainbow trout (*Salmo gairdneri*) is 1. In bottomfeeder bivalves, such as the oyster (*Crassostrea virginica*), blue mussel (*Mytilus edulis*), and soft shell clam (*Mya arenaria*), the BCF values for chromium(III) and chromium(VI) may range from 86 to 192 (EPA 1980, 1984a; Fishbein 1981; Schmidt and Andren 1984). The bioavailability of chromium(III) to freshwater invertebrates (*Daphnia pulex*) decreased with the addition of humic acid (Ramelow et al. 1989). This decrease in bioavailability was attributed to lower availability of the free form of the metal due to its complexation with humic acid. Based on this information, chromium is not expected to biomagnify in the aquatic food chain. Although higher concentrations of chromium have been reported in plants growing in high chromium-containing soils (e.g., soil near ore deposits or chromium-emitting industries and soil fertilized by sewage sludge) compared with plants growing in normal soils, most of the increased uptake in plants is retained in roots, and only a small fraction is translocated in the aboveground part of edible plants (Cary 1982; WHO 1988). Therefore, bioaccumulation of chromium from soil to above-ground parts of plants is unlikely (Petruzzelli et al. 1987). There is no indication of biomagnification of chromium along the terrestrial food chain (soil-plant-animal) (Cary 1982).

EPA, "Ecological Soil Screening Levels for **Cobalt**," Interim Final, OSWER Directive 9285.7-67, November 2003.			
Surrogate Receptor Group	Soil ingestion as a proportion of diet	Soil-to-biota bioaccumulation factor (BAF)	Diet to biota BAF
Avian herbivore (dove)	0.16	0.0075	NA
Avian ground insectivore (woodcock)	0.12	0.122	NA
Avian carnivore (hawk)	0.05	--	NA
Mammalian herbivore (vole)	0.029	0.0075	NA
Mammalian ground insectivore (shrew)	0.03	0.122	NA

ATSDR, "Draft Toxicological Profile For **Cobalt**," U.S. Department Of Health And Human Services Public Health Service, Agency for Toxic Substances and Disease Registry, September 2001.
When plants grow in highly contaminated soil, they accumulate very small amounts of cobalt, especially in the parts of the plant that you eat most often like the fruit, grain, and seeds. While animals that eat these plants will accumulate cobalt, cobalt is not known to biomagnify (produce increasingly higher concentrations) up the food chain. Therefore,

vegetables, fruits, fish, and meat that you consume will generally not contain high amounts of cobalt. Cobalt is an essential element, required for good health in animals and humans, and therefore, it is important that foodstuffs contain adequate quantities of cobalt.

ATSDR, "Draft Toxicological Profile For **Copper**," U.S. Department Of Health And Human Services Public Health Service, Agency for Toxic Substances and Disease Registry, September 2002.
The bioconcentration factor (BCF) of copper in fish obtained in field studies is 10–100, indicating a low potential for bioconcentration. The BCF is higher in molluscs, especially oysters, where it may reach 30,000 (Perwak et al. 1980). This may be due to the fact that they are filter feeders, and copper concentrations are higher in particulates than in water. However, there is abundant evidence that there is no biomagnification of copper in the food chain (Perwak et al. 1980). A study was conducted with white suckers and bullheads, both bottom-feeding fish, in two acidic Adirondack, New York, lakes (Heit and Klusek 1985). These lakes were known to have received elevated loadings of copper, but the suckers and bullhead had average copper levels of only 0.85 and 1.2 ppm (dry weight) in their muscle tissue. The biomagnification ratio (the concentration of copper in the fish to that in potential food) was <l, indicating no biomagnification in the food chain. Similarly, the copper content of muscle tissue of fish from copper-contaminated lakes near Sudbury, Ontario, did not differ significantly from that of fish in lakes far from this source (Bradley and Morris 1986). Diks and Allen (1983) added copper to four sediment/water systems and studied the distribution of copper among five geochemical phases. The investigators then attempted to correlate the concentration in each phase with the copper uptake by tubificid worms. Only copper extracted from the manganese oxide/easily-reducible phase correlated with the copper content of worms at the 95% confidence level. No evidence of bioaccumulation was obtained from a study of pollutant concentrations in the muscle and livers of 10 mammal species in Donana National Park in Spain (Hernandez et al. 1985). The animals were classified into three categories (herbivorous, omnivorous, and carnivorous) to ascertain if the pollutants were showing biomagnification in higher trophic levels of animals. No evidence of copper biomagnification in the food chain was observed. A study of heavy metals in cottontail rabbits on mined land treated with sewage sludge showed that, while the concentration of copper in surface soil was 130% higher than in a control area, the elevation was relatively little in foliar samples. No significant increase in copper was observed in rabbit muscle, femur, kidney, or liver, indicating that copper was not bioaccumulating in the food chain (Dressler et al. 1986). Even at the lowest levels of the food chain, there is little evidence of copper bioaccumulation. In a study of earthworms and soil from 20 diverse sites in Maryland, Pennsylvania, and Virginia, copper concentrations in earthworms poorly correlated with that in soil (Beyer and Cromartie 1987).

ATSDR, "Toxicological Profile For **Polycyclic Aromatic Hydrocarbons**," U.S. Department Of Health And Human Services Public Health Service, Agency for Toxic Substances and Disease Registry, August 1995.
Although PAHs are accumulated in terrestrial and aquatic plants, fish, and invertebrates, many animals are able to metabolize and eliminate these compounds. Bioconcentration factors (BCFs), which express the concentration in tissues compared to concentration in media, for fish and crustaceans are frequently in the 10-10,000 range. Food chain uptake does not appear to be a major source of exposure to PAHs for aquatic animals.

ATSDR, "Technical Report for Fuel Oils," U.S. Department Of Health And Human Services Public Health Service, Agency for Toxic Substances and Disease Registry, November 29, 1993.
Aquatic organisms are known to bioconcentrate hydrocarbons. Mussels (Mytilis edulis) exposed t a small spill (approximately 6,000) liters) of fuel oil no. 2 were followed for 86 days post-spill to assess the uptake and retention of the fuel oil components. Alkane, cycloalkanes, and aromatic concentrations increased

significantly in the mussel tissue the 1st day; however, by day 5 post-spill, the n-alkanes were barely detectable, and by day 21, the concentration of the unresolved complex mixture of alkanes-cycloalkanes was 30% of the day 1 concentrations. Concentrations of lower molecular weight aromatics (e.g., naphthalenes) decreased before the higher molecular weight aromatics (e.g., phenanthrenes). The biological half-lives of some fuel oil no. 2 components in mussels were as follows: n-C_{16} – 0.2 days; n-C_{23} – 0.8 days; C-2 naphthalene – 0.9 days; C-3 naphthalene – 1.5 days; phenanthrene – 2.1 days; and unresolved complex mixture – 2.8 to 3.9 days. . . . When shrimp, clams, and fish were exposed to the water-soluble fraction of fuel oil no. 2, shrimp rapidly accumulated total naphthalenes for an hour then released them, clams accumulated the naphthalenes at a slower but constant rate for 24 hours, and the fish accumulated the naphthalenes very rapidly during 2 hours of exposure; concentrations of the accumulated naphthalenes in all three species were at least an order of magnitude than the concentration of naphthalenes in the exposure water. All three species rapidly released the accumulated naphthalenes when placed in oil-free water with low or undetectable levels present in their tissue by 14 days.

EPA EcoTox Database, accessed 29 April 2004; **Iron**	Brown shrimp	0< BCF < 1200
Wepener, et al, "Uptake and distribution of a copper, iron and zinc mixture in gill, liver and plasma of a freshwater teleost, Tilapia sparrmanii," January 2001 <http://www.wrc.org.za/publications/watersa/2001/January/1308.pdf>	Tilapia sparramanii	5 < blood BCF < 23
(UKMSAC 2004).	Marine organisms accumulate iron but also rapidly excrete iron in clean water conditions. Normally, tissue concentrations of iron are related to the water and sediment concentrations, but there is considerable variability. Tissue concentrations vary seasonally, being lower in winter and spring than in summer and autumn and furthermore tissue and shell concentrations increase with increasing salinity (Mance and Campbell 1988). The bioaccumulation of iron by marine organisms does not appear to pose a hazard to higher trophic levels.	

ATSDR, "Toxicological Profile For **Lead**," U.S. Department Of Health And Human Services Public Health Service, Agency for Toxic Substances and Disease Registry, July 1999.
Lead is not biomagnified in aquatic or terrestrial food chains. It may contaminate terrestrial plants as a result of atmospheric deposition and uptake from soil, and animals as a result of inhalation of contaminated ambient air or ingestion of contaminated plants. Older organisms tend to contain the greatest body burdens of lead. In aquatic organisms, lead concentrations are usually highest in benthic organisms and algae, and lowest in upper trophic level predators (e.g., carnivorous fish). Exposure of a freshwater fish to several sublethal concentrations of lead for a period of 30 days showed significant accumulation of lead in the blood and tissues. The lead accumulation in tissues was found to increase with lead in water up to a concentration of 5 mg/L (µg/mL); at concentrations of 10 and 20 mg/L, the lead accumulation in the tissues, although indicating an increase, was not proportional to the lead concentration in water (Tulasi et al. 1992). High bioconcentration factors (BCFs) were determined in studies using oysters (6,600 for Crassostrea virginica), freshwater algae (92,000 for Senenastrum capricornutum) and rainbow trout (726 for Salmo gairdneri). However, most median BCF values for aquatic biota are significantly lower: 42 for fish, 536 for oysters, 500 for insects, 725 for algae, and 2,570 for mussels (USFWS 1988).

ATSDR, "Toxicological Profile For **Mercury**," U.S. Department Of Health And Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, March 1999.	
Rainbow trout	1800 Mercuric chloride BAF
Fathead minnow	4994 Mercuric chloride BAF

Molybdenum – no data.

ATSDR, "Toxicological Profile For **Nickel**," U.S. Department Of Health And Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, September 2003.
It has been reported that nickel is not accumulated in significant amounts by aquatic organisms (Birge and Black 1980; Zaroogian and Johnson 1984). The concentration of nickel in a major carnivorous fish in New York state, the lake trout, was the lowest, and the concentration did not increase appreciably with the age of the fish (Birge and Black 1980). The mean bioconcentration factor (BCF) for three carnivorous fish was 36. The concentration of nickel in mussels and oysters treated with 5 µg nickel/kg of seawater for 12 weeks averaged 9.62 and 12.96 µg nickel/g, respectively, on a dry weight basis (Zaroogian and Johnson 1984). When these data are adjusted for controls and the nickel concentration in tissue is expressed on a wet weight basis, the BCF for the mussels and oysters is .100. After 2 weeks in flowing seawater, 58 and 38% of the tissue nickel was lost from the mussel and oyster, respectively. No significant loss of nickel occurred during the remainder of the 28-week depuration period. In the work of McGeer et al. (2003), bioconcentration factors (BCF) for nickel in various aquatic organisms (e.g., algae, arthropods, mollusks, and fish) was assessed based on whole-body metal concentrations and exposure concentrations that were obtained from the literature. For exposure concentrations within the range of 5–50 µg/L nickel in water, mean BCF values of 106±53 (1 standard deviation [SD]) were obtained. When the authors also included data for exposure concentrations outside the range of 5–50 µg/L, a BCF value of 157±135 was obtained. The authors noted that the BCF values were inversely correlated with the exposure concentrations, where the highest BCF values were obtained at the lowest exposure concentrations. There was no evidence that nickel biomagnifies in aquatic food webs and, in fact, there is evidence to indicate that the nickel concentrations in organisms decrease with increasing trophic level (McGeer et al. 2003; Suedel et al. 1994). Uptake and accumulation of nickel into various plant species is known to occur. For example, Peralta-Videa et al. (2002) report the accumulation of nickel in alfalfa grown from soils contaminated with a mixture of four metals (e.g., Cd(II), Cu(II), Ni(II), and Zn(II)) at a loading of 50 mg/kg for each metal. Concentration ratios of nickel in plant versus soil (based on dry weights) ranged between 22 and 26 over a pH range of 4.5–7.1. As with most plant species that hyperaccumulate metals, the alfalfa actively removes and translocates heavy metals, like nickel, from the roots to the shoots. Two studies concerning levels in voles and rabbits living on sludge-amended land did not indicate any accumulation of nickel in these herbivores or in the plants they fed upon (Alberici et al. 1989; Dressler et al. 1986). The lack of significant bioaccumulation of nickel in aquatic organisms, voles, and rabbits indicates that nickel is not biomagnified in the food chain.

ATSDR, "Toxicological Profile For **Selenium**," U.S. Department Of Health And Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, September 2003.
Selenium in an aquatic environment is bioaccumulated by aquatic organisms (Chau and Riley 1965; Ohlendorf et al. 1986a; Rudd and Turner 1983a; Saiki and Lowe 1987). Lemly (1985) has reported bioconcentration factors (BCFs) of 150–1,850 and bioaccumulation factors (BAFs) of 1,746–3,975 for selenium in freshwater. Maier et al. (1988) estimated selenium BAFs for algae to range from 100 to 2,600, and Besser et al. (1993)

estimated BCFs of 16,000 for algae, 200,000 for daphnids, and 5,000 for bluegills from exposures to 1 µg/L selenomethionine. Selenite was more concentrated than selenate for algae and daphnids, whereas bluegills concentrated both inorganic species about equally (Besser et al. 1993). Selenium accumulation from selenomethionine occurred more readily than from selenite or selenate (Besser et al. 1989).

INCHEM 2004
The ability to accumulate dissolved silver varies widely between species. Some reported bioconcentration factors for marine organisms (calculated as milligrams of silver per kilogram fresh weight organism divided by milligrams of silver per litre of medium) are 210 in diatoms, 240 in brown algae, 330 in mussels, 2300 in scallops, and 18 700 in oysters, whereas bioconcentration factors for freshwater organisms have been reported to range from negligible in bluegills (*Lepomis macrochirus*) to 60 in daphnids; these values represent uptake of bioavailable silver in laboratory experiments. Laboratory studies with the less toxic silver compounds, such as silver sulfide and silver chloride, reveal that accumulation of silver does not necessarily lead to adverse effects. At concentrations normally encountered in the environment, food-chain biomagnification of silver in aquatic systems is unlikely. In general, accumulation of silver by terrestrial plants from soils is low, even if the soil is amended with silver-containing sewage sludge or the plants are grown on tailings from silver mines, where silver accumulates mainly in the root systems. No data were found on effects of silver on wild birds or mammals.

MELP 2004				
bcf	exposure duration	silver nitrate in the water	fish species	tissues
11	120 days	1 mg/L	*Micropterus salmoides* -largemouth bass	fillet
19	120 days	10 mg/L	*Micropterus salmoides* -largemouth bass	fillet
15	180 days	10 mg/L	*Lepomis macrochirus* -bluegill sunfish	whole
150	180 days	100 mg/L	*Lepomis macrochirus* -bluegill sunfish	whole

ATSDR, "Draft Toxicological Profile For **Zinc**," U.S. Department Of Health And Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, September 2003.
Zinc is an essential nutrient and occurs in the tissues of organisms, even at normal ambient water and soil concentrations. Zinc can accumulate in freshwater animals at 51–1,130 times the concentration present in the water (EPA 1987c). Microcosm studies indicate, in general, that zinc does not biomagnify through food chains (Biddinger and Gloss 1984; EPA 1979d; Hegstrom and West 1989). Furthermore, although zinc actively bioaccumulates in aquatic systems, biota appears to represent a relatively minor sink compared to sediments. Steady-state zinc bioconcentration factors (BCFs) for 12 aquatic species range from 4 to 24,000 (EPA 1987c). Crustaceans and fish can accumulate zinc from both water and food. A BCF of 1,000 was reported for both aquatic plants and fish, and a value of 10,000 was reported for aquatic invertebrates (Fishbein 1981). The order of enrichment of zinc in different aquatic organisms was as follows (zinc concentrations in µg/g dry weight appear in parentheses): fish (25), shrimp (50), mussel (60), periphyton (260), zooplankton (330), and oyster (3,300) (Ramelow et al. 1989). The high enrichment in oysters may be due to their ingestion of particulate matter containing higher concentrations of zinc than ambient water. Other investigators have also indicated that organisms associated with sediments have higher zinc concentrations than organisms

living in the aqueous layer (Biddinger and Gloss 1984). With respect to bioconcentration from soil by terrestrial plants, invertebrates, and mammals, BCFs of 0.4, 8, and 0.6, respectively, have been reported. The concentration of zinc in plants depends on the plant species, soil pH, and the composition of the soil (Dudka and Chlopecka 1990; Rudd et al. 1988). Plant species do not concentrate zinc above the levels present in soil (Levine et al. 1989).

Assessment Endpoints – Indicator Species

American Dipper

The American dipper spends almost all its life along small, clear streams from which it obtains its major food: aquatic insects. The American dipper is highly territorial and may defend more than a half mile of stream in summer and as much as 1,000 feet of stream in winter. Dippers feed almost exclusively underwater on larval forms of aquatic insects. Studies indicate insects of the orders Plecoptera (stoneflies), Ephemeroptera (mayflies), and Trichoptera (caddisflies) are the most often eaten. To a much lesser extent, dippers will feed on small fish and fish eggs. In addition, during times of peak insect emergence, dippers may be seen flying out, in flycatcher fashion, on short round-trips after insects or skimming the newly emerged insects from the water surface. (ADFG 2004.)

Common Snipe

The common snipe (Gallinago gallinago) is similar in length (27 cm) to the woodcock, although lighter in weight. Snipe are primarily found in association with bogs and freshwater wetlands and feed on the various invertebrates associated with wetland soils. Snipe breed primarily in boreal forest regions and thus are found slightly north of the woodcock breeding range, with some areas of overlap in the eastern half of the continent. The breeding range of the snipe, however, extends westward to the Pacific coast and throughout most of Alaska, thus occupying a more extensive east-west range than the woodcock. (EPA 1993).

American Woodcock statistics (EPA 1993):

- Body weight: 133 – 218 g
- Food Ingestion Rate: 0.77 g/g-day

- Home Range: 0.3 to 98 ha (0.75 – 240 acres)
- Population Density: 0.026 – 3.38 birds/ha (0.01 – 1.4 birds/acre)

American Robin

Thrushes are common, medium-sized birds that eat worms, insects, and fruit. They live in a variety of habitats, including woodlands, swamps, suburbs, and parks. The American robin occurs throughout most of the continental United States and Canada during the breeding season and winters in the southern half of the US and Mexico and Central America. (EPA 1993).

Statistics (EPA 1993):

- Body weight: 63.5 – 103 g
- Food Ingestion Rate: 0.89 – 1.96 g/g-day
- Territory Size: 0.11 – 0.84 ha (0.27 – 2.1 acres)
- Foraging Home Range: 0.15 – 0.81 ha (0.37 – 2.0 acres)
- Population Density: 2 – 8.6 pairs/ha (0.8 – 3.5 pairs/acre)

Masked Shrew

The masked shrew (Sorex cinereus) (length 5.1 to 6.4 cm; weight 3 to 6 g) is smaller than the short-tailed shrew and is the most common shrew in moist forests, open country, and brush of the northern United States and throughout Canada and Alaska. It feeds primarily on insects. (EPA 1993).

Statistics based on the Short-Tailed Shrew (EPA 1993):

- Body weight: 12.5 – 19.2 g
- Food Ingestion Rate: 7.95 g/d
- Home Range Size: 0.39 ha (0.96 acres)
- Population Density: 2.3 to 11.4 per ha (0.9 to 4.6 per acre)

6.11 ECOLOGICAL RISKS – TERTIARY CONSUMERS (TROPHIC LEVEL 4)

Belted Kingfisher

Statistics (EPA 1993):

- Body weight: 136 – 158 g
- Food Ingestion Rate: 0.5 g/g-day
- Territory Size: 0.39 to 2.19 km of shoreline (0.24 to 1.2 miles of shoreline)
- Population Density: 0.11 to 0.6 pair/km of shoreline

Northern Shrike

The northern shrike defends large winter territories — as many as 540 acres. (CWM 2004.)

Shorttail Weasel

Short-tailed weasels have home ranges up to 40 acres (16 ha). They have been known to travel over three miles (5 km). Population densities of 20 weasels per square mile (7.8/km^2) have been recorded. However, less than 10 per square mile (3.9/km^2) is more typical under good habitat conditions. As with most predators, fluctuations in prey numbers create corresponding variations in weasel numbers. (ADFG 2004.)

Mink

Statistics (EPA 1993):

- Weight: 777 – 1734 g
- Food Ingestion Rate: 0.12 – 0.22 g/g-day
- Home Range Size: 259 – 770 ha (640 – 1900 acres)
- Population Density: 0.006 – 0.085 per ha (0.0024 – 0.034 per acre)

Table 6-11
Site Soil Concentrations, Human Health Soil Cleanup Values and Ecological Soil Screening Values

1	2				3	4	5	6	7	8	9	10	11
Compound of Potential Concern	Concentrations (mg/kg) (Existing soil concentrations based on past sampling data. Each value represents a sample result.)				Background Concentration (mg/kg) [summary of site background sampling and relevant background reports.]	Cleanup Level (carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)	Cleanup Level (non-carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)	ECOTOX Database (lowest reported value) (mg/kg)	Wildlife (ORNL) (lowest soil ingestion at food rate) (no observed effect / lowest observed effect) (mg/kg)	Plant Community (ORNL) (mg/kg)	Soil & Litter (ORNL) (mg/kg)	Plants / Invertebrates / Avian / Mammalian (EPA ESSL) (mg/kg)	BLM Tech Note 390. (lowest wildlife) (mg/kg)
Aluminum (Al)	7200				65000; 12000 - 100000		83000 *2		4.474 / 38.25	50	600	COPC only when pH < 5.5	
							---		(AlCl3)				

Antimony (Sb)	1.9	3.0 D	nd (10)	nd (10) D	0.66; <1 – 8.8		33		0.248 / 2.478	5		--- / 78 / --- / 0.29	
	2	nd (3.1) D	20.2	12.3	nd (0.50)		---		(antimony potassium tartrate)				
							3						
Arsenic (As)	6.5 D	2.7	1.9	1.1	9.6; <10 – 750	4.5			0.254 / 2.497	10	60 / 100		4
	nd (2)	1.4	1.53	1.43	nd (0.20)	---			(arsenite)		(earthworms / microbes)		
						1.8							
Barium (Ba)	60	9.20	14.4		678; 39 – 3100		5800		17.2 / 34.5	500	3000	--- / 330 / --- / 1000	
							--		(barium hydroxide)				
							982						
Beryllium (Be)	0.081	0.11	0.15	0.13	1.35; <1 – 7	170			2.42 / ---	10		--- / 40 / --- / 36	
	nd (0.5)	0.13 D	nd (1.03)	0.130 J	nd (0.10)	---			(beryllium sulfate)				
						38							
Bismuth (Bi)	6				0.008			530 (deer mouse LD50 gavage 320 mg/kg)					

1	2				3	4	5	6	7	8	9	10	11
Compound of Potential Concern	**Concentrations (mg/kg) (Existing soil concentrations based on past sampling data. Each value represents a sample result.)**				**Background Concentration (mg/kg) [summary of site background sampling and relevant background reports.]**	**Cleanup Level (carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)**	**Cleanup Level (non-carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)**	**ECOTOX Database (lowest reported value) (mg/kg)**	**Wildlife (ORNL) (lowest soil ingestion at food rate) (no observed effect / lowest observed effect) (mg/kg)**	**Plant Community (ORNL) (mg/kg)**	**Soil & Litter (ORNL) (mg/kg)**	**Plants / Invertebrates / Avian / Mammalian (EPA ESSL) (mg/kg)**	**BLM Tech Note 390. (lowest wildlife) (mg/kg)**
Cadmium (Cd)	2.8	59 D	70 D	150 D	0.79; 0.01 – 22		83	0.001	1.2 / 16.56	3	20	32 / 140 / 1.0 / 0.38	0.3
	88	60 D	234	165	0.060		---	(springtail EC50)	(cadmium chloride)				
	0.74	2	1.2	1.5			4.5						
	1.6	24.8	0.27	62.8									
	72.3	2.1	2.5	1.4									
	0.64	0.41	0.32	0.41									
	2.7	0.77	1.4	2.5									
	4.2												
	(95UCL Bootstrap = 35)												
Calcium (Ca)	5700				20000; 400 - 100000		RDI = 1000 mg/day						
Chromium (Cr)	7.8	5.8 D	nd (10) D	nd (10) D	64; 5 - 390		250	100	10020	1	0.4 / 10		
	120	10 D	2.57	16.7	nd (0.50)		---	(earthworm LOEC)	(Cr_2O_3)		(earthworms / microbes)		
							23						
Cobolt (Co)	11				14; <2 - 55		1660 *2 --- ---			20	1000	13 / --- / 190 / 240	
Copper (Cu)	39	110 D	110 D	250 D	29; 3 - 810		3320	1.84	38.9 / 51.1	100	50 / 100		7
	180	100 D	424	350	0.92		---	(earthworm EC50)	(copper oxide)		(earthworms / microbes)		
							6260						
DRO	210						8250 12500 Rsat 230						
Gallium (Ga)	nd (10)				16; <4 - 32								

1 Compound of Potential Concern	2 Concentrations (mg/kg) (Existing soil concentrations based on past sampling data. Each value represents a sample result.)				3 Background Concentration (mg/kg) [summary of site background sampling and relevant background reports.]	4 Cleanup Level (carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)	5 Cleanup Level (non-carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)	6 ECOTOX Database (lowest reported value) (mg/kg)	7 Wildlife (ORNL) (lowest soil ingestion at food rate) (no observed effect / lowest observed effect) (mg/kg)	8 Plant Community (ORNL) (mg/kg)	9 Soil & Litter (ORNL) (mg/kg)	10 Plants / Invertebrates / Avian / Mammalian (EPA ESSL) (mg/kg)	11 BLM Tech Note 390. (lowest wildlife) (mg/kg)
Iron (Fe)	38900	70900	47900		38000; 5500 - 100000		24900 *2 --- ---				200		
Lanthanum (La)	nd (10)				21; <2 - 120						50		
Lead (Pb)	1600 D	4000 D	4600 D	11000 D	14; <4 – 310	400 IEUBK		530 (Deer mouse LD50)	3.19 / --- (metallic)	50	500 / 900 (earthworms / microbes)	110 / 1700 / 16 / 59	6
	>10000	4300 D	28000	12600	0.33	400 IEUBK							
	24.6	26.3	102	257		---							
	227	1000	73.3	6720									
	10000	80.6	101	169									
	129	56.6	46.4	72.6									
	24.8	6.1	301	214									
	1280	92.4	1960	7550									
	21000	10000											
	(95UCL Bootstrap = 4,500)												
Magnesium (Mg)	4000				12000; 1300 - 74000		RDI = 400 mg/day						
Manganese (Mn)	245				670; <200 - 4000		1990 *2 --- ---		377 / 1040 (Mn3O4)	500	100		

1	2				3	4	5	6	7	8	9	10	11
Compound of Potential Concern	**Concentrations (mg/kg)** **(Existing soil concentrations based on past sampling data. Each value represents a sample result.)**				**Background Concentration (mg/kg) [summary of site background sampling and relevant background reports.]**	**Cleanup Level (carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)**	**Cleanup Level (non-carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)**	**ECOTOX Database (lowest reported value) (mg/kg)**	**Wildlife (ORNL) (lowest soil ingestion at food rate) (no observed effect / lowest observed effect) (mg/kg)**	**Plant Community (ORNL) (mg/kg)**	**Soil & Litter (ORNL) (mg/kg)**	**Plants / Invertebrates / Avian / Mammalian (EPA ESSL) (mg/kg)**	**BLM Tech Note 390. (lowest wildlife) (mg/kg)**
Mercury (Hg)	0.17	0.22	0.21	1.0 D	0.09; <0.01–4.6		15.8 *3		0.37 / 0.75	0.3	0.1 / 30		1
	0.6	0.22	3.43	1.69	0.040		13		(mercuric chloride)		(earthworms / microbes)		
	0.026	0.019	0.041	0.12			1.4						
	0.026	nd (0.1)	0.032	0.38									
	0.33	0.027 J	0.027 J	0.026 J									
	0.024 J	0.024 J	0.033 J	0.022 J									
	0.015 J	0.0065 J	0.13	0.13									
	0.32												
	(95UCL H-UCL = 0.39)												
Molybdenum (Mo)	1				1.3; <2 - 15		415 *2		0.52 / 5.15	2	200		
							---		(MnO4)				

Nickel (Ni)	8.5	36	42	17	33; <3 - 320		1700	15.1	64.08 / 88.59	30	200 / 90		
	35	40 D	17.1	19.0	nd (1.0)		---	(Barley EC20)	(nickel sulfate)		(earthworms / microbes)		
							78						
Potassium (K)	910				13000; 900 - 41000		RDI = 99 mg/day						
RRO	1100						8300						
							22000 Rsat						
							9700						
Scandium (Sc)	1				14; <2 - 39								
Selenium (Se)	1.9	2.6 D	2.6 D	4.3 D	0.39; <0.1 – 4.3		420		0.414 / 0.626	1	70 / 100		
	2.3 D	3.47	3.96		0.23		---		(sodium selenite)		(earthworms / microbes)		
							3						
Silver (Ag)	1.2 D	1.8 D	2.6 D	7.4 D	0.33; 0.13–0.77		420			2	50		

1	2				3	4	5	6	7	8	9	10	11
Compound of Potential Concern	**Concentrations (mg/kg)** **(Existing soil concentrations based on past sampling data. Each value represents a sample result.)**				**Background Concentration (mg/kg) [summary of site background sampling and relevant background reports.]**	**Cleanup Level (carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)**	**Cleanup Level (non-carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)**	**ECOTOX Database (lowest reported value) (mg/kg)**	**Wildlife (ORNL) (lowest soil ingestion at food rate) (no observed effect / lowest observed effect) (mg/kg)**	**Plant Community (ORNL) (mg/kg)**	**Soil & Litter (ORNL) (mg/kg)**	**Plants / Invertebrates / Avian / Mammalian (EPA ESSL) (mg/kg)**	**BLM Tech Note 390. (lowest wildlife) (mg/kg)**
	8.4	2.4 D	27.9	18.1	0.028		--- 19						
Sodium (Na)	100				15000; 700 - 36000		RDI = 0.1 g - 3.5 g / day						
Strontium (Sr)	20				198; 21 - 760		49800 *2 --- ---		963 / --- (stable strontium chloride)				
Thallium (Tl)	nd (0.10) nd (10)	nd (0.10) nd (0.10)	nd (0.10) 1.83	nd (0.10) 0.282 J	0.25; 0.1 – 0.8 nd (0.10)		5.48 *2 --- ---	70 (LD50 Deer mouse)	0.027 / 0.27 (thallium sulfate)	1			
Titanium (Ti)	400				5200; 900 - 15000		332000 *2 --- ---		13.2 / --- (depleted metallic)		1000		
Total Organic Carbon	944 325000	64900	155000	156000									
Total Solids	75	64.6											
Tungsten (W)	nd (10)				1.5						400		
Uranium (U)	nd (10)				2.8; <0.22 - 45		16.6 *2 (nonrad) --- ---			5			

1 Compound of Potential Concern	2 Concentrations (mg/kg) (Existing soil concentrations based on past sampling data. Each value represents a sample result.)				3 Background Concentration (mg/kg) [summary of site background sampling and relevant background reports.]	4 Cleanup Level (carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)	5 Cleanup Level (non-carcinogen) ingestion, inhalation, migration to groundwater (mg/kg) (18 AAC 75)	6 ECOTOX Database (lowest reported value) (mg/kg)	7 Wildlife (ORNL) (lowest soil ingestion at food rate) (no observed effect / lowest observed effect) (mg/kg)	8 Plant Community (ORNL) (mg/kg)	9 Soil & Litter (ORNL) (mg/kg)	10 Plants / Invertebrates / Avian / Mammalian (EPA ESSL) (mg/kg)	11 BLM Tech Note 390. (lowest wildlife) (mg/kg)
Vanadium (V)	22				129; 11 – 490		580 --- 3050			2	20		
Zinc (Zn)	410 D	5500 D	6700 D	15000 D	79; <20 – 2700		25000	3.9	19.1 / 172.9	50	200 / 100		43
	9950	6200 D	29400	19100	2.0		---	(Earthworm NOEC)	(sinc sulfate)		(earthworms / microbes)		
	149	213	183	307			8100						
	206	1750	87.7	5030									
	5270	329	440	463									
	344	220	198	236									
	389	130	73.1	142									
	445												
	(95 UCL Bootstrap = 3,590)												

Table 6-12
Site Sediment Concentrations, Human Health Cleanup Values and Ecological Screening Values

1	2	3				4	5	6	7	8	9	10
Compound of Potential Concern	**units**	**Concentrations (Existing sediment concentrations based on past sampling data. Each value represents a sample result.)**				**Background Concentration [summary of site background sampling and relevant background reports.]**	**Cleanup Level (carcinogen) Human Health soil level. Ingestion, inhalation, migration to GW. (18 AAC 75)**	**Cleanup Level (non-carcinogen) Human Health soil level. Ingestion, inhalation, migration to GW. (18 AAC 75)**	**Sediment (ERL / ERM) (ORNL - NOAA)**	**SQuiRT (NOAA) (lowest value from fresh or marine)**	**WAC 173-204-320 Marine sediment quality standards.**	**Sediment Cleanup Screening, Cleanup Level, WAC 173-204-420 (a), WAC 173-204-520 (a)**
Aluminum (Al)	mg/kg	26000				72400; 19000 - 120000		83000 *2 --- ---		18000		
Antimony (Sb)	mg/kg	nd (0.50)	nd (5)	nd (10.5)		0.66; <1 – 8.8 nd (8.32)		33 --- 3	2 / 25	3		
Arsenic (As)	mg/kg	2.7	33	2.58		2.35 14; 10 - 173	4.5 --- 1.8		8.2 / 70	5.9	57	93
Barium (Ba)	mg/kg	106	12.5			682; 69 - 3150 21.3		5800 -- 982		48		
Beryllium (Be)	mg/kg	0.12	0.359 J			1.3; 1.0 - 12 nd (0.832)	170 --- 38					
Bismuth (Bi)	mg/kg	nd (5)				14; 10 - 55						
Cadmium (Cd)	mg/kg	0.21 2.2 3.3 (95UCL Student-t = 2.9)	0.5 2.1 4.7	0.485 J 3.9	0.73 1.7	2.0 nd (0.832)		83 --- 4.5	1.2 / 9.6	0.583	5.1	6.7
Calcium (Ca)	mg/kg	6400				25700; 3600 - 86000		RDI = 1000 mg/day				

1	2	3				4	5	6	7	8	9	10
Compound of Potential Concern	**units**	**Concentrations** **(Existing sediment concentrations based on past sampling data. Each value represents a sample result.)**				**Background Concentration [summary of site background sampling and relevant background reports.]**	**Cleanup Level (carcinogen) Human Health soil level. Ingestion, inhalation, migration to GW. (18 AAC 75)**	**Cleanup Level (non-carcinogen) Human Health soil level. Ingestion, inhalation, migration to GW. (18 AAC 75)**	**Sediment (ERL / ERM) (ORNL - NOAA)**	**SQuiRT (NOAA) (lowest value from fresh or marine)**	**WAC 173-204-320 Marine sediment quality standards.**	**Sediment Cleanup Screening, Cleanup Level, WAC 173-204-420 (a), WAC 173-204-520 (a)**
Chromium (Cr)	mg/kg	8.3	273	23.5		20.7 50; 3.0 - 1040		250 --- 23	81 / 370	36.3	260	270
Cobalt (Co)	mg/kg	51				16; 3.0 - 70		1660 *2 --- ---		10		
Copper (Cu)	mg/kg	6.7	82	23.7		3.43 22; 2.0 - 664		3320 --- 6260	34 / 270	18.7	390	390
Gallium (Ga)	mg/kg	4				14; 4.0 - 38						
Iron (Fe)	mg/kg	72300	28600			47500; 19400 - 129000 16100		24900 *2 --- ---	20000 / 40000 (Ontario MOE)	40000		
Lanthanum (La)	mg/kg	6				24; 3.0 - 80						
Lead (Pb)	mg/kg	39 D 458 327 95UCL Student-t = 255	36 308 128	20.8 94.8	214 30.8	19; 4.0 - 826 nd (8.32)	400 IEUBK 400 IEUBK ---			30	450	530
Lithium (Li)	mg/kg	47				26; 7.0 - 76		1660 *2 --- ---				
Magnesium (Mg)	mg/kg	8500				15800; 2070 - 130000		RDI = 400 mg/day				
Manganese (Mn)	mg/kg	1675				1582; 218 - 8570		1990 *2	460 / 1110	260		

1 Compound of Potential Concern	2 units	3 Concentrations (Existing sediment concentrations based on past sampling data. Each value represents a sample result.)				4 Background Concentration [summary of site background sampling and relevant background reports.]	5 Cleanup Level (carcinogen) Human Health soil level. Ingestion, inhalation, migration to GW. (18 AAC 75)	6 Cleanup Level (non-carcinogen) Human Health soil level. Ingestion, inhalation, migration to GW. (18 AAC 75)	7 Sediment (ERL / ERM) (ORNL - NOAA)	8 SQuiRT (NOAA) (lowest value from fresh or marine)	9 WAC 173-204-320 Marine sediment quality standards.	10 Sediment Cleanup Screening, Cleanup Level, WAC 173-204-420 (a), WAC 173-204-520 (a)
								--- ---	(Ontario MOE)			
Mercury (Hg)	mg/kg	nd (0.020)	0.077	nd (0.0233)		0.004 - 0.051 nd (0.0222)		15.8 *3 13 1.4	0.15 / 0.71	0.13	0.41	0.59
Molybdenum (Mo)	mg/kg	13				2.4; 2.0 - 16		415 *2 --- ---				
Nickel (Ni)	mg/kg	13	48	26.9		8.34 27; 3.0 - 348		1700 --- 78	20.9 / 51.6	15.9		
Niobium (Nb)	mg/kg	2				15; 4.0 - 62						
Potassium (K)	mg/kg	3300				12700; 900 - 32300		RDI = 99 mg/day				
Scandium (Sc)	mg/kg	nd (5)				18; 3.0 - 58						
Selenium (Se)	mg/kg	nd (1.0) D	0.731			0.29 0.303		420 --- 3		1		
Silver (Ag)	mg/kg	0.055	nd (0.2)	nd (1.05)		2.0 nd (0.832)		420 --- 19	1 / 3.7	0.73	6.1	6.1
Sodium (Na)	mg/kg	5500				18800; 4500 - 33000		RDI = 0.1 g - 3.5 g / day				

1 Compound of Potential Concern	2 units	3 Concentrations (Existing sediment concentrations based on past sampling data. Each value represents a sample result.)				4 Background Concentration [summary of site background sampling and relevant background reports.]	5 Cleanup Level (carcinogen) Human Health soil level. Ingestion, inhalation, migration to GW. (18 AAC 75)	6 Cleanup Level (non-carcinogen) Human Health soil level. Ingestion, inhalation, migration to GW. (18 AAC 75)	7 Sediment (ERL / ERM) (ORNL - NOAA)	8 SQuiRT (NOAA) (lowest value from fresh or marine)	9 WAC 173-204-320 Marine sediment quality standards.	10 Sediment Cleanup Screening, Cleanup Level, WAC 173-204-420 (a), WAC 173-204-520 (a)
Strontium (Sr)	mg/kg	96				339; 45 - 952		49800 *2 --- ---				
Tantalum (Ta)	mg/kg	nd (10)				40						
Tellurium (Te)	mg/kg	nd (10)										
Thallium (Tl)	mg/kg	nd (0.50) D	0.186 J			0.214 J		5.48 *2 --- ---				
Tin (Sn)	mg/kg	nd (20)				38; 5.0 - 255		49800 --- ---		> 3.4		
Titanium (Ti)	mg/kg	400				5990; 2340 - 22000		332000 *2 --- ---				
Total Organic Carbon	mg/kg	15460				13880						
Total Solids	%	79.0				82.3						
Tungsten (W)	mg/kg	nd (20)										
Vanadium (V)	mg/kg	103				177; 25 - 632		580 --- 3050		57		
Yttrium (Y)	mg/kg	11				20; 7.0 - 70						

1 Compound of Potential Concern	2 units	3 Concentrations (Existing sediment concentrations based on past sampling data. Each value represents a sample result.)				4 Background Concentration [summary of site background sampling and relevant background reports.]	5 Cleanup Level (carcinogen) Human Health soil level. Ingestion, inhalation, migration to GW. (18 AAC 75)	6 Cleanup Level (non-carcinogen) Human Health soil level. Ingestion, inhalation, migration to GW. (18 AAC 75)	7 Sediment (ERL / ERM) (ORNL - NOAA)	8 SQuiRT (NOAA) (lowest value from fresh or marine)	9 WAC 173-204-320 Marine sediment quality standards.	10 Sediment Cleanup Screening, Cleanup Level, WAC 173-204-420 (a), WAC 173-204-520 (a)
Zinc (Zn)	mg/kg	61 293 849 (95UCL Chebyshev = 1,370)	274 328 1790	163 1310	114 259	105; 30 - 2120 44.4		25000 --- 8100	150 / 410	98	410	960
Zirconium (Zr)	mg/kg	nd (1)										

Table 6-13
Site Water Concentrations, Human health Cleanup Levels and Ecological Screening Values

1	2	3				4	5	6	7	8	9	10	11	12
Compound of Potential Concern	**units**	**Concentrations**				**Background Concentration**	**Cleanup Level (carcinogen)**	**Cleanup Level (non-carcinogen)**	**ECOTOX Database (lowest reported value)**	**Aquatic Life - Freshwater Chronic (AWQCM)**	**Aquatic Biota (ORNL) (lowest value)**	**Wildlife Water Ingestion (ORNL) (lowest value)**	**SQuiRT (NOAA) (chronic freshwater)**	**BLM Tech Note 390. (aquatic life, chronic)**
Antimony (Sb)	ug/L	nd (5)	nd (5)	nd (5)		nd (5)		15 *2	32 (green algae NOEC)	---	30	290 (antimony potassium Tartrate)	30	1600
Arsenic (As)	ug/L	nd (0.5)	nd (0.5)	nd (0.5)		nd (0.5)	0.57 *2	11 *2	11 (Sea urchin LOEC)	150 (disolved)	55 (As III) 3.1 (As V)	292 (arsenite)	150	48 (arsenic V)
Beryllium (Be)	ug/L	nd (1)	nd (1)	nd (1)		nd (1)		73 *2	3.8 (Water flea NOEC)	---	0.66	2830 (beryllium sulfate)	5.3	
Cadmium (Cd)	ug/L	12	nd (0.2)	2.1		nd (0.2)		18 *2	0.2 (Water flea NOEC)	0.10 / 0.094 (total / dissolved) (hardness 25) 0.76 / 0.64 (total / dissolved) (hardness 400)	0.15	4132 (cadmium chloride)	2.2 (hardness 100)	1.1 (hardness 100)
Chromiun (Cr) (as CRIII insoluable)	ug/L	nd (20)	nd (15)	nd (15)		nd (20)		55000 *2	0.75 (Bivalve EC50)	28 / 24 (total / dissolved) (hardness 25) 270 / 230 (total / dissolved) (hardness 400)	8.44	1172 (Cr2O3)	74 (hardness 100)	210 (hardness 100)

1	2	3				4	5	6	7	8	9	10	11	12
Compound of Potential Concern	**units**	**Concentrations**				**Background Concentration**	**Cleanup Level (carcinogen)**	**Cleanup Level (non-carcinogen)**	**ECOTOX Database (lowest reported value)**	**Aquatic Life - Freshwater Chronic (AWQCM)**	**Aquatic Biota (ORNL) (lowest value)**	**Wildlife Water Ingestion (ORNL) (lowest value)**	**SQuiRT (NOAA) (chronic freshwater)**	**BLM Tech Note 390. (aquatic life, chronic)**
Copper (Cu)	ug/L	6.9	nd (2)	2.8		nd (2)		1500 *2	6 (Water flea NOEC)	2.9 / 2.7 (total / dissolved) (hardness 25) 30 / 29 (total / dissolved) (hardness 400)	0.205	65200 (copper sulfate)	9 (hardness 100)	12 (hardness 100)
Conductivity	uS	>1900	10	10-20	40	10								
Flow Rate	cfs	0	>50	125-150	trickle	<0.1								
Hardness	mg/L	14	nd (10)	567		nd (10)								
Lead (Pb)	ug/L	300	nd (2)	7.5		nd (2)		15	4 (Rainbow trout NOEC)	0.54 / 0.54 (total / dissolved) (hardness 25) 19 / 11 (total / dissolved) (hardness 400)	0.35	16540 (metallic)	2.5 (hardness 100)	3.2 (hardness 100)
pH		6.5	6.9	46-48???	5.8	4.6								
Mercury (Hg)	ug/L	nd (0.2)	nd (0.2)	nd (0.2)		nd (0.2)		11 *2	0.006 (Brine shrimp LC50)	0.77 (dissolved)	0.18	1017 (mercuric chloride)	0.77	0.012
Nickel (Ni)	ug/L	nd (10)	nd(10)	nd (10)		nd (10)		730 *2	0.36 (Ciliate LC50)	16 / 16 (total / dissolved) (hardness 25) 170 / 170 (total / dissolved) (hardness 400)	5	171300 (nickel sulfate hexahydrate)	52 (hardness 100)	160 (hardness 100)
Selenium (Se)	ug/L	nd (5)	nd (5)	nd (5)		nd (5)		180 *2	1 (Fathead minnow LT50)	5.0 / 4.6 (total / dissolved)	2.6	857 (selenate, SeO4)	5	35

1	2	3				4	5	6	7	8	9	10	11	12
Compound of Potential Concern	**units**	**Concentrations**				**Background Concentration**	**Cleanup Level (carcinogen)**	**Cleanup Level (non-carcinogen)**	**ECOTOX Database (lowest reported value)**	**Aquatic Life - Freshwater Chronic (AWQCM)**	**Aquatic Biota (ORNL) (lowest value)**	**Wildlife Water Ingestion (ORNL) (lowest value)**	**SQuiRT (NOAA) (chronic freshwater)**	**BLM Tech Note 390. (aquatic life, chronic)**
Silver (Ag)	ug/L	0.97	nd (0.5)	nd (0.5)		nd (0.5)		180	0.24 (Water flea EC50)	0.37 / 0.32 (acute) (total / dissolved) (hardness 25) 44 / 37 (acute) (total / dissolved) (hardness 400)	0.12		0.12	0.12
Temperature	C	24	10	6-7	10	11				---				
Thallium (Tl)	ug/L	nd (1)	nd (1)	nd (1)		nd (1)		2.4 *2	110 (Toad LC50)	---	12	32 (thallium sulfate)	40	40
Zinc (Zn)	ug/L	2100	10	590		nd (10)		11000	0.34 (Rainbow trout LOEC)	37 / 36 (total / dissolved) (hardness 25) 390 / 380 (total / dissolved) (hardness 400)	21	62300 (zinc sulfate)	120 (hardness 100)	110 (hardness 100)

Table 6-14
Site Samples

Date	Sample ID	QC/QA	Pre- (during), Post-, or no-remedi-ation	Notes
1996 July	WFS1 and WFS2		no	Pooled Water in South Portal. No flow.
1996 July	KT46WA01		no	BACKGROUND: unfiltered water samples from an unnamed seep uphill and west of the site, about 500 feet west of the site. Seep was not flowing in 1997.
1996 July	KT46WA02		no	Unfiltered. small seep emanating from mill tailings (D3), (flow less than 0.1 cfs) converges with Mahoney Lake Creek. (Hardness: 14)
1996 July	KT46SO01		no	composite sample from principal tailings, Zone A
1997 May	KT46WA03		no	Taken in Mahoney Lake Creek, downstream from the tailings and the convergence of the seep in WA04. Taken as a composite across the stream, in a boulder-lined area with no fine sediments present. Boulders were iron-stained and the creek flow was about 50 CFS.
1997 May	KT46WA04		no	Filtered sample. From separate seep that trickled past the eastern edge of the tailings pile and emptied into Mahoney Lake Creek. Flowed S-SW through wooded area east of mill and meandered next to the tailings located in the intertidal zone. Slight to moderate amount of sedimentation in streambed that was iron-stained.
1997 May	KT46WA05		no	Rensate Sample
1997 May	KT46SO02		no	Composite. Tailings. Intertidal zone. Zone B, material was gray to brown, silty to sandy, overlain by a 2 inch thick zone of oxisized soil. Tailings depth from 4 to 18 inches. Tailings overlie a pebbly, sandy organic rich layer that was present throughout the intertidal zone. A split was used for TCLP.
1997 May	KT46SO03		no	Composite of four shallow holes. Sediment obtained from a thin layer of soils and pebbles depostied on a boulder-laden spit in the intertidal zone south of the mouth of Mahoney Lake Cree, Intent is to document the migration of hazardous substances away from tailings Zone B. A diverse assemblage of invertebrate life found. No iron-staining. Homogeneous mix of sand, pebbles and broken shells.
1997 May	KT46SO04		no	Composite. Tailings. Intertidal zone. East side of Zone B. Thick beach grasses cover most of this area. Four to six inch layer of sandy, gravelly material that overlie a 3 to 4 icch layer of gray, sandy tailings. No iron-stained layer found.
1997 May	KT46SO05		no	Composite. Sediment from intertidal zone across Mahoney Lake Creek from Zone B. Closest area to the mine site that contains abundant detrital material. Thin iron-stained zone was intersected about 2 inches below the surface in one of the holes. A fine-grained organic-rish layer was also encountered in one of the holes.
1997 May	KT46SO06		no	BACKGROUND: from steep hillside above uppermost mine workings at elevation 300 feet. Composite sample. Four holes dug through a layer of humus, duff and twigs to a thin soil layer.
1997 May	KT46SO07		no	Composite. Tailings. South part of Zone A. Talings are gray to brown with sporadic iron-staining, but have a uniform sandy texture. Tailings depth from 2 to 18 inches deep. Alders and grasses have revegetated the tailings on the eastern-most part of Zone A.
1997 May	KT46SO08	QC of SO07	no	Composite. Tailings.
1997 May	KT46SO09		Pre	REMOVED DURING 2003 SEASON. Composite. Tailings. North area of Zone A. Tailings are gray to orange (abundant iron-staining), up to 6 inches thick. Little to no overburden. Tailings are generally finer-grained here than in other portions of the pile.
2000 May	MMSS#1		Pre	REMOVED IN 2003 ACTION. Mill Site / Zone C Tailings

Date	Sample ID	QC/QA	Pre- (during), Post-, or no-remedi-ation	Notes
2000 May	MMSS#2		no	Mill Site / Zone C Tailings
2000 May	MMSED#1		no	Intertidal Sediment, vicinity of SO05.
2000 May	MMSED#2		no	BACKGROUND sediment
2000 May	MMTP#1		no	TCLP Zone A Tailings
2000 May	WFS3		no	Mahoney Lake Creek downstream of tailings
2003 August	MM-A1001-01		Post	Confirmation sample from Zone C.
2003 August	MM-A1001-02		Post	Confirmation sample from Zone C.
2003 August	MM-A1001-03		Post	Confirmation sample from Zone C. Soil-groundwater interface. Also analyzed for TCLP.
2003 August	MM-A1001-04		Post	Confirmation sample from Zone C. Soil-groundwater interface.
2003 August	MM-A1001-05		Post	Confirmation sample from Zone C. Soil-groundwater interface.
2003 August	MM-A1001-06		no	SEDIMENT
2003 August	MM-A1001-07		no	SEDIMENT
2003 August	MM-A1001-08		no	
2003 August	MM-A1001-09		no	
2003 August	MM-A1001-10		no	
2003 August	MM-A1001-11		no	
2003 August	MM-A1001-12		no	
2003 August	MM-A1001-13		no	
2003 August	MM-A1001-14		no	
2003 August	MM-A1001-15		no	
2003 August	MM-A1001-16		no	
2003 August	MM-A1001-17		no	
2003 August	MM-A1001-18		no	
2003 August	MM-A1001-19		no	
2003 August	MM-A1001-20		no	
2003 August	MM-A1001-21		no	SEDIMENT
2003 August	MM-A1001-22		no	SEDIMENT
2003 August	MM-A1001-23		no	SEDIMENT
2003 August	MM-A1001-24		no	SEDIMENT
2003 August	MM-A1001-25		no	SEDIMENT
2003 August	MM-A1001-26		no	
2003 August	MM-A1001-27		no	
2003 August	MM-A1001-28		no	
2003 August	MM-A1001-29		no	
2004 MAR	-01 SL		no	Tailings
2004 MAR	-02 SL		no	Tailings
2004 MAR	-03 SL		no	Tailings
2004 MAR	-04SL		no	Tailings
2004 MAR	05 SL		no	Tailings

Table 6-15
Notes for Tables

NOTES:

1) Samples from 1997 analyzedi and reported on a wet weight basis.

2) Sample flag "D" indicates analyte was diluted to bring within instrument calibration range or to remove matrix interferences.

3) Sample flag "J" indicates the analyte was positively identified, but numerical value of the concentration is approximated due to compromised quality control or inherent inability to analyse the sample (e.g., matrix effects).

4) Cleanup Values from ADEC 18 AAC 75 (8 AUG 2003) (over 40-inch zone), or ADEC Tech Memo 01-007 (24 NOV 2003) unless indicated otherwise.

5) *2 indicates concentrations from ADEC web-based calculator.

6) *3 indicates non-peer reviewed RfD calculation.

7) Concentrations shaded blue indicate the lower of a duplicate sample.

8) Concentrations shaded gray indicate an interim or pre-remedial sample.

9) AWQCM = "Alaska Water Quality Criteria Manual," = "Alaska Water Quality Criteria for Tocix and Other Deleterious Organic and Inorganic Substances," May 15, 2003.

10) ORNL = Oak Ridge National Laboratory, "Screening Benchmarks for Ecological Risk Assessment," Ver. 1.6, OCT 1996.

11) SQuiRT = NOAA, "Screening Quick Reference Tables," HAZMAT Report 99-1, SEP 1999.

12) EPAESSL, USEPA, "Ecological Soil Screening Levels for xxxxxx," Interim Final, OSWER Directive 9285.7-xx, NOV 2003.

13) BLM Tech Note 390, BLM, "Risk Management Criteria for Metals at BLM Mining Sites," Tech Note 390, DEC 1996.

14) Chapters 173-204 WAC (Washington Administrative Code), Sediment Management Standards, 1995.

15) ECOTOX Database: EPA ECOTOX database (AQUIRE, TERRETOX, PHYTOTOX) <http://www.epa.gov/ecotox/> Gavage doses normalized to species weight and food intake using EPA Wildlife Exposure Factors Handbok.

16) Compounds shaded yellow indicate compound failed Human Health concentration-toxicity screening.

17) Compounds with green shading indicate compound failed Tier 1 Ecological screening.

18) Compounds with pink shading indicate compound with sample results within background ranges.

REFERENCES FOR BACKGROUND LEVELS:

1) USGS 1458, "Element Concentrations in Soils and Other Surficial Materials of Alaska," USGS Professional Paper 1458, 1988.

2) USGS 1270, "Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States," USGS Professional Paper 1270, 1984.

3) USFS 1990, "A Summary of Background Concentrations for 17 Elements in North American Soils," USDA Forest Service, February 1990.

4) USGS 98-355, U.S. Geological Survey (Smith), “Results from the analysis of 723 stream-sediment samples from the Stikine Geophysical Survey area within the Petersburg, Sumdum, Bradfield Canal, and Sitka quadrangles, southeastern Alaska,” Open-File Report 98-355, Denver, Colorado, 1998.

5) SPECTRUM Chemical Fact Sheet, http://www.speclab.com/elements/tungsten.htm, accessed 26 MAR 2004.

6) minerals.usgs.gov/minerals, accessed 25 FEB 2004

REFERENCES FOR SAMPLES:

1) BLM 1998, Bureau of Land Management, Juneau Field Office, "Final Report Removal Preliminary Assessment, Mahoney Mine," April 1998.

2) URS 2001, URS, Dames & Moore, "Final Report Engineering Evaluation/Cpst Analysis (EE/CA) For Mahoney Mine," March 2001.

3) JEG 2004, Jacobs Engineering Group, "Non-time Critical Removal Action Report, Mahoney Mine, Alaska," Draft February 2004.

4) USACE 2004, "Mahoney Mine Pb Sample Results," email dated 31 March 2004.

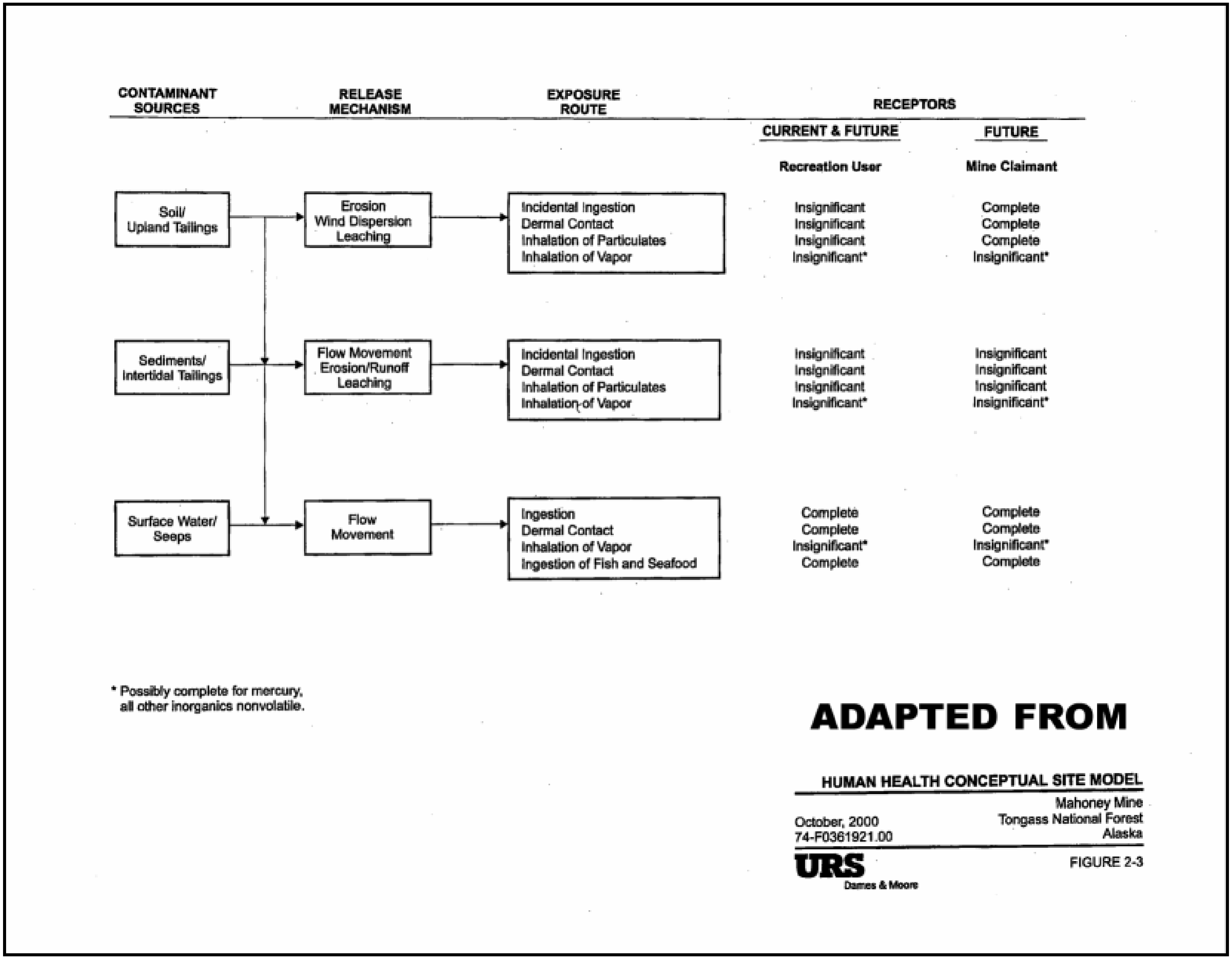

Figure 6-1 - Human Health Conceptual Site Model

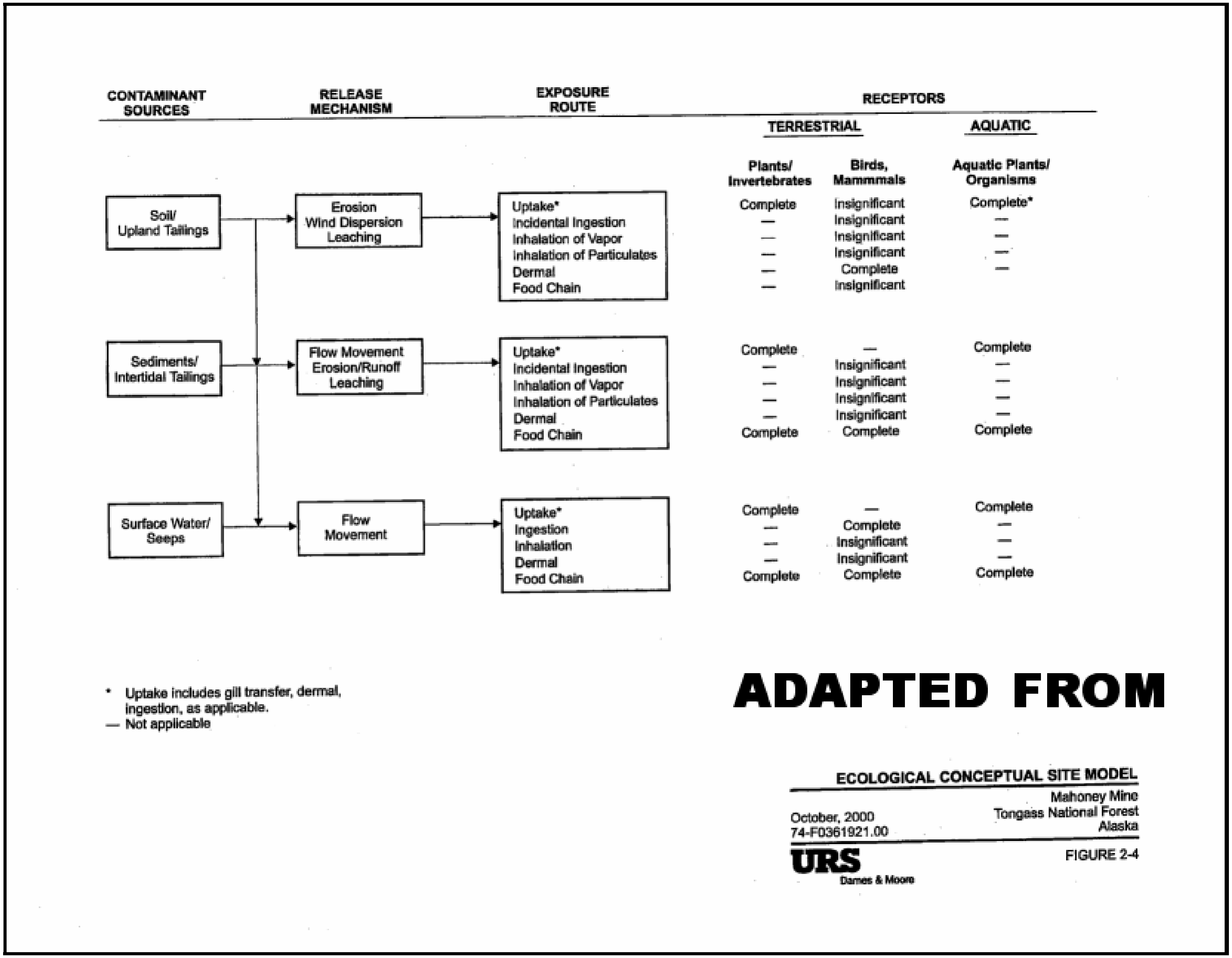

Figure 6-2 - Ecological Conceptual Site Model

APPENDIX D

Cost Estimate Summary Table

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COST ESTIMATE SUMMARY TABLE
U.S. FOREST SERVICE, MAHONEY MINE, KETCHIKAN, ALASKA

	OFFSITE TREATMENT & DISPOSAL			**ONSITE TREATMENT & OFFSITE DISPOSAL**			**ONSITE TREATMENT & DISPOSAL**		
	2A	**2B**	**2C**	**3A**	**3B**	**3C**	**4A**	**4B**	**5**
	Supersack, Helicopter, Barge	Bulk, Barge	Supersack, Helicopter, Truck	Stabilize, Supersack, Helicopter, Barge	Stabilize, Bulk, Barge	Stabilize, Supersack, Helicopter, Truck	Stabilize, Monofill Onsite	Stabilize, Mine Placement	Stabilize In Place, Leave In Place
Prime Labor	$59,000	$41,000	$59,000	$61,000	$43,000	$61,000	$40,000	$50,000	$30,000
Sub & Supply Contracts	$315,000	$233,000	$326,000	$247,000	$164,000	$260,000	$62,000	$57,000	$46,000
Subconsultant	*$47,000*	*$41,000*	*$47,000*	*$47,000*	*$41,000*	*$47,000*	*$45,000*	*$37,000*	*$33,000*
Analytical Testing	*$6,000*	*$6,000*	*$6,000*	*$6,000*	*$6,000*	*$6,000*	*$6,000*	*$6,000*	*$3,000*
Survey	*$2,000*	*$2,000*	*$2,000*	*$2,000*	*$2,000*	*$2,000*	*$2,000*	*$2,000*	*$2,000*
Helicopter	*$85,000*	*$0*	*$85,000*	*$86,000*	*$0*	*$86,000*	*$0*	*$0*	*$0*
Barging	*$85,000*	*$94,000*	*$74,000*	*$58,000*	*$67,000*	*$48,000*	*$9,000*	*$12,000*	*$8,000*
Other Container Transportation	*$34,000*	*$34,000*	*$56,000*	*$31,000*	*$31,000*	*$54,000*	*$0*	*$0*	*$0*
Waste Disposal	*$56,000*	*$56,000*	*$56,000*	*$17,000*	*$17,000*	*$17,000*	*$0*	*$0*	*$0*
Other Direct Costs	$57,000	$44,000	$59,000	$69,000	$53,000	$69,000	$45,000	$59,000	$25,000
Equipment Rental	*$33,000*	*$31,000*	*$35,000*	*$38,000*	*$32,000*	*$38,000*	*$31,000*	*$45,000*	*$12,000*
Field Supplies & Misc.	*$22,000*	*$11,000*	*$22,000*	*$23,000*	*$13,000*	*$23,000*	*$6,000*	*$6,000*	*$5,000*
Treatment Product	*$0*	*$0*	*$0*	*$6,000*	*$6,000*	*$6,000*	*$6,000*	*$6,000*	*$6,000*
Freight (non-barge)	*$1,000*	*$1,000*	*$1,000*	*$1,000*	*$1,000*	*$1,000*	*$1,000*	*$1,000*	*$1,000*
Office Expenses	*$1,000*	*$1,000*	*$1,000*	*$1,000*	*$1,000*	*$1,000*	*$1,000*	*$1,000*	*$1,000*
Travel and Per Diem	$27,000	$16,000	$27,000	$28,000	$27,000	$28,000	$16,000	$21,000	$9,000
Unburdened Contract Cost	$458,000	$334,000	$471,000	$405,000	$287,000	$418,000	$163,000	$187,000	$110,000
Markups	$142,000	$104,000	$147,000	$126,000	$89,000	$130,000	$51,000	$58,000	$35,000
Total Estimated Contractor Price (representing Capital Cost)	***$600,000***	***$438,000***	***$618,000***	***$531,000***	***$376,000***	***$548,000***	***$214,000***	***$245,000***	***$145,000***
Estimated Monitoring Costs (representing O&M Costs)	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	***$90,000***	***$0***	***$90,000***
Total Estimated Capital and O&M Costs	**$600,000**	**$438,000**	**$618,000**	**$531,000**	**$376,000**	**$548,000**	**$304,000**	**$245,000**	**$235,000**