Draft Final Feasibility Study
Red Devil Mine, Alaska

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Executive Summary

Executive summary to be provided following agency review of this draft.

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List of Abbreviations and Acronyms

AAC	Alaska Administrative Code
ACL	alternative cleanup level
ADEC	Alaska Department of Environmental Conservation
ARAR	Applicable or Relevant and Appropriate Requirement
AST	aboveground storage tank
BERA	Baseline Risk Assessment
bgs	below ground surface
BLM	Department of the Interior Bureau of Land Management
BMP	best management practice
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
DRO	diesel-range organics
E & E	Ecology and Environment, Inc.
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
FS	Feasibility Study
GRA	General Response Action
HDPE	high-density polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
HHRA	Human Health Risk Assessment
HQ	hazard quotient
IC	Institutional Control

List of Abbreviations and Acronyms (Cont.)

NCP	National Oil and Hazardous Substance Pollution Contingency Plan
O&M	operation and maintenance
PCB	polychlorinated biphenyls
PVC	polyvinyl chloride
RAO	remedial action objectives
RBCL	risk-based concentration levels
RDM	Red Devil Mine site
RG	Remedial Goal
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RRO	residual-range organics
SPLP	Synthetic Precipitation Leaching Procedure
SSE	selective sequential extraction
SVOC	semivolatile organic compounds
SWPPP	stormwater pollution plan
TBC	to be considered
TCLP	toxicity characteristic leaching procedure
TRV	toxicity reference value
VS2DT	Variably Saturated 2D Flow and Transport
XRF	X-ray fluorescence spectrometry

1 Introduction

This Feasibility Study (FS) Report addresses processed tailings and affected media at the Red Devil Mine site (RDM). Affected media incorporated in the analysis documented in this FS include soil and Red Devil Creek surface water and sediment. This FS Report is based on site characterization information presented in the RDM Remedial Investigation (RI) Report (E & E 2014). It should be noted that this FS Report does not address groundwater or Kuskokwim River sediments. The final RI Report includes data collected on both groundwater and the Kuskokwim River sediment. However, a review of those results led to identifying some key data gaps that are being addressed through additional characterization in 2015. A supplemental FS will evaluate remediation alternatives for groundwater and Kuskokwim River sediments.

RDM consists of an abandoned mercury mine and ore processing facility located on public lands managed by the Department of the Interior, Bureau of Land Management (BLM) in southwest Alaska (see Figure 1-1). Historical mining activities at the site included underground and surface mining. Ore processing included crushing, retorting/furnacing, and milling. Ecology and Environment, Inc., (E & E) has prepared this FS Report on behalf of the BLM under Delivery Order Number L09PD02160 and General Services Administration Contract Number GS-10F-0160J.

The BLM initiated an RI/FS at RDM in 2009 pursuant to its delegated Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) lead-agency authority. This RI/FS is being performed per applicable CERCLA statutes, regulations, and guidance.

Additionally, the BLM implemented an early action at RDM in 2014. An Engineering Evaluation/Cost Analysis was prepared to evaluate early action alternatives intended to address erosion and transport of tailings/waste rock in Red Devil Creek to the Kuskokwim River (E & E 2014). The early action is consistent with the long-term remedy alternatives presented in this FS Report.

1.1 Purpose and Organization of Report

The purpose of the FS Report is to present remedial action objectives (RAOs) and remedial alternatives to address contamination characterized as part of the RI and documented in the RI Report. The FS Report includes a comparative analysis of the remedial alternatives being considered for the site remedy. In accordance with

United States Environmental Protection Agency (EPA) guidance (EPA 1988), the comparative analysis is based on nine criteria to support an informed risk management decision regarding the most appropriate remedy. The preferred remedial alternative will be identified in a Proposed Plan (separate document) that will be made available for public review and comment.

This FS Report consists of the following sections:

- **Section 1: Introduction** – Provides a summary of background information, including a description of the area investigated, summary of historical activities, overview of the nature and extent of contamination and contaminant fate and transport, and summaries of the baseline Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA).
- **Section 2: Identification and Screening of Technologies** – Presents the RAOs, remedial goals, general response actions, and identification and screening of technology types and process options based on effectiveness, implementability, and cost.
- **Section 3: Development of Alternatives** – Develops and describes the remedial action alternatives and describes the major actions to be undertaken for each alternative.
- **Section 4: Analysis and Evaluation of Alternatives** – Presents a detailed analysis of each alternative and a comparative analysis of the alternatives based on nine evaluation criteria.
- **Section 5: References** – Lists the reports and other documents used in the preparation of this FS Report.

1.2 Background Information

This section summarizes background information for RDM presented in the RI Report (E & E 2014).

The primary sources of contamination at RDM are tailings and waste rock that resulted from historical mining and ore processing operations, mineralized bedrock and soil materials exposed by overburden disturbance and removal during surface mining operations, and petroleum releases. Secondary sources of contamination include native soils and creek and river sediments that have been impacted by tailings/waste rock migration and/or leaching.

1.2.1 Site Description

RDM is approximately 250 air miles west and 1,500 marine/river barge miles from Anchorage, Alaska. The mine site was established on the southwest bank of the Kuskokwim River approximately 2 miles from the village of Red Devil and approximately 8 miles from the village of Sleetmute. RDM is generally located on the Kuskokwim River in Township 19 North, Range 44 West, within the southwest quarter of Section 5, southeast quarter of Section 6, northeast quarter section 7 and northwest quarter of section 8, Sleetmute D-4, Seward Meridian. The site encompasses the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action.

Historical mining operations left tailings and other remnants that have affected local soil, surface water, sediment, and groundwater. Based on the location of tailings and other features, RI objectives and associated data collection pertain to each of the following areas that are associated with this FS:

- The Main Processing Area;
- Red Devil Creek, extending from a reservoir upstream of the Main Processing Area to the creek's delta at its confluence with the Kuskokwim River; and
- The area west of the Main Processing Area where historical surface exploration and mining occurred, referred to as the "Surface Mined Area." The Surface Mined Area is underlain by the area of underground mine workings. The "Dolly Sluice" and "Rice Sluice" and their respective deltas on the bank of the Kuskokwim River are associated with the Surface Mined Area.

RI data analysis and reporting were organized according to these areas, and this FS Report is organized in a similar manner. Figure 1-2 illustrates the area encompassed by the RI outside of the Kuskokwim River and the major features identified above based on aerial photographs taken in 2010 (AeroMetric, Inc. 2010a) and 2001 (AeroMetric, Inc. 2010b).

The Main Processing Area contains most of the former mine structures and is the location where ore beneficiation and mineral processing were conducted. The area is split by Red Devil Creek. Underground mine openings (shafts and adits) and ore processing and mine support facilities (e.g., housing and warehousing) were located on the west side of Red Devil Creek until 1955. After 1955, all ore processing was conducted at structures and facilities on the east side of Red Devil Creek.

There are three features at RDM that have come to be known as Monofills 1–3. The contents of Monofills 1 and 2 are described in a report entitled *Red Devil Mine 2002 Debris Consolidation and Deposal Project, Red Devil, Alaska (March 17,2003*; Wilder/URS 2002). The contents of what is now referred to as Monofill 3 are described in *Aboveground Storage Tanks/Ore Hopper demolition and Petroleum Release Investigation, Red Devil Mine, Red Devil, Alaska (June 11, 2004*; MACTEC 2004). In the 2004 report, the feature now referred to as Monofill 3 was called the Aboveground Storage Tank (AST) Metal Disposal Area. The monofills contain demolished mine structure debris and other wastes. Monofills #1 and #3 are unlined. Monofill #2, on the east side of Red Devil Creek, is an engineered and lined containment structure for contaminated debris and materials from the demolished Post-1955 Retort structure.

The east side of Red Devil Creek is also the former location of petroleum ASTs, which were used to store fuel for mine operations. The AST area was the subject of a separate investigation and remediation project (Marsh Creek 2010).

Figure 1-3 illustrates the main historical and current features in the Main Processing Area. Underground and surface mining operations and ore beneficiation and mineral processing are discussed further in Section 1.2.2.

1.2.2 Historical Activities
This section summarizes available information on the history of RDM. The RI Report should be consulted for a more detailed discussion of the topics presented below.

1.2.2.1 Mining Operations
Mercury ore was discovered in the Red Devil Creek drainage in 1933. By 1939, four claims had been established and mercury ore was being mined from creek sediments and overburden.

In the early 1940s, mining was being conducted underground, with access to ore zones through two adits and a main shaft located on the west side of Red Devil Creek. During this period, a 40-ton rotary kiln was installed for thermal processing of the mercury ore.

Between 1947 and 1951, the mine was not in operation due to low mercury prices. In 1952, the mine workings were dewatered and the mine resumed production. In October 1954, a fire destroyed a large portion of the mine surface structures and equipment. The thermal ore processing facilities were rendered unusable by the fire.

Following the 1954 fire, a modern mercury furnace was built on the east side of Red Devil Creek. Extensive surface exploration and mining took place at the mine after 1956. The reservoir was also created after 1956 by constructing an earthen dam across Red Devil Creek.

Hydraulic sluicing operations such as those conducted at the Dolly Sluice and Rice Sluice areas, where loose overburden was sluiced away to expose bedrock ore zones, was initiated in the late 1950s or early 1960s. The waste material from the sluice operation was washed down a gully to the Kuskokwim River. This resulted in the formation of the Dolly Sluice delta and Rice Sluice delta on the Kuskokwim River at the base of the sluice gullies.

As of 1963, the underground workings consisted of approximately 9,600 feet of shafts, adits, crosscuts, drifts, raises, and winzes, with workings on five levels.

The approximate locations of underground workings and associated mine openings as of 1962 are illustrated in Figure 1-4.

In 1969, operations included open pit and underground mining. No information is available regarding the location of the underground workings from this period. Surface mining was conducted over a large portion of the Surface Mined Area by trenching, bulldozing, pit excavation, and possibly sluicing.

Cinnabar and stibnite concentrates were produced after 1969 using flotation and were reportedly shipped to Japan. In addition, there are reports that some mercury was retorted at the mine. The flotation mill operated for most of 1970, and the mine closed in June 1971 due to a sharp drop in the price of both mercury and antimony. No production has occurred at the mine since that time.

On June 1, 1971, the mine owner ceased operations. Dewatering of the underground mine workings continued, with the intent that the disruption in mine operations would be temporary. In 1982, the mine was permanently closed and dewatering operations ceased.

1.2.2.2 Ore Processing

Early production from the mine used a retort to process the ore. The exact location of early retorting operations is unknown. Two "D" retorts were used to process ore beginning in 1940; these retorts are assumed to have been constructed within the Pre-1955 Retort Building.

In 1941, a 40-ton rotary kiln was installed at the mine site. In 1943, modern equipment for furnacing and retorting the Red Devil ore was installed. It is assumed that this rotary kiln was installed in the structures labeled "Pre-1955 Rotary Furnace Building" in Figure 1-3. The term "Pre-1955 Rotary Furnace" is retained for the purpose of this report to maintain consistency with previous reports.

The 1954 fire destroyed the Pre-1955 Retort and Pre-1955 Rotary Furnace facilities. In 1956, a new processing facility and other plant facilities were built on the east side of Red Devil Creek. A modified Herreshoff furnace was installed; the location of this newly installed furnace was the Post-1955 Retort Building. The term "Post-1955 Retort" is retained for the purpose of this report to maintain consistency with previous reports.

Processing of mercury ores at RDM by thermal methods (in retorts, kilns, and furnaces) was greatly complicated by the close association of stibnite (antimony sulfide), realgar, and orpiment (arsenic sulfides) with the cinnabar in the ore. Like cinnabar, stibnite, realgar, and orpiment break down thermally at relatively low temperatures. As a result, antimony and arsenic oxide dust and glass accumulated in the condenser system components, requiring frequent cleanout and separation from recovered mercury.

In 1969, a flotation mill was installed on the northern end of the Post-1955 Retort Building to produce cinnabar and stibnite concentrates. A ball mill was used to mill the ore. Various materials, including pine oil and Dowfroth 250 (frothers and flotation agents), lead acetate (activator for stibnite), and other chemicals may have been used as part of the flotation process. Tailings from the flotation unit were sluiced from the flotation mill into the three settling ponds via a wooden chute.

1.2.2.3 Mining and Ore Processing Wastes

Wastes generated during the mine operations consisted primarily of waste rock and tailings. These and other mining and mineral processing wastes at RDM are discussed further below.

Waste rock included the overburden material that resulted from surface mining processes and sub-ore grade material generated during underground mining activities. Based on a 1941 photograph, at least some waste rock was disposed of in dumps near the 311 Adit and 325 Adit portals, and some of the waste rock was likely deposited in the Red Devil Creek drainage.

During early mine operations, overburden on the southeast-facing slope above Red Devil Creek was sluiced downhill, with some of the sluiced overburden likely washing into Red Devil Creek and downstream to the Kuskokwim River. During the later surface mining activities, overburden was locally bulldozed into dumps northwest of the Main Processing Area, and overburden was sluiced from the Dolly and Rice ore zone areas. Wastes generated from sluicing locally accumulated in deposits, including the Dolly Sluice delta and Rice Sluice delta.

As of 1962, ore processing was conducted on the Post-1955 Main Processing Area. Some segregation of ore and waste rock was likely conducted at the Post-1955 Furnace area. The location of waste rock disposal is not known but was likely in the vicinity of the furnace area and associated with tailings disposal.

Tailings included thermally-processed ore. Such tailings resulted from the various thermal treatment processes that were employed over the history of the site. Historical aerial images and historical documents indicate that over much of the history of mining and ore processing at the site, tailings were sluiced or bulldozed into the channel of Red Devil Creek from the ore processing areas and dozed into dumps.

As of 1962, disposal of tailings generated at the Post-1955 Retort Building was accomplished by sluicing and bulldozing. A 7- by 10-inch sluicebox extended from under the burned-ore bin to a waste dump approximately 100 feet away. From there, the tailings were reportedly bulldozed away every second day.

From 1969 through 1971, ore was processed using a flotation mill yielding cinnabar and stibnite concentrates for shipment to Japan. The resulting flotation tailings were discharged into the settling ponds north of the Post-1955 Retort Building area. Various chemicals (e.g., pine oil, Dowfroth 250, and lead acetate) may have been used as part of the flotation process. Although these materials were likely recycled to some extent, some quantities of the materials potentially were discharged to the settling ponds.

Other wastes generated during mining operations include the oxide dust and glasses generated during the furnacing operations. Dust generated from the cyclone-dust bin was reportedly discharged with the aid of several water jets and discharged to the tailing sluicebox.

Based on review of historical and recent aerial photographs, land-based photographs, and records of mine operations summarized above, the locations where waste rock, thermal process tailings, and flotation tailings are thought to be disposed of are illustrated in Figure 1-5.

1.2.2.4 Petroleum-Related Wastes
Thermal ore processing equipment, generators, and the powerhouse were fueled with diesel stored in five ASTs located northeast of the Main Processing Area (see Figure 1-2). The AST area was investigated, and impacted soil was removed to a landspread facility constructed in the Surface Mined Area. Soil in the Main Processing Area, near the former residential/bunkhouse, and in the vicinity of the settling ponds has also been impacted by petroleum hydrocarbons.

1.2.3 Nature and Extent of Contamination
As presented in the RI Report, background concentrations of inorganic analytes were used to determine chemical concentrations that define the lateral and vertical extents of contamination. Inorganic element concentrations that exceed background values presented in RI Report Section 4.1 are considered “contamination.” In several instances, the concentrations of a given inorganic element in background samples are below detection limits; in such cases, samples with detected concentrations of those analytes also are treated as contamination in this report. For organic analytes, all positive detections are considered to represent site-related contamination. Contaminated media, as depicted in this section, are evaluated further in Chapter 2 of this FS report with regard to the need for remediation and exposure controls.

In accordance with the RI Work Plan (E & E 2011), samples used for background value estimation were collected from locations outside of and upgradient of the areas recognized as potentially impacted by mining, ore processing, waste disposal operations, and potential deposition of emissions from thermal ore processing. RI soil data and geological information indicate that the areas where background soil samples were collected exhibit little natural mineralization compared to areas where mining activity occurred. The extent of such natural mineralization is not known, but likely includes portions of the Main Processing Area and Surface Mined Area that are subject to remediation.

Naturally mineralized soils pre-date mining activities and thus represent pre-mining "background" conditions. Historical mining and ore processing activities, including disposition of the tailings and waste rock, occurred within the Main Processing Area and Surface Mined Area, where naturally mineralized rock and soil is expected to be locally present in the shallow subsurface. Impacts of mine activities throughout most of the Main Processing Area and Surface Mined Area make it difficult to positively identify naturally mineralized conditions. Therefore, it was not possible during the RI to determine the extent and concentration ranges of inorganic elements of naturally mineralized soil. Consequently, the background levels used to identify contamination, particularly those for subsurface soil, likely locally underestimate pre-mining background concentrations of inorganic elements at parts of RDM that are subject to remediation.

1.2.3.1 Surface Soil

Thirteen inorganic elements were detected above background values in the surface soil samples. In addition, semivolatile organic compounds (SVOCs), diesel-range organics (DRO), residual-range organics (RRO), and polychlorinated biphenyls (PCBs) were detected in surface soil samples.

Inorganic elements were detected above background values in all general geographic areas. Of the inorganic elements detected, antimony, arsenic, and mercury concentrations were the most highly elevated above background values. The highest concentrations of these inorganic elements were in the tailings and tailings/waste rock soil types in the Pre-1955 and Post-1955 portions of the Main Processing Area. These inorganic elements were also detected at concentrations well above background levels in the Surface Mined Area. At most locations in the Surface Mined Area, the elevated concentrations are likely attributable to naturally mineralized Kuskokwim group–derived soils, although at some locations along roads near the fringe of the Main Processing Area, elevated concentrations could be due to construction of the roads with tailings and/or waste rock.

Organic compounds were detected in the Pre-1955 and Post-1955 portions of the Main Processing Area. The areas of organic compound detections do not form contiguous zones, suggesting that releases from historical point sources (petroleum tanks, pipelines, etc.) have resulted in localized areas of surface contamination.

1.2.3.2 Subsurface Soil

Seventeen inorganic elements were detected above background values in the subsurface soil samples. In addition, SVOCs, DRO, and RRO were detected in subsurface soil samples.

Inorganic elements were detected above background values in all general geographic areas of the site. Of the inorganic elements detected, antimony, arsenic, and mercury concentrations were the most highly elevated above background values. The highest concentrations of these inorganic elements were in the tailings and tailings/waste rock soil types in the Pre-1955 and Post-1955 portions of the Main Processing Area. These inorganic elements were also detected at concentrations well above background levels in subsurface soil in parts of the Surface Mined Area. At many of those locations, the elevated concentrations are likely attributable to naturally mineralized Kuskokwim group–derived soils.

Organic compounds were detected throughout the subsurface soils of the Pre-1955 and Post-1955 portions of the Main Processing Area. Organic compounds were detected at depths up to 30 feet below ground surface (bgs). Organic compounds were detected in most of the subsurface soil samples submitted for organic compound analyses. The extent of organic compounds in subsurface soil appears to be localized in areas associated with former fuel storage or distribution.

1.2.3.3 Groundwater

Seventeen inorganic elements (including both total and dissolved analyses) and methylmercury were detected above background values in the groundwater samples. In addition, SVOCs, DRO, and RRO were detected in groundwater samples.

Of the inorganic elements detected, antimony, arsenic, and mercury concentrations were the most highly elevated above background values. Concentrations of total and dissolved antimony and arsenic are highest in the Post-1955 Main Processing Area. Elevated concentrations of total and dissolved mercury do not display an obvious spatial trend. Methylmercury was detected above the background value.

In 2010 and 2011, DRO were detected in almost all of the groundwater samples submitted for DRO analyses; however, the concentrations detected were below groundwater cleanup levels as defined in 18 Alaska Administrative Code (AAC) 75.345, Table C. Other organic compounds also were detected in one or more samples. In 2012, groundwater samples were collected from wells MW04 and MW27 for PCB analysis to assess possible impacts of PCBs associated with Monofill # 1. PCBs were not detected in either sample. The extent of petroleum-related organic compounds in groundwater has not been fully delineated. None of the organic compounds detected exceed RI comparison criteria in any of the groundwater samples.

1.2.3.4 Red Devil Creek Surface Water

Seventeen inorganic elements (including both total and dissolved analyses) and methylmercury were detected above background values in the Red Devil Creek surface water samples. In addition, SVOCs were detected at low concentrations in several surface water samples.

Of the inorganic elements detected, antimony, arsenic, and mercury concentrations were the most highly elevated above background values. Total and dissolved concentrations of antimony, arsenic, and mercury are significantly elevated above background in samples collected at several locations extending from the upper end of the Main Processing Area to the mouth of Red Devil Creek. Methylmercury was detected at all sample stations on Red Devil Creek (including near the reservoir dam) and is significantly elevated above background in the Main Processing Area, particularly at the seep location; however, methylmercury concentrations are below RI comparison criteria.

All SVOCs in Red Devil Creek surface water were detected at low concentrations very near their respective method detection limits and below any applicable comparison criteria.

1.2.3.5 Red Devil Creek Sediment

Seventeen inorganic elements and methylmercury were detected above background values in the Red Devil Creek sediment samples. In addition, SVOCs were detected at low concentrations in several surface water samples.

Of the inorganic elements detected, antimony, arsenic, and mercury concentrations were the most highly elevated above background values. These three inorganic elements are significantly elevated above background in the creek section extending from the Main Processing Area to the mouth of Red Devil Creek. The seep in the Main Processing Area is the location of the highest concentrations of arsenic and several other inorganic elements detected in the Red Devil Creek drainage. Methylmercury was detected above the background value in all but one of the Red Devil Creek sediment samples, with the highest concentrations detected at the reservoir dam area and at the seep in the Main Processing Area. None of the methylmercury concentrations exceeded the comparison criteria.

All of the SVOCs in Red Devil Creek sediments were detected at concentrations very near their respective method detection limits and below applicable RI comparison criteria.

1.2.3.6 Vegetation

Sixteen inorganic elements were detected above background values in the vegetation samples. Methylmercury was detected in one sample—a horsetail pond vegetation sample.

Of the inorganic elements detected, antimony, arsenic, barium, mercury, and nickel concentrations were the most highly elevated above background values. The horsetail pond vegetation samples contained the highest concentrations of antimony, arsenic, and mercury. The smallest number of contaminants detected above background values was in the blueberry stem and leaf samples; however, it should be noted that only one blueberry sample was successfully collected during the RI, and its representativeness is questionable.

1.2.4 Contaminant Fate and Transport

The occurrence of contaminants at RDM is chiefly dependent on the distribution of mine waste materials, consisting primarily of tailings, waste rock, and flotation tailings, and also including disturbed soils and sluiced overburden from the Surface Mined Area. The present distribution of these materials is explained by historical mining, ore processing, and modification by cleanup activities and natural processes. Migration of these contaminants associated with these materials is occurring, as described below.

Tailings/waste rock have historically been disposed of or eroded into Red Devil Creek. In addition, natural ore minerals, particularly from the Surface Mined Area, have been eroded and transported into Red Devil Creek and transported down the channel of Red Devil Creek to the Kuskokwim River, where they accumulated on the surface of a delta initially constructed of locally derived alluvial material. Sluicing of overburden from the Surface Mined Area created the Dolly and Rice Sluice deltas in the Kuskokwim River. These materials have migrated downriver to some extent in the Kuskokwim River. Tailings and waste rock that enter Red Devil Creek by erosion and mass wasting have in the past been subject to surface water transport downstream within Red Devil Creek. Materials deposited in the Red Devil Creek delta and sluice deltas may be subject to further erosion and transport.

Contaminants at RDM are transported by the groundwater and surface water pathways. Migration of contaminants to groundwater occurs principally via leaching from tailings, waste rock, and, to a lesser extent, flotation tailings and other soils. Leached contaminants enter groundwater directly where/when groundwater immerses these source materials, and by leaching and downward transport toward groundwater where groundwater level is beneath the source materials. Inorganics may also enter groundwater as a result of flow through naturally mineralized bedrock, soil and the underground mine workings.

RI results indicate that transport of contaminants in surface water is occurring presently at RDM. Contaminant loading (e.g., antimony, arsenic, mercury, and methylmercury) along Red Devil Creek as it flows through the Main Processing Area are attributable to groundwater migration into the stream along gaining reaches and erosion. Groundwater emerges to surface water as baseflow within the Main Processing Area as well as at a seep located adjacent to the creek in the Main Processing Area. Surface water loading along the creek also is attributable to entrainment of contaminants within or adsorbed to particulates and dissolution/desorption of contaminants from bed and suspended sediment. The 2014 non-time-critical removal action was completed in an effort to address this transport mechanism.

Multiple interrelated factors and processes affect the mobility of inorganic elements, impacts on groundwater and surface water, and interactions between groundwater and surface water. The understanding of the relative importance of dissolved versus particulate transport of mercury in groundwater and surface water is complicated by the large differences in some groundwater and surface water samples between total and dissolved (operationally defined as that fraction passing through a 0.45-micrometer filter) concentrations, in contrast to the comparatively small differences between total and dissolved concentrations of arsenic and antimony. Pertinent available data and interpretations of such data are detailed in Sections 5.4 through 5.6 of the final RI report.

Tailings and waste rock are leachable and are thought to make up the primary source of contaminants to groundwater and surface water. Antimony and arsenic in these materials are relatively more leachable than mercury. This is supported by comparison of total metals results to synthetic precipitation leaching procedure (SPLP) and toxicity characteristic leaching procedure (TCLP) results. This is also supported by mercury selective sequential extraction (SSE) test results, which indicate that most of the mercury in these materials is likely cinnabar, which is minimally soluble. Other materials at the site, including soils disturbed by surface mining activities and sediment, exhibited similar characteristics. Elemental mercury was observed locally in subsurface soils within the pre-1955 and post-1955 Main Processing Areas.

Methylmercury is present in surface water, groundwater, and sediment. Methylmercury concentrations in surface water are closely linked to sulfate concentrations, which were considerably higher in water at the seep than in Red Devil Creek. Sediment at the seep, consisting of yellowboy material, had methylmercury concentrations that also were high compared to Red Devil Creek sediment.

As noted in Section 5.3.2 of the final RI Report, known arsenic species at the RDM include sulfides (realgar and orpiment), arsenic oxide, and arsenite and arsenate. The mobilities of these species vary widely. Both arsenite and arsenate species are present in groundwater and surface water. Information on the relative proportions of these species and possible implications for fate and transport of arsenic in groundwater and surface water are described in Sections 5.4.5 and 5.6.2.3, respectively, of the final RI report. In general, arsenate is the dominant arsenic species in all media at RDM. The fraction of arsenate to total inorganic arsenic made up 80 percent or more of total inorganic arsenic in soil samples. Arsenate was the dominant arsenic species in all Red Devil Creek and Kuskokwim River sediment samples. The proportion of arsenate to total inorganic arsenic ranged from 72 to 90 percent in Red Devil Creek surface water samples. The seep water sample, however, was dominated by arsenite. Arsenate made up 95 percent or more of total inorganic arsenic in groundwater samples with comparatively higher total arsenic concentrations. It is anticipated that information on arsenic speciation may help inform the understanding of groundwater fate and transport.

1.2.5 Baseline Risk Assessment

1.2.5.1 Human Health Risk Assessment

An HHRA was conducted for RDM in accordance with Alaska State and EPA human health risk assessment guidance. The following potential receptors were evaluated in the HHRA: future residents, current and future recreational or subsistence users, and future mine workers. As applicable, child receptors were also evaluated. The HHRA was conducted with contaminant data from surface and subsurface soil, near-shore sediment, groundwater, surface water, and biota data. The HHRA assessed potential exposure to contaminants of concern (COCs) in the environmental media from the following pathways:

- Dermal (skin) contact with surface water from Red Devil Creek;
- Dermal (skin) contact with sediments from Red Devil Creek and the near-shore of the Kuskokwim River;
- Ingestion of and dermal contact with groundwater or surface water;
- Incidental ingestion of and dermal contact with soil;
- Ingestion of native wild foods;
- Inhalation of dust or volatile chemicals from soil; and
- Inhalation of volatile chemicals in groundwater.

The potential cancer risks at the site exceed both ADEC and EPA criteria for all receptors assessed. In general, exposure to arsenic in soil and groundwater posed greatest risk. Likewise, the potential hazards at the site exceed both ADEC and EPA criteria for all receptors evaluated in the HHRA. In general, exposure to antimony, arsenic, and mercury in soil, groundwater, and fish posed the greatest hazard. Risks and hazards were the highest for future residents potentially exposed to COCs.

The HHRA included several areas of uncertainty, including the following sources of significant uncertainty:

- Modeled concentrations of COCs in some wild food, specifically game fish;
- Estimated consumption of wild food and assuming that residents harvest and consume wild food from the site; and
- Characterization of true background levels in the mineralized area.

Potential risk-based concentration levels (RBCLs) were proposed for the COCs and determined in the HHRA. RBCLs were developed for arsenic, antimony, and mercury in a number of media, including soil, groundwater, and biota. RBCLs were also developed for the other COCs at RDM for the media of concern (see Sections 6.4.1 and 6.4.2 of the RI).

1.2.5.2 Ecological Risk Assessment

A Baseline Ecological Risk Assessment (BERA) was conducted for RDM in accordance with Alaska State and EPA ecological risk assessment guidance. An assortment of ecologically relevant assessment endpoints were evaluated, including terrestrial plants, soil invertebrates, benthic macroinvertebrates, fish and other aquatic biota, terrestrial wildlife, and aquatic-dependent wildlife. The BERA was conducted using contaminant data from two primary sources: (1) surface soil, sediment, surface water, and vegetation data collected for the RI; and (2) fish (slimy sculpin) and benthic macroinvertebrate contaminant data collected from Red Devil Creek by the BLM as part of a larger study examining contaminants in aquatic biota in the Middle Kuskokwim River.

In general, the greatest hazard quotient (HQ) values were observed for antimony, arsenic, and mercury, as would be expected given the nature of historical activities and local geology. The BERA risk results are discussed below by assessment endpoint.

- For the **terrestrial plant community**, seven contaminants were predicted to be COCs (antimony, arsenic, cobalt, manganese, mercury, nickel, and vanadium). As stated in the RI Report, the greatest HQ values were for antimony, arsenic, and mercury, and these contaminants have the greatest potential to adversely affect the terrestrial plant community at the site. As presented in the RI, confidence in the COC list and magnitude of the HQ values is considered low, primarily because of the conservative nature of the soil screening levels for plants and because contaminant bioavailability in soil was not considered. For the **soil invertebrate community**, seven contaminants were predicted to be COCs. The greatest HQ values were for antimony, arsenic, and mercury. Confidence in the COC list and magnitude of the HQ values is considered low, primarily because of the conservative nature of the soil screening levels for soil invertebrates and because contaminant bioavailability in soil was not considered. If the HQ values for soil invertebrates were adjusted to account for solubility of site contaminants (e.g., using the SPLP and mercury SSE results), the magnitude of the HQ values for antimony, arsenic, and mercury would be significantly lower. For **aquatic biota** (periphyton, amphibians, benthic macroinvertebrates, fish, etc.), exposed to surface water, five COCs were identified based on comparing chemical concentrations in surface water with water quality criteria. The greatest HQ values were for antimony, arsenic, and mercury. Potential risk to aquatic life from arsenic, iron, and manganese in surface water in Red Devil Creek appears to be localized to an area near where a seep discharges to the creek in the Main Processing Area.

- For the **fish community** in Red Devil Creek, arsenic, antimony, mercury, and possibly selenium were predicted to be COCs based on comparing chemical concentration in whole-body sculpin samples with tissue screening concentrations. Confidence in the risk estimates is considered moderate to low, depending on the contaminant. For the **benthic macroinvertebrate community**, nine contaminants were predicted to be COCs based on comparing contaminant concentrations in sediment with sediment screening levels. Confidence in the COC list and HQ values based on this assessment method is considered low because site-specific bioavailability was not considered in the evaluation. Also, a benthic macroinvertebrate survey conducted in Red Devil Creek identified no adverse impacts to abundance and diversity of benthic macroinvertebrates compared with nearby reference creeks. The site-specific survey is considered to be a more reliable assessment method and suggests no impacts to the benthic community from site-related contaminants. Lastly, potential risks to benthic macroinvertebrates also were assessed by comparing contaminant levels in benthic macroinvertebrate tissues with critical tissue concentrations. This assessment method identified only methylmercury as a COC for the benthic macroinvertebrate community (HQ 1.3).
- For the **terrestrial avian invertivore** assessment endpoint, represented by the **American robin**, arsenic and lead were identified as COCs. Confidence in the arsenic and lead risk estimates is considered low for two reasons: (1) site-specific contaminant bioavailability in soil was not quantitatively considered; and (2) literature-based models were used to estimate contaminant concentrations in prey (earthworms). In addition, for lead, the risk is driven by a highly elevated lead concentration in surface soil at one location. Hence, potential risks to the robin from lead at RDM are highly localized.
- For the **terrestrial mammalian invertivore** assessment endpoint, represented by the **masked shrew**, antimony, arsenic, cadmium, copper, lead, nickel, selenium, thallium, and zinc were identified. The greatest HQ values were for antimony and arsenic. Confidence in the risk estimates is considered low for two reasons: (1) site-specific contaminant bioavailability in soil was not quantitatively considered; and (2) literature-based models were used to estimate contaminant concentrations in prey (earthworms). For the **terrestrial avian herbivore** assessment endpoint, represented by the **spruce grouse**, six contaminants (antimony, arsenic, beryllium, mercury, thallium, and vanadium) were predicted to be COCs. The greatest HQ values were for arsenic and mercury. Confidence in the arsenic and mercury risk estimates is considered low. For the **terrestrial mammalian herbivore** assessment endpoint, represented by the **tundra vole**, antimony, arsenic, and manganese were identified as COCs. The great HQ value was for antimony. Confidence in the risk estimates is considered low. For the **terrestrial carnivorous bird** assessment

endpoint, represented by the **northern shrike**, no HQ values were greater than 1For the **terrestrial carnivorous mammal** assessment endpoint, represented by the **least weasel**, no COCs were identified.

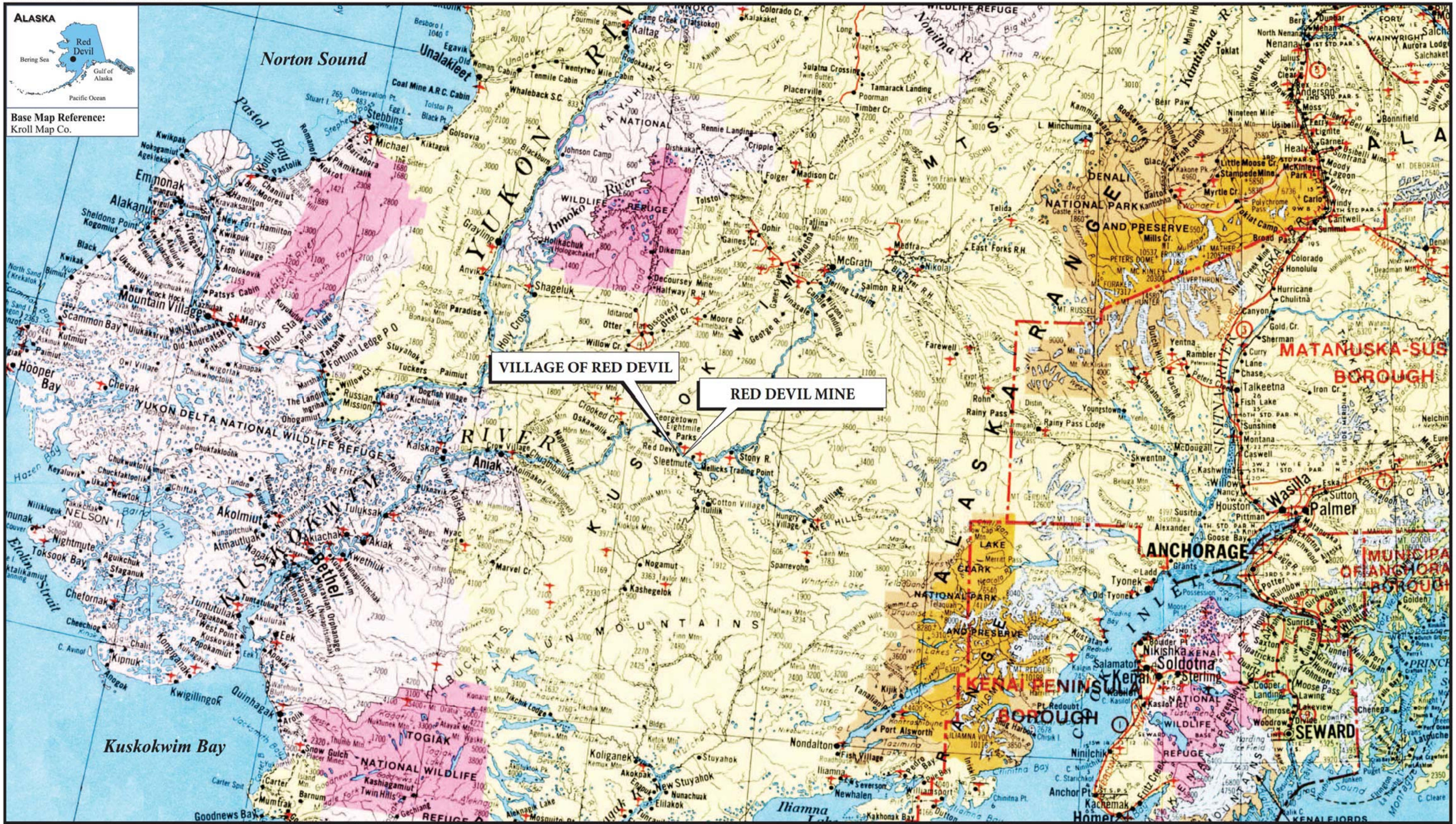
- For the **semi-aquatic avian invertivore** assessment endpoint, represented by the **common snipe**, five COCs (antimony, arsenic, beryllium, selenium, and thallium) were identified. The greatest HQ was for arsenic. Confidence in the arsenic risk estimate for the snipe is considered moderate. For the **semi-aquatic mammalian herbivore** assessment endpoint, represented by the **beaver**, arsenic was identified as a COC. Confidence in the arsenic risk estimate for the beaver is considered low. For the **semi-aquatic avian herbivore** assessment endpoint, represented by the **green-winged teal**, no HQ values were greater than 1, but potential risks from antimony, beryllium, and thallium could not be quantitatively evaluated.
- For the **avian piscivore** assessment endpoint, represented by the **belted kingfisher**, no HQ values were greater than 1, but potential risks from antimony, beryllium, and thallium could not be quantitatively evaluated.
- For the **mammalian piscivore** assessment endpoint, represented by the **mink**, antimony, arsenic, and selenium were identified as COCs. Confidence in the risk estimates for the mink are considered moderate to high.

All risk assessments include elements of uncertainty, and the BERA for RDM is no exception. Noteworthy sources of uncertainty in the BERA and their potential effect on the risk results are summarized in the RI Report (E & E 2013).

Several contaminants identified as BERA COCs at RDM occur at concentrations in site media that are similar to background. Specifically, beryllium, manganese, vanadium, and selenium were predicted to pose a potential risk to one or more ecological receptors at RDM, but their concentrations in site media lie within the range of background.

Ecological risk-based remedial goals for arsenic, antimony, and mercury in surface soil and sediment were developed for RDM. Exceedances of soil and sediment remedial goals are greatest in the Main Processing Area.

02:EE-001096-0070-08\Figure 1-1 Site Location Map.ai-01/25/13-GRA



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0 40 80
Approximate Scale in Miles

RED DEVIL MINE
Red Devil, Alaska

Figure 1-1
SITE LOCATION MAP

Date:	Drawn by:	
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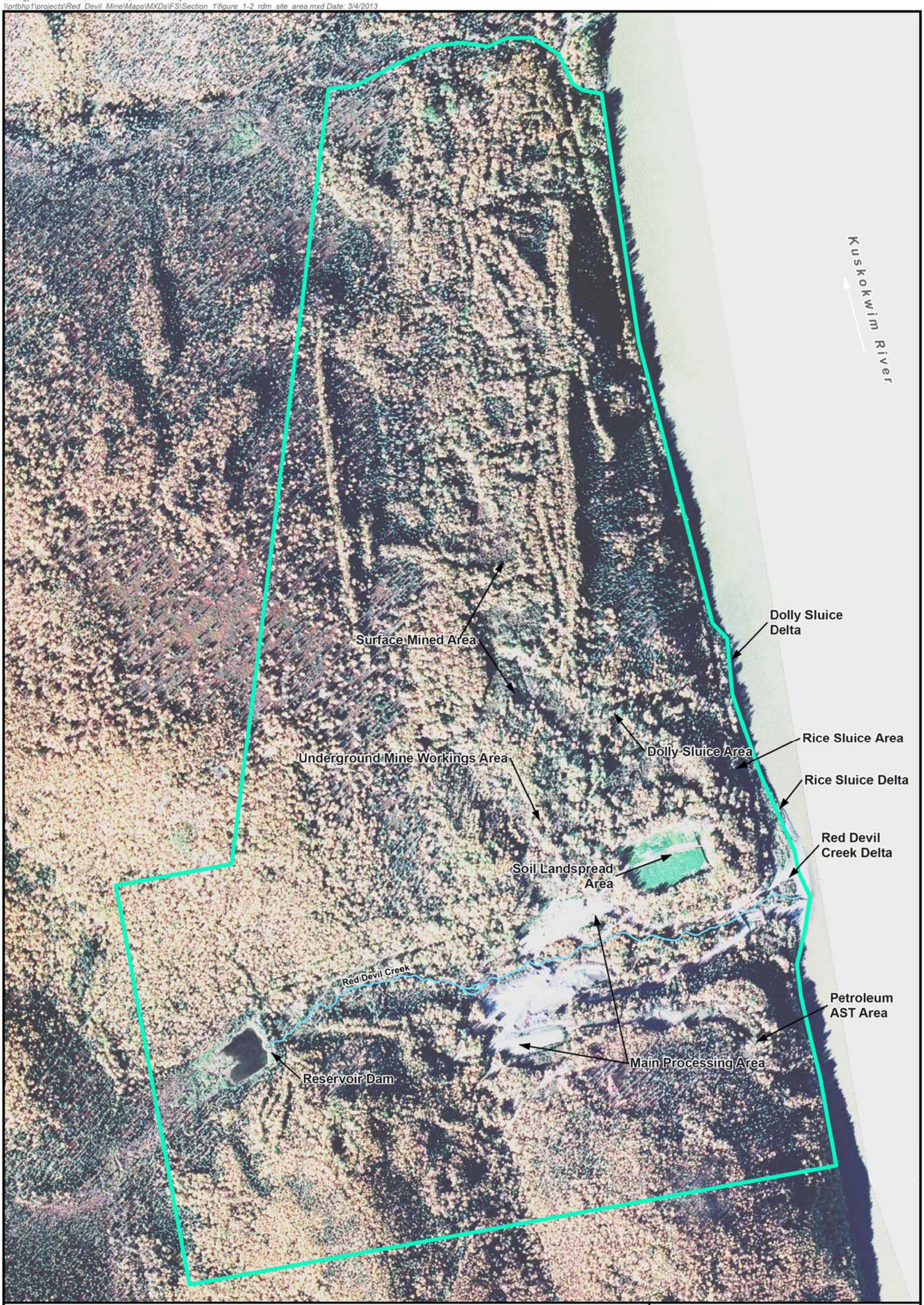

Site Boundary

RED DEVIL MINE

Red Devil, Alaska

Figure 1-2
Site Area

0 75 150 300 450 600 750
Feet
0 37.5 75 150 225
Meters
Scale 1:4,562

Image Source: Aero-Metric, Inc. 2010a

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RED DEVIL MINE

Red Devil, Alaska

Figure 1-3
Main Processing Area

Image Source: Aero-Metric, Inc. 2010a

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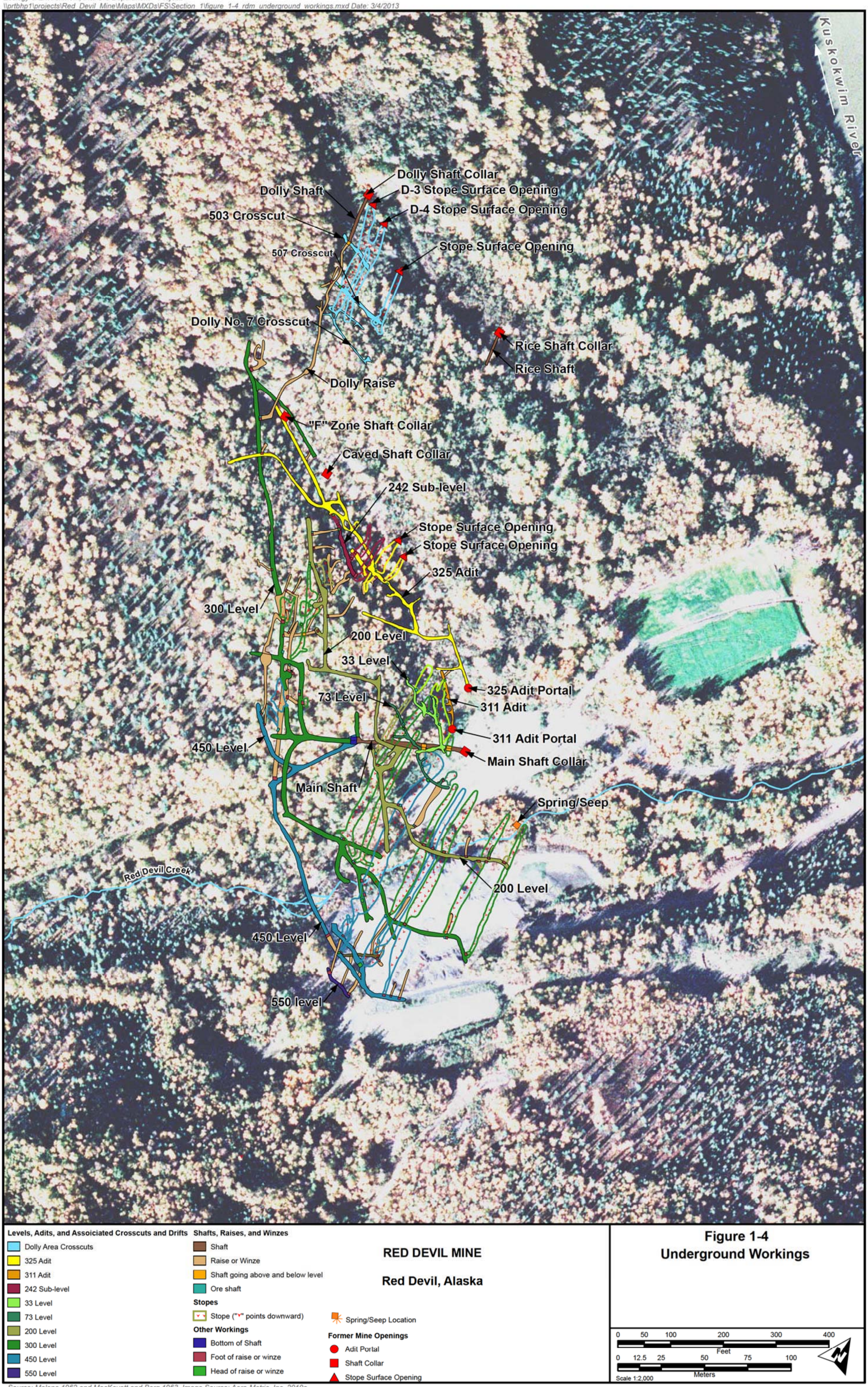

Source: Malone 1962 and MacKevett and Berg 1963, Image Source: Aero-Metric, Inc. 2010a

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Ore processing waste source locations
Potential areas containing tailings/waste rock
Areas where disturbed soil is present

RED DEVIL MINE

Red Devil, Alaska

Figure 1-5
Mining and Ore Processing Wastes

0 100 200 400 600
Feet
0 25 50 100 150 200
Meters
Scale 1:3,600

Image Source: Aero-Metric, Inc. 2010a

2 Identification and Screening of Remedial Technologies

This chapter presents the RAOs and remedial goals (RGs), applicable or relevant and appropriate requirements (ARARs), general response actions (GRAs), and identification and screening of remedial technology types and specific process options to address the media of concern at RDM. "General response actions" refers to broad categories of remedial actions, "technology types" refers to categories of remedial technologies, and "process options" refers to processes within each technology type (EPA 1988). Remedial technology types and specific process options retained at the conclusion of screening are carried forward and incorporated into Chapter 3 for the development of remedial alternatives.

Overview

RAOs and RGs have been identified for media of concern at RDM: tailings/waste rock, contaminated soil, and contaminated Red Devil Creek sediment. Three media addressed during the RI—Red Devil Creek surface water, groundwater, and Kuskokwim River sediment—are not further addressed in this FS Report, as described below. Accordingly, this FS is anticipated to result in an interim Record of Decision (ROD) for RDM. A final ROD will be executed following assessment of the success of source control actions (addressing tailings/waste rock, contaminated soil, and contaminated Red Devil Creek sediment) and the associated effect on groundwater and Kuskokwim River sediment quality.

Red Devil Creek Surface Water

RI sample results indicate that ambient water flowing in Red Devil Creek does not contain contaminant concentrations above Alaska surface water quality criteria. The seep located at sample location RD05 (see RI Report Figure 2-8) contains contaminant concentrations above the water quality criteria; however, the impacts of the seep on the ambient Red Devil Creek surface water do not result in exceedances of the Alaska ambient water quality criteria in the creek. Therefore, active remedies for Red Devil Creek surface water have not been developed, and RAOs, RGs, and GRAs for Red Devil Creek surface water are not presented in this FS Report.

Groundwater

RI sample results indicate that groundwater is contaminated in the Main Processing Area, largely as a result of contact with source materials (tailings/waste rock). Active remediation of tailings/waste rock in the Main Processing Area is anticipated to reduce contaminant loading to groundwater in the future. In addition, the BLM intends to further characterize the nature and extent of groundwater contamination before remedial decision-making is completed. Active remedies for groundwater would be most effectively evaluated following source control actions and further site characterization; therefore, RAOs, RGs, and GRAs for groundwater are not presented in this FS Report.

Kuskokwim River Sediments

Similar to groundwater, RI sample results indicate that sediments in the Kuskokwim River near the mouth of Red Devil Creek and in downstream areas are contaminated, largely as a result of erosional transport of tailings from the Main Processing Area. Active remediation of tailings/waste rock in the Main Processing Area is anticipated to reduce contaminant loading to the Kuskokwim River in the future. In addition, the BLM intends to further characterize the nature and extent of sediment contamination in the Kuskokwim River before remedial decision-making is completed. Active remedies for Kuskokwim River sediments would be most effectively evaluated following source control actions and further site characterization; therefore, RAOs, RGs, and GRAs for Kuskokwim River sediments are not presented in this FS Report.

Contaminants of Concern

A list of COCs in each medium to be addressed is provided in Table 2-1. These COCs were identified in the RI Report and represent inorganic elements detected above background levels, as well as positively detected organic contaminants. Collectively, they include all COCs that contribute to estimated human health and ecological risks at the site, and calculation of risks at the site were performed as documented in the RI. The RAOs presented in the following subsection were developed based on these media and contaminants.

Table 2-1 Summary of Contaminants of Concern at the Red Devil Mine Site

Contaminant of Concern	Tailings/ Waste Rock	Contaminated Soil	Red Devil Creek Sediment
Antimony	X	X	X
Arsenic	X	X	X
Barium	X	X	-
Chromium	X	X	X
Copper	-	-	X
Lead	X	-	-
Manganese	-	-	X
Mercury	X	X	X
Methylmercury	-	-	X
Nickel	X	X	X
Selenium	-	X	-

Table 2-1 Summary of Contaminants of Concern at the Red Devil Mine Site

Contaminant of Concern	Tailings/ Waste Rock	Contaminated Soil	Red Devil Creek Sediment
Vanadium	-	-	-
Zinc	-	-	-
Petroleum Hydrocarbons	X	X	-

Key:
X Contaminant is a COC
- Contaminant is not a COC

For methylmercury, the highest detected concentration in the Red Devil Creek sediment was found at the seep (station RD05) rather than within Red Devil Creek, and the next highest methylmercury concentration was detected at location RD02, located near the reservoir dam, well upgradient of the Main Processing Area. Methylmercury in the remaining Red Devil Creek sediment samples was detected at concentrations one to two orders of magnitude lower. Additionally, a benthic macroinvertebrate survey conducted in Red Devil Creek identified no adverse impacts to abundance and diversity of benthic macroinvertebrates in Red Devil Creek when compared with nearby reference creeks (see RI Report Section 6.3.7.4). Potential risks to benthic macroinvertebrates also were assessed by comparing contaminant levels in benthic macroinvertebrate tissues with critical tissue concentrations. This assessment method identified methylmercury as a COC for the benthic macroinvertebrate community, with an HQ of 1.3.

2.1 Remedial Action Objectives and Goals

The overall goal of the remedial action at RDM is to protect human health and the environment from elevated risks associated with COCs in tailings/waste rock, contaminated soil, and contaminated Red Devil Creek sediment. The development of RAOs and RGs is the first step in the development of remedial alternatives. RAOs are medium-specific goals for protecting human health and the environment that address specific exposure route(s) and receptors, and RGs are numeric values that define a concentration that correlates to an acceptable level of risk, generally referred to as cleanup levels.

To develop site-specific RAOs, results of the human health and ecological risk assessments were evaluated. Table 2-2 summarizes the receptors and exposure media associated with excess cancer risks greater than 1×10^{-5} for human receptors, and hazard quotients greater than 1.0 for human and ecological receptors. Based on information provided in the RI Report detailing contaminant fate and transport at the site, the RAOs specific to the site are:

- Prevent or reduce human future resident exposure (through ingestion or dermal contact) to COCs in tailings/waste rock, soil, and creek sediment at concentrations above RGs to acceptable levels.

- Prevent or reduce human future resident exposure (through inhalation) to COCs in dust from tailings/waste rock and soil at concentrations above RGs to acceptable levels.
- Prevent or reduce human future resident exposure (through ingestion) to COCs in harvested fish, mammals, and birds to acceptable levels.
- Prevent or reduce exposures to plants, soil fauna, terrestrial wildlife, aquatic-dependent wildlife, fish, and benthic organisms from COCs in onsite media at concentrations above RGs.
- Prevent or reduce potential migration of COCs in the Main Processing Area and Surface Mined Area to surface water from stormwater erosion, and to groundwater from leaching through tailings/waste rock.
- Prevent or reduce potential migration of COCs in Red Devil Creek resulting from tailings/waste rock erosion.

Table 2-2 Summary of Media and Receptors of Concern

Exposure Medium	Receptor(s)	Exposure Route(s)	Cancer Risk[(1)]	Hazard Index[(1,2,3)]
Tailings/Waste Rock and Soil	Human – Future Adult Resident	Ingestion	$1x10^{-02}$	284
		Dermal Contact	$2x10^{-03}$	22
	Plants	Direct Contact and Bioaccumulation	NA	847 (antimony)
	Soil Fauna	Direct Contact and Bioaccumulation	NA	2516 (mercury)
	Terrestrial Wildlife	Ingestion	NA	2478 (antimony, shrew)
	Aquatic-Dependent Wildlife	Ingestion	NA	57 (arsenic, snipe)
Creek Sediment	Human – Future Resident	Dermal Contact	$5x10^{-03}$	55
Air	Human – Future Resident	Inhalation	$2x10^{-05}$	56
Fish	Human – Future Resident	Ingestion	$1x10^{-01}$	987
Mammals	Human – Future Resident	Ingestion	$4x10^{-04}$	22
Birds	Human – Future Resident	Ingestion	$2x10^{-03}$	30
Berries and Plants	Human – Future Resident	Ingestion	$1x10^{-02}$	381

Notes:
(1) Cancer Risks and Hazard Indices listed are for the Main Processing Area, which are greater than at the Surface Mined Area.
(2) Ecological Hazard Indices listed represent the greatest hazard quotient for the given exposure pathway for all chemicals and receptors.
(3) Human hazard indices are based on a future child resident scenario.

Key:
NA = Not applicable

Based on the RAOs listed above, potential RGs for specific exposure media were compiled. The potential RGs analyzed for tailings/waste rock, contaminated soil, and contaminated Red Devil Creek sediment at RDM include:

- Site-specific, risk-based alternative cleanup levels (ACLs), in accordance with 18 AAC 75.340 (see Section 6.4 of RI Report);
- Site-specific, RBCLs for protection of ecological receptors (see Section 6.4 of RI Report);
- Chemical-specific ARARs for soil in accordance with18 AAC 75.341 (see Section 2.3); and
- Site-specific background values developed in the RI report (see Section 4.1 of RI Report).

Potential RGs for air and biotic exposure media (fish, mammals, birds, and berries) were not identified for the following reasons:

- For human exposures through inhalation of dust via the air pathway, the RGs developed for tailings/waste rock and soil are expected to remedy this exposure pathway.
- For biotic exposure media to humans, RGs developed for tailings/waste rock, contaminated soil, and contaminated Red Devil Creek sediment are based on background levels and are not based on calculated risk based concentrations addressing biotic exposure media to humans.

Accordingly, RGs were selected through a process that balances applicable regulatory criteria, site-specific RBCLs, and site-specific background levels relevant to the media addressed in this FS Report. It should be noted that the RBCLs were developed for a number of media as part of the HHRA and BERA. See Sections 6.4.1 and 6.4.2 of the RI for additional information. The RG selection process was conducted as follows:

- If chemical-specific ARAR concentrations and site-specific RBCLs were below background levels, the background value was selected as the RG.
- If chemical-specific ARAR concentrations and site-specific RBCLs were above background levels, the lowest of the ARAR concentration or RBCL was selected as the RG.
- If either the ARAR concentration or site-specific RBCL was greater than the background level, the greater value of the ARAR or site-specific RBCL was selected as the RG.

Table 2-3 summarizes the RG values selected for media addressed in this FS Report.

Table 2-3 Remedial Goals

Medium and Contaminant of Concern	Chemical-specific ARAR Concentration (mg/kg)	Calculated Human Health RBCL for Future Resident(3) (mg/kg)	Lowest Calculated Ecological RBCL(4,5) (mg/kg)	Background Level(6) (mg/kg)
Tailings/Waste Rock and Soil				
Antimony	3.6(1)	41	14	52.2(7)
Arsenic	3.9(1)	6.1	18	28.58(7)
Barium	1,100(1)	-	-	266
Chromium	25(1)	-	-	30(7)
Lead	400(1)	-	-	14.3
Mercury	1.4(1)	30	34.5	3.92(7)
Nickel	86(1)	-	-	52.2
Diesel-Range Organics	250(2)	-	-	-
Red Devil Creek Sediment				
Antimony	-	-	113(7)	0.54
Arsenic	-	130(7)	445	65
Chromium	-	-	-	20.4(7)
Copper	-	-	-	21.7(7)
Manganese	-	-	-	579(7)
Mercury	-	-	-	0.18(7)
Nickel	-	-	-	32(7)

Notes:
(1) 18 AAC 75.340 Table B1 Migration to Groundwater
(2) 18 AAC 75.340 Table B2 Migration to Groundwater
(3) RBCLs were developed using the exposure equations and parameters identified in the HHRA (RI Report Chapter 6) and back-calculating a target concentration in each individual medium, and RBCLs for non-carcinogens were calculated based on child exposure for the resident and recreational/subsistence user since that represents the most highly potentially exposed receptor. The RBCLs do not account for cumulative risk resulting from exposure to multiple contaminants simultaneously.
(4) Based on No Observed Adverse Effect Level (NOAEL)
(5) Ecological RBCLs are based on information presented Section 6.4.2 of the RI report.
(6) Background Levels for Tailings/Waste Rock and Soil represent the higher of the values calculated for surface soil and subsurface soil
(7) Numerical Value Selected as Remedial Goal

Key:
AAC = Alaska Administrative Code
ARAR = Applicable and relevant or appropriate requirement
HHRA = human health risk assessment
mg/kg = milligrams per kilogram
RBCL = Risk-Based Cleanup Level
RI = Remedial Investigation
- = No applicable regulatory criterion is available or risk-based level calculated

Table 2-4 summarizes the selected RGs and their capacity to achieve the RAOs.

Table 2-4 Remedial Goals and Remedial Action Objective Conformity

Media and Contaminant of Concern	Selected Remedial Goal (mg/kg)	RAO Conformity
Tailings/Waste Rock and Soil		
Antimony	52.2	Selected RG exceeds chemical-specific ARAR based on groundwater protection, but is less than the direct contact criterion of 55 mg/kg. RG exceeds risk-based ACL based on future human resident. RG is less than ecological RBCL. **RAO Conformity: Cleanup below selected RG is impracticable because RG represents site-specific background level.**
Arsenic	28.58	Selected RG exceeds chemical-specific ARAR based on groundwater protection and direct contact. RG exceeds risk-based ACL based on future human resident, and the ecological RBCL. **RAO Conformity: Cleanup below selected RG is impracticable because RG represents site-specific background level.**
Barium	1,100	Selected RG is the chemical-specific ARAR. **RAO Conformity: Protective.**
Chromium	30	Selected RG slightly exceeds chemical-specific ARAR based on groundwater protection, but is less than the direct contact criterion of 410 mg/kg. **RAO Conformity: Cleanup below selected RG is impracticable because RG represents site-specific background level.**
Lead	400	Selected RG is the chemical-specific ARAR based on groundwater protection and direct contact. **RAO Conformity: Protective.**
Mercury	3.92	Selected RG slightly exceeds chemical-specific ARAR based on groundwater protection, but is less than the direct contact criterion of 41 mg/kg. RG exceeds risk-based ACL based on future human resident. RG is less than ecological RBCL. **RAO Conformity: Cleanup below selected RG is impracticable because RG represents site-specific background level.**
Nickel	86	Selected RG is the chemical-specific ARAR. **RAO Conformity: Protective.**
Diesel-Range Organics	250	Selected RG is the chemical-specific ARAR. **RAO Conformity: Protective.**
Red Devil Creek Sediment		
Antimony	113	Selected RG is the ecological RBCL. **RAO Conformity: Protective.**
Arsenic	130	Selected RG is the risk-based ACL for future human resident. **RAO Conformity: Protective.**
Chromium	20.4	Selected RG is the background level, no chemical-specific ARAR exists. **RAO Conformity: Protective.**
Copper	21.7	Selected RG is the background level, no chemical-specific ARAR exists. **RAO Conformity: Protective.**
Manganese	579	Selected RG is the background level, no chemical-specific ARAR exists. **RAO Conformity: Protective.**
Mercury	0.18	Selected RG is the background level, no chemical-specific ARAR exists. **RAO Conformity: Protective.**

Table 2-4 Remedial Goals and Remedial Action Objective Conformity

Media and Contaminant of Concern	Selected Remedial Goal (mg/kg)	RAO Conformity
Nickel	32	Selected RG is the background level, no chemical-specific ARAR exists. **RAO Conformity: Protective.**

Key:

ACL = Alternate Concentration Limit
ARAR = Applicable or Relevant and Appropriate Requirements
mg/kg = milligrams per kilogram
RAO = Remedial Action Objective
RG = Remedial Goal

2.2 Areas and Volumes of Media to be Addressed by the Remedial Action

2.2.1 Tailings/Waste Rock, Soil, and Red Devil Creek Sediments

At RDM, tailings/waste rock, contaminated soil, and contaminated Red Devil Creek sediment were identified as the media of concern. Contamination is defined as containing COCs at concentrations exceeding the RGs presented in Table 2-4 Areas and volumes of tailings/waste rock, and contaminated soil and creek sediment to be addressed by the remedial action were estimated as described below.

For the purpose of delineating the extent of tailings/waste rock, and contaminated soil and creek sediment, a combination of physical characteristics (e.g., soil type, topography, and bathymetry) and COC concentrations were used. Soil COC concentrations were determined based on laboratory analytical data, if available for a given soil sample, or were estimated based on X-ray fluorescence spectrometry (XRF) field screening data. Laboratory sample results, field screening results, and results of soil type identification are presented in the RI Report (E & E 2013). Estimated lateral limits of soil exceeding RGs for various areas of RDM are illustrated in Figures 2-1 and 2-2.

Tailings/waste rock and soil with total concentrations of antimony, arsenic, and/or mercury—the primary soil COCs at RDM—exceeding the soil RGs is targeted for remedial action. This encompasses all surface and subsurface soil containing tailings/waste rock and flotation tailings within the Main Processing Area and the Red Devil Creek Downstream Alluvial Area and Delta. It also includes sediment within Red Devil Creek that contains tailings/waste rock, some native soil beneath tailings/waste rock, and some surface soil in or adjacent to the Main Processing Area. For the purpose of this FS Report, flotation tailings are subsequently grouped with tailings/waste rock.

Based on groundwater concentrations and flowpaths, the greatest potential impacts on groundwater COC concentrations occur where waste materials, as described above, are situated within the saturated zone for all or part of the year. The impacts on groundwater due to contaminant leaching above the water table appear to be significantly fewer than for materials lying within the saturated zone. For this reason, it is important, to the extent practicable, to address tailings/waste rock and other source media subject to groundwater saturation in the remedial action.

In general, estimated depths of soil targeted for remedial action are based on the soil boring data presented in the RI. Estimated depths of soil targeted for remedial action for soil borings are summarized in Table 2-5 and illustrated in Figures 2-1 and 2-2.

Table 2-5 Estimated Depth of Soil Remedial Goal Exceedance

Soil Boring ID	Estimated Depth of Remedial Goal Exceedance (feet bgs)	Total Boring Depth (feet bgs)
11DS01	13	16
11DS02	10	14
11MP01	2	16
11MP10	2 (Monofill #2 Area)	6
11MP11	10 (Monofill #2 Area)	8
11MP12	15 (Monofill #2 Area)	22
11MP13	>6 (Monofill #2 Area)	6
11MP14	28 (Monofill #2 Area)	60
11MP15	10 (Monofill #2 Area)	8
11MP16	14 (Monofill #2 Area)	10
11MP17	14 (Monofill #2 Area)	32
11MP18	20 (Monofill #2 Area)	22
11MP19	2	32
11MP20	6	31
11MP21	4	16
11MP22	18	16
11MP23	24	22
11MP24	25	22
11MP25	36	36
11MP26	20	18
11MP27	8	6
11MP28	14	10
11MP29	30	26
11MP30	16	24
11MP32	16	14
11MP34	18	22
11MP35	16	22

Table 2-5 Estimated Depth of Soil Remedial Goal Exceedance

Soil Boring ID	Estimated Depth of Remedial Goal Exceedance (feet bgs)	Total Boring Depth (feet bgs)
11MP36	10	16
11MP37	14	22
11MP38	17	16
11MP39	12	16.5
11MP40	9.5	14.5
11MP45	16	12
11MP46	24	20
11MP47	27	26
11MP48	18	14
11MP49	15	14
11MP50	3.5	6
11MP51	10.5	14
11MP52	6	42
11MP53	14	8
11MP54	12	8
11MP55	8	6
11MP56	8	10
11MP57	12	10
11MP58	16	14
11MP59	18	16
11MP60	29	33
11MP61	8	6
11MP62	4	29
11MP63	8	6
11MP66	2	28
11MP88	29	63
11MP89	12	41
11MP91	16	51.5
11RD01	0	16
11RD02	10	14
11RD03	14	16
11RD04	4	14
11RD05	2	25
11RD06	8	14
11RD07	2	12
11RD20	5	23
11RS01	12	14

Table 2-5 Estimated Depth of Soil Remedial Goal Exceedance

Soil Boring ID	Estimated Depth of Remedial Goal Exceedance (feet bgs)	Total Boring Depth (feet bgs)
11RS02	12	16
MW01	24	31
MW03	20	26
MW04	30	34
MW06	20	24

Key:
bgs = below ground surface
ID = identifier

Throughout most of the Main Processing Area, tailings/waste rock was identified in soil borings to varying depths. Underlying native soils with concentrations of one or more or the primary COCs exceeding RGs also were identified. The depth below the base of tailings/waste rock of soil with concentrations exceeding the RGs is not known at some soil boring locations. The soil boring depths at most locations were limited, in accordance with the Final RI Work Plan (E & E 2011), to approximately 3 feet below the base of tailings/waste rock, thus limiting information on COC concentrations at depths greater than approximately 3 feet below the base of tailings/waste rock at most soil boring locations. Concentrations of antimony, arsenic, and mercury are commonly elevated above the RGs in soils below tailings/waste rock to at least the depth of the deepest sample collected from a given soil boring. As such, the depth of soil with concentrations exceeding RGs in some areas with tailings/waste rock is not fully delineated. For the purpose of the FS, where the depth of exceedance of RGs is not fully defined by the RI data, the depth of RG exceedance was estimated by extrapolating below the depth of the soil boring.

Bedrock and/or weathered bedrock was encountered in some soil borings within the areas targeted for remedial action. Where the depth of exceedance of one or more RGs occurs continuously from the surface down to the depth of the weathered bedrock surface, the targeted remedial action depth was estimated at the top of the weathered bedrock surface.

At some soil boring locations, the targeted remedial action depths are below the water table for at least part of the year.

Surface soil contamination was identified in an area east of the Post-1955 Main Processing Area. This area is illustrated in Figures 2-1 and 2-2. The targeted remedial action depth for this area was estimated at 1.5 feet bgs based on sampling in that area.

Mixed tailings/waste rock and contaminated soil is present in the area of the Red Devil Creek Delta, Rice Sluice Delta, and Dolly Sluice Delta Area (see Figures 2-1 and 2-2). These deltas extend into the Kuskokwim River. For the purpose of the FS, the material within the deltas that may be exposed during part of the year is considered soil, and the material that lies at elevations expected to be consistently below the river level is considered sediment. The approximate extent of soil exceeding soil RGs within the Red Devil Creek Delta, Rice Sluice Delta, and Dolly Sluice Delta area is illustrated in Figures 2-1 and 2-2. Kuskokwim River sediment is discussed further in Section 2.2.2, below.

Volumes of Soil and Sediment Targeted for Remedial Action

In general, the volume of soil and sediment targeted for remedial action for a given area was estimated by calculating the volume of soil between the existing topographic surface and the approximate base of soil RG exceedances. An existing topographic surface was generated using the 5-foot topographic contours developed by AeroMetric (2012) based on aerial photographs taken on September 21, 2010 (AeroMetric 2010a). For the sediment portion of the Red Devil Creek Delta, the Rice Sluice Delta, and the Dolly Sluice Delta that was submerged below the Kuskokwim River surface at the time the 2010 aerial photographs were taken, the configuration of the upper surface was approximated based on bathymetric data collected during the RI (E & E 2013).

Within the Main Processing Area (see Figures 2-1 and 2-2), where numerous soil boring points exist, a surface representing the base of soil RG exceedances was generated using AutoCAD Civil3D software by interpolating between individual soil boring data points and extrapolating to the perimeter of area.

Contaminated creek sediment and soil along Red Devil Creek within the Main Processing Area and downstream areas is expected to exceed RGs to varying depths below the present stream bed elevation. Within the Main Processing Area, where soil boring data are available to constrain the depth of RG exceedances, the depth of sediment RG exceedances was estimated based on data from individual soil borings. In the portion of the Red Devil Creek alignment downstream of the Main Processing Area where few soil boring data points exist (see Figures 2-1 and 2-2, Red Devil Creek Downstream Alluvial Area, Creek Channel Area), the depth of sediment RG exceedances was estimated at 6 feet bgs based on sampling data from the RI.

For the two areas of soil contamination on either side of Red Devil Creek where few soil boring data points are available, the depths of RG exceedance for the areas were estimated based on the average depth of RG exceedances for those soil borings that lie within the areas (see Figures 2-1 and 2-2).

For contaminated soil/sediment within the area of the Red Devil Creek Delta, Rice Sluice Delta, and Dolly Sluice Delta, the depth of soil RG exceedances was estimated based on depth of RG exceedances in soil borings and the estimated elevation of the Kuskokwim River at low river level. For the purpose of the FS, an elevation of 164 feet is assumed to represent the low river stage elevation. Therefore, for the portion of the delta area that extends into the river channel, the base of soil RG exceedances was set at an elevation of 164 feet.

2.2.2 Sediments

Within Red Devil Creek, sediments are contaminated as a result of migration of alluvial materials, including tailings/waste rock. For the purpose of the FS, the extent of sediment contamination was estimated based on exceedance of sediment RGs for total antimony, arsenic, mercury, and/or methylmercury (see Table 2-3).

Contaminated are located within the area of the Red Devil Creek Delta, Rice Sluice Delta, and Dolly Sluice Delta. For the purpose of the FS, any material within the deltas at elevations expected to be consistently below the river level is considered sediment. Also for the purpose of the FS, an elevation of 164 feet is assumed to represent low river level elevation. Some of the contaminated sediment within the delta areas is overlain by contaminated soil (see Figures 2-1 and 2-2). The extent of sediment RG exceedances based on RI sediment data is illustrated in Figure 2-3. The RI sediment sample results do not fully delineate the lateral extent of contamination; therefore, for the purpose of the FS, an additional area equal to 25 percent of the area of contaminated sediments shown in Figure 2-3 is assumed.

2.2.3 Surface Mined Area

Pockets of exposed natural ore and highly mineralized soil/bedrock have been observed within the Surface Mined Area and are actively eroding and transporting contaminated material into Red Devil Creek. Sufficient site reconnaissance to identify these localized pockets has not been performed to provide an accurate estimate. Therefore, it has been assumed that a maximum of 5 acres of area within the Surface Mined area will need to be addressed.

2.3 Applicable or Relevant and Appropriate Requirements

This section identifies ARARs and other standards, criteria, and guidance "to be considered" (TBC) for remedial activities at RDM. Identification of ARARs and TBCs is used in assessing the feasibility of remedial action alternatives; however, ARARs and TBCs are identified iteratively throughout the RI/FS process leading up to the Record of Decision.

ARARs are defined by the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300.5). Applicable requirements are cleanup and control standards, as well as other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be considered applicable.

Relevant and appropriate requirements, while not applicable requirements, do address problems or situations sufficiently similar to those encountered at a particular CERCLA site that their use is well suited to that site.

TBCs are non-promulgated federal or state advisories, guidance, or proposed rules that are not legally binding and do not have the status of a potential ARAR but are useful in determining the necessary level of cleanup for protection of human health and the environment if ARARs are unavailable.

ARARs and TBCs are divided into three categories:

- Chemical-specific ARARs, usually health- or risk-based numerical values or methodologies that establish an acceptable amount or concentration of a chemical in the ambient environment;
- Action-specific ARARs, usually technology- or activity-based requirements for remedial actions; and
- Location-specific ARARs, restrictions placed on the concentration of hazardous substances or the conduct of activity solely because they occur in special locations.

Chemical-, location-, and action-specific ARARs and TBCs for RDM were identified on the basis of existing site data and are presented in Table 2-6. If both federal and state laws address the same issues that are applicable, appropriate, and relevant, the more stringent or specific one is cited below to reduce redundancy. In addition, many regulations refer to other regulations for specific guidance. In these cases, the substantive guidance has been cited.

2.4 General Response Actions

GRAs are broad categories of remedial actions that may, either individually or in combination, achieve the RAOs established in Section 2.1 and, like RAOs, are medium-specific. The identification of GRAs is the first step in the identification of remedial technology types and specific process options.

The following GRAs are applicable for addressing tailings/waste rock, contaminated soil, and contaminated Red Devil Creek sediment at RDM:

- The *No Action Alternative* is included as a baseline for comparing other potential response actions. Consideration of a no action approach is required by the NCP (40 CFR 300.430).
- *Institutional Controls (ICs)* may be used to restrict access to and uses of land and contaminated material, thereby limiting exposure. ICs may include administrative and/or legal controls, public awareness efforts, and/or a combination of these to minimize the potential for exposure to contaminants.
- *Access Controls (ACs)* may be used to physically limit direct contact with contaminated material, thereby limiting exposure. ACs may include physical barriers, such as fencing and gates, and warning signs.

Table 2-6 Applicable or Relevant and Appropriate Requirements

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC
Chemical-Specific			
Federal			
Resource Conservation and Recovery Act, Subtitle C – Identification and Listing of Hazardous Waste	40 CFR 261 42 USC 6921	Defines solid wastes which are subject to regulation as RCRA hazardous wastes. Solid wastes are considered hazardous if they are specifically listed in 40 CFR 261 Subpart D or if they exhibit one of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity).	Applicable
Safe Drinking Water Act	42 USC 300f et seq.	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Relevant and Appropriate
Clean Water Act	33 USC 12511 et seq.	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC
State			
Alaska Oil and Other Hazardous Substance Pollution Control Regulations	18 AAC 75.340 18 AAC 75.341 18 AAC 75.345 (except (a))	Provides method for determining cleanup levels for soil (under 40-inch soil zone) contaminated with petroleum hydrocarbons [18 AAC 75.340(a)(1)(A)] or with chemicals other than petroleum hydrocarbons [AAC 75.340 (a) (2) (A)].	Applicable
Location-Specific			
Federal			
Archaeological and Historic Preservation Act of 1974	16 USC 469 40 CFR 6.301(c)	Provides for the preservation of historical and archaeological data that might otherwise be lost as a result of terrain alterations. If any remedial action could cause irreparable loss to significant scientific, pre-historical, or archaeological data, the act requires the agency undertaking the project to preserve the data or request the U.S. Department on the Interior to do so.	Applicable

Table 2-6 Applicable or Relevant and Appropriate Requirements

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC
Location-Specific (Cont.)			
Federal (Cont.)			
Archaeological Resources Protection Act of 1979	16 USC 470aa-mm 43 CFR Part 7	Requires permits for excavation of archaeological resources on public or tribal lands.	Applicable
Native American Graves Protection and Reparation Act	25 USC 3001-3013 43 CFR 10	Regulations that pertain to the identification, protection, and appropriate disposition of human remains, funerary objects, sacred objects, or objects of cultural patrimony.	Applicable
Protection of Wetlands, Executive Order 11990	40 CFR 6	Requires federal agencies to avoid adversely impacting wetlands wherever possible, to minimize wetlands destruction, and to preserve the values of wetlands.	Applicable
Flood Plain Management, Executive Order 11988	40 CFR 6	Requires federal agencies to avoid, to the extent practicable, the long- and short-term adverse impacts associated with the occupancy and modification of flood plains, and to avoid direct and indirect support of flood plain development wherever there is a practicable alternative.	Applicable
Fish and Wildlife Coordination Act	16 USC 1251 661 et seq. 40 CFR 6.302(g)	Requires consultation with the U.S. Fish and Wildlife Service for the protection of fish and wildlife when a proposed action may result in modifications to stream, river, or other surface water of the U.S.	Applicable
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable
Endangered Species Act	16 USC 1531 40 CFR 6.302(b) 50 CFR 17, 402	Provides for the protection of fish, wildlife, and plants that are threatened with extinction. Federal agencies are required under Section 7 of the ESA to ensure that their actions will not jeopardize the continued existence of a listed species or result in destruction of or adverse modification to its critical habitat. If the proposed action may affect the listed species or its critical habitat, consultation with the U.S. Fish and Wildlife Service may be required.	Applicable
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable

Table 2-6 Applicable or Relevant and Appropriate Requirements

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC
Location-Specific (Cont.)			
Federal (Cont.)			
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate
State			
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Relevant and Appropriate
Alaska Solid Waste Regulations	18 AAC 60.410	Location standards for monofills	Relevant and Appropriate
Alaska Department of Fish and Game Anadromous Fish Act	AS 16.05.871- .901	Provides for the protection of fish and game habitats in the State of Alaska. Consultation with the Alaska Department of Fish and Game is required for any activities that could impede fish passage or that could divert, obstruct, pollute, or change the natural flow or bed of an anadromous water body. Tidelands (to mean low water at the mouth) are included.	Applicable
Action-Specific			
Federal			
Clean Water Act – National Pollutant Discharge Elimination System	40 CFR 122-125 and 403	Establishes discharge limits and monitoring requirements for direct discharges of treated effluent and stormwater runoff to surface waters of the EPA gives states the authority to implement the National Pollutant Discharge Elimination System program.	Applicable
Clean Water Act, Section 404	33 USC 1344 40 CFR 230 33 CFR 320-330	Restricts discharge of dredged or fill material into surface waters of the U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation on site or offsite.	Applicable

Table 2-6 Applicable or Relevant and Appropriate Requirements

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC
Action-Specific (Cont.)			
Federal (Cont.)			
Clean Water Act – Water Quality Standards	40 CFR 131	Sets criteria for water quality based on toxicity to aquatic organisms and human health. States are given the responsibility of establishing and revising the standards, and the authority to develop standards more stringent than required by Clean Water Act.	Applicable
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable
Clean Air Act – National Ambient Air Quality Standards	40 CFR 50.1-50.17 42 USC 7409	Establishes National Ambient Air Quality Standards for six criteria pollutants (including particulate matter) to protect human health and the environment.	Applicable
Resource Conservation and Recovery Act – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides criteria by which solid waste disposal facilities and processes must operate to prevent adverse effects on human health or the environment. Facilities failing to meet these criteria are classified as open dumps, which are prohibited. Any remedial alternative that includes construction of a solid waste disposal facility would have to meet these requirements.	Applicable
Resource Conservation and Recovery Act – Hazardous Waste Management	40 CFR 260 42 USC 6921	Specifies hazardous waste management requirements. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate
Resource Conservation and Recovery Act – Generator Standards	40 CFR 262 42 USC 6922	Establishes standards for generators of hazardous waste. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate
Resource Conservation and Recovery Act –Treatment, Storage, and Disposal Facility Requirements	40 CFR 264 42 USC 6924	Provides requirements for the generation, transportation, storage, and disposal of hazardous waste, including design and operating standards for hazardous waste treatment, storage, and disposal units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate

Table 2-6 Applicable or Relevant and Appropriate Requirements

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC
Action-Specific (Cont.)			
Federal (Cont.)			
Resource Conservation and Recovery Act – Closure and Post-Closure Requirements	40 CFR 264.110-120	Specifies requirements for the closure and post-closure care of RCRA hazardous waste management units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate
Resource Conservation and Recovery Act – Standards Applicable to Transporters of Hazardous Waste	40 CFR 263 42 USC 6923	Establishes standards for the transportation of hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR Part 262.	Applicable
Hazardous Materials Transportation Act	49 USC 1801-1813 40 CFR 107, 171-173, and 177	Regulates the transportation of hazardous	Applicable
Invasive Species, Executive Order 13112		Prevents the introduction of invasive species and provides guidance for their control.	Applicable
State			
Alaska Solid Waste Regulations	18 AAC 60.007(b) 18 AAC 60.010(a) 18 AAC 60.015 18 AAC 60.025 (b)(4)	Provides standards for management of solid waste, including requirements pertaining to accumulation, storage, treatment, transport, disposal, land spreading, landfills, monofills, monitoring, and corrective action.	Relevant and Appropriate

Key:
AAC = Alaska Administrative Code
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
ESA = Endangered Species Act
MCL = Maximum Contaminant Level
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = To Be Considered
USC = United States Code

- *Stabilization/Containment* limits contaminant mobility via technologies such as surface water controls, erosion and sediment controls and capping, thus substantially reducing pathways of potential exposure.
- *Treatment* addresses the toxicity, mobility, or volume of contaminants through physical, chemical, or biological processes. Treatment of contaminated material includes remedial actions that can be conducted in situ or ex situ.
- *Excavation and Onsite Repository* addresses the mobility of contaminants and can be used in conjunction with treatment and/or disposal GRAs that reduce contaminant toxicity, mobility, or volume. Contaminated material could be excavated from all or portions of the site for subsequent consolidation in an onsite repository.
- *Excavation and Offsite Disposal* includes excavation of contaminated material from all or portions of the site and disposal at an offsite permitted disposal facility(ies).

2.5 Identification, Screening, and Evaluation of Remedial Technology Types and Process Options

This section further refines the GRAs into potentially applicable remedial technology types and specific process options to address tailings/waste rock, contaminated soil, and contaminated creek and river sediment at RDM. A description is provided for each remedial technology type and process option, followed by the rationale for retaining or eliminating it from further consideration.

The goal of screening is to identify one process option to represent each technology type to simplify the development of alternatives (Chapter 3). In some cases, more than one process option may be selected per technology type if two or more process options are sufficiently different in their performance that one would not adequately represent the other.

Remedial technology types and specific process options were identified based on the current understanding of site conditions, previous mine site and FS experience, a review of literature, and vendor information. The following guidance documents were reviewed to aid in the identification of potentially applicable remedial technology types:

- *Mining Waste Treatment Technology Selection, Web-Based Technical and Regulatory Guidance Document* (ITRC 2011).
- *Abandoned Mine Site Characterization and Cleanup Handbook* (EPA 2000).
- *Arsenic Treatment Technologies for Soil, Waste, and Water* (EPA 2002).
- *Treatment Technologies for Mercury in Soil, Waste, and Water* (EPA 2007).

Three evaluation criteria are used to screen remedial technologies and specific process options:

- Effectiveness – The degree to which the technology or process option is (1) capable of handling the estimated areas or volumes of contaminated media and meeting the RGs identified in the RAOs (i.e., reduces the toxicity, mobility, or volume of contaminants); (2) protective of human health and the environment during the construction and implementation phase (i.e., minimizes short-term impacts); and (3) proven and reliable with respect to site-specific contaminants and conditions.
- Implementability – The technical feasibility (i.e., the applicability in regard to the areas and volumes of contaminated media and the types of contaminants) and administrative feasibility (i.e., the ability to comply with ARARs; the availability and capacity of treatment, storage and disposal services; and the availability of necessary equipment and skilled workers) of implementing the technology or process option.
- Cost – The cost (capital and operation and maintenance) of the technology or process option.

GRAs, remedial technology types, and specific process options that do not satisfy RAOs and/or are inconsistent with the above three evaluation criteria were not retained for further consideration. Table 2-7 summarizes the screening and evaluation of remedial technologies and process options and identifies which remedial technologies and process options were retained for further consideration.

2.5.1 Remedial Technology Types and Process Options

2.5.1.1 Institutional Controls

ICs are non-engineered controls intended to minimize the potential for human exposure to contamination and/or protect the integrity of a remedy by limiting land or resource use. ICs do not actively address contamination, but attempt to meet the RAOs by reducing the potential for exposure to contamination. ICs are often used in conjunction with an active technology and/or ACs (e.g., fencing or warning signs). Technologies considered under this GRA include administrative and/or legal controls and public awareness.

Table 2-7 Evaluation of Remedial Technology Types and Process Options for Tailings/Waste Rock, Contaminated Soil, and Contaminated Creek Sediment

General Response Actions	Remedial Technology Type	Process Option	Effectiveness	Implementability	Cost	Screening Comments
No Action	NA	NA	Does not meet RAOs and does not reduce toxicity, mobility, or volume of contaminants	Implementable	Negligible to low	Retained as required by NCP
Institutional Controls	Administrative and/or Legal Controls	Land Use Restrictions	Depends on continued future use at the site; does not reduce contamination	Implementable. All processes and methods are established.	Low capital costs; negligible to low O&M costs	Potentially applicable in combination with other remedial actions
		Zoning Restrictions				
		Special Permits				
	Public Awareness	Deed Notices	Difficult to ensure that information reaches parties or ensure that the parties will heed the notice; does not reduce contamination	Implementable. All processes and methods are established.	Low capital and O&M costs	Potentially applicable in combination with other remedial actions
		Public Advisories				
		Public Outreach				
Access Controls	Physical Barriers	Fencing and Gates	Depends on continued future maintenance; does not reduce contamination	Implementable. All processes and methods are established.	Low capital and O&M costs	Potentially applicable in combination with other remedial actions
	Warning Signs	NA	Difficult to ensure that information reaches parties or ensure that the parties will heed the notice; does not reduce contamination	Implementable. All processes and methods are established.	Low capital and O&M costs	Potentially applicable in combination with other remedial actions

Table 2-7 Evaluation of Remedial Technology Types and Process Options for Tailings/Waste Rock, Contaminated Soil, and Contaminated Creek Sediment

General Response Actions	Remedial Technology Type	Process Option	Effectiveness	Implementability	Cost	Screening Comments
Stabilization / Containment	Surface Water Controls	Dikes / Berms	Reduces mobility of contaminants but not toxicity or volume	Implementable	Low capital and O&M costs	Potentially applicable in combination with other remedial actions
		Ditches	Reduces mobility of contaminants but not toxicity or volume	Implementable	Low capital and O&M costs	Potentially applicable in combination with other response actions
		Culverts / Pipes	Reduces mobility of contaminants but not toxicity or volume	Implementable	Low capital and O&M costs	Potentially applicable in combination with other remedial actions
	Erosion and Sediment Controls	Sedimentation Ponds	Reduces mobility of contaminants but not toxicity or volume	Implementable	Low to moderate capital and O&M costs	Potentially applicable in combination with other remedial actions
		Slope Layback	Reduces mobility of contaminants but not toxicity or volume	Implementable	Low to moderate capital and O&M costs	Potentially applicable in combination with other remedial actions
		Grading	Reduces mobility of contaminants but not toxicity or volume	Implementable	Low to moderate capital and O&M costs	Potentially applicable in combination with other remedial actions
		Re-vegetation	Reduces mobility of contaminants but not toxicity or volume	Implementable	Low to moderate capital and O&M costs	Potentially applicable in combination with other remedial actions

Table 2-7 Evaluation of Remedial Technology Types and Process Options for Tailings/Waste Rock, Contaminated Soil, and Contaminated Creek Sediment

General Response Actions	Remedial Technology Type	Process Option	Effectiveness	Implementability	Cost	Screening Comments
Stabilization/ Containment, cont'd	Capping	Soil / Vegetative	Reduces mobility of contaminants but not toxicity or volume	Implementable	Moderate to high capital costs; moderate O&M costs	Potentially applicable in combination with other remedial actions
		Rock	Reduces mobility of contaminants but not toxicity or volume	Implementable	Moderate to high capital costs; moderate O&M costs	Potentially applicable in combination with other remedial actions
		Synthetic Material (e.g., concrete, asphalt, geomembrane)	Reduces mobility of contaminants but not toxicity or volume	Implementable	Moderate to high capital costs; moderate O&M costs	Potentially applicable in combination with other remedial actions
Treatment	Ex Situ Chemical Treatment	Solidification/ Stabilization	Reduces mobility and/or toxicity of contaminants but not volume	Implementable	Moderate to high capital costs; moderate O&M costs	Potentially applicable in combination with other remedial actions
		Soil Washing(1)	Not effective in reducing mobility, toxicity or volume of site contaminants(1)	Moderate to difficult to implement(1)	High capital costs; moderate O&M costs(1)	Not retained after initial screening(1)

Table 2-7 Evaluation of Remedial Technology Types and Process Options for Tailings/Waste Rock, Contaminated Soil, and Contaminated Creek Sediment

General Response Actions	Remedial Technology Type	Process Option	Effectiveness	Implementability	Cost	Screening Comments
Treatment, cont'd.	In Situ Chemical Treatment	Solidification/ Stabilization(1)	Not likely to be effective in reducing mobility, toxicity or volume of site contaminants(1)	Implementable for portions of the site(1)	Moderate to high capital costs; moderate O&M costs(1)	Potentially applicable in combination with other remedial actions.
		Vitrification(1)	Reduces mobility of contaminants but not toxicity or volume(1)	Not implementable(1)	Prohibitively high capital costs; moderate O&M costs(1)	Not retained after initial screening(1)
Excavation/ Dredging and Disposal in an Onsite Repository	NA	NA	Reduces mobility of contaminants, but not toxicity or volume	Implementable	High capital costs; moderate O&M costs	Potentially applicable in combination with other remedial actions
Excavation/ Dredging and Offsite Disposal	NA	NA	Reduces mobility of contaminants, but not toxicity or volume, but does reduce toxicity and volume of material to be handled on-site.	Difficult to implement given the volume of contaminated material and remote nature of RDM	High capital costs; negligible to low O&M costs	Retained based on low O & M costs, potentially applicable in combination with other remedial actions.

Note:
(1) Represents process technology options that were not retained after initial screening.

Key:
NA = Not Applicable
NCP = National Oil and Hazardous Substance Pollution Contingency Plan
O&M = Operations and Maintenance
RAO = remedial action objective

Administrative and/or Legal Controls

Administrative and/or legal controls use the regulatory authority of a government entity to impose restrictions on citizens or property under its jurisdiction, custody or control to ensure long-term protection of contaminated or remediated sites. Process options include land use restrictions, zoning restrictions, and special permits.

- Land Use Restrictions – Restrictions that may impose a variety of limitations and conditions on the use of property (e.g., limit future land uses, soil management, groundwater use, etc.).
- Zoning Restrictions – Restrictions that specify land uses for particular areas (e.g., a local government could prohibit residential development in a contaminated or remediated area).
- Special Permits – Permits that outline specific requirements that must be met before an activity can be authorized (e.g., building, groundwater use, etc.)

These process options would provide limitations on future land use; however, mine wastes would remain at the site in their current condition. These process options would not reduce contaminant mobility, toxicity or volume, but could meet RAOs when combined with other remedial actions. No technical or administrative issues are known that would adversely affect the implementation of these process options, capital costs are considered to be low, and operation and maintenance (O&M) costs are considered to be negligible to low. This alternative would not address ecological risks.

Public Awareness

Public awareness process options include deed notices, public advisories, and public outreach, which inform landowners and the public about potential risks at a site.

- Deed Notices – Non-enforceable, informational documents filed in public land records to alert anyone searching the records to important information about the property.
- Public Advisories – Warnings, usually issued by public health agencies, either at the federal, state, or local level, that provide notice to potential users of land, surface water, or groundwater of potential risks associated with their use (e.g., fishing advisories).
- Public Outreach – Informational meetings, programs or pamphlets that alert potential users of land, surface water, or groundwater of potential risks associated with their use.

These process options may educate potential land users of potential risks associated with the site; however, mine wastes would remain at the site in their current condition. These process options would not reduce contaminant mobility, toxicity, or volume but could meet RAOs when combined with other remedial actions. Furthermore, there are few effective means for ensuring that public awareness efforts will result in reduced exposure to mine waste. No technical or administrative issues are known that would adversely affect the implementation of these process options. Capital and O&M costs associated with these process options are considered to be low.

2.5.1.2 Access Controls

ACs are physical controls put in place to prevent human and ecological receptor exposure to contamination and/or protect the integrity of a remedy by limiting direct contact with particular areas of concern. Like ICs, ACs do not actively address contamination but rather attempt to meet the RAOs by reducing the potential for exposure to contamination. ACs are often used in conjunction with an active remedy and/or ICs. ACs considered under this GRA include physical barriers, such as fencing and gates, and warning signs.

Physical barriers and warning signs can be readily installed with minimal disturbance of existing contaminated material, but ongoing O&M would be required to ensure ongoing effectiveness. Physical barriers may prevent exposure of both humans and large ecological receptors, but would not likely be effective in preventing exposure of smaller ecological receptors. Warning signs, however, would not be effective in preventing ecological receptors from exposure to mine contaminated material. These process options would not reduce contaminant mobility, toxicity, or volume but could meet RAOs when combined with other remedial actions. No technical or administrative issues are known that would adversely affect the implementation of these process options. Capital and O&M costs associated with these process options are considered to be low.

2.5.1.3 Stabilization/Containment

Stabilization/containment involves stabilization and containment of contaminated material through control of surface water, erosion and sediment control, and/or capping.

Surface Water Controls

Surface water controls are structures engineered to divert surface water, such as dikes/berms, ditches, culverts/pipes, etc. Surface water controls could be implemented at RDM to prevent surface water from coming into contact with contaminated material or engineered covers, thus reducing erosion and subsequent offsite transport of contaminants via the surface water pathway. Surface water controls do not actively address contamination but rather attempt to meet the RAOs by reducing the potential for exposure to contamination. Surface water controls may be used in conjunction with other remedial actions to enhance optimal performance.

Dikes/berms are earthen walls that prevent run-on and run-off from reaching sensitive areas. Ditches are constructed to collect and direct run-on and run-off captured by dikes/berms or slopes away from sensitive areas. Water is diverted in ditches to nearby surface water bodies or sedimentation ponds. Culverts/pipes can be used to direct water away from or beneath sensitive areas.

Surface water controls would reduce contaminant mobility by reducing erosion processes, but would not be effective in reducing the toxicity, or volume of contaminants. These process options could meet RAOs when combined with other remedial actions. No technical or administrative issues are known that would adversely affect the implementation of these process options. Ongoing O&M of surface water controls would be necessary. Capital and O&M costs associated with these process options are considered to be low.

Erosion and Sediment Controls

Erosion and sediment controls are implemented to stabilize soil, minimizing erosion and the conveyance of sediment to surface water. Technologies considered under this GRA include sedimentation ponds, slope layback, grading, and vegetation. Erosion and sediment controls could be implemented at RDM to minimize erosion of contaminated material and control eroded sediment. Erosion and sediment controls do not actively address contamination but rather attempt to meet the RAOs by reducing the potential for exposure to contamination. Erosion and sediment controls may be used in conjunction with other remedial actions to enhance optimal performance.

Sedimentation ponds capture sediment-laden water, limiting the transport of sediment to surface water. Slope layback entails reducing steep slopes back to no steeper than three horizontal to one vertical (3:1), which minimizes slope failure and erosion. Grading promotes surface water runoff and protects against erosion. Revegetation may consist of seeding with grass or shrubs to provide a vegetative cover that will protect against erosion and stabilize soil.

Erosion and sediment controls would reduce contaminant mobility by reducing erosion processes, but would not be effective in reducing the toxicity or volume of contaminants. These process options could meet RAOs when combined with other remedial actions. No technical or administrative issues are known that would adversely affect the implementation of these process options. Ongoing O&M of erosion and sediment controls would be necessary. Capital and O&M costs associated with these process options are considered to be low to moderate.

Capping

Contaminated material could be contained by placing a physical barrier (cap) over the surface. All, or a portion, of the contaminated material could be capped. The cap could be composed of soil, rock, and/or clay material designed to reduce the potential for erosion and water infiltration and resist the degrading effects of freeze/thaw cycles. Similarly, a synthetic material could be used as a cap or component of a cap for all or a portion of the contaminated material. Capping would limit direct contact with contamination, reduce erosion, and may reduce or eliminate water infiltration, depending on the cap components included and materials used. Process options considered under this technology for RDM include a soil/rock cover and a synthetic cover.

Capping is an effective and proven remedial technology and would be effective in meeting the RAOs to differing degrees, depending on the type of cap selected. Capping would reduce contaminant mobility but would not be effective in reducing the toxicity or volume of contaminants. This remedial technology could meet RAOs when combined with other remedial actions. No technical or administrative issues are known that would adversely affect the implementation of this remedial technology. ICs, surface water controls, erosion and sediment controls, and ongoing O&M would be necessary in conjunction with capping. Capital costs associated with this technology are considered to be moderate to high. O&M costs would be moderate.

2.5.1.4 Treatment

Technology types considered for RDM under the treatment GRA were ex situ and in situ chemical, physical, and biological treatment of contaminated material. No potentially applicable biological treatment methods were identified to handle the types, concentrations, and/or volume of contaminants at RDM.

Ex Situ Chemical Treatment

Solidification/Stabilization

Solidification/stabilization is a process that physically binds or encloses contaminants within a stabilized mass and/or chemically alters contaminants to reduce solubility, mobility, and/or toxicity. Ex situ solidification/stabilization involves mixing excavated soil or waste with binders such as cement, lime, fly ash, cement kiln dust, or polymers to create a slurry, paste, or other semi-liquid state, which is allowed time to cure into a solid form. Pozzolanic binders such as portland cement and fly ash are most frequently used for the solidification/stabilization of arsenic. For the solidification/stabilization of mercury, portland cement, sulfur polymer cement, sulfide and phosphate binders, cement kiln dust, polyester resins, or polysiloxane compounds are often used. The process may include the addition of pH adjustment agents, phosphates, or sulfur reagents to reduce the setting or curing time, increase the compressive strength, or reduce the leachability of contaminants.

Solidification/stabilization is an effective and proven process option – it is the most frequently used technology to treat soil and waste contaminated with arsenic or mercury. Data show that this technology has been used to meet regulatory cleanup levels (i.e., TCLP criteria), is commercially available to treat both soil and waste and generates a residual that typically does not require further treatment prior to disposal.

Solidification/stabilization would be effective in reducing the mobility and toxicity of the contaminants; however, it would increase the volume of waste material. This process option could meet RAOs when combined with other remedial actions. No technical or administrative issues are known that would adversely affect the implementation of this process option; however, solidification/stabilization would require specialized equipment. Capital costs associated with this technology are considered to be moderate to high, depending on the volume of waste to be treated and the quantity of treatment material required. O&M costs would be moderate.

Soil Washing

Soil washing is a water-based process that uses a combination of physical particle size separation and aqueous-based chemical separation on excavated soil to dissolve or suspend the contaminants in the wash solution, thereby reducing the contaminant concentrations in the soil. For soil washing to be applicable, the contaminants must be preferentially adsorbed onto the finer-grained soil (clay and silt) rather than the coarser-grained soil (sand and gravel). The separated fines must be further treated to remove or immobilize the contaminants. The liquid stream may require additional treatment prior to disposal.

An advantage of soil washing is that it can be used to reduce the volume of material that will require further treatment, which potentially lowers the cost of cleanup and disposal of the contaminated material. However, tailings are mixed with waste rock in most locations at RDM, and contaminants are present in both the finer- and coarser-grained soil. Furthermore, soil washing has only been used to treat arsenic in a limited number of applications, and its effectiveness can be limited for complex waste mixtures (such as metals mixed with organic compounds). Therefore, soil washing has been omitted from further evaluation.

In Situ Chemical Treatment

Solidification/Stabilization

This process option is similar to that described for ex situ chemical treatment, above, except that contaminated material is treated in situ, rather than excavated and treated ex situ. Rather than mixing excavated soil or waste, soil or waste is treated in place by injecting solutions of chemical precipitants, pH adjustment agents, and chemical oxidants.

Limited data are available regarding the effectiveness of in situ solidification/ stabilization in reducing the leachability (i.e., mobility) of arsenic or mercury. Furthermore, the most highly contaminated area of mine waste lies within the Red Devil Creek drainage, in contact with both surface water and groundwater, making the effectiveness of this process option even more unlikely. Therefore, in situ solidification/stabilization has been omitted from further evaluation.

Vitrification
Vitrification is a high temperature treatment designed to immobilize contaminants by incorporating them into a chemically durable, leach resistant, glass-like structure. Vitrification can be conducted in situ or ex situ (at an offsite facility). This technology typically requires a large amount of energy to achieve vitrification temperatures. In situ vitrification uses electrical current to heat (melt) and vitrify the treatment material in-place. Electric current is passed through soil by an array of electrodes inserted vertically into the surface of the contaminated zone. Vitrification is used to treat wastes to a maximum demonstrated depth of 20 feet (EPA 2002). Large contaminated areas are treated in multiple blocks that fuse together to form one large treated zone.

While vitrification is a proven process option for treating arsenic and mercury in soil or waste, it has not commonly been used at mine sites. Due to the large energy requirement together with the remote nature of RDM, capital costs would be prohibitively high for this process; therefore, vitrification has been omitted from further evaluation.

2.5.1.5 Excavation/Dredging and Onsite Repository
Construction of an onsite repository involves excavation and moving contaminated material to an engineered repository designed to contain a specific type of contaminated material. Mine waste would be excavated using heavy equipment such as an excavator and moved by truck to the repository. Material would be placed within the repository footprint using heavy equipment such as loaders, dozers, and compactors.

The onsite repository location would be selected based on the available surface area, lithology, groundwater table elevation, surface water drainage, flood plain, and other relevant factors. Upon completion of mine waste and sediment placement, final grading would be performed and cover layers would be placed. Cover layers could consist of soil, rock, clay material, and/or a synthetic material designed to reduce or eliminate the potential for erosion and water infiltration and resist the degrading effects of freeze/thaw cycles.

An onsite repository is an effective and proven remedial technology. An onsite repository would greatly reduce contaminant mobility but would not be effective in reducing the toxicity or volume of contaminants. This remedial technology could meet RAOs when combined with other remedial actions. For example, mobility and toxicity may be further reduced if solidification/stabilization techniques are used in conjunction with an onsite repository. No technical or administrative issues are known that would adversely affect the implementation of this remedial technology. ICs, surface water controls, erosion and sediment controls, and ongoing O&M would be necessary in conjunction with an onsite repository. Capital costs associated with this technology are considered to be high. O&M costs are considered moderate to high.

2.5.1.6 Excavation/Dredging and Offsite Disposal

Offsite disposal involves excavation and transport of contaminated material to an offsite, permitted disposal facility(ies). Due to the remote nature of RDM, excavated material would be transported by barge down the Kuskokwim River. A proper disposal facility(ies) would be selected based on the types and concentrations of contaminants in the mine waste, and testing would be required to ensure the waste meets the disposal facility's waste-acceptance criteria. Following disposal at an offsite facility(ies), the excavated area would be re-graded and re-vegetated.

Placement of mine waste in an appropriate offsite disposal facility(ies) would substantially reduce contaminant mobility; however, it would not address mine waste toxicity or volume of contaminants. However, offsite disposal would reduce the toxicity and volume of waste onsite. This remedial technology would be difficult to implement given the volume of contaminated material and the remote nature of RDM. No technical or administrative issues are known that would adversely affect the implementation of this remedial technology. However, due to the large volume of mine waste estimated for excavation and the remote nature of RDM, capital costs associated with this remedial technology are considered to be extremely high. Offsite disposal is retained for further analysis based on the low O&M costs associated with it.

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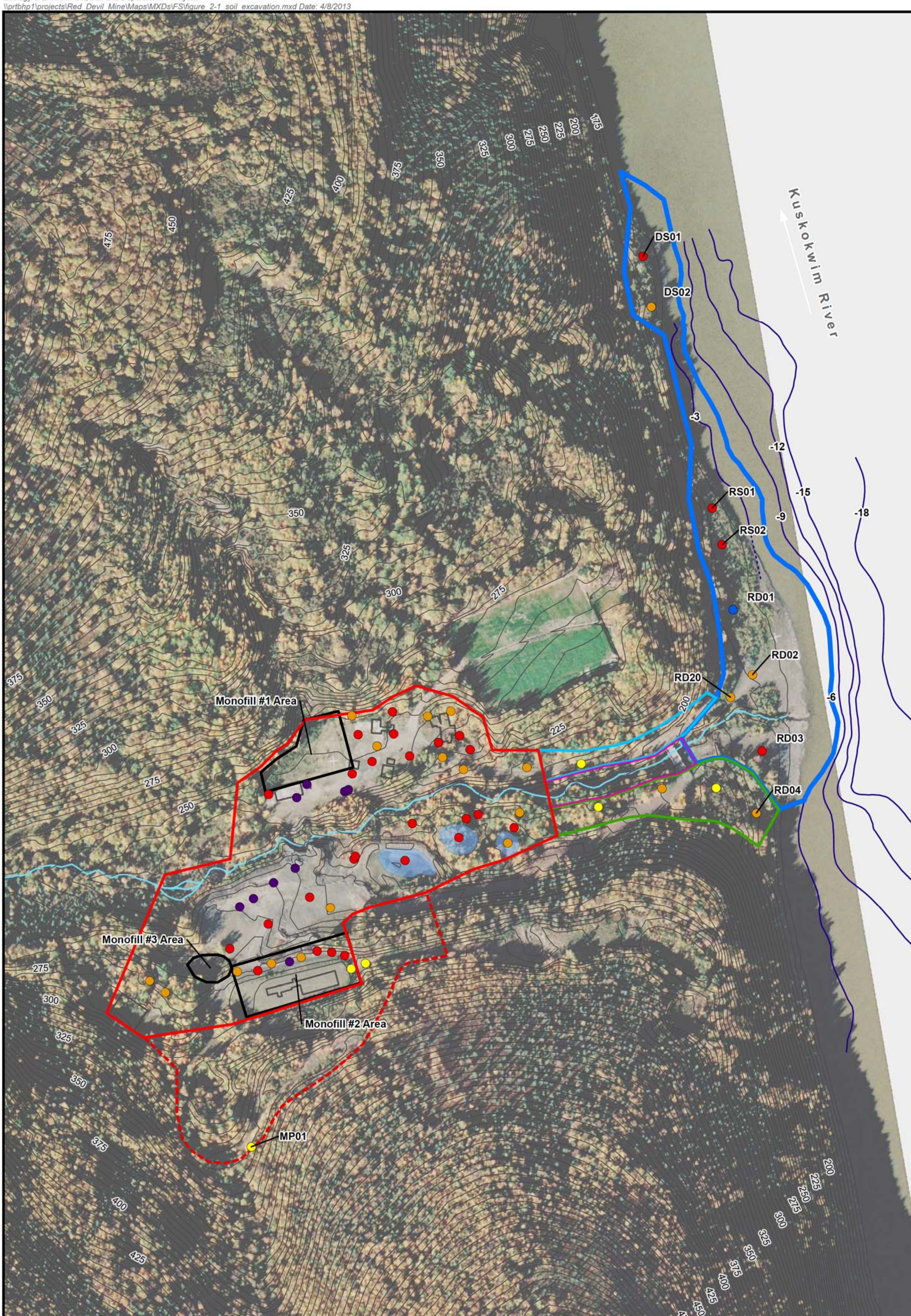

Soil Boring Locations and Estimated Depth of Remedial Goal Exceedance

- 0 feet bgs
- >0 to 2 feet bgs
- >2 to 10 feet bgs
- >10 to 20 feet bgs
- > 20 feet bgs

Note: See Figure 2-2 for detail of Main Processing Area and Red Devil Creek

bgs = below ground surface

Areas Targeted for Remedial Action

- Main Porcessing Area
- Red Devil Creek Downstream Alluvial Area, Creek Channel Area
- Area of Estimated Average 2 Foot Depth of Remedial Goal Exceedance
- Area of Estimated Average 4 Foot Depth of Remedial Goal Exceedance
- Area of Red Devil Creek Delta, Rice Sluice Delta, and Dolly Sluice Delta
- Area of Surface Soil Contamination East of Main Processing Area

- Monofill Area
- Bathymetric Contour (in feet). Contours represent approximate depth below river surface on September 25, 2011
- Topographic contour (feet NAVD88)
- Settling Pond
- Historical Structure

RED DEVIL MINE

Red Devil, Alaska

Figure 2-1

Estimated Areas and Depth of Soil Exceeding Remedial Goals

0 50 100 200 300 Feet

0 12.5 25 50 75 100 Meters

Scale 1:2,500

Image Source: Aero-Metric, Inc. 2010
Topographic contour source: AeroMetric, Inc. 2012

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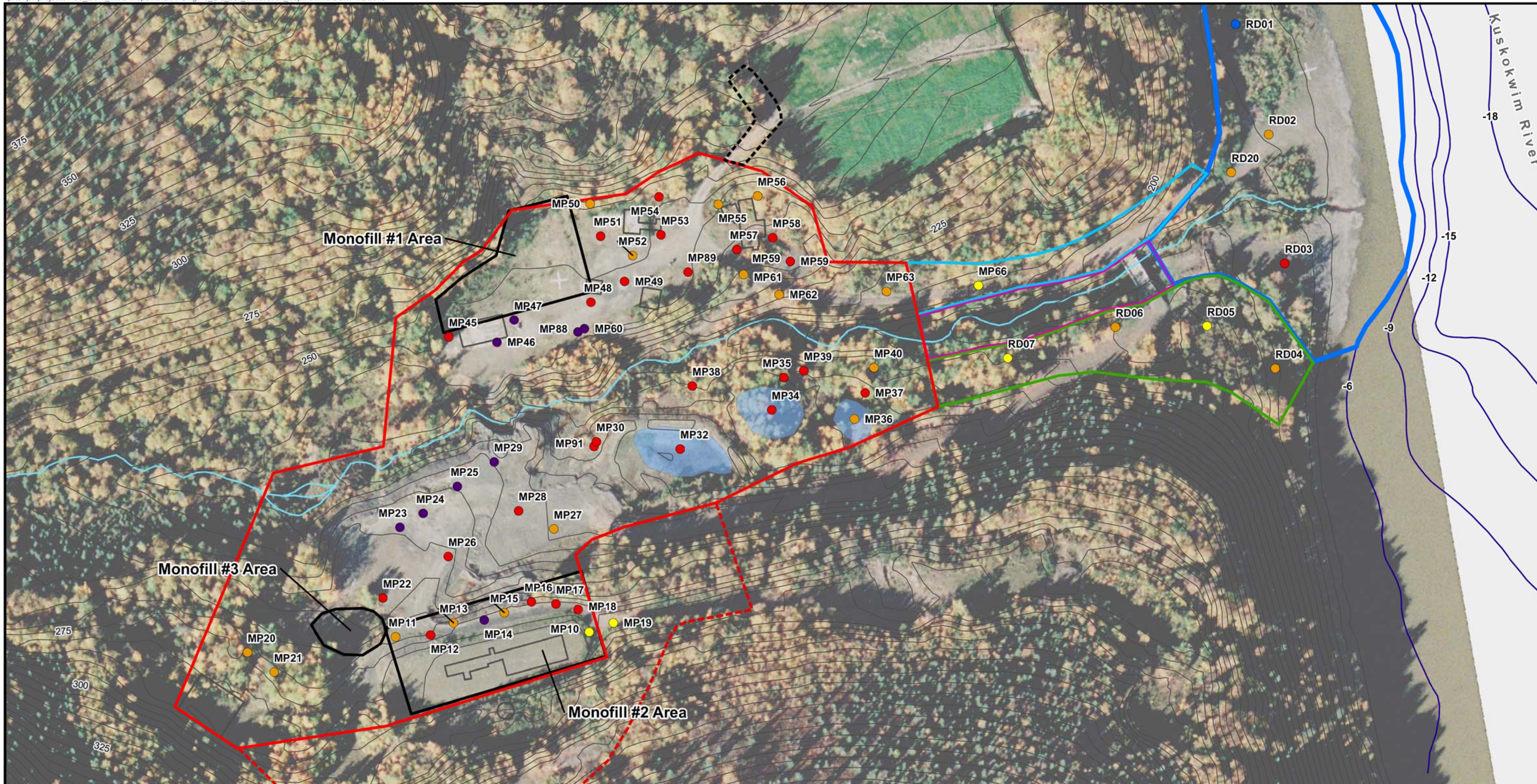

Soil Boring Locations and Estimated Depth of Remedial Goal Exceedance
- 0 feet bgs
- >0 to 2 feet bgs
- >2 to 10 feet bgs
- >10 to 20 feet bgs
- > 20 feet bgs

Areas Targeted for Remedial Action
- Main Porcessing Area
- Red Devil Creek Downstream Alluvial Area, Creek Channel Area
- Area of Estimated Aver 2 Foot Depth of Remedial Goal Exceedance
- Area of Esimated Average 4 Foot Depth of Remedial Goal Exceedance
- Area of Red Devil Creek Delta, Rice Sluice Delta, and Dolly Sluice Delta
- Area of Surface Soil Contamination East of Main Processing Area
- Area of Surface Soil Contamination, Road

- Monofill Area
- Bathymetric Contour (in feet). Contours represent approximate depth below river surface on September 25, 2011
- Topographic contour (feet NAVD88)
- Settling Pond
- Historical Structure

RED DEVIL MINE

Red Devil, Alaska

Figure 2-2

Estimated Areas and Depths of Soil Exceeding Remedial Goals, Main Processing Area

0 37.5 75 150 225
Feet
0 7.5 15 30 45 60
Meters
Scale 1:1,500

Image Source: Aero-Metric, Inc. 2010
Topographic contour source: AeroMetric, Inc. 2012

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3 Identification of Remedial Alternatives

In this chapter, medium-specific remedial technology types and process options retained for further consideration in Chapter 2 are combined to form remedial alternatives for RDM as a whole. The primary objective of this phase of the FS is to develop an appropriate range of site-wide remedial alternatives that will achieve the project's RAOs. The alternatives were developed based on their capacity to achieve site-wide protectiveness, combining different remedial technology types to address different volumes of media and/or areas of the site. They were further refined in regard to process option details (i.e., containment or treatment system sizing, remediation timeframe, spatial requirements, transportation distances, required permits, etc.).

This chapter describes each alternative in detail. Due to the setting of the site, the type of contamination (i.e., COCs listed in Table 2-1), and the volume of material to be addressed, a limited number of technology types and process options were retained for discussion in Chapter 2. Therefore, a screening of alternatives was not required in order to select a reasonable number of alternatives for detailed analysis.

An early action was conducted in 2014 that modified the tailings pile south of Red Devil Creek and two sections of the creek itself in the vicinity of the Main Processing Area. The modifications to the tailings pile and creek are designed to prevent migration to the Kuskokwim River during the pre-remediation interim period and are, in that context, compatible with the remedial alternatives presented in this section. The FS remedial alternatives are not affected by changed site conditions resulting from the early action.

3.1 Development of Remedial Alternatives

A range of remedial alternatives was developed to address the media of concern as follows:

- Alternative 1 – No Action;
- Alternative 2 – Institutional and Access Controls;

- Alternative 3a – Excavation of Solids and Sediments, Solidification, Onsite Consolidation, and Capping;
- Alternative 3b – Excavation of Solids and Sediments, Solidification, Onsite Consolidation, Capping, and Collection and Offsite Disposal of Leachate;
- Alternative 3c – Excavation of Solids and Sediments, Solidification, Onsite Consolidation, Excavation and Consolidation of Monofill #2, and Capping;
- Alternative 3d – Excavation of Solids and Sediments, Solidification, Onsite Consolidation, Excavation and Consolidation of Monofill #2, Capping, and Collection and Offsite Disposal of Leachate; and
- Alternative 4 – Excavation of Solids and Sediments, and Offsite Disposal.

3.1.1 Alternative 1 – No Action

The No Action alternative is included as the first alternative in this FS as part of the requirements of the NCP. This alternative is used as a baseline against which other alternatives are measured and is included for comparative purposes.

Under the No Action alternative, the tailings, waste rock, contaminated soil, and sediments at the site would remain at their current location and condition, and no action would be taken to reduce the potential for human or ecological receptor exposure to COCs present onsite or for offsite migration of COCs. Under this alternative, no maintenance or monitoring would be performed at the site.

3.1.2 Alternative 2 – Institutional and Access Controls

- Land use restrictions
- Fencing and gates
- Signage
- Five-year review

Alternative 2 requires implementation of ICs in the form of deed restriction and ACs (fencing and signage) to restrict access to the site. Establishing ICs and ACs that restrict site access has implications in long-term management of the land. The long-term retention or disposal of the site lands by the government will involve development of a site management strategy separate from the CERCLA process.

Alternative Summary

Under Alternative 2, contaminated tailings, soils, and sediments would be left in place, and active remediation would be limited to erecting exclusion fencing (AC) to reduce the potential for potential receptors to gain access to the site and become exposed to onsite COCs. ICs in the form of land use restrictions would be established at the site to restrict future human exposure by limiting activity, use, and access to the property. Establishing ICs that restrict site access has implications in long-term management of the land. The long-term retention or disposal of the site lands by the government will involve development of a site management strategy separate from the CERCLA process.

The fencing AC would be constructed of material 16 gauge or heavier suitable to resist subarctic environments. Gates would be installed for controlled access and secured. For cost-estimating purposes, the fence and gate material would consist of 1-inch horizontal by 2-inch vertical galvanized welded wire, 72 inches in height. During the detailed design phase, the potential use of a finer mesh fence material to exclude additional ecological receptors would be evaluated. The exclusion fence material would be buried a minimum of 12 inches bags, leaving approximately 60 inches above the ground. It has been assumed that approximately 5,000 linear feet of fencing would be required. Figure 3-1 depicts the approximate location of the fencing. Warning signs would be installed along the perimeter fencing at the mine site at intervals of approximately 100 yards.

With contaminated tailings, soils, and sediments being left in place, five-year reviews meeting the requirements in Section 121 of CERCLA would need to be performed. The intent of five-year review is to assess the protectiveness of the remedy (i.e., alternative) by evaluating whether the remedy is functioning as intended, exposure assumptions are still valid, and new data have been obtained that could alter its effectiveness.

3.1.3 Alternative 3

The focus of Alternative 3 is to excavate COC contaminated tailings/soils and sediments, solidify excavated materials that exceed TCLP analysis for arsenic, and place them in a dedicated repository that would be constructed in the Surface Mined Area. It should be noted that this alternative would involve the placement of a protective loess cover on isolated hot spots of exposed highly mineralized areas within the Surface Mined Area. In developing Alternative 3, there are multiple options associated with its design. For this FS, four variations of the repository have been selected for development and analysis, as follows:

- Alternative 3a – The repository would be designed using a geomembrane cover. The contents of Monofill #2 would remain in place, and a new protective cover placed over it. No bottom liner or leachate collection system would be installed.
- Alternative 3b – In addition to the geomembrane cover, a bottom liner and leachate collections system would be installed. As with Alternative 3a, the contents of Monofill #2 would remain in place and a new protective cover installed.
- Alternative 3c – For this variation, the geomembrane cover would be installed and the contents of Monofill #2 excavated and placed within the

repository. As with Alternative 3a, no bottom liner or leachate collection system would be installed.

- Alternative 3d – For this variation, both a geomembrane cover and a bottom liner equipped with a leachate collection system would be installed. Additionally, the contents of Monofill #2 would be excavated and placed into the repository.

Each of the four variations for Alternative 3 are further described and developed in the following sections.

3.1.3.1 Alternative 3a – Excavation of Solids and Sediments, Solidification, Onsite Consolidation, and Capping

The following key components characterize Alternative 3a:

- Implement ICs and ACs (as described for Alternative 2). ICs in the form of land use restrictions would be established at the site to restrict future human exposure by limiting activity and use. The AC would be a fence to limit access to the repository area. Such ICs and ACs would remain in place for a duration determined by five-year reviews.
- Excavate tailings/waste rock, contaminated soil, and exposed delta material (i.e., soils and sediments within the upper 5 feet that contain COC concentrations above the RGs).
- In the event the interim removal left sediments in place that contain COC concentrations above the cleanup objectives, excavate that remaining materials.
- Excavate contaminated sediment located in and immediately adjacent to Red Devil Creek. Areas within and downstream of the Main Processing Area that were not addressed under the early action, and that include the barge landing area, would be excavated as well. Provide temporary erosion and sediment controls during construction, including temporary diversion of Red Devil Creek.
- Conduct solidification of excavated materials that fail TCLP for arsenic and consolidate materials in an onsite repository with a geomembrane cover (including a geocomposite drainage layer and rock cover layer) and drainage ditches for control of surface water run-on and run-off.
- Construct a cover system for Monofill #2 to prevent direct exposure to contaminated soils and tailings.
- Re-grade exposed highly mineralized soil/bedrock in the Surface Mined Area to consolidate it at stable slopes, cap with locally obtained loess, and install drainage ditches to control surface water run-on and run-off.
- Conduct maintenance and monitoring.

The ICs and ACs to be implemented as part of Alternative 3a restrict access to the site. Establishing ICs and ACs that restrict site access has implications in long-term management of the land. The long-term retention by the government or disposition by the government will require development of a separate plan of action.

Alternative Summary

Under Alternative 3a, approximately 210,000 cubic yards of contaminated tailings/waste rock, contaminated soil, delta material, and Red Devil Creek sediment would be excavated and consolidated in an onsite repository. It should be noted that if the interim removal action left sediments having COC concentrations that exceed the cleanup objectives, they will also be excavated as part of the final remedy. This onsite repository would be constructed in the westernmost portion of the Surface Mined Area and would encompass an area of approximately 5 acres (see Figure 3-1). Tailings that fail the TCLP leach test would be transported to an area near the repository, solidified, and then directed to the repository location. Of the 210,000 cubic yards of material, approximately 31,500 cubic yards (i.e., 15 percent) would undergo solidification using portland cement as a binding agent. Material would then be placed and graded in the repository footprint using heavy equipment such as loaders, dozers, and compactors. Cross sectional details of the repository are presented in Figure 3-2.

Excavation

Contaminated material would be excavated using conventional open cut excavation methods with heavy equipment such as track excavators, wheel loaders, and scrapers. The depth of excavation would extend to the design depth (see Figure 3-1) or weathered bedrock, whichever were encountered first. In the event that groundwater is encountered in the excavation, the excavation would be dewatered using a pumping system. It should be noted that for locations where excavations may encounter groundwater, digging/removal would be performed to the extent practical during periods of decreased groundwater elevations to reduce the amount of pumping to the extent possible; however, it is understood that due to the limited field season, groundwater dewatering is anticipated, particularly in the spring during periods of snowmelt and thaw. For the purpose of this FS, it is assumed that pumped groundwater would not require treatment. The remedial design for RDM will identify whether there is a need for groundwater treatment. At a minimum, it is assumed that the extracted groundwater would have to pass through a settling basin to remove solids prior to being discharged. The collected sediments would then be placed in the repository. For excavation in the Red Devil Creek channel area, surface water would be temporarily diverted as necessary to allow efficient excavation of the contaminated material.

Tailings/waste rock and contaminated soil and sediment would be excavated, solidified (as needed), and moved to the onsite repository. Contaminated soil and sediment requiring consolidation would be excavated based on visual observations of soil type, where feasible. As noted in the RI Report, tailings/waste rock and native soil and sediment have similar lithological (i.e., physical) characteristics (E & E 2014). As such, careful lithological characterization would be required during excavation to identify contaminated materials to be excavated. Lithological observations would be used in conjunction with XRF field screening, which is field analysis for metals, to identify contaminated media and to guide the depth of excavation and help determine which material would require solidification. Laboratory confirmation samples would be collected over the course of excavation to confirm the completeness of the excavation. Laboratory confirmation sample results obtained during excavation would be combined with existing RI XRF field screening and laboratory results to refine the correlation of the XRF field screening and laboratory results.

As noted in Chapter 1 and detailed in the RI Report (E & E 2014), the background levels used to identify contamination, particularly those for subsurface soil, are considered to be conservative and likely underestimate pre-mining background concentrations of inorganic elements in some locations where naturally mineralized soils underlie the site, including parts of RDM that are subject to remediation. As also noted in the RI Report, the BLM has not yet been able to delineate the area or ranges of concentrations of naturally mineralized soil. Therefore, it is expected that during excavation, areas containing naturally mineralized soil with concentrations above the RGs would be encountered. The completion of excavation at such locations would be determined based on additional data scheduled to be collected prior to and during the field action.

Monofill #2

The surface area of Monofill #2 contains spent tailings and soils containing contaminant concentrations that exceed the RGs for RDM. To address the exposure risk associated with the contamination in this area, a protective concrete cloth cover would be placed over the footprint of Monofill #2 to prevent direct contact with or exposure to the contaminated media.

Concrete cloth is a flexible, cement-infused fabric that hardens when hydrated. It forms a thin, durable, low-permeability concrete layer that takes the shape of the surface to which it is applied. The benefit of this material, particularly for RDM, is that it does not require a concrete mix plant or mixing equipment to prepare, nor does it require heavy equipment for installation. Once installed, the concrete cloth cover lifespan is approximately 25 years, assuming minimal O&M. The cover also has the ability to withstand freeze-thaw cycles. A copy of the cut sheets published for the concrete cloth is provided in Appendix A.

As part of the detailed design phase, the design engineer would determine the horizontal extent of the cover, sub-base preparation, slope requirement, and what erosion controls were needed, if any. For the purpose of this FS, it is assumed that the vertical extent of the cap would extend approximately 3 feet beyond the known perimeter of Monofill #2. The side slopes would be graded at a 2H to 1V slope to an overall 4-foot height above the surrounding ground surface. If the material from Monofill #2 is not sufficient to achieve the proposed slope grade and cap height, then additional tailings materials will be used. For cost estimate purposes, it was assumed that the volume of material on top of Monofill #2 will be sufficient to construct the grades necessary for the placement of the cover over this area. It is also assumed that no erosion controls, (i.e., surface water diversion trenches, vegetative cover, etc.) would be needed. Installation can be achieved using conventional construction methods and equipment. The cloth would be unrolled in horizontal strips along the width of Monofill #2, keyed into the base of the perimeter, and secured with stakes at 2- to 3-foot intervals. At the overlap of the cloth strips, a layer of bonding sealant would be installed and the concrete cloth layers would be screwed together prior to setting the material. The design documents will provide the final construction details and specifications for installation. Additionally, it has been assumed that will be taken from up stream of Red Devil and used for hydration of the concrete cloth.

Surface Mined Area

Pockets of exposed natural ore and highly mineralized soil/bedrock have been observed within the Surface Mined Area and are actively eroding and transporting material into Red Devil Creek. In order to stabilize these areas, exposed ore would be delineated in the field and re-graded to provide stable slopes, and then these isolated areas would be covered with locally derived natural occurring silt (i.e., loess). Loess would provide a suitable vegetative growth medium. For the purposes of this FS, it was assumed that approximately 5 acres worth of isolated areas of the Surface Mined Area will require a loess cover based on contamination observed in samples collected from the surface soils at the site.

Additionally, drainage ditches will be installed around the upgradient perimeter of each exposed area to divert runoff and help mitigate future infiltration and erosion of these mineralized soils. Material excavated from the Surface Mined Area that results from the re-grading and drainage ditch installation would be solidified and consolidated in the repository.

Red Devil Creek Sediment Excavation

Partial sediment excavation was completed during the 2014 field season under the early action (removal action) and included contaminated sediment identified along the portion of the Red Devil Creek channel adjacent to the Main Processing Area. Material excavated from the creek bed and stream banks during the early action has been stored in temporary stockpiles until the sediment can be incorporated into the proposed repository.

Under Alterative 3a, it is assumed that the remaining sediment along Red Devil Creek downstream of the Main Processing Area will be excavated to remove contaminants above RGs while minimizing the spread of contaminants to the surrounding environment during excavation. Additionally, sediment having COC concentrations above the RGs that may not have been addressed as part of the 2014 early action will be excavated as part of the final remedy. Sediment removal along Red Devil Creek will address erosion and transport of residual contaminated sediments from the site via Red Devil Creek into the Kuskoskwim River. The extent of excavation of the remaining contaminated sediment along Red Devil Creek is presented in Figure 3-1.

Excavation is a commonly used technology that can be readily implemented, and it has a high potential for achieving RGs for RDM. Excavating would be accomplished by diverting portions of the creek, isolating the sediments and dewatering followed by the excavation. Standard construction equipment would then be used to remove the sediment, loading directly into dump trucks for transport to the staging/processing area for solidification (as necessary) and placement in the repository. The excavation would be conducted from the shoreline using long-stick equipment or by placing temporary mats for the equipment to enter the creek bed. Given the relatively low flow associated with the creek, a temporary diversion line would be installed, allowing the creek to continue to flow while excavation and restoration activities can be initiated and completed. Prior to discharging, the water generated by dewatering sediments (i.e., not naturally flowing as part of Red Devil Creek), would be analyzed to determine whether it meets Alaska Water Quality Standards (18 AAC 70) or if treatment is required prior to discharge.

Backfill

During the course of excavation activities, upon receipt of analytical results confirming that the lateral extent and the bottom of the excavation have met the RGs, backfilling would be performed. It is anticipated that the existing borrow source located along the river, as well as loess, sand, and gravel from offsite sources, can be moved to the site as needed and would provide a sufficient amount of material for both backfilling and construction of the new repository and haul roads.

As part of the detailed design phase, the design engineer would determine the compaction requirements for providing a firm base and stable slopes. For the purpose of this FS, it is assumed that material placement would be 95 percent compacted. Additionally, the design documents will identify the permits that may be necessary to obtain offsite source material. Final grade, top soil thickness, and seeding requirements will be identified in the remedial design documents.

Material Movement

Haul roads would be constructed from the excavation areas, including the borrow areas, to the repository location (see Figures 3-1 and 3-2). Preferably, sand, pit run gravel, and crushed gravel would be used in the construction of the haul roads. For the purpose of this FS, it is assumed that roughly half of the materials would be obtained from a nearby borrow source and the other half from nearby offsite locations. For each case, it has been assumed that the material can be moved to the site. Sand and gravel layers would be placed in lifts and compacted in accordance with the final design. Haul roads would be wide enough to allow for safe passing of two-way traffic. The haul road grade would follow the existing area contours; however, the final design specifications would utilize gentle curves to reduce the overall grade so as to not exceed approximately 8 percent, and the haul road crown would be graded at approximately 3 percent. Regular maintenance of the haul roads during the remedial action would include grading and resurfacing. Figure 3-2 provides select cross-sectional details of the proposed haul road at a conceptual design level; final design will be developed during the remedial design effort.

Onsite Consolidation and Solidification

Onsite consolidation and solidification has been selected as the treatment technology under Alternative 3a for the mine tailings that fail TCLP analysis for arsenic. Solidification is a technology that encapsulates a waste to form a solid mass or coat the waste with a low-permeability material in order to restrict contamination migration and reduce the potential for leaching of contamination into the surrounding environment.

The solidification process selected for RDM involves ex-situ treatment using portland cement and consists of the following steps:

1. Staging the excavated material;
2. Screening the material to remove oversized gravel and cobbles that are too large in diameter to be treated effectively;
3. Blending the binding agents and water obtained from Red Devil Creek with the excavated solids in a pug mill; and
4. Stockpiling the treated solids for testing prior to placement repository.

Contaminated material that has been identified as being too large to incorporate into the solidification treatment process will be hauled and placed directly into the repository. For the purposes of this FS, it was assumed that 15 percent of the total excavated volume would require solidification based on observations of contaminant levels at the site.

Although a treatability study has been performed to determine the effectiveness of the technology, the study was limited in volume. A large scale field test needs to be conducted prior to initiating full-scale solidification so as to determine the effectiveness for large volumes of material and to help refine the treatment process that will be implemented. It is anticipated that the field test would be performed prior to the site-wide removal action.

Repository

While multiple types of cover systems could be implemented at RDM, an impermeable geomembrane cover was selected as the preferred type for this project. While a permeable rock cover system could be readily implemented, it would not significantly reduce the amount of metals leaching from the contaminated media that would be stored in the repository. A concrete cloth liner system was deemed feasible; however, given the cost associated with barging the necessary materials to RDM and the infrastructure that would have to be established to support the construction, it was excluded from further consideration. A geomembrane cover was instead selected for the repository based on its ability to reduce the potential for surface water infiltration and the relative ease of transporting the necessary materials and installation equipment. Under this alternative, it is assumed that a bottom liner for the repository would not be necessary because the cover would be designed to provide adequate protection from water infiltration. By limiting water flow through the waste, contaminated leachate generation would be minimal and the need for a collection system and associated O&M negated.

The repository would be constructed by compacting the base soils within the footprint of the repository, placing tailings and contaminated sediments material in 2-foot lifts, and compacted in accordance with the final design documents. Side slopes would have a maximum slope of 2.5H:1V, and the top of the repository would be graded at 3 percent to promote drainage. To limit infiltration into the repository from precipitation, a protective geotextile underlay and geomembrane would be placed over the contaminated material and overlain with 18 inches of cover soil. Vegetation would then be established on the cover soils to protect against erosion. For the purpose of this FS, the cover is assumed to be a 60-millimeter reinforced polyvinyl chloride (PVC) geomembrane. The geotextile and geomembrane would be secured in an anchor trench design to account for soil solifluction. The geofabric would be installed above the geomembrane liner and would act to stabilize the cover soils and provide drainage through the cover system. Additionally, the geotextile can act as a cushion between the cover soils and the geomembrane, protecting the geomembrane from tearing or puncturing during construction of the repository.

It should be noted that in an attempt to reduce the amount of material needed to construct the repository, excavated Red Devil Creek sediments would be placed on top of the tailings to reduce the need for a layer of sand/fine soils to protect the geomembrane from puncture from the angular tailings. Soil properties for Red Devil Creek sediments, sluices, and delta material will be analyzed as part of the remedial design to determine their usability. In the event that there is insufficient volume of creek sediments or it is determine that it is not suitable, material from an off-site borrow source will be used. Figure 3-2 provides select cross-sectional details for the proposed repository.

The repository cover soil would be seeded with native plants, including grasses. The actual seed mix and plant species would be determined during the detailed design phase. Attempts would be made to select a seed mix that utilized plants with tap roots that do not exceed the thickness of the soil layer overlying the geotextile. Due to the subarctic environment at RDM, the vegetative cover may require several growing seasons to effectively establish. During this period, erosion control measures such as erosion control blankets, tackifier, and certified weed-free straw mulch would be employed. Seeding should occur between June and August to take advantage of the local rainy season and warmer temperatures. It is assumed that the soil cover would be irrigated using water from Red Devil Creek during construction to help stabilize it and that no irrigation would be required following construction.

During grading of the onsite repository, drainage ditches would be constructed along the upgradient perimeters to intercept surface water flow and direct it around the repository. The ditches would be constructed in native soil. Rock armoring or other energy-diffusing best management practices (BMPs) would be installed at the ditch discharge locations. An estimated 1,500 feet of drainage ditches would be required for the onsite repository. Figure 3-1 shows the estimated locations of the proposed drainage ditches.

Drainage controls, including those for the engineered covers over the mine waste piles, should accommodate, at a minimum, a 10-year, 24-hour storm event. The discharge locations of the drainage pathways would utilize energy dissipation methods to control erosion at the discharge.

Temporary erosion and sediment controls would be implemented during excavation activities. These controls could include silt fencing and hay bales strategically placed to prevent the offsite migration of site sediments, and leachable contaminants.

Operations and Maintenance

The cover systems for both the repository and Monofill #2 would be inspected annually for indications of erosion, instability, or damage. Repairs would be performed on an as-needed basis. The cover systems should be inspected during the spring thaw when melting ice and snow produce maximum seasonal runoff, as this is the time period when erosion and instability are likely to occur and could lead to offsite migration of contaminated material. Low permeability caps would be checked semiannually for the first three years. Additionally, and as noted for Alternative 2, while the repository is considered to be the final remedy, five-year reviews will be conducted until it is determined they are no longer necessary. Run-on and run-off controls would be inspected annually for erosion, blockage, or unexpected drainage patterns at the release site and repaired, maintained, or replaced on an as-needed basis.

In addition to O&M associated with maintaining the cover systems, groundwater monitoring will be performed. For the purpose of developing this alternative, it has been assumed that new wells will be drilled for the repository. It is anticipated that existing monitoring wells in the Main Processing Area will be decommissioned during the remedial action, making it necessary to install monitoring wells for Monofill #2. The new wells will be incorporated into the existing baseline groundwater monitoring program. For cost estimating purposes, it has been assumed that a total of 10 groundwater monitoring wells will be sampled yearly, with the samples being submitted for metals analysis.

3.1.3.2 Alternative 3b – Excavation of Solids and Sediments, Solidification, Onsite Consolidation, Capping, and Collection and Offsite Disposal of Leachate

Alternative 3b was developed to evaluate a repository design that includes a bottom liner. In all other respects, Alternative 3b is similar to Alternative 3a. The following specific elements of Alternative 3b are identical to Alternative 3a:

- The same ICs and ACs;
- Tailings/waste rock and soil excavation in the Main Processing Area;
- Monofill #2 cover system;
- Red Devil Creek sediment excavation;
- Backfilling;
- Material movement;
- Onsite consolidation and solidification;
- Identical repository design with the addition of a liner and leachate collection system; and
- Identical O & M activities.

In developing the conceptual design of the leachate collection system, a leachate generation analysis was conducted to evaluate the potential for leachate generation and its potential effects associated with local groundwater. Leachate generated through surface water infiltrating through the cover system and coming into contact with the repository contents was evaluated for two different scenarios that collectively represent the two most likely way that surface water could come into contact with the repository contents: 1) infiltration generation under normal conditions and 2) infiltration generation under a tear/break of protective cover. The analysis was performed using a model to simulate the volume and COC concentrations in leachate.

Repository Leachate Collection and Removal System

To mitigate the potential for leachate migration to come into contact with the underlying groundwater, a leachate collection and recovery system would be installed beneath the material placed in the repository and would consist of the following components:

- Compacted repository subgrade consisting of natural soil;
- A primary composite liner consisting of 2 feet of compacted cohesive, low permeable soil (loess);
- A 60-milliliter PVC geomembrane liner;

- A 12-inch drainage layer consisting of stone, 6-inch high-density polyethylene (HDPE) perforated leachate collection piping and lined with a geotextile filter fabric; and
- 6 inches of granular protective soil (i.e., Red Devil Creek excavated sediment) placed between drainage layer and the consolidated waste.

The liner and drainage system would be installed so that the slope along the base of the repository is graded to a minimum of one percent to direct infiltrated water toward the leachate collection pipes. Within the drainage layer, the leachate collection pipes would be placed within a 12-inch coarse aggregate base and lined with geotextile filter fabric to limit fines from clogging the pipes. The collection pipes would be directed toward the lowest point of the landfill, where collected leachate would be removed via a sump to be pumped from the repository to a barge for transport and offsite disposal. Figure 3-2 shows a representative cross section detailing the components of the proposed leachate collection and removal system. Periodically, the leachate would need to be drained from the repository and pumped into drums or totes in order to be transported by barge to the offsite disposal and/or treatment facility. This alternative also includes a second sump pumping system and buried pipeline that would run from the repository to the loading dock on the Kuskokwim River to facilitate loading of the leachate onto the barges. Based on the results of the leachate modeling (presented below and in Appendix B), the collected leachate would likely be classified as a hazardous waste (D004, arsenic).

Hydrologic Analysis

The hydrologic analysis was based on the cover design described under Alternative 3a. The analysis was performed using two models: Hydrologic Evaluation of Landfill Performance (HELP) and Variably Saturated 2D Flow and Transport (VS2DT). Both models are industry standard programs developed and maintained by EPA and United States Geological Survey, respectively. Both models are capable of simulating variably saturated conditions using a finite-difference grid. Visual HELP for Windows 2000/XP was used to simulate infiltration through the cover system and repository contents. The HELP results were used as input to VS2DT to simulate migration through the unsaturated zone. VS2DT is a comprehensive one-dimensional unsaturated zone model that simulates transport processes, including hydraulic diffusion, dispersion, decay, and adsorption. Natural attenuation processes were modeled in the VS2DT simulation to estimate the depth below ground surface at which the concentration of each contaminant (antimony, arsenic, mercury, and DRO) would be reduced to zero.

Model input reflects site-specific conditions where such data are available based on RI data and other sources, and literature values for those parameters that could not be estimated using site-specific data. Details of the modeling technical approach, assumptions, and results are presented in the draft Hydrogeologic Analysis report, included in Appendix B. Table 3-1 presents the results of the model simulations.

Table 3-1 Summary of Leachate Modeling Results

Holes in Geo-membrane (per acre)	Accumulative Water Balance (inches per acre for 50 Years)			Leachate Generated Per Year (gallons)	Depth after 50 Years at Which Concentration Reaches Zero (feet bgs) (1)			
	Runoff	Evapo Transport	To Groundwater		Arsenic	Antimony	Mercury	DRO
0	286	881	0.4	1,100	7.2	6.1	1.7	<0.1
10	234	881	33	90,000	9.6	7.2	1.7	<0.1
50	115	881	136	369,000	17.2	13.7	2.6	0.9

Note:
(1) bgs starts at the interface between the natural occurring ground surface and the repository.
Key:
bgs = below ground surface
DRO = diesel range organics

The technical approach adopted for the analysis assumed that the proposed geomembrane cover system would be installed using industry standard methods. Incidental infiltration induced by normal conditions (i.e., the cover system is intact) was simulated by assuming the presence of ten 1-square-centimeter holes evenly distributed over the entire repository, which assumes a fair to poor installation quality for the geomembrane (Schroeder et al. 1994). A hypothetical breach was simulated by assuming the presence of fifty 1-square centimeter holes evenly distributed over the entire repository. It was assumed that the holes in the cover system would be present for the full time period for both the normal (i.e., incidental infiltration) and breach simulations.

The current monitoring well network at RDM covers the Main Processing Area extensively, but only three wells were installed in the area northwest of the Main Processing Area as part of the RI. Of these wells, two (MW29 and MW30) are located approximately 200 feet and 100 feet west of the MPA, and one (MW31) is located in the upland background area approximately 500 feet southwest of the proposed repository location. Well MW31 is the well located closest to the repository.

The assumed depth to groundwater at the repository was based on water levels measured in monitoring well MW31. Between August 2011 and September 2012, the depth to groundwater in well MW31 ranged from 31.92 to 35.55 feet bgs. Based on those data, for the purpose of the analysis it was assumed that the depth to groundwater within the footprint of the repository is 30 feet bgs. It should be noted that preliminary observations made during installation of a new monitoring well installed approximately 100 feet southeast of the proposed repository as part of the 2015 RI Supplement activities indicate a significantly greater depth to water, possibly due to the influence of underground mine workings.

The simulation for incidental infiltration scenario resulted in an estimate of 90,000 gallons of water infiltrating through the geomembrane and into fill material over the 5-acre area of the repository per year. The simulation results predict that elevated concentrations of the COCs (arsenic, antimony, mercury) and petroleum hydrocarbons in leachate would not reach the groundwater table during the model duration period of 50 years.

The simulation for the breach scenario resulted in an estimate of 369,000 gallons of water infiltrating through the geomembrane and into fill material over the 5-acre area of the repository per year. The simulation results predict that elevated concentrations of the COCs (arsenic, antimony, and mercury) and petroleum hydrocarbons in leachate would not reach the groundwater table during the model duration period of 50 years.

The analysis results presented in Table 3-1 indicates that concentrations of COCs and petroleum hydrocarbons in leachate are reduced to negligible levels at a depth bgs that is well within the vadose zone. Based on those results, modeling of potential leakage of leachate through a bottom liner was not performed.

Operations and Maintenance

In addition to the O&M requirements presented for Alternative 3a, evaluation of the leachate collection system and the bottom liner would be required annually to assess whether damage to the bottom liner had occurred, clogs exist in the collection piping, sump and pipeline operational issues are occurring, or repairs are needed. Repairs would be performed on an as-needed basis. The system should be inspected during the spring thaw when melting ice and snow produce maximum seasonal runoff, as this is the time period when infiltration potential will be highest. Given the volume of leachate that will be generated, it has been assumed that leachate will be pumped twice a year (just after breakup and prior to the first snow). Also, based on the results of the leachate modeling, it has been assumed that the leachate will be classified as a hazardous waste.

3.1.3.3 Alternative 3c – Excavation of Solids and Sediments, Solidification, Onsite Consolidation, Excavation and Consolidation of Monofill #2, and Capping

Alternative 3c was developed to evaluate the technical feasibility of moving the contents of Monofill #2 and incorporating them into the proposed repository. In all other respects, Alternative 3c is similar to Alternative 3a. The following specific elements of Alternative 3c are identical to Alternative:

- ICs and ACs;
- Tailings/waste rock and soil excavation in the Main Processing Area;

- Red Devil Creek sediment excavation;
- Backfilling;
- Material movement;
- Onsite consolidation and solidification;
- Identical repository design with the addition of a liner and leachate collection system; and
- Identical O & M activities.

differs from Alternative 3a in that approximately 4,500 cubic yards of additional material associated with Monofill #2 would be excavated, sorted, and placed into the repository in a manner similar to the materials excavated from the Main Processing Area and as described for Alternative 3a. The proposed repository would accommodate this additional volume with little to no change in overall area or construction.

Monofill #2

Based on investigative data from the RI and review of previous site documents, it is estimated that approximately 4,500 cubic yards of material would be excavated as part of the Monofill #2 removal. Records indicate that approximately 940 cubic yards of treated debris was placed in the monofill. Additionally, it has been estimated that approximately 1,700 cubic yards of tailings were used as cover material (e.g., an area that is 250 by 60 by 3 feet thick). Using boring information, an additional 1,900 yards of material (i.e., surrounding soil and tailings) would also have to be removed. Therefore, under this alternative, 4,500 cubic yards of material would be excavated from the monofill and transported to the onsite repository.

Contents of the monofill would be excavated using conventional open cut excavation methods with heavy equipment such as track excavators, wheel loaders, and scrapers. The depth of excavation would extend to the design depth of 9 feet or weathered bedrock, whichever were encountered first. In the event that groundwater is encountered in the excavation, it would be handled in a manner similar to that described for Alternative 3a. For the purpose of this FS, it is assumed that pumped groundwater would not require treatment. The remedial design for RDM will identify whether there is a need for groundwater treatment. Some material within the monofill that is not suitable for disposal within the repository (i.e., wood, angular scrap metal, etc.) would be shipped offsite for disposal. This material would be decontaminated onsite as part of the preparations for offsite transport and disposal. Water that results from decontamination activities would be containerized and shipped offsite for proper treatment and disposal. Costs associated with transport and disposal associated with decontamination water and debris is included for this alternative.

Backfill/restoration of the Monofill #2 area after excavation would be accomplished in a manner similar to that described for Alternative 3a. However, the excavation of Monofill #2 would reduce the need for groundwater monitoring. Therefore, the new monitoring wells proposed under Alternative 3a for the Monofill #2 area are not proposed for Alternative 3c.

3.1.3.4 Alternative 3d – Excavation of Solids and Sediments, Solidification, Onsite Consolidation, Excavation and Consolidation of Monofill #2, Capping, and Collection and Offsite Disposal of Leachate

Alternative 3d represents a combination of features developed for Alternatives 3a, 3b, and 3c. Under Alternative 3d, tailings/waste rock and impacted media would be excavated and moved to a repository as presented in Alternative 3a. The repository would have a bottom liner and leachate collection system as presented in 3b, and the contents of Monofill #2 would be excavated and moved to the repository as presented in Alternative 3c. Alternative 3d includes the following key components presented for previous alternatives:

- The same ICs and ACs;
- Tailings/waste rock and soil excavation in the Main Processing Area, Red Devil Creek sediment, and Monofill #2;
- Red Devil Creek sediment excavation;
- Backfilling;
- Material movement;
- Onsite consolidation and solidification;
- Identical repository design with the addition of a liner and leachate collection system; and
- Identical O & M activities.

No significant change in the amount or quality of leachate is expected from that presented in Alternative 3b because the characteristics and volume of the additional material from Monofill #2 are relatively minor when compared to the over 200,000 cubic yards of material to be placed in the repository.

3.1.4 Alternative 4 – Excavation of Solids and Sediments, and Offsite Disposal

The following key components characterize Alternative 4:

- Excavate tailings/waste rock, contaminated soil, and exposed delta material.
- Excavate contaminated sediment located in and immediately adjacent to Red Devil Creek in areas downstream of the Main Processing Area.

Sediments not addressed under the early action, will be addressed under the final remedy. Temporary erosion and sediment controls will be provided during construction, including temporary diversion of Red Devil Creek.

- Re-grade exposed, highly mineralized soil/bedrock in the Surface Mined Area to consolidate it at stable slopes, cover it with locally obtained, naturally occurring loess, and install drainage ditches to control surface water run-on and run-off.
- Excavate the contents of Monofill #2 and backfill/restore the excavation.
- Provide temporary erosion and sediment controls during construction, including temporary diversion of Red Devil Creek.
- Transport and dispose of contaminated materials in a secured disposal facility.
- Perform maintenance and monitoring.

Alternative Summary

Under Alternative 4, approximately 210,000 cubic yards of contaminated tailings/waste rock, contaminated soil, delta material, Red Devil Creek sediment, and 4,500 cubic yards of material associated with the removal of Monofill #2—for a total of approximately 214,,000 cubic yards of material—would be excavated and shipped offsite for disposal. The transport of this material would require the use of approximately 152,000 super sacks. It should be noted that the State of Alaska does not have a disposal facility capable of accepting RDM materials. Therefore, it would be necessary to ship the excavated material to a facility in the continental United States for its final disposition.

Under Alternative 4, the methods of excavation, backfilling, grading and restoration would be the same as those outlined for Alternative 3a. However, under Alternative 4, the contents of Monofill #2 would be excavated and shipped offsite with the tailings/waste rock and contaminated soil for disposal.

Monofill #2

Approximately 4,500 cubic yards of contaminated material would be excavated from Monofill #2 using conventional open cut excavation methods with heavy equipment such as track excavators, wheel loaders, and scrapers; placed into super sacks; and shipped offsite for disposal. The depth of excavation would extend to the design depth of 9 feet or weathered bedrock, whichever were encountered first. In the event that groundwater is encountered in the excavation, it would be handled in a similar manner as described for Alternative 3a. For the purpose of this FS, it is assumed that pumped groundwater would not require treatment. The remedial design for RDM will identify whether there is a need for groundwater treatment.

Backfill/restoration of the Monofill #2 area after excavation would be accomplished in a manner similar to that described for Alternative 3a.

Transportation

As part of the excavation process, material would be placed into super sacks and moved to a staging area near the shoreline of the Kuskokwim River. Super sacks are made of a polywoven material that can withstand the rigors of being loaded with angular material such as the mine tailing generated at RDM. Super sacks can typically hold up to 1.5 cubic yards of material. Once loaded with material, the sacks, which are equipped with loading straps, can be moved using standard construction equipment. Additionally, the excavated sediments would be placed on a dewatering pad and left to "dry out" until they attained sufficiently low moisture content for placement into the super sacks.

Once a sufficient number of sacks had accumulated, a crane would be used to load them into a barge for transport to Seward, Alaska. Since a barge shipment can hold approximately 1,850 cubic yards, it is estimated that approximately 123 barge runs would be needed. The barge transport time is estimated to be five days, and three construction seasons have been assume for FS costing purposes.

Once in Bethel, the material would be unloaded and stored at the docks to await loading onto an ocean barge for transport to the Port of Seward in Seward, Alaska. Once in Seward, the super sacks would be off-loaded, transferred to rail box cars, and transported via freight train to a Resource Conservation and Recovery Act–approved offsite disposal facility in the continental United States. It has been assumed that the ocean shipment would take seven days and that approximately 1,850 cubic yards of material could be shipped in each barge. Additionally, it has been assumed that approximately 15 percent of the material would be classified as hazardous waste by the TCLP method for arsenic. The remaining material would be classified as non-special waste. For the purpose of developing this alternative, it has been assumed that the material would be disposed of at the waste management facility in Arlington, Oregon.

Surface Mined Area

As with Alternative 3a, Alternative 4 addresses localize hot spot areas. Exposed ore would be delineated in the field, re-graded to provide stable slopes and then these isolated areas will be covered with loess. For the purposes of this FS, it was assumed that 1 percent of the Surface Mined Area will require regarding and the placement of loess.

Drainage ditches will be installed around the upgradient perimeter of each exposed area to divert runoff and help mitigate future infiltration and erosion of these mineralized soils. Material excavated from the Surface Mined Area that results from the re-grading and drainage ditch installation will be shipped offsite for disposal.

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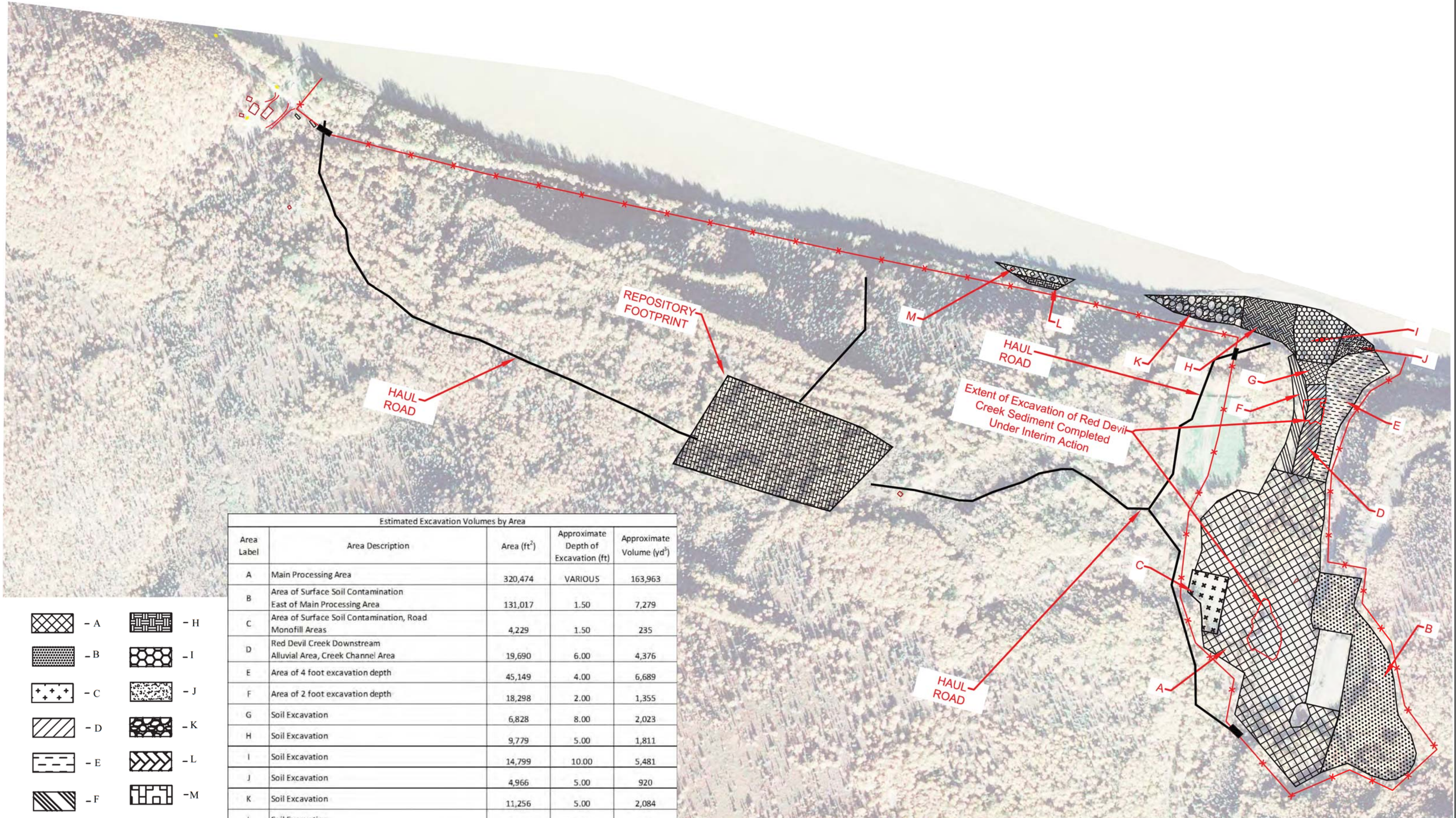

Estimated Excavation Volumes by Area

Area Label	Area Description	Area (ft^2)	Approximate Depth of Excavation (ft)	Approximate Volume (yd^3)
A	Main Processing Area	320,474	VARIOUS	163,963
B	Area of Surface Soil Contamination East of Main Processing Area	131,017	1.50	7,279
C	Area of Surface Soil Contamination, Road Monofill Areas	4,229	1.50	235
D	Red Devil Creek Downstream Alluvial Area, Creek Channel Area	19,690	6.00	4,376
E	Area of 4 foot excavation depth	45,149	4.00	6,689
F	Area of 2 foot excavation depth	18,298	2.00	1,355
G	Soil Excavation	6,828	8.00	2,023
H	Soil Excavation	9,779	5.00	1,811
I	Soil Excavation	14,799	10.00	5,481
J	Soil Excavation	4,966	5.00	920
K	Soil Excavation	11,256	5.00	2,084
L	Soil Excavation	3,182	4.00	471
M	Soil Excavation	6,165	8.00	1,827

NO.	DATE	DWN	APP'D	DESCRIPTION
REVISIONS				

ecology and environment, inc.

DESIGNED BY: M. LONGTINE / R. CURRY

CHECKED BY: N. BROWN

DRAWN BY: V. GEE

DRAFT

DRAFT

RED DEVIL MINE FEASIBILITY STUDY

FIGURE 3-1
SOIL EXCAVATION AREA AND REPOSITORY

RED DEVIL, ALASKA

SCALE	DATE ISSUED	CAD FILE NO.	FIGURE NO.
NOTED	08-25-2014		1 OF 2

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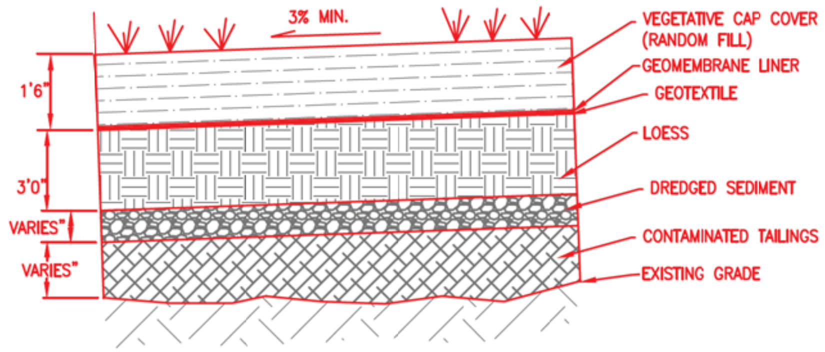

CAP LAYERING DETAIL
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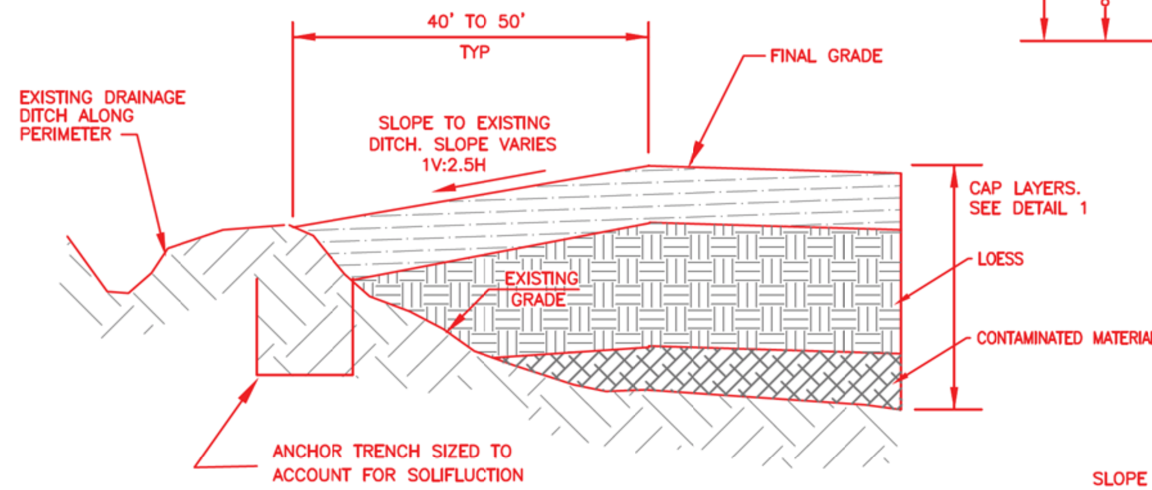

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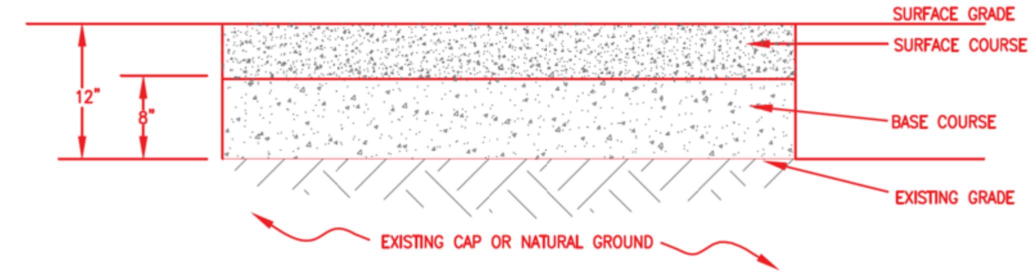

GRAVEL ACCESS ROAD DETAIL
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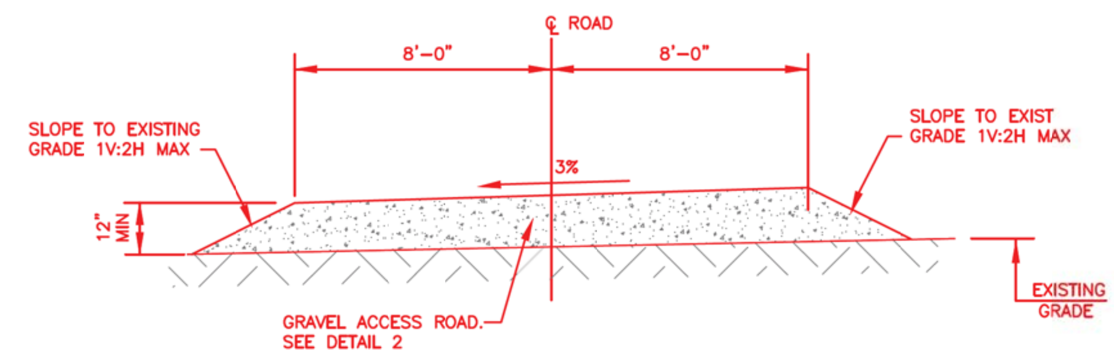

GRAVEL ACCESS ROAD SECTION (TYP)
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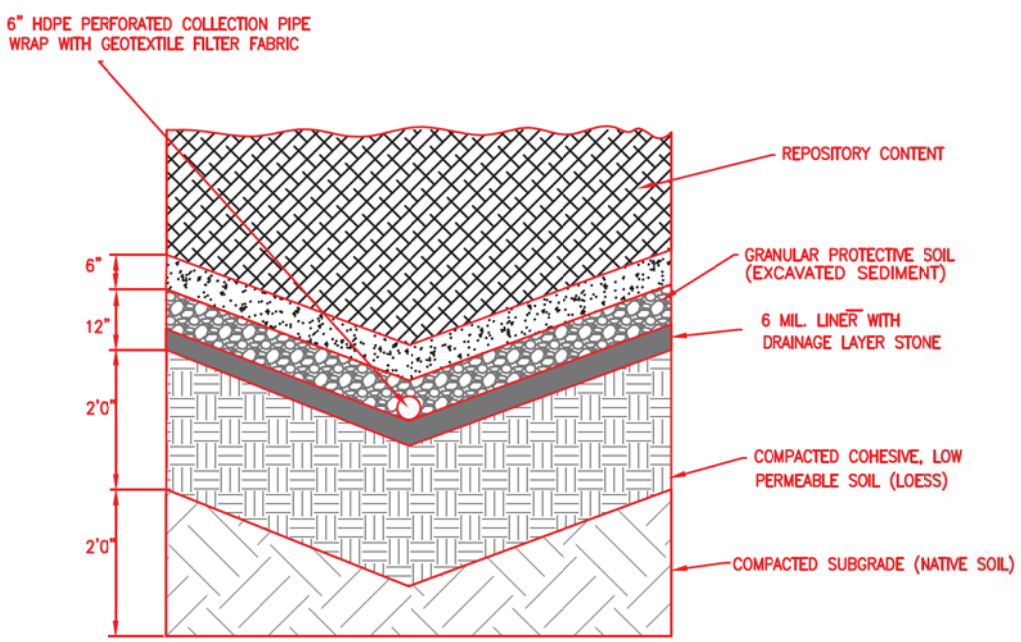
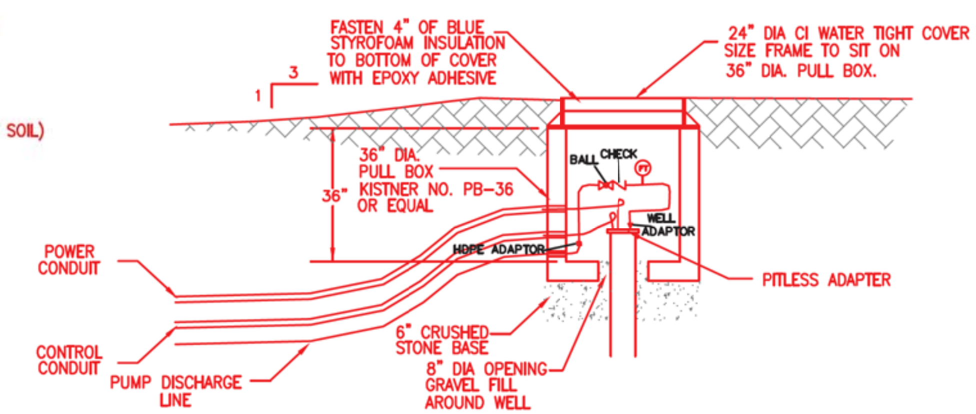
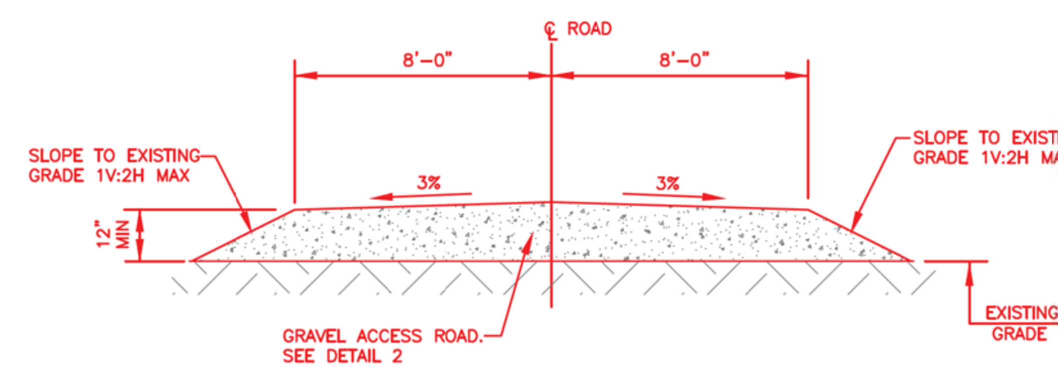


CROSS SECTION OF PROPOSED LEACHATE COLLECTION SYSTEM
NTS



LEACHATE TRANSFER PUMP DETAIL
NTS



GRAVEL ACCESS ROAD SECTION (TYP)
NTS

1	8/25/14	JNJ	NJB	PRE-FINAL

REVISIONS

ecology and environment, inc.

DESIGNED BY: M. LONGTINE / R. CURRY
CHECKED BY: N. BROWN
DRAWN BY: V. GEE

PRE-FINAL

PRE-FINAL

RED DEVIL MINE FEASIBILITY STUDY

FIGURE 3-2
REPOSITORY & ROAD CROSS-SECTIONS AND DETAILS

RED DEVIL, ALASKA

SCALE	DATE ISSUED	CAD FILE NO.	FIGURE NO.
NOTED	08-11-2015		2 OF 2

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4 Detailed Analysis of Remedial Alternatives

This chapter presents the NCP evaluation criteria and provides detailed individual and comparative analyses of the remedial alternatives.

4.1 Evaluation Criteria

The NCP specifies nine evaluation criteria. The first two relate to statutory requirements and are considered threshold criteria, which each remedial alternative must satisfy in order to be eligible for selection. The next five are referred to as primary or balancing criteria and are used to evaluate the technical aspects of a remedial alternative. The final two criteria are considered modifying criteria and are addressed in the ROD once comments are received on the RI and FS Reports and the Proposed Plan.

The nine NCP evaluation criteria are as follows:

Threshold Criteria:

1. Overall Protection of Human Health and the Environment
2. Compliance with ARARs

Primary Criteria:

3. Long-Term Effectiveness and Permanence
4. Reduction of Toxicity, Mobility, and Volume through Treatment
5. Short-Term Effectiveness
6. Implementability
7. Cost

Modifying Criteria:

8. State Acceptance
9. Community Acceptance

The following subsections describe each evaluation criterion.

4.1.1 Overall Protection of Human Health and the Environment

This criterion is used to assess the ability of a remedial alternative to protect human health and the environment from identified risks. The overall assessment of protection draws on the assessments conducted under other evaluation criteria and describes how site risks posed through each pathway addressed by the FS are eliminated, reduced, or controlled through treatment, engineering controls, or ICs. Based on findings from the human health and ecological risk assessments and the development of site-specific background concentrations, protectiveness of human health and the environment is evaluated based on the remedial alternative's ability to reduce contaminant concentrations to meet the RAOs and/or reduce or eliminate exposure pathways.

4.1.2 Compliance with ARARs

This criterion is used to determine whether a remedial alternative would meet the federal and state ARARs identified in Chapter 2, Table 2-6. Additionally, for each developed alternative (excluding the No Action alternative), this section presents a table identifying whether and/or how the alternative complies with the pertinent individual ARARs.

The ability of a remedial alternative to comply with certain ARARs that have been identified for the remedial action can depend entirely on the manner in which the remedy is implemented. For evaluation purposes, it is assumed that any action remedy selected would be implemented in a manner that would meet these ARARs.

4.1.3 Long-Term Effectiveness and Permanence

This criterion is used to assess the long-term ability of the remedial alternative to address the threshold criteria by (1) assessing the risk remaining at the site after implementation of the remedial alternative, and (2) evaluating the long-term adequacy and reliability of the remedial alternative, including requirements for management and monitoring.

4.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

This criterion is used to assess the ability of a remedial alternative to reduce the inherent risk of the waste material through treatment. Treatment technologies that permanently and significantly reduce toxicity, mobility, or volume are preferred over alternatives that manage untreated waste.

4.1.5 Short-Term Effectiveness

This criterion is used to assess the risks posed to the community, workers, and the environment during implementation of the remedial action. Measures that would be taken to mitigate these risks are addressed under this criterion. This criterion also considers the time required to achieve RGs.

4.1.6 Implementability

The implementability criterion addresses how readily a remedy can be constructed, as well as the presence of the necessary support infrastructure and the permitting requirements. This criterion involves analysis of the technical feasibility, administrative feasibility, and availability of services and materials.

4.1.7 Cost

This criterion is used to assess the anticipated capital and annual O&M and monitoring costs associated with a remedial alternative over a 30-year period. Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs. Capital and annual costs in this FS are presented in 2013 dollars, shown as net present worth costs calculated with a 3.5 percent discount factor. Detailed cost estimates are provided in Appendix C. A summary of capital and annual costs is provided in the detailed evaluation for each alternative.

4.1.8 State Acceptance

This assessment evaluates the technical and administrative issues and concerns that the State (or support agency) may have regarding each of the remedial alternatives. State acceptance is not part of the evaluation process provided within this document. Following the issuance of a Proposed Plan for RDM, this criterion would then be evaluated.

4.1.9 Community Acceptance

This assessment evaluates the issues and concerns the public may have regarding each of the remedial alternatives. Community acceptance is not part of the evaluation process provided within this document. As with State Acceptance, this criterion would then be evaluated following the issuance of a Proposed Plan for RDM.

4.2 Individual Analysis of Remedial Alternatives

Each evaluation criterion is broken down into sub-criteria for the evaluation of each alternative. The following subsections summarize the major components of each remedial alternative and, where necessary, provide additional information pertinent to the analysis. Details of each remedial alternative were presented in Chapter 3.

4.2.1 Alternative 1 – No Action

Under Alternative 1, a remedy would not be implemented; therefore, RDM would remain in its current state. Tailings would continue to leach metals into surface soil and groundwater. Additionally, the metals loading into Red Devil Creek and the Kuskokwim River would continue unabated. The evaluation of Alternative 1 is provided below.

Overall Protection of Human Health and the Environment

Since no action would be implemented, this alternative offers no protection of human health and the environment. The human and ecological risks identified in the RI would remain present. In addition to not reducing risk, the lack of action could also cause contaminant concentrations in sediments and soil to increase given that the tailings may still be leaching metals, resulting in increased exposure risks.

Compliance with ARARs

Because no action is being taken, this alternative would not meet the ARARs. Since this alternative provides no controls, all current and potential site risks would remain.

Long-Term Effectiveness and Permanence

The No Action alternative does not offer long-term effectiveness or permanence.

Reduction of Toxicity, Mobility, and Volume through Treatment

The toxicity and mobility of contaminants would remain the same under this alternative; however, given that the tailings may still be leaching metals, there would be an increase in the volume of contamination. Therefore, there is no reduction in these three evaluation criteria under this alternative.

Short-Term Effectiveness

Because no action would be taken, Alternative 1 does not provide for a significant increase in short-term risks associated with construction activities.

Implementability

While technically implementable in the sense that no action would be taken, Alternative 1 is not considered to be administratively implementable. Given that metals contamination has migrated into the Kuskokwim River, measures need to be taken in order to meet the RGs.

Cost

Because no action would be taken, no construction or O&M costs would be associated with Alternative 1.

4.2.2 Alternative 2 – Institutional and Access Controls

Under Alternative 2, fencing with posted warning signs would be installed along the perimeter of the site. It is anticipated that ICs and ACs intended to restrict site access would be implemented to enhance the effectiveness of this alternative

Protection of Human Health and the Environment

The use of fencing and warning signs would reduce potential human and ecological exposure associated with direct contact with tailings and contaminated soils. Land use restrictions could be crafted such that public access to the site would be limited and performed in a manner that reduced the potential for exposure. Consequently, the potential for direct contact and intrusive activities and potential human exposure would be reduced as well. Therefore, Alternative 2 provides a limited amount of protection for human health and the environment.

Compliance with ARARs

Installing exclusion fencing, implementing ICs, and posting warning signs could be implemented in a way that achieved compliance with the site ARARs. Land use restrictions could be crafted such that public access to the site would be limited and performed in a manner that reduced the potential for exposure. However, compliance with chemical-specific ARARs would not be achieved. Table 4-1 identifies the ARARs applicable to Alternative 2 and whether the alternative could be implemented to be compliant with them.

Long-Term Effectiveness and Permanence

Once implemented, the risk of human exposure to tailings, soil, and sediments containing concentrations of contaminants above the RGs would be reduced. Provided that the fence and warning signs are maintained, and land use is restricted to reduce potential exposure to contaminated material, Alternative 2 does offer a long-term effective and permanent solution for human exposure. However, it offers little reduction with regards to ecological exposure. While fencing could reduce the exposure to terrestrial wildlife, birds could still enter the area, and there would be no reduction in their exposure associated with contamination. Additionally, this alternative would not be effective in reducing contaminant migration from the site. Therefore, overall permanence is not provided for under this alternative.

Reduction of Toxicity, Mobility, and Volume through Treatment

Under Alternative 2, there would be no reduction of toxicity, mobility, or volume.

Short-Term Effectiveness

Given that the installation of fencing does not require heavy equipment, and fence post installation could require holes as deep as 4 feet bgs, Alternative 2 would pose minimal risks to the community, workers, and the environment during its implementation.

Implementability

Technically, Alternative 2 is implementable. Deed restrictions are established and have well-documented procedural methods. Fence installation and sign preparation are straightforward and common construction activities. Because of the presence of high concentration tailings, the workers may have to receive 40-hour Occupational Safety and Health Administration Hazardous Waste Operations and Emergency Response Standard training. Even with the remote nature of RDM, no problems are anticipated in obtaining and transporting the materials, labor, and equipment to the site.

Table 4-1 Alternative 2 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Chemical-Specific				
Federal				
Resource Conservation and Recovery Act, Subtitle C – Identification and Listing of Hazardous Waste	40 CFR 261 42 USC 6921	Defines solid wastes which are subject to regulation as RCRA hazardous wastes. Solid wastes are considered hazardous if they are specifically listed in 40 CFR 261 Subpart D or if they exhibit one of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity).	Applicable	This ARAR would not be triggered. Toxicity Characteristic waste material would remain within the AOC under Alternative 2.
Safe Drinking Water Act	42 USC 300f et seq.	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Relevant and Appropriate	Alternative 2 does not address groundwater and would not achieve MCLs in surface water.
Clean Water Act	33 USC 1251l et seq.	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 2 would not affect water quality.
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC	Alternative 2 does not address sediment quality in Red Devil Creek.

Table 4-1 Alternative 2 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
State				
Alaska Oil and Other Hazardous Substance Pollution Control Regulations	18 AAC 75.340 18 AAC 75.341 18 AAC 75.345 (except (a))	Provides method for determining cleanup levels for soil (under 40-inch soil zone) contaminated with petroleum hydrocarbons [18 AAC 75.340(a)(1)(A)] or with chemicals other than petroleum hydrocarbons [AAC 75.340 (a) (2) (A)].	Applicable	Alternative 2 does not address soil cleanup. This ARAR would not be achieved.
Location-Specific				
Federal				
Archaeological and Historic Preservation Act of 1974	16 USC 469 40 CFR 6.301(c)	Provides for the preservation of historical and archaeological data that might otherwise be lost as a result of terrain alterations. If any remedial action could cause irreparable loss to significant scientific, pre-historical, or archaeological data, the act requires the agency undertaking the project to preserve the data or request the U.S. Department on the Interior to do so.	Applicable	This ARAR would not be triggered.. Alternative 2 would not include any deep ground disturbing activity or other activities that could impact archaeological or historic resources.
Archaeological Resources Protection Act of 1979	16 USC 470aa-mm 43 CFR Part 7	Requires permits for excavation of archaeological resources on public or tribal lands.	Applicable	This ARAR would not be triggered.. Alternative 2 would not include any deep ground disturbing activity.
Native American Graves Protection and Reparation Act	25 USC 3001-3013 43 CFR 10	Regulations that pertain to the identification, protection, and appropriate disposition of human remains, funerary objects, sacred objects, or objects of cultural patrimony.	Applicable	This ARAR would not be triggered.. Alternative 2 would not include any deep ground disturbing activity.

Table 4-1 Alternative 2 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Protection of Wetlands, Executive Order 11990	40 CFR 6	Requires federal agencies to avoid adversely impacting wetlands wherever possible, to minimize wetlands destruction, and to preserve the values of wetlands.	Applicable	This ARAR would not be triggered.. Alternative 2 would not include any ground disturbing activity that could affect wetlands.
Flood Plain Management, Executive Order 11988	40 CFR 6	Requires federal agencies to avoid, to the extent practicable, the long- and short-term adverse impacts associated with the occupancy and modification of flood plains, and to avoid direct and indirect support of flood plain development wherever there is a practicable alternative.	Applicable	This ARAR would not be triggered.. Alternative 2 would not include any construction activity in a floodplain.
Fish and Wildlife Coordination Act	16 USC 1251 661 et seq. 40 CFR 6.302(g)	Requires consultation with the U.S. Fish and Wildlife Service for the protection of fish and wildlife when a proposed action may result in modifications to stream, river, or other surface water of the U.S.	Applicable	Alternative 2 could be implemented in compliance with this act.
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable	Alternative 2 could be implemented in compliance with this act.
Endangered Species Act	16 USC 1531 40 CFR 6.302(b) 50 CFR 17, 402	Provides for the protection of fish, wildlife, and plants that are threatened with extinction. Federal agencies are required under Section 7 of the ESA to ensure that their actions will not jeopardize the continued existence of a listed species or result in destruction of or adverse modification to its critical habitat. If the proposed action may affect the listed species or its critical habitat, consultation with the U.S. Fish and Wildlife Service may be required.	Applicable	Alternative 2 could be implemented in compliance with this act.

Table 4-1 Alternative 2 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable	Alternative 2 could be implemented in compliance with this act.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate	Alternative 2 could be implemented in compliance with this act.
State				
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable	This ARAR would not be triggered.. Alternative 2 would not include any deep ground disturbing activity or other activities that could impact archaeological or historic resources.
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Relevant and Appropriate	Existing site conditions combined with implementation of Alternative 2 would comply with these regulations.

Table 4-1 Alternative 2 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Alaska Department of Fish and Game Anadromous Fish Act	AS 16.05.871- .901	Provides for the protection of fish and game habitats in the State of Alaska. Consultation with the Alaska Department of Fish and Game is required for any activities that could impede fish passage or that could divert, obstruct, pollute, or change the natural flow or bed of an anadromous water body. Tidelands (to mean low water at the mouth) are included.	Applicable	Alternative 2 could be implemented in compliance with this act.
Action-Specific				
Federal				
Clean Water Act – National Pollutant Discharge Elimination System	40 CFR 122-125 and 403	Establishes discharge limits and monitoring requirements for direct discharges of treated effluent and stormwater runoff to surface waters of the U.S. EPA gives states the authority to implement the National Pollutant Discharge Elimination System program.	Applicable	This ARAR would not be triggered.. Alternative 2 would not involve discharges of waste water or newly generated stormwater to surface water.
Clean Water Act, Section 404	33 USC 1344 40 CFR 230 33 CFR 320-330	Restricts discharge of dredged or fill material into surface waters of the U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation onsite or offsite.	Applicable	This ARAR would not be triggered.. Alternative 2 would not involve any dredging or placement of fill material in surface water or wetlands.

Table 4-1 Alternative 2 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Clean Water Act – Water Quality Standards	40 CFR 131	Sets criteria for water quality based on toxicity to aquatic organisms and human health. States are given the responsibility of establishing and revising the standards, and the authority to develop standards more stringent than required by Clean Water Act.	Applicable	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 2 would not affect water quality.
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable	This ARAR would not be triggered.. Alternative 2 would not involve any dredging of creek or river sediments.
Clean Air Act – National Ambient Air Quality Standards	40 CFR 50.1-50.17 42 USC 7409	Establishes National Ambient Air Quality Standards for six criteria pollutants (including particulate matter) to protect human health and the environment.	Applicable	Alternative 2 could be implemented in compliance with the referenced provisions of this act.
Resource Conservation and Recovery Act – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides criteria by which solid waste disposal facilities and processes must operate to prevent adverse effects on human health or the environment. Facilities failing to meet these criteria are classified as open dumps, which are prohibited. Any remedial alternative that includes construction of a solid waste disposal facility would have to meet these requirements.	Applicable	This ARAR would not be triggered.. Alternative 2 would not involve construction of a solid waste disposal facility.

Table 4-1 Alternative 2 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Resource Conservation and Recovery Act – Hazardous Waste Management	40 CFR 260 42 USC 6921	Specifies hazardous waste management requirements. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered.. Alternative 2 would not involve movement of waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.
Resource Conservation and Recovery Act – Generator Standards	40 CFR 262 42 USC 6922	Establishes standards for generators of hazardous waste. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered.. Alternative 2 would not involve movement of waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.
Resource Conservation and Recovery Act – Treatment, Storage, and Disposal Facility Requirements	40 CFR 264 42 USC 6924	Provides requirements for the generation, transportation, storage, and disposal of hazardous waste, including design and operating standards for hazardous waste treatment, storage, and disposal units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered.. Alternative 2 would not involve movement of waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.

Table 4-1 Alternative 2 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Resource Conservation and Recovery Act – Closure and Post-Closure Requirements	40 CFR 264.110-120	Specifies requirements for the closure and post-closure care of RCRA hazardous waste management units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered.. Alternative 2 would not involve movement of waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.
Resource Conservation and Recovery Act – Standards Applicable to Transporters of Hazardous Waste	40 CFR 263 42 USC 6923	Establishes standards for the transportation of hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR Part 262.	Applicable	This ARAR would not be triggered.. Alternative 2 would not involve movement of waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.
Hazardous Materials Transportation Act	49 USC 1801-1813 40 CFR 107, 171-173, and 177	Regulates the transportation of hazardous waste on public roads.	Applicable	This ARAR would not be triggered.. Alternative 2 would not involve offsite movement of waste.
Invasive Species, Executive Order 13112		Prevents the introduction of invasive species and provides guidance for their control.	Applicable	Alternative 2 could be implemented in compliance with this order.

Table 4-1 Alternative 2 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
State				
Alaska Solid Waste Regulations	18 AAC 60.007(b) 18 AAC 60.010(a) 18 AAC 60.015 18 AAC 60.025 (b)(4)	Provides standards for management of solid waste, including requirements pertaining to accumulation, storage, treatment, transport, disposal, land spreading, landfills, monofills, monitoring, and corrective action.	Applicable	Existing site conditions combined with implementation of Alternative 2 would comply with these regulations.

Key:
AAC = Alaska Administrative Code
AOC = Area of Contamination
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
MCL = Maximum Contaminant Level
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = To Be Considered
USC = United States Code

Cost

The total capital cost associated with Alternative 2 is $816,000. The annual O&M cost is estimated to be $48,000, and the 30-year present worth cost has been determined to be $1,700,000. A summary of the key cost components is presented in Table 4-2, with additional supporting information provided in Appendix C.

Table 4-2 Cost Estimate Alternative 2 – Institutional and Access Controls

Item	Description	Quantity	Unit	Cost/Unit	Cost
Direct Capital Costs					
DCIC1	Mobilization/Demobilization	1	lump sum	$58,510	$58,510
DCIC2	Field Overhead and Oversight	2	month	$133,668	$267,336
DCIC4	Install Access Controls	1	lump sum	$153,850	$153,850
Total Direct Capital Costs (rounded to nearest $1,000)					***$480,000***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$580,000***
Indirect Capital Costs					
Engineering and Design (5%)		5%			$29,000
Administration (4%)		4%			$23,000
Legal Fees and License/Permit Costs (4%)		4%			$23,000
3rd Party Construction Oversight (5%)		5%			$29,000
Subtotal Indirect Capital Costs (rounded to nearest $10,000)					***$100,000***
Subtotal Capital Costs					$680,000
Contingency Allowance (20%)					$136,000
Total Capital Cost (rounded to nearest $1,000)					**$816,000**
Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM1	Operation and Maintenance Cost	1	lump sum	$23,100	$23,100
ES	5-Year Review	1	lump sum	$7,500	$7,500
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$31,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$37,000*
Annual Indirect O&M Costs					
Administration		5%			$1,850
Insurance, Taxes, Licenses		3%			$1,110
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$3,000*
Subtotal Annual O&M Costs					*$40,000*
Contingency Allowance		20%			$8,000
Total Annual O&M Cost (Rounded to Nearest $1,000)					**$48,000**
30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					816,000
Present Worth of O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$880,000
Total Present Worth Cost for Alternative (Rounded to Nearest $10,000)					**$1,700,000**

Notes
(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 27th Ed., 2013.*
(2) A location factor of 1.198 (Anchorage, Alaska) was applied for all direct costs.
(3) Costs presented in 2013 dollars.

Key:
ES = Engineer's Estimate
O&M = Operations and Maintenance

4.2.3 Alternative 3a – Excavation of Soils and Sediments, Solidification, Onsite Consolidation, and Capping

Alternative 3a includes the excavation of tailings/waste rock and soils, and the removal of residual Red Devil Creek sediments that contain contaminant concentrations above the established RGs. Additionally, in areas downstream of the Main Processing Area that were not addressed under the interim removal action, sediments containing COC concentrations greater than the RGs will also be excavated. A dedicated repository would be constructed in the Surface Mined Area for onsite consolidation of excavated materials; excavated soils or sediment that failed the TCLP analysis would be solidified prior to placement in the repository. A low-permeability cover would be installed on the repository to prevent direct contact with contaminants and reduce infiltration of surface water to the consolidated tailings and soils. Additionally, a low-permeability cover would be designed and installed to prevent direct contact with contaminants that remained within Monofill #2, and loess would be used as a cover material in highly mineralized exposed areas within the Surface Mined Area. In addition to O&M, Alternative 3a requires implementation of ICs and ACs to restrict access to the site.

Protection of Human Health and the Environment

By excavating metals-laden tailings, soil, and contaminated sediments, and placing them into a repository, installing a new cover system over Monofill #2, and placing loess covers over isolated hot spots in the Surface Mined Area, Alternative 3a would provide protection of human health and the environment. While this alternative would involve no reduction in the contaminant concentrations, the solidification of tailings, soil, and sediments that have failed TCLP, installation of the low-permeability cover system at both the repository and Monofill 2, and the placement of loess over exposed areas in the Surface Mined Area would reduce the potential for exposure, in turn reducing the overall risk. Modeling of the proposed repository cover system shows that the leachate generation and migration of COCs would not adversely affect the groundwater beneath the repository, thereby adding to the overall protectiveness. Additionally, the cover systems for both the repository and Monofill #2 would reduce the likelihood of erosion of contaminated materials into Red Devil Creek and of animals coming into contact with such materials, thus providing environmental protection for terrestrial and aquatic life.

Compliance with ARARs

During the design phase, ARARs would be further reviewed, and their requirements could be incorporated into the design. The repository could be both designed and constructed to be compliant with ARARs. Excavating could also be designed and implemented to be compliant with the ARARs. In short, Alternative 3a provides for compliance with ARARs. Table 4-3 identifies the ARARs applicable to Alternative 3a and whether the alternative can be implemented to be compliant with them.

Table 4-3 Alternative 3a ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Chemical-Specific				
Federal				
Resource Conservation and Recovery Act, Subtitle C – Identification and Listing of Hazardous Waste	40 CFR 261 42 USC 6921	Defines solid wastes which are subject to regulation as RCRA hazardous wastes. Solid wastes are considered hazardous if they are specifically listed in 40 CFR 261 Subpart D or if they exhibit one of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity).	Applicable	This ARAR would not be triggered. Toxicity Characteristic waste material would remain within the AOC under Alternative 3a.
Safe Drinking Water Act	42 USC. 300f et seq.	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Relevant and Appropriate	Alternative 3a does not address groundwater.
Clean Water Act	33 USC 1251l et seq.	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 3a would improve creek water quality.
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC	Alternative 3a would improve sediment quality in Red Devil Creek, and it is anticipated these guidelines would be met over time.

Table 4-3 Alternative 3a ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
State				
Alaska Oil and Other Hazardous Substance Pollution Control Regulations	18 AAC 75.340 18 AAC 75.341 18 AAC 75.345 (except (a))	Provides method for determining cleanup levels for soil (under 40-inch soil zone) contaminated with petroleum hydrocarbons [18 AAC 75.340(a)(1)(A)] or with chemicals other than petroleum hydrocarbons [AAC 75.340 (a) (2) (A)].	Applicable	Alternative 3a would comply with these regulations because contaminated soil would be excavated and contained in the repository.
Location-Specific				
Federal				
Archaeological and Historic Preservation Act of 1974	16 USC 469 40 CFR 6.301(c)	Provides for the preservation of historical and archaeological data that might otherwise be lost as a result of terrain alterations. If any remedial action could cause irreparable loss to significant scientific, pre-historical, or archaeological data, the act requires the agency undertaking the project to preserve the data or request the U.S. Department on the Interior to do so.	Applicable	Alternative 3a could be implemented in compliance with this act.
Archaeological Resources Protection Act of 1979	16 USC 470aa-mm 43 CFR Part 7	Requires permits for excavation of archaeological resources on public or tribal lands.	Applicable	Alternative 3a could be implemented in compliance with this act.
Native American Graves Protection and Reparation Act	25 USC 3001-3013 43 CFR 10	Regulations that pertain to the identification, protection, and appropriate disposition of human remains, funerary objects, sacred objects, or objects of cultural patrimony.	Applicable	Alternative 3a could be implemented in compliance with this act.
Protection of Wetlands, Executive Order 11990	40 CFR 6	Requires federal agencies to avoid adversely impacting wetlands wherever possible, to minimize wetlands destruction, and to preserve the values of wetlands.	Applicable	Alternative 3a could be implemented in compliance with this order.

Table 4-3 Alternative 3a ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Flood Plain Management, Executive Order 11988	40 CFR 6	Requires federal agencies to avoid, to the extent practicable, the long- and short-term adverse impacts associated with the occupancy and modification of flood plains, and to avoid direct and indirect support of flood plain development wherever there is a practicable alternative.	Applicable	Alternative 3a could be implemented in compliance with this order.
Fish and Wildlife Coordination Act	16 USC 1251 661 et seq. 40 CFR 6.302(g)	Requires consultation with the U.S. Fish and Wildlife Service for the protection of fish and wildlife when a proposed action may result in modifications to stream, river, or other surface water of the U.S.	Applicable	Alternative 3a could be implemented in compliance with this act.
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable	Alternative 3a could be implemented in compliance with this act.
Endangered Species Act	16 USC 1531 40 CFR 6.302(b) 50 CFR 17, 402	Provides for the protection of fish, wildlife, and plants that are threatened with extinction. Federal agencies are required under Section 7 of the ESA to ensure that their actions will not jeopardize the continued existence of a listed species or result in destruction of or adverse modification to its critical habitat. If the proposed action may affect the listed species or its critical habitat, consultation with the U.S. Fish and Wildlife Service may be required.	Applicable	Alternative 3a could be implemented in compliance with this act.
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable	Alternative 3a could be implemented in compliance with this act.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate	Alternative 3a could be implemented in compliance with this act.

Table 4-3 Alternative 3a ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
State				
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable	Alternative 3a could be implemented in compliance with these requirements.
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Relevant and Appropriate	Existing site conditions combined with implementation of Alternative 3a would comply with these regulations.
Alaska Department of Fish and Game Anadromous Fish Act	AS 16.05.871- .901	Provides for the protection of fish and game habitats in the State of Alaska. Consultation with the Alaska Department of Fish and Game is required for any activities that could impede fish passage or that could divert, obstruct, pollute, or change the natural flow or bed of an anadromous water body. Tidelands (to mean low water at the mouth) are included.	Applicable	Alternative 3a could be implemented in compliance with this act.

Table 4-3 Alternative 3a ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Action-Specific				
Federal				
Clean Water Act – National Pollutant Discharge Elimination System	40 CFR 122-125 and 403	Establishes discharge limits and monitoring requirements for direct discharges of treated effluent and stormwater runoff to surface waters of the U.S. EPA gives states the authority to implement the National Pollutant Discharge Elimination System program.	Applicable	Alternative 3a could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.
Clean Water Act, Section 404	33 USC 1344 40 CFR 230 33 CFR 320-330	Restricts discharge of dredged or fill material into surface waters of the U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation onsite or offsite.	Applicable	Alternative 3a could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.
Clean Water Act – Water Quality Standards	40 CFR 131	Sets criteria for water quality based on toxicity to aquatic organisms and human health. States are given the responsibility of establishing and revising the standards, and the authority to develop standards more stringent than required by Clean Water Act.	Applicable	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 3a would improve water quality.
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable	Alternative 3a could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.

Table 4-3 Alternative 3a ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Clean Air Act – National Ambient Air Quality Standards	40 CFR 50.1-50.17 42 USC 7409	Establishes National Ambient Air Quality Standards for six criteria pollutants (including particulate matter) to protect human health and the environment.	Applicable	Alternative 3a could be implemented in compliance with the referenced provisions of this act.
Resource Conservation and Recovery Act – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides criteria by which solid waste disposal facilities and processes must operate to prevent adverse effects on human health or the environment. Facilities failing to meet these criteria are classified as open dumps, which are prohibited. Any remedial alternative that includes construction of a solid waste disposal facility would have to meet these requirements.	Applicable	Alternative 3a could be implemented in compliance with the referenced provisions of this act.
Resource Conservation and Recovery Act – Hazardous Waste Management	40 CFR 260 42 USC 6921	Specifies hazardous waste management requirements. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered.. Alternative 3a would not involve movement of waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.
Resource Conservation and Recovery Act – Generator Standards	40 CFR 262 42 USC 6922	Establishes standards for generators of hazardous waste. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered. Alternative 3a would not involve movement of waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.

Table 4-3 Alternative 3a ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Resource Conservation and Recovery Act – Treatment, Storage, and Disposal Facility Requirements	40 CFR 264 42 USC 6924	Provides requirements for the generation, transportation, storage, and disposal of hazardous waste, including design and operating standards for hazardous waste treatment, storage, and disposal units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered. Alternative 3a would not involve movement of waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.
Resource Conservation and Recovery Act – Closure and Post-Closure Requirements	40 CFR 264.110-120	Specifies requirements for the closure and post-closure care of RCRA hazardous waste management units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered. Alternative 3a would not involve movement of waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.
Resource Conservation and Recovery Act – Standards Applicable to Transporters of Hazardous Waste	40 CFR 263 42 USC 6923	Establishes standards for the transportation of hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR Part 262.	Applicable	This ARAR would not be triggered. Alternative 3a would not involve movement of waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.

Table 4-3 Alternative 3a ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Hazardous Materials Transportation Act	49 USC 1801-1813 40 CFR 107, 171-173, and 177	Regulates the transportation of hazardous waste on public roads.	Applicable	This ARAR would not be triggered. Alternative 3a would not involve offsite movement of waste.
Invasive Species, Executive Order 13112		Prevents the introduction of invasive species and provides guidance for their control.	Applicable	Alternative 3a could be implemented in compliance with this order.
State				
Alaska Solid Waste Regulations	18 AAC 60.007(b) 18 AAC 60.010(a) 18 AAC 60.015 18 AAC 60.025 (b)(4)	Provides standards for management of solid waste, including requirements pertaining to accumulation, storage, treatment, transport, disposal, land spreading, landfills, monofills, monitoring, and corrective action.	Applicable	Existing site conditions combined with implementation of Alternative 3a would comply with these regulations.

Key:
AAC = Alaska Administrative Code
AOC = Area of Contamination
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
BMP = Best Management Practice
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = To Be Considered
USC = United States Code

Long-Term Effectiveness and Permanence

Placing excavated material with concentrations above the established RGs into a dedicated repository could provide a long-term and permanent solution. Incorporating solidified material in the repository would improve long-term effectiveness. Additionally, this alternative would reduce human and ecological exposure to contaminants and reduce potential for continued contaminant migration from the site. Modeling has shown that leachate would not adversely affect the groundwater beneath the repository footprint even after 50 years of operation. Provided that an appropriate confirmation sampling and analysis plan is implemented as part of the remedy, this alternative would provide a high level of certainty that areas of contamination would be removed to meet the RAOs.

The concrete cloth cover system offers long-term effectiveness and permanence. Based on testing and field applications, the cloth has a life expectancy of at least 25 years. Given that five-year reviews will be conducted until they are deemed no longer needed, should the cover system begin to show unfavorable wear, its condition would be documented and repairs and/or replacement provided as needed.

Additionally, diverting surface water runoff away from loess-covered areas of mineralized rock in the Surface Mined Area would reduce the potential for erosion and increase the long-term effectiveness and permanence of the proposed remedy.

The repository and Monofill #2 covers proposed under Alternative 3a would require O&M activities. Activities that would be required to maintain their functionality include, but are not limited to, site inspections, cover repairs, and cleaning of the drainage ditches that divert stormwater runoff around and away from the repository. With adequate O&M, the repository, Monofill #2's new cover, and remedy for the Surface Mined Area as proposed in Alternative 3a could provide long-term effectiveness and permanence.

Reduction of Toxicity, Mobility, and Volume through Treatment

Treatment using solidification of material exceeding TCLP for arsenic is proposed as part of Alternative 3a. Although this treatment would not decrease the overall toxicity and volume of contamination that would be left onsite in the proposed repository, it would reduce the mobility of contamination through encapsulation. Additionally, the repository would offer an overall reduction in contaminant mobility for all excavated material, although not through treatment. Generation and mobility would be greatly reduced by consolidating media contaminated with metals above the RGs (as supported by the leachate modeling), solidifying media exceeding TCLP, and placing a PVC cover system over them. The concrete cloth cover selected to be installed over Monofill #2 and loess cover used in the Surface Mined Area would help reduce the site's contaminant mobility from the tailings and soils remaining at the site. In short, while there is no reduction in toxicity and volume through treatment under this alternative, there is a reduction in mobility through treatment for the most heavily contaminated materials.

Short-Term Effectiveness

Given RDM's remote location, there is limited short-term risk associated with the local population. Workers involved in remedial action would be subject to exposure to media containing elevated concentrations of arsenic, antimony, and mercury. The use of personal protective equipment and water sprays to reduce dust are just two of the ways by which the short-term risks associated with working with metals-laden material can be reduced. While it is possible that sediments having concentrations above the RGs may still be present after the interim removal action, measures would be adopted during excavation along the portions of Red Devil Creek not addressed under the interim removal action to prevent contaminated sediments from becoming fluidized and migrating from areas of contamination to "clean" areas.

Depending on the method of excavation selected by the design engineer, sheet piling, coffer dams, and stream diversion are some of the methods that could be implemented to reduce the potential for contaminated sediments from migrating to clean areas. A stormwater pollution prevention plan (SWPPP) will identify ways to limit surface water runoff from leaching metals with subsequent migration/spreading of contamination.

Implementability

Technically, this alternative is implementable. Construction of repositories to contain metals-laden waste tailings and contaminated soils and sediments is a common remediation technique at abandoned mine sites. The design procedures associated with building a stable repository are also well established. Solidification would require a large-scale field test prior to full site mobilization to determine the final process; however, solidification is a commonly used treatment technology and is readily implementable through the use of common construction equipment and materials. Concrete cloth does not require specialized tools or labor to install and has a demonstrated effectiveness in cold weather climates. The loess covers to address localized hot spots in the Surface Mined Area require common earthwork equipment and practices.

Administratively, Alternative 3a is also implementable. ICs and access agreements to excavate the material needed to complete the liner cover would need to be developed and executed.

While there may not be a sufficient amount of earthen material located within the site boundaries to construct the cover systems, offsite areas should satisfy the remaining material requirements and associated trucking. While heavy construction equipment would be needed, the loaders, trucks, and other pieces of equipment, along with materials such as concrete cloth for the cover proposed for Monofill #2, could be barged to the site. Given the remote nature of the site, mobilization would be a major logistical component. However, the services and materials needed to implement Alternative 3a are reasonably obtainable.

Cost

The total capital cost associated with Alternative 3a is $26,490,000. The annual O&M cost is estimated to be $72,000, and the 30-year present worth cost has been determined to be $27,810,000. A summary of the key cost components is presented in Table 4-4, with additional supporting information provided in Appendix C.

Table 4-4 Cost Estimate Alternative 3a-Excavation, Dredging, and Onsite Consolidation,

Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
DC1a	Mobilization/Demobilization	2	lump sum	$2,025,003	$4,050,006
DC2	Field Overhead and Oversight	10	month	$202,563	$2,025,630
DC3a	Site Preparation	1	lump sum	$1,034,757	$1,034,757
DCIC4	Install Access Controls	1	lump sum	$153,850	$153,850
DC4a	Excavate Contaminated Material and Haul to Repository	1	lump sum	$2,687,130	$2,687,130
DC5a	Solidification	1	lump sum	$2,297,465	$2,297,465
DC6a	Backfill Excavated Areas	1	lump sum	$2,037,765	$2,037,765
DC7a	Dredge Red Devil Creek and Haul to Repository	1	lump sum	$125,089	$125,089
DC10a	Repository Construction	1	lump sum	$550,794	$550,794
DC11	Monofill Concrete Cloth Cover	1	lump sum	$323,922	$323,922
DC12a	Site Restoration	1	lump sum	$13,748	$13,748
DC13a	Construction Completion	1	lump sum	$121,195	$121,195
DC14a	Install Groundwater Monitoring Wells	1	lump sum	$60,000	$60,000
DC15	Loess cover in surface mining area	1	lump sum	$136,492	$136,492
Total Direct Capital Costs (rounded to nearest $10,000)					***$15,617,841***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$18,710,000***
Indirect Capital Costs					
	Engineering and Design (5%)	5%			$936,000
	Administration (4%)	4%			$748,000
	Legal Fees and License/Permit Costs (4%)	4%			$748,000
	3rd Party Construction Oversight (5%)	5%			$936,000
Total Indirect Capital Costs					***$3,368,000***
Total Capital Costs					
	Subtotal Capital Costs				$22,078,000
	Contingency Allowance	20%			$4,486,000
Total Capital Cost (rounded to nearest $10,000)					**$26,490,000**

Table 4-4 Cost Estimate Alternative 3a-Excavation, Dredging, and Onsite Consolidation,

Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM2a	Annual Operation and Maintenance Costs	1	lump sum	$23,100	$23,100
OM3a	Groundwater Sampling, Analysis and Reporting	1	lump sum	$14,100	$14,100
ES	5-Year Review	1	lump sum	$10,000	$10,000
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$47,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$56,000*
Annual Indirect O&M Costs					
	Administration	5%			$2,800
	Insurance, Taxes, Licenses	3%			$1,680
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$4,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$60,000*
	Contingency Allowance	20%			$12,000
Total Annual O&M Cost (Rounded to Nearest $1,000)					$72,000
30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					$26,490,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$1,320,000
Total Cost (Rounded to Nearest $10,000)					**$27,810,000**

Notes
(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 27th Ed., 2013.*
(2) A 6-month work season and a 6-day work week were assumed.
(3) One month for pre-construction and one month for post-construction activities were assumed.
(4) A location factor of 1.198 (Anchorage, Alaska) was applied for all direct costs.
(5) Costs presented in 2013 dollars

Key:
ES = Engineer's Estimate
O&M = Operations and Maintenance

4.2.4 Alternative 3b – Excavation of Solid Sediments; Solidification, Onsite Consolidation, Collection, and Offsite Disposal of Leachate; and Capping

Alternative 3b includes the excavation of tailings/waste rock and soils and the removal of residual Red Devil Creek sediments that contain contaminant concentrations above the established RGs. Additionally, in areas downstream of the Main Processing Area that were not addressed under the interim removal action, sediments containing COC concentrations greater than RGs would also be excavated. A dedicated repository would be constructed in the Surface Mined Area for onsite consolidation of excavated materials; tailings, soils, or sediment that failed the TCLP analysis would be solidified prior to placement in the repository. A low-permeability geomembrane cover would be installed on the repository to prevent direct contact with contaminants and reduce infiltration of surface water to the consolidated tailings and soils.

An additional bottom liner and leachate collection system would be installed to collect leachate that may accumulate within the repository. Leachate would be pumped semiannually and transported offsite for disposal. Additionally, a low-permeability cover would be designed and installed to prevent direct contact with contaminants that remained within Monofill #2, and loess would be used as the cover material within the Surface Mined Area. In addition to O&M, Alternative 3b requires implementation of ICs and ACs to restrict access to the site.

Protection of Human Health and the Environment

By excavating metals-laden tailings, soil, and contaminated sediments and placing them into a repository; installing a new cover system over Monofill #2; and placing loess covers over isolated hot spots in the Surface Mined Area, Alternative 3b would provide protection of human health and the environment. While this alternative would involve no reduction in the contaminant concentrations, the solidification of tailings, soils, and sediments that have failed TCLP, installation of the low-permeability cover system at both the repository and Monofill #2, and the placement of loess over exposed areas in the Surface Mined Area would reduce the potential for exposure, in turn reducing the overall risk. Modeling of the proposed repository cover system shows that the leachate generation and migration of COCs would not adversely affect the groundwater beneath the repository; however, Alternative 3b does incorporate a bottom liner and leachate collection as part of the repository design.

The leachate collection system and bottom liner would further mitigate the potential for infiltration of contaminants into local groundwater. However, the risks to human health and environment associated with transporting leachate classified as hazardous would be transferred to the selected shipper, then to the treatment and disposal facility.

Finally, the cover systems for both the repository and Monofill #2 would reduce the likelihood of erosion of contaminated materials into Red Devil Creek and of animals coming into contact with such materials, thus providing environmental protection for terrestrial and aquatic life.

Compliance with ARARs

During the design phase, ARARs would be further reviewed, and their requirements could be incorporated into the design. The repository could be both designed and constructed to be compliant with the ARARs. Excavating could also be designed and implemented to be compliant with the ARARs. Shipping of hazardous wastes is also a well-documented and established process, although not necessarily for the volume associated with this alternative. Alternative 3b can provide compliance with ARARs. Table 4-5 identifies the ARARs applicable to Alternative 3b and whether the alternative can be implemented to be compliant with them.

Table 4-5 Alternative 3b ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Chemical-Specific				
Federal				
Resource Conservation and Recovery Act, Subtitle C – Identification and Listing of Hazardous Waste	40 CFR 261 42 USC 6921	Defines solid wastes which are subject to regulation as RCRA hazardous wastes. Solid wastes are considered hazardous if they are specifically listed in 40 CFR 261 Subpart D or if they exhibit one of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity).	Applicable	This ARAR would be triggered. Leachate would be classified as a hazardous waste.
Safe Drinking Water Act	42 USC. 300f et seq.	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Relevant and Appropriate	Alternative 3b would reduce the potential for contamination to infiltrate groundwater at the site through the use of a geomembrane cover and leachate collection and recovery system within the repository. It is anticipated that Alternative 3b would achieve MCLs in ground water over time.
Clean Water Act	33 USC 1251l et seq.	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 3b would improve creek water quality.

Table 4-5 Alternative 3b ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC	Alternative 3b would improve sediment quality in Red Devil Creek and the it is anticipated these guidelines would be met over time.
State				
Alaska Oil and Other Hazardous Substance Pollution Control Regulations	18 AAC 75.340 18 AAC 75.341 18 AAC 75.345 (except (a))	Provides method for determining cleanup levels for soil (under 40-inch soil zone) contaminated with petroleum hydrocarbons [18 AAC 75.340(a)(1)(A)] or with chemicals other than petroleum hydrocarbons [AAC 75.340 (a) (2) (A)].	Applicable	Alternative 3b would comply with these regulations because contaminated soil would be excavated and contained in the repository.
Location-Specific				
Federal				
Archaeological and Historic Preservation Act of 1974	16 USC 469 40 CFR 6.301(c)	Provides for the preservation of historical and archaeological data that might otherwise be lost as a result of terrain alterations. If any remedial action could cause irreparable loss to significant scientific, pre-historical, or archaeological data, the act requires the agency undertaking the project to preserve the data or request the U.S. Department on the Interior to do so.	Applicable	Alternative 3b could be implemented in compliance with this act.
Archaeological Resources Protection Act of 1979	16 USC 470aa-mm 43 CFR Part 7	Requires permits for excavation of archaeological resources on public or tribal lands.	Applicable	Alternative 3b could be implemented in compliance with this act.

Table 4-5 Alternative 3b ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Native American Graves Protection and Reparation Act	25 USC 3001-3013 43 CFR 10	Regulations that pertain to the identification, protection, and appropriate disposition of human remains, funerary objects, sacred objects, or objects of cultural patrimony.	Applicable	Alternative 3b could be implemented in compliance with this act.
Protection of Wetlands, Executive Order 11990	40 CFR 6	Requires federal agencies to avoid adversely impacting wetlands wherever possible, to minimize wetlands destruction, and to preserve the values of wetlands.	Applicable	Alternative 3b could be implemented in compliance with this order.
Flood Plain Management, Executive Order 11988	40 CFR 6	Requires federal agencies to avoid, to the extent practicable, the long- and short-term adverse impacts associated with the occupancy and modification of flood plains, and to avoid direct and indirect support of flood plain development wherever there is a practicable alternative.	Applicable	Alternative 3b could be implemented in compliance with this order.
Fish and Wildlife Coordination Act	16 USC 1251 661 et seq. 40 CFR 6.302(g)	Requires consultation with the U.S. Fish and Wildlife Service for the protection of fish and wildlife when a proposed action may result in modifications to stream, river, or other surface water of the U.S.	Applicable	Alternative 3b could be implemented in compliance with this act.
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable	Alternative 3b could be implemented in compliance with this act.
Endangered Species Act	16 USC 1531 40 CFR 6.302(b) 50 CFR 17, 402	Provides for the protection of fish, wildlife, and plants that are threatened with extinction. Federal agencies are required under Section 7 of the ESA to ensure that their actions will not jeopardize the continued existence of a listed species or result in destruction of or adverse modification to its critical habitat. If the proposed action may affect the listed species or its critical habitat, consultation with the U.S. Fish and Wildlife Service may be required.	Applicable	Alternative 3b could be implemented in compliance with this act.

Table 4-5 Alternative 3b ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable	Alternative 3b could be implemented in compliance with this act.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate	Alternative 3b could be implemented in compliance with this act.
State				
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable	Alternative 3b could be implemented in compliance with these requirements.
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Relevant and Appropriate	Existing site conditions combined with implementation of Alternative 3b, particularly the installation of the leachate collection and removal system, would comply with these regulations.
Alaska Department of Fish and Game Anadromous Fish Act	AS 16.05.871- .901	Provides for the protection of fish and game habitats in the State of Alaska. Consultation with the Alaska Department of Fish and Game is required for any activities that could impede fish passage or that could divert, obstruct, pollute, or change the natural flow or bed of an anadromous water body. Tidelands (to mean low water at the mouth) are included.	Applicable	Alternative 3b could be implemented in compliance with this act.

Table 4-5 Alternative 3b ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Action-Specific				
Federal				
Clean Water Act – National Pollutant Discharge Elimination System	40 CFR 122-125 and 403	Establishes discharge limits and monitoring requirements for direct discharges of treated effluent and stormwater runoff to surface waters of the U.S. EPA gives states the authority to implement the National Pollutant Discharge Elimination System program.	Applicable	Alternative 3b could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.
Clean Water Act, Section 404	33 USC 1344 40 CFR 230 33 CFR 320-330	Restricts discharge of dredged or fill material into surface waters of the U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation onsite or offsite.	Applicable	Alternative 3b could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.
Clean Water Act – Water Quality Standards	40 CFR 131	Sets criteria for water quality based on toxicity to aquatic organisms and human health. States are given the responsibility of establishing and revising the standards, and the authority to develop standards more stringent than required by Clean Water Act.	Applicable	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 3b would improve water quality.
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable	Alternative 3b could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.

Table 4-5 Alternative 3b ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Clean Air Act – National Ambient Air Quality Standards	40 CFR 50.1-50.17 42 USC 7409	Establishes National Ambient Air Quality Standards for six criteria pollutants (including particulate matter) to protect human health and the environment.	Applicable	Alternative 3b could be implemented in compliance with the referenced provisions of this act.
Resource Conservation and Recovery Act – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides criteria by which solid waste disposal facilities and processes must operate to prevent adverse effects on human health or the environment. Facilities failing to meet these criteria are classified as open dumps, which are prohibited. Any remedial alternative that includes construction of a solid waste disposal facility would have to meet these requirements.	Applicable	Alternative 3b could be implemented in compliance with the referenced provisions of this act.
Resource Conservation and Recovery Act – Hazardous Waste Management	40 CFR 260 42 USC 6921	Specifies hazardous waste management requirements. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would be triggered. Leachate would be classified as a hazardous waste. Alternative 3b would not involve movement of waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.
Resource Conservation and Recovery Act – Generator Standards	40 CFR 262 42 USC 6922	Establishes standards for generators of hazardous waste. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would be triggered. Leachate would be classified as a hazardous waste.

Table 4-5 Alternative 3b ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Resource Conservation and Recovery Act – Treatment, Storage, and Disposal Facility Requirements	40 CFR 264 42 USC 6924	Provides requirements for the generation, transportation, storage, and disposal of hazardous waste, including design and operating standards for hazardous waste treatment, storage, and disposal units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would be triggered. Leachate would be classified as a hazardous waste.
Resource Conservation and Recovery Act – Closure and Post-Closure Requirements	40 CFR 264.110-120	Specifies requirements for the closure and post-closure care of RCRA hazardous waste management units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would be triggered. Leachate would be classified as a hazardous waste.
Resource Conservation and Recovery Act – Standards Applicable to Transporters of Hazardous Waste	40 CFR 263 42 USC 6923	Establishes standards for the transportation of hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR Part 262.	Applicable	This ARAR would be triggered. Leachate would be classified as a hazardous waste.
Hazardous Materials Transportation Act	49 USC 1801-1813 40 CFR 107, 171-173, and 177	Regulates the transportation of hazardous waste on public roads.	Applicable	This ARAR would be triggered. Leachate would be classified as a hazardous waste.
Invasive Species, Executive Order 13112		Prevents the introduction of invasive species and provides guidance for their control.	Applicable	Alternative 3b could be implemented in compliance with this order.
State				
Alaska Solid Waste Regulations	18 AAC 60.007(b) 18 AAC 60.010(a) 18 AAC 60.015 18 AAC 60.025 (b)(4)	Provides standards for management of solid waste, including requirements pertaining to accumulation, storage, treatment, transport, disposal, land spreading, landfills, monofills, monitoring, and corrective action.	Applicable	Existing site conditions combined with implementation of Alternative 3b would comply with these regulations.

Table 4-5 Alternative 3b ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance

Key:
AAC = Alaska Administrative Code
AOC = Area of Contamination
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
BMP = Best Management Practice
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = To Be Considered
USC = United States Code

Long-Term Effectiveness and Permanence

Placing excavated material with concentrations above the RGs into a dedicated repository can provide a long-term and permanent solution. Incorporating solidified material in the repository would improve long-term effectiveness. Additionally, this alternative would reduce human and ecological exposure to contaminants and reduce potential for continued contaminant migration from the site. Modeling has shown that leachate would not adversely affect the groundwater beneath the repository footprint even after 50 years of operation. However, a bottom liner and leachate collection system has been incorporated as part of Alternative 3b. Provided that an appropriate confirmation sampling and analysis plan is implemented as part of the remedy, this alternative would provide a high level of certainty that areas of contamination would be removed to meet the RGs.

The concrete cloth offers long-term effectiveness and permanence. Based on testing and field applications, the cloth has a life expectancy of at least 25 years. Given that five-year reviews will be conducted until they are deemed no longer needed, should the cover system begin to show unfavorable wear, its condition would be documented and repairs and/or replacement provided as needed.

Additionally, diverting surface water runoff away from loess-covered areas of mineralized rock in the Surface Mined Area would reduce the potential for erosion and increase the long-term effectiveness and permanence of the proposed remedy.

The repository proposed under Alternative 3b would require O&M activities. Activities that would be required to maintain the functionality of the repository and leachate collection system include, but are not limited to, site inspections, cover repairs, and cleaning of the drainage ditches that divert stormwater runoff around and away from the repository. With adequate O&M, the repository and leachate collection system, Monofill #2's new cover, and remedy for the Surface Mined Area as proposed in Alternative 3b can provide long-term effectiveness and permanence. However, the disposition of hazardous waste leachate would be an ongoing process throughout the operational life of the repository. Changes in law and/or shipping requirements may adversely affect the ability to properly dispose of the collected leachate.

Reduction of Toxicity, Mobility, and Volume through Treatment

Treatment using solidification of material exceeding TCLP for arsenic is proposed as part of Alternative 3b. Although this treatment would not decrease the overall toxicity and volume of contamination that would be left onsite in the proposed repository, it would reduce the mobility of contamination through encapsulation. Additionally, the repository would offer an overall reduction in contaminant mobility for all excavated material, although not through treatment. Generation and mobility would be greatly reduced by consolidating media contaminated with metals at concentrations above the RGs (as supported by the leachate modeling), solidifying media with the potential for leachate, and placing a PVC cover system over them. However, the leachate that is collected would be classified as a hazardous waste. Given that, this alternative does not achieve a reduction, but actually increases the mobility and volume of contaminated material that needs to be addressed.

The concrete cloth cover selected to be installed over Monofill #2 and loess cover used in the Surface Mined Area would also help reduce the site's contaminant mobility from the tailings and soils remaining at the site. In short, while there is no reduction in toxicity and volume through treatment under this alternative, there is a reduction in mobility through treatment for the most heavily contaminated materials associated with Monofill #2 and the Surface Mined Area.

Short-Term Effectiveness

Given RDM's remote location, there is limited short-term risk associated with the local population. Workers involved in remedial action would be subject to exposure to media containing elevated concentrations of arsenic, antimony, and mercury. The use of personal protective equipment and water sprays to reduce dust are just two of the ways by which the short-term risks associated with working with metals-laden material could be reduced. Measures would be adopted during excavation along the portions of Red Devil Creek not addressed under the interim remedial action to prevent contaminated sediments from becoming fluidized and migrating from areas of contamination to "clean" areas.

The leachate would have to be transported by barge, increasing the potential for arsenic, antimony, mercury, and petroleum-laden waste to migrate (i.e., mobility increase) through the Alaska waterway if a release were to occur.

Depending on the method of excavation selected by the design engineer, sheet piling, coffer dams, and stream diversion are some of the methods that could be implemented to reduce the potential for contaminated sediments from migrating to clean areas. A SWPPP will identify ways to limit surface water runoff from leaching metals with subsequent migration/spreading of contamination.

Implementability

Technically, this alternative is implementable. Construction of repositories to contain metals-laden waste tailings and contaminated soils and sediments is a common remediation technique at abandoned mine sites. The design procedures associated with building a stable repository are also well established. Solidification would require a large-scale field test prior to full site mobilization to determine the final process; however, solidification is a commonly used treatment technology and is readily implementable through the use of common construction equipment and materials. The disposal of the leachate could be problematic. The leachate will likely be classified as a hazardous waste (for arsenic). There are no treatment, storage, and disposal facilities in the State of Alaska. Therefore, the leachate would have to be transported to Anchorage, Alaska, and then shipped to the continental United States for final disposition.

Concrete cloth does not require specialized tools or labor to install and has a demonstrated effectiveness in cold weather climates. The loess covers to address localized hot spots in the Surface Mined Area require general earthwork equipment and practices.

Administratively, Alternative 3b is also implementable. ICs and Access agreements to excavate the material needed to complete the geomembrane cover and low permeability bottom liner would need to be developed and executed.

While there may not be a sufficient amount of earthen material located within the site boundaries to construct the cover system and bottom liner subgrade, offsite areas should satisfy the remaining material requirements. While heavy construction equipment would be needed, the loaders, trucks, and other pieces of equipment, along with materials such as concrete cloth for the cover proposed for Monofill #2 and piping for the leachate collection system, could be barged to the site. Given the remote nature of the site, mobilization and disposal of the leachate would be a major logistical component. However, the services and materials needed to implement Alternative 3b are obtainable.

Cost

The total capital cost associated with Alternative 3b is $31,070,000. The annual O&M cost is estimated to be $1.374,000, and the 30-year present worth cost has been determined to be $56,340,000. A summary of the key cost components is presented in Table 4-6, with additional supporting information provided in Appendix C.

4.2.5 Alternative 3c – Excavation of Solids and Sediments, Solidification, Onsite Consolidation, Excavation and Consolidation of Monofill #2, and Capping

Alternative 3c includes the excavation of tailings/waste rock and soils, and the removal of residual Red Devil Creek sediments that contain contaminant concentrations above the established RGs. Additionally, in areas downstream of the Main Processing Area that were not addressed under the interim removal action, sediments containing COC concentrations greater than the RGs would also be excavated. Also under this alternative, the contents of Monofill #2 would be excavated.

A dedicated repository would be constructed in the Surface Mined Area for onsite consolidation of excavated materials; excavated tailings, soils, or sediment that failed the TCLP analysis would be solidified prior to placement in the repository. A low-permeability cover would be installed on the repository to prevent direct contact with contaminants and reduce infiltration of surface water to the consolidated tailings and soils. Additionally, loess would be used as the cover material within the Surface Mined Area. In addition to O&M, Alternative 3c requires implementation of ICs and ACs to restrict access to the site.

Table 4-6 Cost Estimate Alternative 3b – Excavation, Dredging, and Onsite Consolidation in Repository with Leachate Collection System

Item	Description	Quantity	Unit	Cost/Unit	Cost
Direct Capital Costs					
DC1a	Mobilization/Demobilization	2	lump sum	$2,025,003	$4,050,006
DC2	Field Overhead and Oversight	10	month	$202,563	$2,025,630
DC3a	Site Preparation	1	lump sum	$1,034,757	$1,034,757
DCIC4	Install Access Controls	1	lump sum	$153,850	$153,850
DC4a	Excavate Contaminated Material and Haul to Repository	1	lump sum	$2,687,130	$2,687,130
DC5a	Solidification	1	lump sum	$2,297,465	$2,297,465
DC6a	Backfill Excavated Areas	1	lump sum	$2,037,765	$2,037,765
DC7a	Dredge Red Devil Creek and Haul to Repository	1	lump sum	$125,089	$125,089
DC10a	Repository Construction	1	lump sum	$550,794	$550,794
DC10b	Leachate Liner Construction	1	lump sum	$2,694,627	$2,694,627
DC11	Monofill Concrete Cloth Cover	1	lump sum	$323,922	$323,922
DC12a	Site Restoration	1	lump sum	$13,748	$13,748
DC13a	Construction Completion	1	lump sum	$121,195	$121,195
DC14a	Install Groundwater Monitoring Wells	1	lump sum	$60,000	$60,000
DC15	Loess cover in surface mining area	1	lump sum	$136,492	$136,492
Total Direct Capital Costs (rounded to nearest $10,000)					***$18,310,000***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$21,940,000***
Indirect Capital Costs					
	Engineering and Design (5%)	5%			$1,097,000
	Administration (4%)	4%			$878,000
	Legal Fees and License/Permit Costs (4%)	4%			$878,000
	3rd Party Construction Oversight (5%)	5%			$1,097,000
Total Indirect Capital Costs (rounded to nearest $10,000)					***$3,950,000***
Total Capital Costs					
	Subtotal Capital Costs				$25,890,000
	Contingency Allowance	20%			$5,178,000
Total Capital Cost (rounded to nearest $10,000)					**$31,070,000**

Item	Description	Quantity	Unit	Cost/Unit	Cost
Annual Direct Operation & Maintenance Costs					
OM2a	Annual Operation and Maintenance Costs	1	lump sum	$23,100	$23,100
OM2b	Leachate Collection, Offsite Transportation, and Disposal	1	lump sum	$847,829	$847,829
OM3a	Sample and Analyze 10 groundwater samples for metals and TPH	1	lump sum	$14,100	$14,100
ES	5-Year Review	1	lump sum	$10,000	$10,000
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$885,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$1,060,000*
Annual Indirect O&M Costs					
	Administration	5%			$53,000
	Insurance, Taxes, Licenses	3%			$31,800
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$85,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$1,145,000*
	Contingency Allowance	20%			$229,000
Total Annual O&M Cost (Rounded to Nearest $1,000)					$1,374,000

Table 4-6 Cost Estimate Alternative 3b – Excavation, Dredging, and Onsite Consolidation in Repository with Leachate Collection System

30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)	
Total Capital Costs	$31,070,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)	$25,270,000
Total Cost (Rounded to Nearest $10,000)	**$56,340,000**

Notes
(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 27th Ed., 2013.*
(2) A 6-month work season and a 6 day work week were assumed.
(3) One month for pre-construction and one month for post-construction activities were assumed.
(4) A location factor of 1.198 (Anchorage, Alaska) was applied for all direct costs.
(5) Costs presented in 2013 dollars
Key:
O&M = Operations and Maintenance
ES = Engineer's Estimate

Protection of Human Health and the Environment

By excavating metals-laden tailings, soil, and contaminated sediments, the contents of Monofill #2, and placing them into a repository, as well as placing loess covers over isolated hot spots in the Surface Mined Area, Alternative 3c would provide protection of human health and the environment. While this alternative would involve no reduction in the contaminant concentrations, the solidification of tailings, soils, and sediments that have failed TCLP for arsenic, installation of the low-permeability cover system, and the placement of loess over exposed areas in the Surface Mined Area would reduce the potential for exposure, in turn reducing the overall risk. Modeling of the proposed repository cover system shows that the leachate generation and migration of COCs would not adversely affect the groundwater beneath the repository, thereby adding to the overall protectiveness. Additionally, the cover system for the repository would reduce the likelihood of erosion of contaminated materials into Red Devil Creek and of animals coming into contact with such materials, thus providing environmental protection for terrestrial and aquatic life.

Compliance with ARARs

During the design phase, ARARs would be further reviewed, and their requirements could be incorporated into the design. The repository could be both designed and constructed to be compliant with the ARARs. Excavating could also be designed and implemented to be compliant with the ARARs. In short, Alternative 3c provides for compliance with ARARs. Table 4-7 identifies the ARARs applicable to Alternative 3c and whether the alternative can be implemented to be compliant with them.

Table 4-7 Alternative 3c ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Chemical-Specific				
Federal				
Resource Conservation and Recovery Act, Subtitle C – Identification and Listing of Hazardous Waste	40 CFR 261 42 USC 6921	Defines solid wastes which are subject to regulation as RCRA hazardous wastes. Solid wastes are considered hazardous if they are specifically listed in 40 CFR 261 Subpart D or if they exhibit one of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity).	Applicable	This ARAR would not be triggered. Toxicity Characteristic waste material would remain within the AOC under Alternative 3c.
Safe Drinking Water Act	42 USC. 300f et seq.	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Relevant and Appropriate	Alternative 3c does not address groundwater. It is anticipated that Alternative 3c would achieve MCLs in surface water over time.
Clean Water Act	33 USC 1251l et seq.	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 3c would improve creek water quality.

Table 4-7 Alternative 3c ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC	Alternative 3c would improve sediment quality in Red Devil Creek and the Kuskokwim River and it is anticipated these guidelines would be met over time.
State				
Alaska Oil and Other Hazardous Substance Pollution Control Regulations	18 AAC 75.340 18 AAC 75.341 18 AAC 75.345 (except (a))	Provides method for determining cleanup levels for soil (under 40-inch soil zone) contaminated with petroleum hydrocarbons [18 AAC 75.340(a)(1)(A)] or with chemicals other than petroleum hydrocarbons [AAC 75.340 (a) (2) (A)].	Applicable	Alternative 3c would comply with these regulations because contaminated soil would be excavated and contained in the repository.
Location-Specific				
Federal				
Archaeological and Historic Preservation Act of 1974	16 USC 469 40 CFR 6.301(c)	Provides for the preservation of historical and archaeological data that might otherwise be lost as a result of terrain alterations. If any remedial action could cause irreparable loss to significant scientific, pre-historical, or archaeological data, the act requires the agency undertaking the project to preserve the data or request the U.S. Department on the Interior to do so.	Applicable	Alternative 3c could be implemented in compliance with this act.
Archaeological Resources Protection Act of 1979	16 USC 470aa-mm 43 CFR Part 7	Requires permits for excavation of archaeological resources on public or tribal lands.	Applicable	Alternative 3c could be implemented in compliance with this act.

Table 4-7 Alternative 3c ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Native American Graves Protection and Reparation Act	25 USC 3001-3013 43 CFR 10	Regulations that pertain to the identification, protection, and appropriate disposition of human remains, funerary objects, sacred objects, or objects of cultural patrimony.	Applicable	Alternative 3c could be implemented in compliance with this act.
Protection of Wetlands, Executive Order 11990	40 CFR 6	Requires federal agencies to avoid adversely impacting wetlands wherever possible, to minimize wetlands destruction, and to preserve the values of wetlands.	Applicable	Alternative 3c could be implemented in compliance with this order.
Flood Plain Management, Executive Order 11988	40 CFR 6	Requires federal agencies to avoid, to the extent practicable, the long- and short-term adverse impacts associated with the occupancy and modification of flood plains, and to avoid direct and indirect support of flood plain development wherever there is a practicable alternative.	Applicable	Alternative 3c could be implemented in compliance with this order.
Fish and Wildlife Coordination Act	16 USC 1251 661 et seq. 40 CFR 6.302(g)	Requires consultation with the U.S. Fish and Wildlife Service for the protection of fish and wildlife when a proposed action may result in modifications to stream, river, or other surface water of the U.S.	Applicable	Alternative 3c could be implemented in compliance with this act.
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable	Alternative 3c could be implemented in compliance with this act.

Table 4-7 Alternative 3c ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Endangered Species Act	16 USC 1531 40 CFR 6.302(b) 50 CFR 17, 402	Provides for the protection of fish, wildlife, and plants that are threatened with extinction. Federal agencies are required under Section 7 of the ESA to ensure that their actions will not jeopardize the continued existence of a listed species or result in destruction of or adverse modification to its critical habitat. If the proposed action may affect the listed species or its critical habitat, consultation with the U.S. Fish and Wildlife Service may be required.	Applicable	Alternative 3c could be implemented in compliance with this act.
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable	Alternative 3c could be implemented in compliance with this act.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate	Alternative 3c could be implemented in compliance with this act.
State				
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable	Alternative 3c could be implemented in compliance with these requirements.
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Relevant and Appropriate	Existing site conditions combined with implementation of Alternative 3c would comply with these regulations.

Table 4-7 Alternative 3c ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Alaska Department of Fish and Game Anadromous Fish Act	AS 16.05.871- .901	Provides for the protection of fish and game habitats in the State of Alaska. Consultation with the Alaska Department of Fish and Game is required for any activities that could impede fish passage or that could divert, obstruct, pollute, or change the natural flow or bed of an anadromous water body. Tidelands (to mean low water at the mouth) are included.	Applicable	Alternative 3c could be implemented in compliance with this act.
Action-Specific				
Federal				
Clean Water Act – National Pollutant Discharge Elimination System	40 CFR 122-125 and 403	Establishes discharge limits and monitoring requirements for direct discharges of treated effluent and stormwater runoff to surface waters of the U.S. EPA gives states the authority to implement the National Pollutant Discharge Elimination System program.	Applicable	Alternative 3c could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.
Clean Water Act, Section 404	33 USC 1344 40 CFR 230 33 CFR 320-330	Restricts discharge of dredged or fill material into surface waters of the U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation onsite or offsite.	Applicable	Alternative 3 could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.
Clean Water Act – Water Quality Standards	40 CFR 131	Sets criteria for water quality based on toxicity to aquatic organisms and human health. States are given the responsibility of establishing and revising the standards, and the authority to develop standards more stringent than required by Clean Water Act.	Applicable	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 3c would improve water quality.

Table 4-7 Alternative 3c ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable	Alternative 3c could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.
Clean Air Act – National Ambient Air Quality Standards	40 CFR 50.1-50.17 42 USC 7409	Establishes National Ambient Air Quality Standards for six criteria pollutants (including particulate matter) to protect human health and the environment.	Applicable	Alternative 3c could be implemented in compliance with the referenced provisions of this act.
Resource Conservation and Recovery Act – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides criteria by which solid waste disposal facilities and processes must operate to prevent adverse effects on human health or the environment. Facilities failing to meet these criteria are classified as open dumps, which are prohibited. Any remedial alternative that includes construction of a solid waste disposal facility would have to meet these requirements.	Applicable	Alternative 3c could be implemented in compliance with the referenced provisions of this act.
Resource Conservation and Recovery Act – Hazardous Waste Management	40 CFR 260 42 USC 6921	Specifies hazardous waste management requirements. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered. Alternative 3c would not involve movement of hazardous waste outside of the AOC; therefore, the waste is not regulated as a RCRA hazardous waste.

Table 4-7 Alternative 3c ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Resource Conservation and Recovery Act – Generator Standards	40 CFR 262 42 USC 6922	Establishes standards for generators of hazardous waste. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered. Although. Alternative 3c may involve movement of hazardous waste outside of the AOC it will be decontaminated prior to transport and would not be considered hazardous waste; therefore, the waste is not regulated as a RCRA hazardous waste.
Resource Conservation and Recovery Act – Treatment, Storage, and Disposal Facility Requirements	40 CFR 264 42 USC 6924	Provides requirements for the generation, transportation, storage, and disposal of hazardous waste, including design and operating standards for hazardous waste treatment, storage, and disposal units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered. Although. Alternative 3c may involve movement of hazardous waste outside of the AOC it will be decontaminated prior to transport and would not be considered hazardous waste; therefore, the waste is not regulated as a RCRA hazardous waste.

Table 4-7 Alternative 3c ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Resource Conservation and Recovery Act – Closure and Post-Closure Requirements	40 CFR 264.110-120	Specifies requirements for the closure and post-closure care of RCRA hazardous waste management units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would not be triggered. Although Alternative 3c may involve movement of hazardous waste outside of the AOC it will be decontaminated prior to transport and would not be considered hazardous waste; therefore, the waste is not regulated as a RCRA hazardous waste.
Resource Conservation and Recovery Act – Standards Applicable to Transporters of Hazardous Waste	40 CFR 263 42 USC 6923	Establishes standards for the transportation of hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR Part 262.	Applicable	Although Alternative 3c may involve movement of waste outside of the AOC it will be decontaminated prior to transport and would not be considered hazardous waste; therefore, the waste is not regulated as a RCRA hazardous waste.

Table 4-7 Alternative 3c ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Hazardous Materials Transportation Act	49 USC 1801-1813 40 CFR 107, 171-173, and 177	Regulates the transportation of hazardous waste on public roads.	Applicable	Although. Alternative 3c may involve movement of waste outside of the AOC it will be decontaminated prior to transport and would not be considered hazardous waste
Invasive Species, Executive Order 13112		Prevents the introduction of invasive species and provides guidance for their control.	Applicable	Alternative 3c could be implemented in compliance with this order.
State				
Alaska Solid Waste Regulations	18 AAC 60.007(b) 18 AAC 60.010(a) 18 AAC 60.015 18 AAC 60.025 (b)(4)	Provides standards for management of solid waste, including requirements pertaining to accumulation, storage, treatment, transport, disposal, land spreading, landfills, monofills, monitoring, and corrective action.	Applicable	Existing site conditions combined with implementation of Alternative 3c would comply with these regulations.

Key:
AAC = Alaska Administrative Code
AOC = Area of Contamination
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
BMP = Best Management Practice
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = To Be Considered
USC = United States Code

Long-Term Effectiveness and Permanence

Placing excavated material with concentrations above the RGs into a dedicated repository could provide a long-term and permanent solution. Incorporating solidified material in the repository would improve long-term effectiveness. Additionally, this alternative would reduce human and ecological exposure to contaminants and reduce potential for continued contaminant migration from the site. Modeling has shown that leachate would not adversely affect the groundwater beneath the repository footprint even after 50 years of operation. Provided that an appropriate confirmation sampling and analysis plan is implemented as part of the remedy, this alternative would provide a high level of certainty that areas of contamination would be removed to meet the RGs.

Additionally, diverting surface water runoff away from loess-covered areas of mineralized rock in the Surface Mined Area would reduce the potential for erosion and increase the long-term effectiveness and permanence of the proposed remedy.

The repository proposed under Alternative 3c would require O&M activities. Activities that would be required to maintain the functionality of the repository include, but are not limited to, site inspections, cover repairs, and cleaning of the drainage ditches that divert stormwater runoff around and away from the repository. With adequate O&M, the remedy for the Surface Mined Area as proposed in Alternative 3c can provide long-term effectiveness and permanence.

Reduction of Toxicity, Mobility, and Volume through Treatment

Treatment using solidification of material exceeding TCLP for arsenic is proposed as part of Alternative 3c. Although this treatment would not decrease the overall toxicity and volume of contamination that would be left onsite in the proposed repository, it would reduce the mobility of contamination through encapsulation. Additionally, the repository would offer an overall reduction in contaminant mobility for all excavated material, although not through treatment. Generation and mobility would be greatly reduced by consolidating media contaminated with metals at concentrations above the RGs (as supported by the leachate modeling), solidifying media with the potential for leaching, and placing a PVC cover system over them. In short, while there is no reduction in toxicity and volume through treatment under this alternative, there is a reduction in mobility through treatment for the most heavily contaminated materials.

Short-Term Effectiveness

Given RDM's remote location, there is limited short-term risk associated with the local population. Workers involved in remedial action would be subject to exposure to media containing elevated concentrations of arsenic, antimony, and mercury. The use of personal protective equipment and water sprays to reduce dust are just two of the ways by which the short-term risks associated with working with metals-laden material could be reduced. While it is possible that sediments having concentrations above the RGs may still be present after the interim removal action, measures would be adopted during excavation along the portions of Red Devil Creek not addressed under the interim removal action to prevent contaminated sediments from becoming fluidized and migrating from areas of contamination to “clean” areas.

Depending on the method of excavation selected by the design engineer, sheet piling, coffer dams, and stream diversion are some of the methods that could be implemented to reduce the potential for contaminated sediments from migrating to clean areas. A SWPPP will identify ways to limit surface water runoff from leaching metals with subsequent migration/spreading of contamination.

Implementability

Technically, this alternative is implementable. Construction of repositories to contain metals-laden waste tailings and contaminated sediments is a common remediation technique at abandoned mine sites. The design procedures associated with building a stable repository are also well established. Solidification would require a large-scale field test prior to full site mobilization to determine the final process; however, solidification is a commonly used treatment technology and is readily implementable through the use of common construction equipment and materials. The loess covers to address localized hot spots in the Surface Mined Area require general earthwork equipment and practices.

Administratively, Alternative 3c is also implementable. ICs and access agreements to excavate the material needed to complete the liner cover would need to be developed and executed.

While there may not be a sufficient amount of earthen material located within the site boundaries to construct the cover systems, offsite areas should satisfy the remaining material requirements. While heavy construction equipment would be needed, the loaders, trucks, and other pieces of equipment could be barged to the site. Given the remote nature of the site, mobilization would be a major logistical component. However, the services and materials needed to implement Alternative 3c are reasonably obtainable.

Cost

The total capital cost associated with Alternative 3c is $27,650,00. The annual O&M cost is estimated to be $69,000, and the 30-year present worth cost has been determined to be $28,920,000. A summary of the key cost components is presented in Table 4-8, with additional supporting information provided in Appendix C.

Table 4-8 Cost Estimate Alternative 3c – Excavation, Dredging, and Onsite Consolidation in Repository with Monofill #2 Excavation, Separation, and Solidification

Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
DC1a	Mobilization/Demobilization	2	lump sum	$2,025,003	$4,050,006
DC2	Field Overhead and Oversight	12	month	$202,563	$2,430,756
DC3a	Site Preparation	1	lump sum	$1,034,757	$1,034,757
DCIC4	Install Access Controls	1	lump sum	$153,850	$153,850
DC4a	Excavate Contaminated Material and Haul to Repository	1	lump sum	$2,687,130	$2,687,130
DC5a	Solidification	1	lump sum	$2,297,465	$2,297,465
DC5b	Monofill #2 Separation, Excavation, and Solidification	1	lump sum	$438,125	$438,125
DC6a	Backfill Excavated Areas	1	lump sum	$2,037,765	$2,037,765
DC7a	Dredge Material from Red Devil Creek and Haul to Repository	1	lump sum	$125,089	$125,089
DC10a	Repository Construction (includes Monofill #2; an additional 10% was added to account for the addition of Monofill #2 contents)	1	lump sum	$605,873	$605,873
DC12a	Site Restoration	1	lump sum	$13,748	$13,748
DC13a	Construction Completion	1	lump sum	$121,195	$121,195
DC14b	Install Groundwater Monitoring Wells	1	lump sum	$30,000	$30,000
DC15	Loess cover in surface mining area	1	lump sum	$136,492	$136,492
Total Direct Capital Costs (rounded to nearest $10,000)					***$16,160,000***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$19,360,000***
Indirect Capital Costs					
	Engineering and Design (6%)	6%			$1,162,000
	Administration (4%)	4%			$774,000
	Legal Fees and License/Permit Costs (4%)	4%			$774,000
	3rd Party Construction Oversight (5%)	5%			$968,000
Total Indirect Capital Costs					***$3,678,000***
Total Capital Costs					
	Subtotal Capital Costs				$23,038,000
	Contingency Allowance	20%			$4,608,000
Total Capital Cost (rounded to nearest $10,000)					**$27,650,000**
Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM2a	Annual Operation and Maintenance Costs	1	lump sum	$23,100	$23,100
OM3b	Sample and Analyze 5 groundwater samples for metals and TPH	1	lump sum	$12,050	$12,050
ES	5-Year Review	1	lump sum	$10,000	$10,000
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$45,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$53,910*
Annual Indirect O&M Costs					
	Administration	5%			$2,696
	Insurance, Taxes, Licenses	3%			$1,617
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$4,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$57,910*
	Contingency Allowance	20%			$11,582
Total Annual O&M Cost (Rounded to Nearest $1,000)					$69,000

Table 4-8 Cost Estimate Alternative 3c – Excavation, Dredging, and Onsite Consolidation in Repository with Monofill #2 Excavation, Separation, and Solidification

30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)	
Total Capital Costs	$27,650,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)	$1,270,000
Total Cost (Rounded to Nearest $10,000)	**$28,920,000**

Notes

(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 27th Ed., 2013.*
(2) A 6-month work season and a 6-day work week were assumed.
(3) One month for pre-construction and one month for post-construction activities were assumed.
(4) A location factor of 1.198 (Anchorage, Alaska) was applied for all direct costs.
(5) Costs presented in 2013 dollars

Key:

O&M = Operations and Maintenance
TPH = total petroleum hydrocarbons

4.2.6 Alternative 3d – Excavation of Solids and Sediments; Solidification, Onsite Consolidation, Excavation and Consolidation of Monofill #2, Capping, and Collection and Offsite Disposal of Leachate

Alternative 3d includes the excavation of tailings/waste rock and soils, and the removal of residual Red Devil Creek sediments that contain contaminant concentrations above the established RGs. Under this alternative, the contents of Monofill #2 would also be excavated. Additionally in areas downstream of the Main Processing Area that were not addressed under the interim removal action, sediments containing COC concentrations greater than the RGs would also be excavated.

A dedicated repository would be constructed in the Surface Mined Area for onsite consolidation of excavated materials; excavated soils or sediment that failed the TCLP analysis would be solidified prior to placement in the repository. A low-permeability cover would be installed on the repository to prevent direct contact with contaminants and reduce infiltration of surface water to the consolidated tailings and soils.

An additional bottom liner and leachate collection system would be installed to collect leachate that may accumulate within the repository. Leachate would be pumped out of the repository semiannually and transported offsite for disposal. Additionally, loess would be used as the cover material within the Surface Mined Area. In addition to O&M, Alternative 3d requires implementation of ICs and ACs to restrict access to the site.

Protection of Human Health and the Environment

By excavating metals-laden tailings, soil, and contaminated sediments, and placing them into a repository, and placing loess covers over isolated hot spots in the Surface Mined Area, Alternative 3d would provide protection of human health and the environment. While this alternative would involve no reduction in the contaminant concentrations, the solidification of tailings that have failed TCLP for arsenic, and the placement of loess over exposed areas in the Surface Mined Area would reduce the potential for exposure, in turn reducing the overall risk. Modeling of the proposed repository cover system shows that the leachate generation and migration of COCs would not adversely affect the groundwater beneath the repository; however, Alternative 3d does incorporate a bottom liner and leachate collection as part of the repository design.

The leachate collection system and liner would further mitigate the potential for infiltration of contaminants into local groundwater. However, the risks to human health and environment associated with transporting leachate classified as a hazardous would be transferred to the selected shipper, and then to the treatment and disposal facility.

Finally, the cover system for the repository would reduce the likelihood of erosion of contaminated materials into Red Devil Creek and of animals coming into contact with such materials, thus providing environmental protection for terrestrial and aquatic life.

Compliance with ARARs

During the design phase, ARARs would be further reviewed, and their requirements could be incorporated into the design. The repository could be both designed and constructed to be compliant with the ARARs. Excavating could also be designed and implemented to be compliant with the ARARs. Shipping of hazardous wastes is also a well-documented and established process, although not necessarily for the volume associated with this alternative. Alternative 3d can provide compliance with ARARs. Table 4-9 identifies the ARARs applicable to Alternative 3d and whether the alternative can be implemented to be compliant with them.

Long-Term Effectiveness and Permanence

Placing excavated material with detected concentrations above the established RGs into a dedicated repository could provide a long-term and permanent solution. Incorporating solidified material in the repository would improve long-term effectiveness. Additionally, this alternative would reduce human and ecological exposure to contaminants and reduce potential for continued contaminant migration from the site. Modeling has shown that leachate would not adversely affect the groundwater beneath the repository footprint even after 50 years of operation. However, for the development of Alternative 3d, a bottom liner and leachate collection system has incorporated. Provided that an appropriate confirmation sampling and analysis plan is implemented as part of the remedy, this alternative would provide a high level of certainty that areas of contamination would be removed to meet the RGs.

Table 4-9 Alternative 3d ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Chemical-Specific				
Federal				
Resource Conservation and Recovery Act, Subtitle C – Identification and Listing of Hazardous Waste	40 CFR 261 42 USC 6921	Defines solid wastes which are subject to regulation as RCRA hazardous wastes. Solid wastes are considered hazardous if they are specifically listed in 40 CFR 261 Subpart D or if they exhibit one of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity).	Applicable	This ARAR would be triggered. Leachate will be considered a hazardous waste.
Safe Drinking Water Act	42 USC. 300f et seq.	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Relevant and Appropriate	Alternative 3d would reduce the potential for contamination to infiltrate the groundwater at the site through the use of a leachate collection and recovery system within the repository. It is anticipated that Alternative 3d would achieve MCLs in ground water over time.
Clean Water Act	33 USC 1251l et seq.	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 3d would improve creek water quality.

Table 4-9 Alternative 3d ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC	Alternative 3d would improve sediment quality in Red Devil Creek it is anticipated these guidelines would be met over time.
State				
Alaska Oil and Other Hazardous Substance Pollution Control Regulations	18 AAC 75.340 18 AAC 75.341 18 AAC 75.345 (except (a))	Provides method for determining cleanup levels for soil (under 40-inch soil zone) contaminated with petroleum hydrocarbons [18 AAC 75.340(a)(1)(A)] or with chemicals other than petroleum hydrocarbons [AAC 75.340 (a) (2) (A)].	Applicable	Alternative 3d would comply with these regulations because contaminated soil would be excavated and contained in the repository.
Location-Specific				
Federal				
Archaeological and Historic Preservation Act of 1974	16 USC 469 40 CFR 6.301(c)	Provides for the preservation of historical and archaeological data that might otherwise be lost as a result of terrain alterations. If any remedial action could cause irreparable loss to significant scientific, pre-historical, or archaeological data, the act requires the agency undertaking the project to preserve the data or request the U.S. Department on the Interior to do so.	Applicable	Alternative 3d could be implemented in compliance with this act.
Archaeological Resources Protection Act of 1979	16 USC 470aa-mm 43 CFR Part 7	Requires permits for excavation of archaeological resources on public or tribal lands.	Applicable	Alternative 3d could be implemented in compliance with this act.

Table 4-9 Alternative 3d ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Native American Graves Protection and Reparation Act	25 USC 3001-3013 43 CFR 10	Regulations that pertain to the identification, protection, and appropriate disposition of human remains, funerary objects, sacred objects, or objects of cultural patrimony.	Applicable	Alternative 3d could be implemented in compliance with this act.
Protection of Wetlands, Executive Order 11990	40 CFR 6	Requires federal agencies to avoid adversely impacting wetlands wherever possible, to minimize wetlands destruction, and to preserve the values of wetlands.	Applicable	Alternative 3d could be implemented in compliance with this order.
Flood Plain Management, Executive Order 11988	40 CFR 6	Requires federal agencies to avoid, to the extent practicable, the long- and short-term adverse impacts associated with the occupancy and modification of flood plains, and to avoid direct and indirect support of flood plain development wherever there is a practicable alternative.	Applicable	Alternative 3d could be implemented in compliance with this order.
Fish and Wildlife Coordination Act	16 USC 1251 661 et seq. 40 CFR 6.302(g)	Requires consultation with the U.S. Fish and Wildlife Service for the protection of fish and wildlife when a proposed action may result in modifications to stream, river, or other surface water of the U.S.	Applicable	Alternative 3d could be implemented in compliance with this act.
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable	Alternative 3d could be implemented in compliance with this act.

Table 4-9 Alternative 3d ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Endangered Species Act	16 USC 1531 40 CFR 6.302(b) 50 CFR 17, 402	Provides for the protection of fish, wildlife, and plants that are threatened with extinction. Federal agencies are required under Section 7 of the ESA to ensure that their actions will not jeopardize the continued existence of a listed species or result in destruction of or adverse modification to its critical habitat. If the proposed action may affect the listed species or its critical habitat, consultation with the U.S. Fish and Wildlife Service may be required.	Applicable	Alternative 3d could be implemented in compliance with this act.
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable	Alternative 3d could be implemented in compliance with this act.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate	Alternative 3d could be implemented in compliance with this act.
State				
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable	Alternative 3d could be implemented in compliance with these requirements.

Table 4-9 Alternative 3d ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, and controlling impacts outside property boundaries.	Relevant and Appropriate	Existing site conditions combined with implementation of Alternative 3d, particularly the installation of the leachate collection and removal system, could comply with these regulations.
Alaska Department of Fish and Game Anadromous Fish Act	AS 16.05.871- .901	Provides for the protection of fish and game habitats in the State of Alaska. Consultation with the Alaska Department of Fish and Game is required for any activities that could impede fish passage or that could divert, obstruct, pollute, or change the natural flow or bed of an anadromous water body. Tidelands (to mean low water at the mouth) are included.	Applicable	Alternative 3d could be implemented in compliance with this act.
Action-Specific				
Federal				
Clean Water Act – National Pollutant Discharge Elimination System	40 CFR 122-125 and 403	Establishes discharge limits and monitoring requirements for direct discharges of treated effluent and stormwater runoff to surface waters of the U.S. EPA gives states the authority to implement the National Pollutant Discharge Elimination System program.	Applicable	Alternative 3d could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.

Table 4-9 Alternative 3d ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Clean Water Act, Section 404	33 USC 1344 40 CFR 230 33 CFR 320-330	Restricts discharge of dredged or fill material into surface waters of the U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation onsite or offsite.	Applicable	Alternative 3d could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.
Clean Water Act – Water Quality Standards	40 CFR 131	Sets criteria for water quality based on toxicity to aquatic organisms and human health. States are given the responsibility of establishing and revising the standards, and the authority to develop standards more stringent than required by Clean Water Act.	Applicable	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 3d would improve water quality.
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable	Alternative 3d could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.
Clean Air Act – National Ambient Air Quality Standards	40 CFR 50.1-50.17 42 USC 7409	Establishes National Ambient Air Quality Standards for six criteria pollutants (including particulate matter) to protect human health and the environment.	Applicable	Alternative 3d could be implemented in compliance with the referenced provisions of this act.

Table 4-9 Alternative 3d ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Resource Conservation and Recovery Act – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides criteria by which solid waste disposal facilities and processes must operate to prevent adverse effects on human health or the environment. Facilities failing to meet these criteria are classified as open dumps, which are prohibited. Any remedial alternative that includes construction of a solid waste disposal facility would have to meet these requirements.	Applicable	Alternative 3d could be implemented in compliance with the referenced provisions of this act.
Resource Conservation and Recovery Act – Hazardous Waste Management	40 CFR 260 42 USC 6921	Specifies hazardous waste management requirements. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would be triggered. Alternative 3d involves shipping of leachate that would be classified as a hazardous waste.
Resource Conservation and Recovery Act – Generator Standards	40 CFR 262 42 USC 6922	Establishes standards for generators of hazardous waste. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would be triggered. Alternative 3d would involve movement of waste outside of the AOC (i.e., leachate).
Resource Conservation and Recovery Act –Treatment, Storage, and Disposal Facility Requirements	40 CFR 264 42 USC 6924	Provides requirements for the generation, transportation, storage, and disposal of hazardous waste, including design and operating standards for hazardous waste treatment, storage, and disposal units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would be triggered. Leachate will be classified as a hazardous waste..
Resource Conservation and Recovery Act – Closure and Post-Closure Requirements	40 CFR 264.110-120	Specifies requirements for the closure and post-closure care of RCRA hazardous waste management units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	This ARAR would be triggered. Alternative 3d would involve movement of waste outside of the AOC.

Table 4-9 Alternative 3d ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Resource Conservation and Recovery Act – Standards Applicable to Transporters of Hazardous Waste	40 CFR 263 42 USC 6923	Establishes standards for the transportation of hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR Part 262.	Applicable	This ARAR would be triggered. Leachate will be classified as a hazardous waste..
Hazardous Materials Transportation Act	49 USC 1801-1813 40 CFR 107, 171-173, and 177	Regulates the transportation of hazardous waste on public roads.	Applicable	This ARAR would be triggered. Leachate will be classified as a hazardous waste..
Invasive Species, Executive Order 13112		Prevents the introduction of invasive species and provides guidance for their control.	Applicable	Alternative 3d could be implemented in compliance with this order.
State				
Alaska Solid Waste Regulations	18 AAC 60.007(b) 18 AAC 60.010(a) 18 AAC 60.015 18 AAC 60.025 (b)(4)	Provides standards for management of solid waste, including requirements pertaining to accumulation, storage, treatment, transport, disposal, land spreading, landfills, monofills, monitoring, and corrective action.	Applicable	Existing site conditions combined with implementation of Alternative 3d would comply with these regulations.

Key:
AAC = Alaska Administrative Code
AOC = Area of Contamination
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
BMP = Best Management Practice
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = To Be Considered
USC = United States Code

Additionally, diverting surface water runoff away from loess-covered areas of mineralized rock in the Surface Mined Area would reduce the potential for erosion and increase the long-term effectiveness and permanence of the proposed remedy.

The repository proposed under Alternative 3d would require O&M activities. Activities that would be required to maintain the functionality of the repository and leachate collection system include, but are not limited to, site inspections, cover repairs, and cleaning of the drainage ditches that divert stormwater runoff around and away from the repository. With adequate O&M, the repository and leachate collection system, and remedy for the Surface Mined Area as proposed in Alternative 3d can provide long-term effectiveness and permanence. However, the disposition of hazardous waste leachate would be an ongoing process throughout the operational life of the repository. Changes in law and/or shipping requirements may adversely affect the ability to properly dispose of the collected fluids.

Reduction of Toxicity, Mobility, and Volume through Treatment

Treatment using solidification of material exceeding TCLP for arsenic is proposed as part of Alternative 3d. Although this treatment would not decrease the overall toxicity and volume of contamination that would be left onsite in the proposed repository, it would reduce the mobility of contamination through encapsulation. Additionally, the repository would offer an overall reduction in contaminant mobility for all excavated material, although not through treatment. Generation and mobility would be greatly reduced by consolidating media contaminated with metals at concentrations above the RGs (as supported by the leachate modeling), solidifying media with the potential for leaching, and placing a PVC cover system over them. However, the leachate that is collected would be classified as a hazardous waste. As such, this alternative would not achieve a reduction, but actually would increase the mobility and volume of contaminated material that needs to be addressed.

The loess cover used in the Surface Mined Area would also help reduce the site's contaminant mobility from the tailings and soils remaining at the site. While there is no reduction in toxicity and volume through treatment under this alternative, there is a reduction in mobility of the exposed contaminated media associated with the Surface Mined Area.

Short-Term Effectiveness

Given RDM's remote location, there is limited short-term risk associated with the local population. Workers involved in remedial action would be subject to exposure to media containing elevated concentrations of arsenic, antimony, and mercury. The use of personal protective equipment and water sprays to reduce dust are just two of the ways by which the short-term risks associated with working with metals-laden material could be reduced. Measures would be adopted during excavation along the portions of Red Devil Creek not addressed under the interim remedial action to prevent contaminated sediments from becoming fluidized and migrating from areas of contamination to "clean" areas.

The leachate would have to be transported by barge, greatly increasing the potential for arsenic, antimony, mercury, and petroleum-laden waste to migrate (i.e., mobility increase) through the Alaska waterway if a release were to occur.

Depending on the method of excavation selected by the design engineer, sheet piling, coffer dams, and stream diversion are some of the methods that could be implemented to reduce the potential for contaminated sediments from migrating to clean areas. A SWPPP will identify ways to limit surface water runoff from leaching metals with subsequent migration/spreading of contamination.

Implementability

Technically, this alternative is implementable. Construction of repositories to contain metals-laden waste tailings and contaminated sediments is a common remediation technique at abandoned mine sites. The design process associated with building a stable repository is also well established. Solidification would require a large-scale field test prior to full site mobilization to determine the final process; however, solidification is a commonly used treatment technology and is readily implementable through the use of common construction equipment and materials. The disposal of the leachate could pose to be problematic. The leachate would be classified as a hazardous waste (for arsenic). There are no treatment, storage, and disposal facilities in the State of Alaska. Therefore, the leachate would have to be transported to Anchorage, Alaska and then shipped to the lower 48 for final disposition.

Administratively, Alternative 3d is also implementable. ICs and access agreements to excavate the material needed to complete the liner cover and low permeability bottom liner would need to be developed and executed.

While there may not be a sufficient amount of earthen material located within the site boundaries to construct the cover system and bottom liner, offsite areas should satisfy the remaining material requirements. While heavy construction equipment would be needed, the loaders, trucks, and other pieces of equipment, along with materials and piping for the leachate collection system, could be barged to the site. Given the remote nature of the site, mobilization and disposal of the leachate would be a major logistical component. However, the services and materials needed to implement Alternative 3b are obtainable.

Cost

The total capital cost associated with Alternative 3d is $32,590,000. The annual O&M cost is estimated to be $1,387,000, and the 30-year present worth cost has been determined to be $58,100,000. A summary of the key cost components is presented in Table 4-10, with additional supporting information provided in Appendix C.

Table 4-10 Cost Estimate Alternative 3d – Excavation, Dredging, and Onsite Consolidation in Repository with Monofill #2 Excavation, Separation, and Solidification and Leachate Collection System

Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
DC1a	Mobilization/Demobilization	2	lump sum	$2,025,003	$4,050,006
DC2	Field Overhead and Oversight	10	month	$202,563	$2,025,630
DC3a	Site Preparation	1	lump sum	$1,034,757	$1,034,757
DCIC4	Install Access Controls	1	lump sum	$153,850	$153,850
DC4a	Excavate Contaminated Material and Haul to Repository	1	lump sum	$2,687,130	$2,687,130
DC5a	Solidification	1	lump sum	$2,297,130	$2,297,130
DC5b	Monofill #2 Separation, Excavation, and Solidification	1	lump sum	$438,125	$438,125
DC6a	Backfill Excavated Areas	1	lump sum	$2,037,765	$2,037,765
DC7a	Dredge Remaining Red Devil Creek and Haul to Repository	1	lump sum	$125,089	$125,089
DC10a	Repository Construction (includes Monofill #2; an additional 10% was added to account for the addition of Monofill #2 contents)	1	lump sum	$605,873	$605,873
DC10b	Leachate Liner Construction (includes Monofill #2; an additional 10% was added to account for the addition of Monofill #2 contents)	1	lump sum	$2,964,090	$2,964,090
DC11	Excavate Contaminated Material and Haul to Repository	1	lump sum	$323,922	$323,922
DC12a	Site Restoration	1	lump sum	$13,748	$13,748
DC13a	Construction Completion	1	lump sum	$121,195	$121,195
DC14b	Install Groundwater Monitoring Wells	1	lump sum	$30,000	$30,000
DC15	Loess cover in surface mining area	1	lump sum	$136,492	$136,492
Total Direct Capital Costs (rounded to nearest $10,000)					***$19,050,000***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$22,820,000***
Indirect Capital Costs					
	Engineering and Design (6%)	6%		$1,369,000	
	Administration (4%)	4%		$913,000	
	Legal Fees and License/Permit Costs (4%)	4%		$913,000	
	3rd Party Construction Oversight (5%)	5%		$1,141,000	
Total Indirect Capital Costs					***$4,336,000***
Total Capital Costs					
	Subtotal Capital Costs				$27,156,000
	Contingency Allowance	20%			$5,431,000
Total Capital Cost (rounded to nearest $10,000)					**$32,590,000**

Table 4-10 Cost Estimate Alternative 3d – Excavation, Dredging, and Onsite Consolidation in Repository with Monofill #2 Excavation, Separation, and Solidification and Leachate Collection System

Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM2a	Annual Operation and Maintenance Costs	1	lump sum	$23,100	$23,100
OM2b	Leachate Collection, Offsite Transportation, and Disposal	1	lump sum	$847,829	$847,829
OM3b	Sample and Analyze 5 groundwater samples for metals and TPH	1	lump sum	$12,050	$12,050
ES	5-Year Review	1	lump sum	$10,000	$10,000
Total Annual Direct O&M Costs(Rounded to Nearest $1,000)					*$893,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$1,070,000*
Annual Indirect O&M Costs					
	Administration	5%			$53,500
	Insurance, Taxes, Licenses	3%			$32,100
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$86,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$1,156,000*
	Contingency Allowance	20%			$231,200
Total Annual O&M Cost (Rounded to Nearest $1,000)					$1,387,000
30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)					
Total Capital Costs					$32,590,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)					$25,510,000
Total Cost (Rounded to Nearest $10,000)					**$58,100,000**

Notes
(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 27th Ed., 2013.*
(2) A 6-month work season and a 6-day work week were assumed.
(3) One month for pre-construction and one month for post-construction activities were assumed.
(4) A location factor of 1.198 (Anchorage, Alaska) was applied for all direct costs.
(5) Costs are presented in 2013 dollars.

Key:
ES = Engineer’s Estimate
O&M = Operations and Maintenance
TPH = total petroleum hydrocarbons

4.2.7 Alternative 4 – Excavation of Soils and Sediments and Offsite Disposal

Alternative 4 includes the excavation of tailings and soils, as well as residual Red Devil Creek sediments that were not addressed by the interim remedial action. The tailings cover and contents of Monofill #2 would be excavated and shipped offsite for disposal, as well. A loess cover would be constructed that is designed to prevent direct contact with exposed areas in the Surface Mined Area. Finally, excavated material would be containerized and shipped to a disposal facility in the continental United States (assumed to be located in Oregon for FS costing purposes).

Overall Protection of Human Health and the Environment
By excavating material containing contaminant concentrations above the established RGs and removing them from the site, potential exposure pathways associated with arsenic, antimony, mercury, and other COCs would be eliminated. Since this alternative would result in a site with no remaining exposure pathways within the boundaries of RDM, it would provide overall protection of human health and the environment at RDM

Compliance with ARARs
During the design phase, ARARs would be further reviewed, and their requirements could be incorporated into the design. Excavating would therefore be designed and implemented in a manner compliant with the ARARs. Table 4-11 identifies the ARARs applicable to Alternative 4 and whether the alternative can be implemented to be compliant with them.

Long-Term Effectiveness and Permanence
Excavation of material having contaminant concentrations above the established RGs and placing them into an appropriately licensed and maintained landfill located in the continental United States could provide a long-term and permanent solution. Removing the contaminated materials from RDM would provide an effective means of reducing human and ecological exposure, as well as future migration of contaminants from the site. Provided that an appropriate confirmation sampling and analysis plan were implemented as part of the remedy, there could be a high level of certainty that areas of contamination would be removed to meet the RGs.

Reduction of Toxicity, Mobility, and Volume through Treatment
There is no onsite treatment component associated with Alternative 4. However, by excavating, transporting, and ultimately placing material with contaminant concentrations above the RGs into a secured, permitted landfill, Alternative 4 does offer an overall reduction in contaminant mobility. While it is anticipated that no onsite treatment (the disposal facility may have to treat material that fails TCLP) would be performed under this alternative, depending upon the permit requirements for the landfill, some of the RDM material could actually undergo a solidification process to reduce its mobility and/or toxicity prior to placing it into the landfill. Should this occur, there would be an increase in the overall volume due to the addition of the solidification agent and/or binders.

Short-Term Effectiveness
Given RDM's remote location, there is a limited short-term risk associated with the local population. Workers involved with remedial action would be subject to exposure to media containing elevated concentrations of arsenic, antimony, and mercury. The use of personal protective equipment and water sprays to reduce dust are just two ways that the short-term risks associated with working with metals-laden material could be reduced.

Table 4-11 Alternative 4 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Chemical-Specific				
Federal				
Resource Conservation and Recovery Act, Subtitle C – Identification and Listing of Hazardous Waste	40 CFR 261 42 USC 6921	Defines solid wastes which are subject to regulation as RCRA hazardous wastes. Solid wastes are considered hazardous if they are specifically listed in 40 CFR 261 Subpart D or if they exhibit one of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity).	Applicable	Alternative 4 would be implemented in compliance with these regulations.
Safe Drinking Water Act	42 USC 300f et seq.	Establishes MCLs for priority contaminants in drinking water systems, including groundwater and surface water bodies used as public drinking water supplies.	Relevant and Appropriate	Alternative 4 does not address groundwater. It is anticipated that Alternative 4 would achieve MCLs in surface water over time.
Clean Water Act	33 USC 1251l et seq.	Establishes ambient water quality criteria necessary to support designated surface water body uses.	Relevant and Appropriate	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 4 would improve creek water quality.

Table 4-11 Alternative 4 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems	MacDonald et al. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31	Provides consensus-based sediment quality guidelines for 28 chemicals of concern.	TBC	Alternative 4 would improve sediment quality in Red Devil Creek, and it is anticipated these guidelines would be met over time.
State				
Alaska Oil and Other Hazardous Substance Pollution Control Regulations	18 AAC 75.340 18 AAC 75.341 18 AAC 75.345 (except (a))	Provides method for determining cleanup levels for soil (under 40-inch soil zone) contaminated with petroleum hydrocarbons [18 AAC 75.340(a)(1)(A)] or with chemicals other than petroleum hydrocarbons [AAC 75.340 (a) (2) (A)].	Applicable	Alternative 4 could comply with these regulations because contaminated soil would be excavated and disposed off-site.

Table 4-11 Alternative 4 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Location-Specific				
Federal				
Archaeological and Historic Preservation Act of 1974	16 USC 469 40 CFR 6.301(c)	Provides for the preservation of historical and archaeological data that might otherwise be lost as a result of terrain alterations. If any remedial action could cause irreparable loss to significant scientific, pre-historical, or archaeological data, the act requires the agency undertaking the project to preserve the data or request the U.S. Department on the Interior to do so.	Applicable	Alternative 4 could be implemented in compliance with this act.
Archaeological Resources Protection Act of 1979	16 USC 470aa-mm 43 CFR Part 7	Requires permits for excavation of archaeological resources on public or tribal lands.	Applicable	Alternative 4 could be implemented in compliance with this act.
Native American Graves Protection and Reparation Act	25 USC 3001-3013 43 CFR 10	Regulations that pertain to the identification, protection, and appropriate disposition of human remains, funerary objects, sacred objects, or objects of cultural patrimony.	Applicable	Alternative 4 could be implemented in compliance with this act.
Protection of Wetlands, Executive Order 11990	40 CFR 6	Requires federal agencies to avoid adversely impacting wetlands wherever possible, to minimize wetlands destruction, and to preserve the values of wetlands.	Applicable	Alternative 4 could be implemented in compliance with this order.
Flood Plain Management, Executive Order 11988	40 CFR 6	Requires federal agencies to avoid, to the extent practicable, the long- and short-term adverse impacts associated with the occupancy and modification of flood plains, and to avoid direct and indirect support of flood plain development wherever there is a practicable alternative.	Applicable	Alternative 4 could be implemented in compliance with this order.

Table 4-11 Alternative 4 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Fish and Wildlife Coordination Act	16 USC 1251 661 et seq. 40 CFR 6.302(g)	Requires consultation with the U.S. Fish and Wildlife Service for the protection of fish and wildlife when a proposed action may result in modifications to stream, river, or other surface water of the U.S.	Applicable	Alternative 4 could be implemented in compliance with this act.
Migratory Bird Treaty Act	16 USC 703 50 CFR 10.13	Provides for the protection of international migratory birds. Requires remedial actions to conserve critical habitat and consultation with the U.S. Department of the Interior if any critical habitat is to be impacted.	Applicable	Alternative 4 could be implemented in compliance with this act.
Endangered Species Act	16 USC 1531 40 CFR 6.302(b) 50 CFR 17, 402	Provides for the protection of fish, wildlife, and plants that are threatened with extinction. Federal agencies are required under Section 7 of the ESA to ensure that their actions will not jeopardize the continued existence of a listed species or result in destruction of or adverse modification to its critical habitat. If the proposed action may affect the listed species or its critical habitat, consultation with the U.S. Fish and Wildlife Service may be required.	Applicable	Alternative 4 could be implemented in compliance with this act.
Bald and Golden Eagles Protection Act	16 USC 668	Provides for the protection of bald and golden eagles.	Applicable	Alternative 4 could be implemented in compliance with this act.
Magnuson-Stevens Fishery Conservation and Management Act	16 USC 1801-1884	Establishes rules and process for essential fish habitat in marine and freshwater environments.	Relevant and Appropriate	Alternative 4 could be implemented in compliance with this act.

Table 4-11 Alternative 4 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
State				
Alaska Historic Preservation Requirements	11 AAC 16	Provides for the protection of historic places on State of Alaska lands.	Applicable	Alternative 4 could be implemented in compliance with these requirements.
Alaska Solid Waste Regulations	18 AAC 60.217 18 AAC 60.233(1)	Provides requirements for separation of landfills from groundwater, placement of waste in landfills, and location standards for monofills.	Relevant and Appropriate	Existing site conditions combined with implementation of Alternative 4 would comply with these regulations.
Alaska Department of Fish and Game Anadromous Fish Act	AS 16.05.871- .901	Provides for the protection of fish and game habitats in the State of Alaska. Consultation with the Alaska Department of Fish and Game is required for any activities that could impede fish passage or that could divert, obstruct, pollute, or change the natural flow or bed of an anadromous water body. Tidelands (to mean low water at the mouth) are included.	Applicable	Alternative 4 could be implemented in compliance with this act.
Action-Specific				
Federal				
Clean Water Act – National Pollutant Discharge Elimination System	40 CFR 122-125 and 403	Establishes discharge limits and monitoring requirements for direct discharges of treated effluent and stormwater runoff to surface waters of the U.S. EPA gives states the authority to implement the National Pollutant Discharge Elimination System program.	Applicable	Alternative 4 could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.

Table 4-11 Alternative 4 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Clean Water Act, Section 404	33 USC 1344 40 CFR 230 33 CFR 320-330	Restricts discharge of dredged or fill material into surface waters of the U.S., including wetlands. If there is no practicable alternative to impacting navigable waters of the U.S., then the impact must be minimized and unavoidable loss must be compensated for through mitigation onsite or offsite.	Applicable	Alternative 4 could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.
Clean Water Act – Water Quality Standards	40 CFR 131	Sets criteria for water quality based on toxicity to aquatic organisms and human health. States are given the responsibility of establishing and revising the standards, and the authority to develop standards more stringent than required by Clean Water Act.	Applicable	Ambient water quality criteria are presently met in Red Devil Creek. Implementation of Alternative 4 would improve water quality.
Rivers and Harbors Act, Section 10	33 USC 403 33 CFR 320-330	Prohibits unauthorized obstruction or alternation of navigable waters of the U.S. Any remedial alternative that includes dredging of river sediment would have to meet these requirements.	Applicable	Alternative 4 could be implemented in compliance with the referenced provisions of this act with appropriate BMPs.
Clean Air Act – National Ambient Air Quality Standards	40 CFR 50.1-50.17 42 USC 7409	Establishes National Ambient Air Quality Standards for six criteria pollutants (including particulate matter) to protect human health and the environment.	Applicable	Alternative 4 could be implemented in compliance with the referenced provisions of this act.

Table 4-11 Alternative 4 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Resource Conservation and Recovery Act – Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR 257 42 USC 6944	Provides criteria by which solid waste disposal facilities and processes must operate to prevent adverse effects on human health or the environment. Facilities failing to meet these criteria are classified as open dumps, which are prohibited. Any remedial alternative that includes construction of a solid waste disposal facility would have to meet these requirements.	Applicable	This ARAR would be triggered associated with off-site disposal of waste. Alternative 4 does not involve construction of a waste disposal facility.
Resource Conservation and Recovery Act – Hazardous Waste Management	40 CFR 260 42 USC 6921	Specifies hazardous waste management requirements. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	Alternative 4 could be implemented in compliance with these regulations.
Resource Conservation and Recovery Act – Generator Standards	40 CFR 262 42 USC 6922	Establishes standards for generators of hazardous waste. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	Alternative 4 could be implemented in compliance with these regulations.
Resource Conservation and Recovery Act – Treatment, Storage, and Disposal Facility Requirements	40 CFR 264 42 USC 6924	Provides requirements for the generation, transportation, storage, and disposal of hazardous waste, including design and operating standards for hazardous waste treatment, storage, and disposal units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	Alternative 4 could be implemented in compliance with these regulations.
Resource Conservation and Recovery Act – Closure and Post-Closure Requirements	40 CFR 264.110-120	Specifies requirements for the closure and post-closure care of RCRA hazardous waste management units. Waste at RDM would be classified as hazardous if moved offsite.	Relevant and Appropriate	Alternative 4 could be implemented in compliance with these regulations.

Table 4-11 Alternative 4 ARARs Compliance

Standard, Requirement, Criteria, or Limitation	Citation	Description	ARAR or TBC	ARAR Compliance
Resource Conservation and Recovery Act – Standards Applicable to Transporters of Hazardous Waste	40 CFR 263 42 USC 6923	Establishes standards for the transportation of hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR Part 262.	Applicable	Alternative 4 could be implemented in compliance with these regulations.
Hazardous Materials Transportation Act	49 USC 1801-1813 40 CFR 107, 171-173, and 177	Regulates the transportation of hazardous waste on public roads.	Applicable	Alternative 4 could be implemented in compliance with these regulations.
Invasive Species, Executive Order 13112		Prevents the introduction of invasive species and provides guidance for their control.	Applicable	Alternative 4 could be implemented in compliance with this order.

Key:
AAC = Alaska Administrative Code
ARAR = Applicable or Relevant and Appropriate Requirements
AS = Alaska Statutes
BMP = Best Management Practices
CFR = Code of Federal Regulations
EPA = U.S. Environmental Protection Agency
MCL = Maximum Contaminant Levels
RCRA = Resource Conservation and Recovery Act
RDM = Red Devil Mine
TBC = To Be Considered
USC = United States Code

Measures would be adopted during excavation along the portions of Red Devil Creek not addressed under the interim remedial action to prevent contaminated sediments from becoming fluidized and migrating from areas of contamination to “clean” areas. Depending upon the excavation method, sheet piling, coffer dams, and diversion are some of the methods that could be implemented to reduce the potential for contaminated sediments from migrating to clean areas. A SWPPP will identify ways to limit surface water runoff from leaching metals with subsequent migration/spreading of contamination.

With approximately 214,000 cubic yards of material being transported by barge, ocean liner, and finally, locomotive, there is a considerable amount of short-term risk associated with Alternative 4. Given that there would be over 150,000 super sacks requiring handling and transport, it is possible that sacks would be punctured, spilled, and/or ripped, resulting in a release of material in a location that is likely not equipped to handle this type of response. Substituting larger metal containers could prevent potential spills due to damaged super sacks, but that material transfer would occur at three different sea ports. No matter what container is used, a release during transit is possible, making it necessary to consider potential impacts to navigable waterways of the United States in evaluating this alternative.

Implementability

Technically, Alternative 4 is implementable. Excavation and offsite disposal are common remediation techniques. The design process associated with ensuring stable excavation walls and water diversion is also well established. Although RDM is located in a remote area, transporting heavy equipment and materials to the site is feasible.

Alternative 4 is also implementable administratively. ICs and access agreements to excavate the material needed for backfill and the loess cover associated with the Surface Mined Area would need to be developed and executed. The logistics of shipping the excavated material would be challenging given the volume of material 214,000 cubic yards) and would require a large effort to permit transporting hazardous waste between states using the navigable waterways of the United States.

While heavy construction equipment would be needed to perform the excavation, the loaders, trucks, and other pieces of equipment could be barged to the site. Given the remote location, mobilization would be a major logistical component. However, mobilizing the resources needed to implement Alternative 4 is feasible.

Cost

The total capital cost associated with Alternative 4 is $182,060,00. The annual O&M cost associated with maintaining the loess cover system is estimated to be $48,000, and the 30-year present worth cost has been determined to be

$182,940,000. A summary of the key cost components is presented in Table 4-12, with additional supporting information provided in Appendix C.

Table 4-12 Cost Estimate Alternative 4 – Excavation, Dredging, and Off-Site Disposal

Direct Capital Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
DC1b	Mobilization/Demobilization	3	lump sum	$2,463,665	$7,390,995
DC2	Field Overhead and Oversight	15	month	$202,563	$3,038,445
DC3b	Site Preparation	1	lump sum	$808,097	$808,097
DCIC4	Install Access Controls	1	lump sum	$153,850	$153,850
DC4b	Excavation of Contaminated Material	1	lump sum	$1,775,060	$1,775,060
DC6b	Backfill Excavated Areas	1	lump sum	$2,037,765	$2,037,765
DC7b	Dredge Contaminated Material	1	lump sum	$143,067	$143,067
DC8	Transportation	1	lump sum	$70,989,637	$70,989,637
DC9	Disposal	1	lump sum	$17,885,173	$17,885,173
DC11	Excavate with offsite Disposal of Monofill #2	1	lump sum	$1,9,34,390	$1,9,34,390
DC12	Site Restoration	1	lump sum	$13,748	$13,748
DC13b	Construction Completion	1	lump sum	$109,999	$109,999
DC15	Loess cover in surface mining area	1	lump sum	$136,492	$136,492
Total Direct Capital Costs (rounded to nearest $10,000)					***$106,420,000***
Total Direct Capital Costs with Location Factor of 1.198 (rounded to nearest $10,000)					***$127,490,000***
Indirect Capital Costs					
	Engineering and Design (6%)		6%		$7,649,000
	Administration (4%)		4%		$5,100,000
	Legal Fees and License/Permit Costs (4%)		4%		$5,100,000
	3rd Party Construction Oversight (5%)		5%		$6,375,000
Total Indirect Capital Costs					***$24,224,000***
Total Capital Costs					
	Subtotal Capital Costs				$151,714,000
	Contingency Allowance		20%		$30,343,,000
Total Capital Cost (rounded to nearest $10,000)					**$182,060,000**
Annual Direct Operation & Maintenance Costs					
Item	**Description**	**Quantity**	**Unit**	**Cost/Unit**	**Cost**
OM1	Annual Operation and Maintenance Costs	1	lump sum	$23,100	$23,100
ES	5-Year Review	1	lump sum	$7,500	$7,500
Total Annual Direct O&M Costs (Rounded to Nearest $1,000)					*$31,000*
Total Annual Direct O&M Costs with Location Factor of 1.198 (Rounded to Nearest $1,000)					*$37,000*
Annual Indirect O&M Costs					
	Administration	5%			$1,850
	Insurance, Taxes, Licenses	3%			$1,110
Total Annual Indirect O&M Costs (Rounded to Nearest $1,000)					*$3,000*
Total Annual O&M Costs					
	Subtotal Annual O&M Costs				*$40,000*
	Contingency Allowance	20%			$8,000

Table 4-12 Cost Estimate Alternative 4 – Excavation, Dredging, and Off-Site Disposal

Total Annual O&M Cost (Rounded to Nearest $1,000)	$48,000
30-Year Cost Projection (Assume Discount Rate Per Year: 3.5%)	
Total Capital Costs	$182,060,000
Present Worth of 30 Years O&M assuming 3.5% Discount Factor (Rounded to Nearest $10,000)	$880,000
Total Cost (rounded to nearest $10,000)	**$182,940,000**

Notes
(1) Unit costs provided by Means were taken from *RSMeans Heavy Construction Cost Data, 27th Ed., 2013.*
(2) A 6-month work season and a 6 day work week were assumed.
(3) One month for pre-construction and one month for post-construction activities were assumed.
(4) A location factor of 1.198 (Anchorage, Alaska) was applied for all direct costs.
(5) Costs presented in 2013 dollars

Key:
ES = Engineer's Estimate
O&M = Operations and Maintenance

4.3 Comparative Analysis of Remedial Alternatives

A comparative analysis of the remedial alternatives is provided in the following subsections.

4.3.1 Overall Protection of Human Health and the Environment

Of the seven alternatives, Alternative 4 offers the most protection of human health and the environment because not only does it remove source and nearby affected soil and sediment and Monofill #2, it also places them in a secure landfill. While Alternatives 3a, 3b, 3c, and 3d place approximately the same volume of contaminated media in a secured area, they do not offer the same level of protection as a secure landfill, which is monitored continuously. Because Alternatives 3b and 3d include a bottom liner, they offer slightly more protection in that leachate is collected. However, based on the modeling results associated with the proposed cover system, there is no predicted adverse impact associated with 3a and 3c not having a bottom liner. Additionally, while a cover system does allow for infiltration, the same principles apply to a bottom liner in that there would be leakage from the bottom liner into the underlying soils, and there would be continual generation of leachate classified as a hazardous waste.

Of the two remaining alternatives, Alternative 2, while limited, does offer some reduction in human health risk exposure by reducing the public's ability to access the site. While Alternative 2 does not address all ecological receptors or contaminant migration, it provides more protection than Alternative 1, which does not provide any reduction in human exposure and/or risk.

4.3.2 Compliance with ARARs

Of the six "action" alternatives, Alternatives 3a, 3b, 3c, 3d, and 4 could be implemented to be compliant with the ARARs. While Alternative 2 could be implemented in a manner that complies with the ARARs, the waste tailings and contaminated soil would continue to leach metals into the groundwater and Red Devil Creek.

4.3.3 Long-Term Effectiveness and Permanence

Alternative 1 does not provide for long-term effectiveness and/or permanence. Alternative 2 offers slightly more effectiveness and permanence than Alternative 1, but not nearly as much as the remaining alternatives.

While Alternatives 3a, 3b, 3c, 3d, and 4 provide removal of areas containing contaminant concentrations above the RGs and placement of the material in a secured area, there are still slight differences. Alternative 4 would employ a secure, appropriately licensed landfill, while the other alternatives would use an onsite repository. Alternatives 3a and 3c would place a new cover system over Monofill #2, while for Alternatives 3b and 3d, the contents of Monofill #2 would be excavated and incorporated into the new onsite repository.

With a secure licensed landfill being continuously monitored and maintained, Alternative 4 takes advantage of closure plans and related administrative processes already established for the disposal facility. While an onsite repository can be designed and implemented in a way that matches the protectiveness of a secure landfill, RDM’s remote location increases the cost and complexity of long-term monitoring and O&M that is typically performed at such a facility. Therefore, an existing landfill provides better long-term effectiveness and permanence. For the alternatives that utilize an onsite repository, there is essentially no difference between them with regards to effectiveness and permanence associated with site-related risks. The effectiveness of the proposed cover system as demonstrated by the leachate modeling results shows that a leachate collection system does not offer a significant improvement. Regardless of the cover system(s) that are implemented, O & M must be performed to provide for long-term effectiveness and permanence.

4.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

None of the alternatives developed and presented in this document provide for reduction of toxicity, and volume through treatment. However, the alternatives that utilize solidification as part of their remedy do provide for a partial reduction of mobility for the most contaminated media. For Alternatives 3a, 3b, 3c, 3d, and 4, the placement of contaminated media into a landfill or repository would achieve a considerable reduction in contaminant mobility, although not through treatment. However, the collection of leachate would cause an increase in the potential mobility and volume of site contaminants, making Alternatives 3b and 3d less effective with regards to this criterion.

Alternatives 1 and 2 do nothing to prevent surface water from coming into contact with metal-laden tailings. Therefore, under these two alternatives, there is still the potential for metals to leach unabated into the environment, which equates to an increase in the volume of contamination.

4.3.5 Short-Term Effectiveness

Under Alternative 4, approximately 214,000 cubic yards of material would be transported several thousand miles to its final disposal site, Under Alternatives 3b and 3d, an estimated 90,000 gallons of leachate would have to be transport to the same location each year. Alternatives 3b, 3d, and 4 offer the least amount of short-term effectiveness and generate the most adverse risk. For these alternatives, the super sacks and leachate would be loaded and off-loaded multiple times, so there is also an increase in the risk of a release due to the sacks or leachate containers being punctured. Given that the transfers would be performed at several ports, a container failure could result in the discharge of metals-laden tailings and/or leachate into navigable waters.

Of the remaining alternatives, Alternatives 3a and 3c would generate adverse short-term risk, but considerably less than previously mentioned alternatives. Excavation activities, hauling materials, and placement/compaction would generate dust containing arsenic, antimony, and mercury. Water trucks and personal protective equipment could be used to reduce the potential for exposure. Additionally, stormwater run-off controls would be implemented during the construction phase to reduce the potential for contaminated media to leach additional contamination. Alternative 3a has very slightly less adverse risk associated with it as compared to Alternative 3c and 3d in that there would be less material excavated and hauled associated with leaving Monofill #2 in place. It should be noted that these material handling risks also apply to Alternatives 3b, 3d, and 4.

With no action being performed, Alternative 1 has the least amount of adverse short-term risk. While there is a finite amount of site work being performed (i.e., fence installation), Alternative 2 has slightly more adverse short-term risk than Alternative 1 and far less than the previously discussed alternatives.

4.3.6 Implementability

All of the action alternatives can be implemented. From a technical, administrative, and supply vantage, Alternative 2 would be the easiest to implement. Installing fencing and deed restrictions are straightforward processes that are commonly implemented at sites undergoing some type of environmental remediation and/or restoration. Even with the remoteness of RDM, fencing material, labor, and installation equipment can be readily obtained and transported to the site.

With the exception of Alternatives 1 and 2, the remaining alternatives involve excavation of contaminated media, as well as backfilling/grading the open excavations and placement of cover material. However, Alternative 4 requires transporting hundreds of thousands of cubic yards, and Alternatives 3b and 3d involve annual transport of leachate classified as hazardous waste to the continental United States. Because of these shipping requirements, Alternative 3a and 3c are considered to be more implementable. While Alternative 3a requires the placement of a concrete cloth cover over Monofill #2, Alternative 3c requires the excavation and hauling of Monofill #2's contents, as well as backfilling, which would also require decontamination of debris. Therefore, Alternative 3a is slightly more implementable than Alternative 3c.

Given that no work would be performed, Alternative 1 is the easiest alternative to implement.

4.3.7 Cost

Alternative 4 is the most expensive alternative, with a present worth cost of $182,940,000. The cost of Alternative 4 is three times greater than the next alternative, Alternative 3d, which has a present worth cost of $58,100,000 and is the most expensive of the four scenarios that were developed using a repository. For those four alternatives, Alternative 3a is the least expensive.

The present worth cost associated with Alternative 2 is $1,700,000, and there is no cost associated with Alternative 1. Table 4-13 provides a summary of the individual alternative costs.

Table 4-13 Summary of Individual Alternative Costs

Alternative	Total Capital Cost	Yearly O & M Cost	Present Worth O & M Cost	Total Present Worth Cost
1	-	-	-	-
2	$816,000	$48,000	$880,000	$1,700,000
3A	$26,490,000	$72,000	$1,320,000	$27,810,000
3B	$31,070,000	$1,374,000	$25,270,000	$56,340,000
3C	$27,650,000	$69,000	$1,270,000	$28,920,000
3D	$32,590,000	$1,387,000	$25,510,000	$58,100,000
4	$182,060,000	$48,000	$880,000	$182,940,,000

Key:
O&M = Operations and Maintenance

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A Concrete Cloth Cut Sheets

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Milliken®

Concrete Cloth™

CC Data Sheet

Physical Properties*

CC	Thickness in (mm)	Roll Width ft (m)	Weight Unset lb/sf (kg/sm)	Batch Roll Length ft (m)	Batch Roll Area sf (sqm)	Batch Roll Weight Unset lbs (kg)	Bulk Roll Length ft (m)	Bulk Roll Size sf (sqm)	Bulk Roll Weight Unset lbs (kg)
CC5	0.20 (5)	3.28 (1)	1.43 (7.0)	30 (10.0)	100 (10)	143 (64.9)	656 (200)	2153 (200)	3080 (1397)
CC8	0.31 (8)	3.61 (1.1)	2.46 (12.0)	15 (4.5)	55 (5)	135 (61.2)	373 (113.6)	1345 (125)	3300 (1497)
CC13	0.51 (13)	3.61 (1.1)	3.89 (19.0)	n/a	n/a	n/a	239 (72.7)	861 (80)	3345 (1517)

Density

The dry density of Concrete Cloth before hydration is 93.6 pounds per cubic foot (1500 kg/m^3). Upon complete hydration, the density increases 30-35% to a range of about 122-126 pounds per cubic foot (1950-2025 kg/m^3).

Setting

- Initial Set ~ 120 min.
- Final Set ≥ 240 min.

CC will achieve 70-80% strength at 24 hours after hydration.

Method of hydration

Spray the fiber surface multiple times until the CC is saturated. The wet CC will first darken and then become lighter as it absorbs the water. CC is saturated when water pools on the surface or runs off. See the hydration guide for more information.

Reaction to Fire

CC has achieved Euroclass B certification:
BS EN 13501-1:2007+A1:2009 B-s1, d0

Strength

Very high early strength is a fundamental characteristic of CC. Typical strengths and physical characteristics are as follows:

Compressive testing based on ATSM C473 - 07

- 10 day compressive failure stress (Psi) 5800
- 10 day compressive Young's modulus (Psi) 217,600

Bending tests based on BS EN 12467:2004

- 10 day bending failure stress (Psi) 493
- 10 day bending Young's modulus (Psi) 26,100

Abrasion resistance (DIN 52108)

- Similar to wear resistant ceramic Max 0.10 gm/cm^2

MOHS hardness 4-5

CBR Puncture Resistance EN ISO 12236: 2007 (CC8 & CC13 only)

- Min. Push-through force 605 lb/f
- Max. Deflection at Peak 1.5"

Standard Test Method for Impact Resistance of Pipeline Coatings

ASTM G13 (CC13 only) Passed

Other

- Freeze-thaw testing (BS EN 12467:2004 part 5.5.2) Passed
- Soak-Dry testing (BS EN 12467:2004 part 5.5.5) Passed
- Water impermeability (BS EN 12467:2004 part 5.4.4) Passed

Moisture vapor transmission rate

PVC Thickness 0.017"
PVC MVTR range 0.836 - 0.924 g.mm/(m2.day)

CC Static Head <9.8ft

Patent Information

Patent Protected by Granted/Pending Patents:
CA 2655054, EP 2027319, GB 2455008, US US-2010-0233417-A1, ZA 2009/00222, SA 12/303,864, WO WO 2010/086618

*Indicative values

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Milliken™

August 10, 2012

Freeze-Thaw Evaluation of Concrete Cloth

Objective

Determination of the flexural strength of Concrete Cloth exposed to 200 cycles of freeze-thaw action.

Procedure

The flexural strength of cured Concrete Cloth was determined per the standard ASTM C1185, "*Standard Test Methods for Sampling and Testing Non-Asbestos Fiber-Cement Flat Sheet, Roofing and Siding Shingles, and Clapboards."* In preparing the freeze/thaw test samples, in order to represent extreme water exposure/curing conditions, Concrete Cloth specimens were exposed to incremental wetting at a slope of 45^{O}, and another specimen was fully submerged in a horizontal orientation for 24 hours. Slope 45^{O} samples were obtained by incrementally wetting a 62" X 42" sheet of Concrete Cloth™ over a 45 degree slope surface until saturation, while fully submerged samples were prepared by submerging a concrete cloth of dimensions 62" X 42" under water for 24 hours. In both the cases, after the initial wetting and curing, the specimens were transferred to a moist room (with ~100% RH) for further curing. After 28 days of moist curing, two sections of Concrete Cloth™ (6" x 42") were extracted from the curing 62" X 42" sheets. Using a hand-held, dry-cut saw the sections were cut from the cloth. The extracted sections of cured cloth (6" x 42") were then formed in to 4" X 12" samples for flexural testing purposes. A diamond-tipped, wet-cut saw was used to fabricate flexural testing samples. To avoid edge effects, each 4" X 12" sample was extracted from the center while the edges were discarded. Flexural test samples were split into two sets of three, of which one set was subjected to freeze/thaw action while the other set served as a control that was kept under water. In preparation for freeze/thaw cycling, samples were sealed per the requirements of ASTM C1185, Section 12.3.3. The sealed samples were then subjected to 50,100 and 200 cycles of freeze/thaw action after which they were centrally loaded to determine their flexural strength.

As per ASTM C1185, three point bending tests were performed on the individual 4" X 12" samples to determine their flexural strengths. The flexural tests were performed on a universal testing machine with displacement controlled loading (0.2 in/min). During the tests, load versus displacement data was recorded over a central deflection of 2 in., which was later utilized to calculate the flexural strength of samples. Strength was evaluated using two distinct failure peak loads that were recorded during the test, one at the beginning of the test illustrating the initial break of the cementitious material, and the other a maxima over the entire curve. Average flexural strength of the samples subjected to 50,100 and 200 freeze/thaw cycles are listed in the table below. Flexural strength values for intial peak load and secondary peak load are included.

Test Results

Freeze/Thaw Cycles	Avg. Flexural Strength Based on Initial Peak (psi)	Avg. Flexural Strength Based on Secondary Peak (psi)
50 Cycles	586	632
100 Cycles	567	651
200 Cycles	578	641

Interpretation

The freeze-thaw test results indicate that the Concrete Cloth material demonstrates excellent freeze-thaw resistance through the 200 cycles tested. The average flexural strength values for the freeze/thaw specimens are greater than the values published on the Milliken® Concrete Cloth™ data sheet.

B Leachate Modeling Results

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Hydrogeologic Analysis
Red Devil Mine, Alaska
Project No. 1001096.0070

August 19, 2015

SHANNON & WILSON, INC.

GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Excellence. Innovation. Service. Value.
Since 1954.

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21-1-12509-001

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HYDROGEOLOGIC ANALYSIS
RED DEVIL MINE SITE
PROJECT NO. 1001096.0070

1.0 INTRODUCTION

This report presents the results of Shannon & Wilson, Inc.'s hydrogeologic evaluation of the proposed waste rock repository at the Red Devil mine, located in Red Devil, Alaska (Figure 1).

In 2009, the Bureau of Land Management (BLM) initiated a Comprehensive Environmental Response, Compensation, and Liability Act Remedial Investigation and Feasibility Study (RI/FS) at the Red Devil Mine (Site) to address environmental risks related to past mining and ore processing. Ecology and Environment, Inc. (E & E) performed the RI/FS on behalf of the BLM, and prepared a final RI report (E & E, 2014b); two drafts of the FS have been prepared and reviewed by regulatory stakeholders (E & E, 2014a). One of the remediation alternatives in the draft final FS is Alternative 3 (Excavation of Soils and Sediments Solidification, Onsite Consolidation, and Capping). Alternative 3 would involve excavating and consolidating approximately 210,000 cubic yards of contaminated tailings/waste rock, contaminated soil, delta material, and Red Devil Creek sediment, in an onsite, 5-acre repository (Figure 2).

For the third draft of the FS, E & E is analyzing variations of Alternative 3 that exclude a liner beneath the repository while maintaining the cover system design presented in the draft FS. The present analysis was conducted to evaluate the potential for leachate generation and its potential effects associated with local groundwater for a repository that would not include a bottom liner. For this study, leachate that could be generated through water infiltrating the cover system and coming into contact with the repository contents was evaluated for three different scenarios that collectively represent the most likely ways in which water could come into contact with repository contents: 1) infiltration under normal conditions of the protective cover (no defects or breaches in the cover system); 2) infiltration due to the incidental breach of the protective cover (assumed 10 holes per acre); and 3) infiltration due to a tear/break of the protective cover (assume 50 holes per acre). The analysis was performed to simulate the volume, contaminant concentrations, and migration of leachate for each of these scenarios.

This analysis is based on existing information and site data provided to us by E & E. We did not perform site exploration or testing to support this study.

2.0 CONCEPTUAL MODEL

2.1 Geology

Information on the geology of the site is based on subsurface information presented in the final RI report and boring logs completed for the RI. The geology at the location of the repository consists of loess, soils derived from the Kuskokwim Group bedrock and the Kuskokwim Group bedrock. The loess generally overlies the soils derived from the Kuskokwim Group bedrock and consists of fine-grained, wind-blown sediments that range from a few inches to 30 inches thick. The soils derived from the Kuskokwim Group bedrock consists of silt, sand, and gravel from the weathered bedrock. The Kuskokwim Group bedrock consists of interbedded greywacke and argillaceous rock.

2.2 Hydrogeology

Information on the hydrogeology of the site is based on the final RI report. The current monitoring well network at the site covers the Main Processing Area (MPA) extensively, but only three wells were installed in the area northwest of the MPA as part of the RI. Of these wells, two (MW29 and MW30) are located approximately 200 feet and 100 feet west of the MPA, and one well (MW31) is located in the upland background area approximately 500 feet southwest of the proposed repository location. Well MW31 is the well located closest to the repository.

We assumed a depth to groundwater at the repository based water levels measured in monitoring well MW31. Between August 2011 and September 2012, the depth to groundwater in well MW31 ranged from 31.92 to 35.55 feet below ground surface. For the purpose of this analysis, we assumed a depth to groundwater at the repository of 30 feet below ground within the bedrock. It should be noted that preliminary observations made during installation of a new monitoring well (as part of the 2015 RI Supplement field activities) located approximately 100 feet southeast of the proposed repository indicate a significantly greater depth to water in that area, possibly due to the influence of underground mine workings.

2.3 Climate

The Site is located in the upper Kuskokwim River Basin and lies in a climatic transition between the continental zone of Alaska's interior and the maritime zone of the coastal regions. Average daily temperatures can vary from 7 to 65 degrees Fahrenheit. The total mean annual precipitation is approximately 18.8 inches based on final RI report (E & E, 2014b).

2.4 Modeled Contaminants

The RI identified antimony, arsenic, and mercury as the principal contaminants of concern (COCs) at the site. These COCs and diesel range organics (DRO) are the contaminants addressed in the subject hydrogeologic analysis.

2.5 Structure of Repository

For the purpose of this study, the assumed profile of the proposed repository and underlying native materials consists of the following (see Figure 3):

- A cover system consisting of an 18-inch-thick vegetated layer of fill/topsoil overlying a protective geotextile underlay and geomembrane consisting of a polyvinyl chloride (PVC) liner; and a 3-foot layer of loess underlying the geomembrane;
- Fifty-one (51) feet of repository contents consisting of tailings/waste rock, and contaminated soils and sediment; and
- Thirty (30) feet of native, unsaturated soil and bedrock above the water table.

We based the thicknesses of the unsaturated native soils on lithology and groundwater levels observed in monitoring well MW31, the well located closest to the repository. The proposed repository profile was provided to us by E & E (pers comm, 2015).

3.0 NUMERICAL MODEL

3.1 Hydrologic Evaluation of Landfill Performance (HELP) and Variably Saturated 2D Flow and Transport (VS2DT) Models and Modeling Approach

The analysis was performed using two models: Visual HELP and VS2DT. Both models are industry-standard programs developed and maintained by the U.S. Environmental Protection Agency (EPA) (Healy 1990) and United States Geological Survey (USGS), respectively. Both models are capable of simulating variably-saturated conditions using a finite-difference grid. Visual HELP was used to simulate infiltration through the cover system and repository contents. The HELP results were used as input to VS2DT to simulate migration of contaminants through the vadose zone. Natural attenuation processes were incorporated into the VS2DT simulation in order to estimate the depth below ground surface at which concentration of each COC was reduced to zero.

We used the software program *Visual HELP for Windows 2000/XP* (v.3.07, Waterloo Hydrogeologic Inc., November 2014) as a platform to run the HELP model. The HELP model is a quasi-two-dimensional, multi-layer hydrologic model requiring the following input data for a vertical hydrostratigraphic profile:

- Climate data – precipitation, solar radiation, temperature, evapotranspiration parameters)
- Data on soil and rock physical properties – porosity, field capacity, wilting point, and hydraulic conductivity
- Design information – liner properties and surface slopes

HELP uses numerical solution techniques that account for the effects of surface storage; snowmelt; runoff; infiltration; evapotranspiration; vegetative growth; soil moisture storage; lateral subsurface drainage; leachate recirculation; unsaturated vertical drainage; and leakage through soil, geomembranes, or composite liners.

We used the HELP model to predict the infiltration rate through the unsaturated zone under different liner breach scenarios.

We modeled the migration of the selected contaminants through the unsaturated zone using the VS2DT model. VS2DT is a finite difference numerical model developed by the USGS (Schroeder and others, 1994) for modeling the fate of contaminants in the unsaturated zone. VS2DT is a comprehensive one-dimensional unsaturated zone model based on the solution of Richard's equation, van Genuchten, Brooks and Corey and Haverkamp functions. Contaminant transport processes include hydraulic diffusion, dispersion, decay, and adsorption (Freundlich and Langmuir isotherms).

The VS2DT model was constructed using the same profile (layer thickness and materials) and hydraulic parameters as assumed in the HELP modeling. The upper boundary for VS2DT is a flux boundary, which is the infiltration rate obtained from HELP model.

3.2 Model Development

3.2.1 Model Structure and Weather Data

Based on the proposed repository design and local geology, we divided the unsaturated zone into seven layers (Figure 3). Table A-1 presents the layer elevation, thickness, and hydraulic parameters for the materials. The upper boundary is the repository cover system and the lower boundary is groundwater table. As noted above, we assumed a depth to groundwater under existing site conditions of 30 feet below ground surface in the area of the repository. The modeled profile included 51 feet of waste material on top of the native soil. The waste material would be covered by the repository cover system. The cover system would consist of 18 inches of topsoil overlying a PVC liner and three feet of loess. The cover system design also shows the cover system would be vegetated and has a 20 percent of surface slope.

We used the synthetic weather generator option in the HELP model to create 50 years of weather data (precipitation, solar radiation, temperature, and evapotranspiration parameters). The HELP model uses a synthetic weather generator to create weather data with approximately the same statistical characteristics as historical data for a selected city. We selected a city from amongst the cities built into the model that represents the closest location to the Site, which is Anchorage, Alaska. Figure A-1 (in Appendix A) shows the simulated annual precipitation totals for a 50-year period, and Figure A-2 shows the simulated average monthly precipitation. The average annual precipitation is 18 inches per year.

3.2.2 Material Hydraulic Properties

We estimated the hydraulic conductivity of the soil based on grain size data and recommended values from literature.

Repository Liner. We assigned the PVC liner permeability based on information from “Leakage through Liners Constructed with Geomembranes – Part I. Geomembrane Liners” (Giroud and Bonaparte, 1989). This reference document estimated leakage through a 4,000-square-foot liner with 0.01 foot of water on the liner with different sizes of holes in the liner. We converted the leakage rates estimated by Giroud and Bonaparte (1989) to a representative permeability of 1 x 10^{14} centimeters per second.

Tailings/Waste Rock. We estimated the hydraulic conductivity of the tailings/waste rock based on an empirical analysis of grain size data collected during field explorations. This involved using the D_{10}, D_{20}, D_{50}, and D_{60} (percentage of samples pass #10, 20, 50 and 60 sieves) in the methods of Kozeny-Carman and Hazen (see Odong, 2007). Table A-2 (in Appendix A) provides a summary of the hydraulic conductivities estimated from the grain size method and Table A-1 provides a summary of the hydraulic conductivity values used for the model.

Native Soils and Bedrock. We used published hydraulic conductivity for the bedrock; native, fine-grained soils, and loess.

3.2.3 Waste Material Geochemical Properties

We evaluated four contaminants commonly detected in the materials proposed for inclusion in the repository: the primary COCs identified in the RI – arsenic (As), antimony (Sb), and mercury (Hg) – and DRO. We calculated weighted average concentrations for the metals based on the material volumes and geomean concentration of the COCs from RI samples collected in the proposed excavation areas shown in Figure 2. Table A-3 summarizes the results of the weighted average concentration calculations. Insufficient sample data exist to determine a weighted average DRO concentration; therefore, for DRO we conservatively used the highest detected DRO concentration of 7,300 milligrams per kilogram as the assumed DRO concentration of the repository contents in the model. The model approach assumed that the 51 feet of repository material would have a uniform concentration. We assigned geochemical partitioning coefficients for the three metals based on EPA chemical-specific inputs (U.S. EPA, 1998). We developed a carbon-weighted partitioning coefficient for the DRO (Table A-4) based a hydrocarbon risk calculator and example characterizations of selected Alaska fuels (Geosphere and CH2M Hill, 2006).

3.2.4 Simulated Hydrology

We used the HELP model to predict the soil-moisture profile in the unsaturated zone in response to infiltration under the modeled infiltration scenarios. The model predicted a soil moisture flux to the top boundary of the VS2DT model domain. We applied the daily precipitation, temperature, and solar radiation data for the site generated by the HELP model for a 50-year period based on the built-in HELP database for Anchorage, Alaska, as described above in Section 2.4.

3.3 Predictive Simulations

3.3.1 Model Scenarios

The modeling approach adopted for the analysis assumed that the proposed geomembrane cover system would be installed using industry standard methods. Incidental infiltration induced by normal conditions (i.e., the cover system is intact) was simulated by assuming the presence of ten 1-square centimeter holes per acre evenly distributed over the entire repository. A hypothetical breach was simulated by assuming the presence of fifty 1-square centimeter holes per acre evenly distributed over the entire repository. For both the incidental infiltration and breach simulations, it was assumed that the holes in the cover system would be present for the full time period for both the normal and breach simulations. We also modeled a scenario under which there are no defects or breaches in the cover. For this case, infiltration would occur only through the liner and is a function of the intact liner permeability.

Cover system effectiveness depends on the liner installation quality, slope, and growth of vegetation on the topsoil. For all three cases, the model assumed that the top of the soil cover as random fill with good vegetation coverage and a surface slope of 20 percent, with 100 percent of the surface area available for runoff. HELP model and VS2DT model specifications are listed in Appendices B and C.

3.3.2 Results

Table 1 shows the HELP model water budget results for the three cases defined above. The predicted infiltration rate at the base of the cover system ranges from 0.15 inch per year for intact cover system to 4.8 inches per year for the 50 holes per acre case.

Figures A-3 to A-6 show the simulated vertical chemical concentration profiles for the three cases after 50 years of repository operation for arsenic, antimony, mercury and DRO, respectively. The results indicate the following:

- For the intact scenario (no defects or breaches in the cover system), the depths below the base of the repository at which the predicted constituent concentration would be zero range from less than 0.1 foot (for DRO) to 7.2 feet (for arsenic).
- For the incidental infiltration scenario (assumed 10 holes per acre), the depths below the base of the repository at which the predicted constituent concentration would be zero range from less than 0.1 foot (for DRO) to 9.6 feet (for arsenic).
- For the breach scenario (assume 50 holes per acre), the depths below the base of the repository at which the predicted constituent concentration would be zero range from less than 1 foot (for DRO) to 17.2 feet (for arsenic).

Therefore, the model predicts that the groundwater, at a depth of 30 feet below the base of the repository, would not be affected during the modeled 50 years of operation.

Shannon & Wilson, Inc. has prepared Appendix D, "Important Information About Your Geotechnical/ Environmental Proposal," to assist you and others in understanding the use and limitations of our proposals.

SHANNON & WILSON, INC.

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U.S. EPA, 1998. Human Health Risk Assessment Protocol, Appendix A-3, Table A-3-11, Table A-3-14, and Table A-3-131, July.

Table 1. Red Devil Mine HELP and VS2DT Model Results

Cap Material Thickness		Cap Material Quality			Groundwater Depth from Top of the Cap	Maximum Leakage Rate		Cumulative Water Balance at 50 years			Depths at Which Contaminate Concentration Goes to Zero in Native Soil at 50 years			
Fill	Loess	K of Fill	K of Loess	# of holes in the geomembrane/acre		At Bottom of Loess	At Groundwater Table	Runoff	ET	Leakage to groundwater	Arsenic	Antimony	Mercury	DRO
ft		cm/sec			ft	in/yr		inches in 50 yrs			ft			
1.6	3	1.E-04	1.E-05	0	85.6	0.15	0.14	286	881	0.4	7.2	6.1	1.7	<0.1
				10		1.4	1.2	234	881	33	9.6	7.2	1.7	<0.1
				50		4.8	4.5	115	881	136	17.2	13.7	2.6	0.9

Notes:
k = hydraulic conductivity (cm/sec) ET = Evapotranspiration
DRO = Diesel Range Organics
Depths at Which Contaminant Concentration Coes to Zero in Native Soil at 50 years refers to the depth below the top of the native soil beneath the base of the repository.

Not to Scale

NOTE

Map adapted from USGS index to state topographic maps of Alaska, dated 2-88.

Red Devil Mine
Red Devil, Alaska

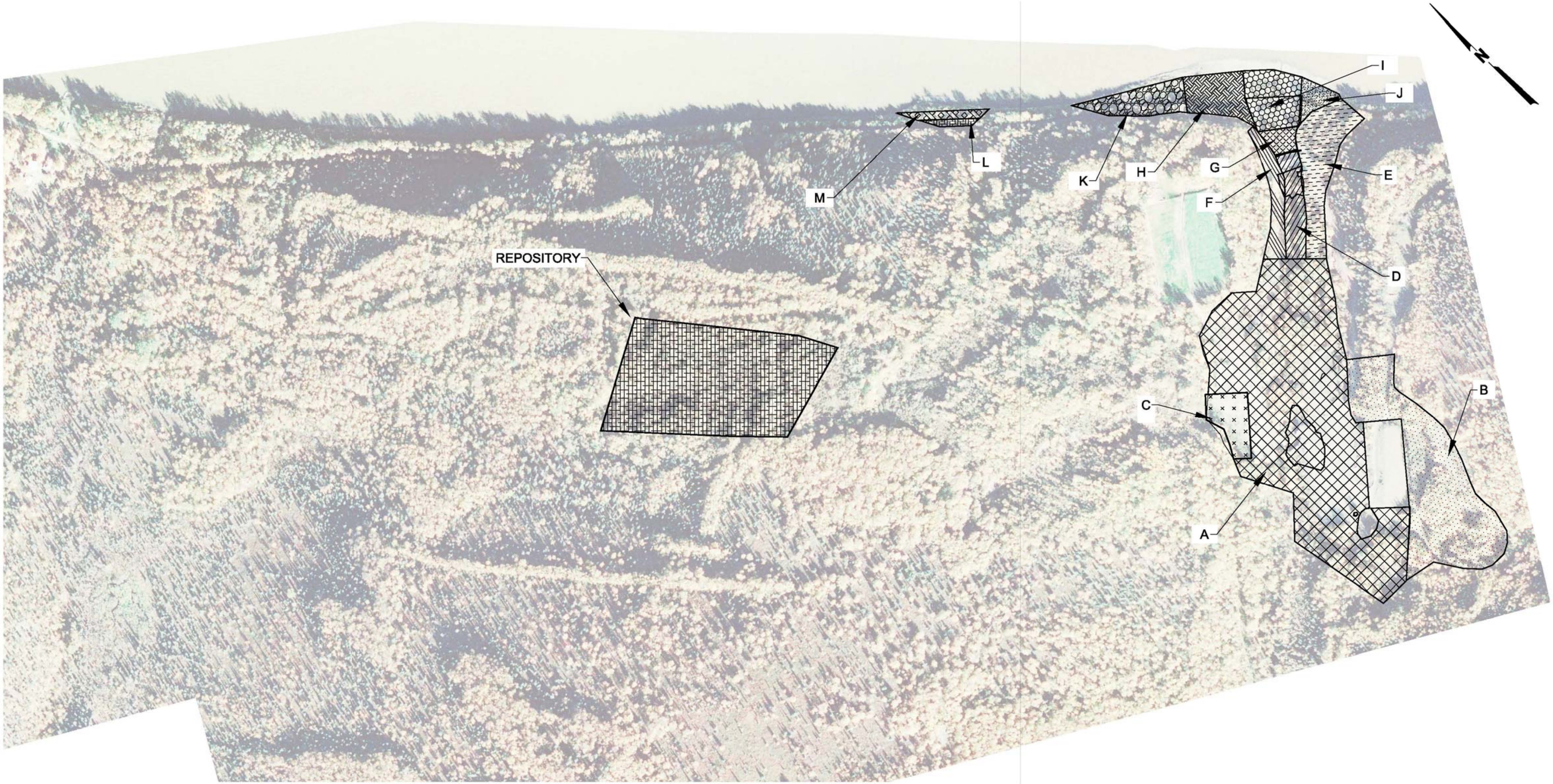
VICINITY MAP

July 2015 21-1-12509-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 1

Filename: J:\211\12509-001\21-1-12509-001 vic map.dwg Date: 07-14-2015 Login: bac



NOTES

1. Figure adapted from files *Red_Devil_Mine_VOL FS 4-8 Polygon.dxf* received 06-12-2015 and *Red_Devil_Mine_VOL FS 4-8 061115-3-1 11x17.pdf* received 06-15-2015.

2. Letters refer to different areas of soil that will be excavated, refer to report for description of areas.

0 300 600

Approximate Scale in Feet

Red Devil Mine
Red Devil, Alaska

SITE PLAN

July 2015 21-1-12509-001

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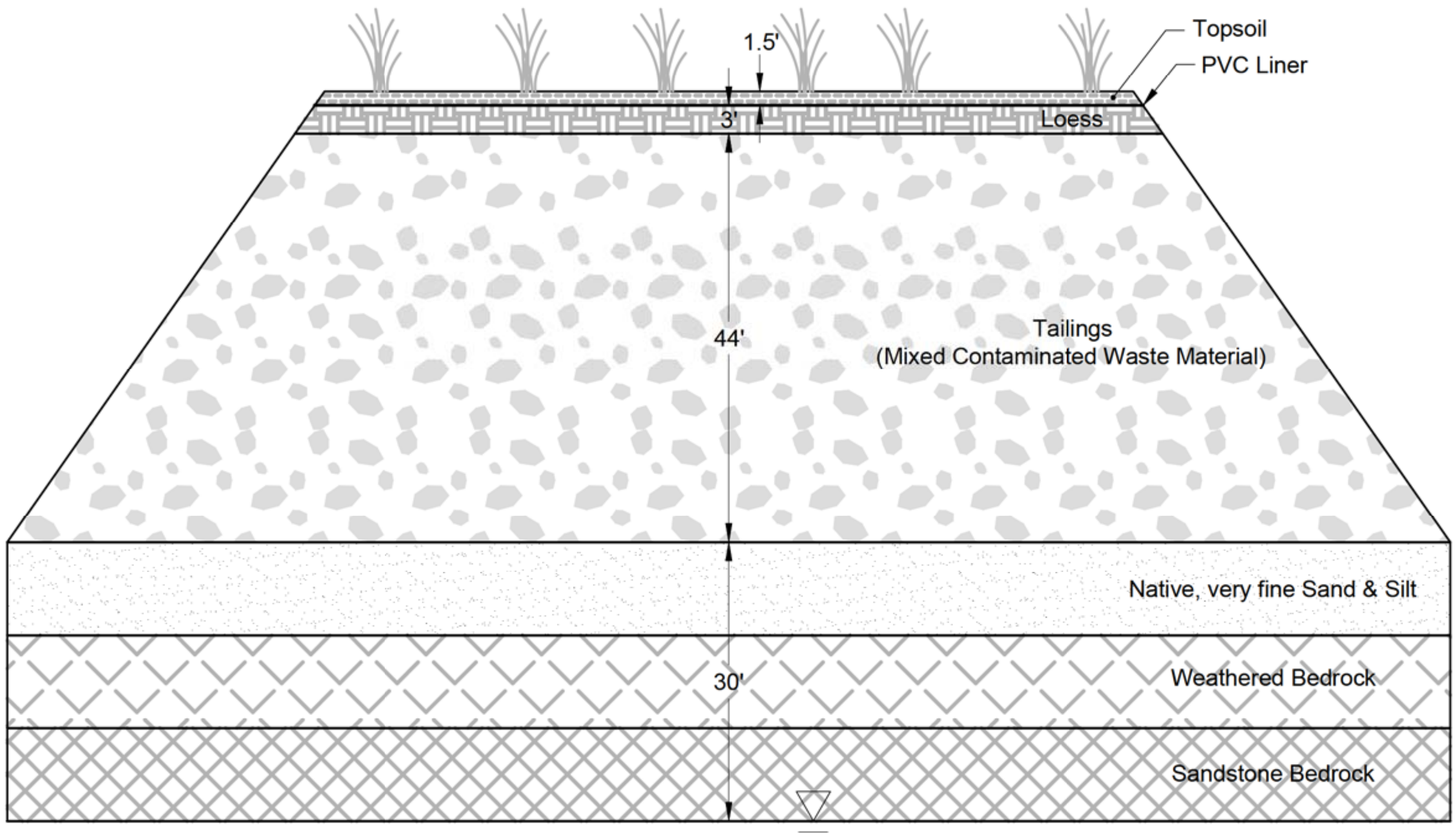
FIG. 2

Filename: J:\211\12509-001\21-1-12509-001 fig 3.dwg   Layout: Sheet 1   Date: 07-14-2015   Login: bac



Red Devil Mine
Red Devil, Alaska

CONCEPTUAL PROFILE OF REPOSITORY

July 2015   21-1-12509-001

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FIG. 3

FIG. 3

APPENDIX A

SOIL PROPERTIES AND GEOCHEMICAL DATA

APPENDIX A

SOIL PROPERTIES AND GEOCHEMICAL DATA

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TABLES

FIGURES

Table A-1
HELP Model Input Parameters and Layering
Red Devil Mine, AK
Vadoze Zone Geochemical Modeling

Model Layers	Top Elevation	Bottom Elevation	Layer Thickness	Cumulative Depth	Material	Porosity	Hydraulic Conductivity (K)				
							High[3]	Low[3]	Recommended Kh	Kv used in HELP Model	Source of values
	feet elevation		feet			-	cm/sec				
1	447.6	446.1	1.5	1.5	Vegetative cap cover with random fill (equiv. SILTY SAND)	0.35	1.E-04	1.E-05	1.E-04	**1.E-04**	Freeze & Cherry[1, 2]
2	446.1	446.0	-	1.5	Geomembrane liner	NR	2.E-06	4.E-14	4.E-14	**1.E-14**	J.P. Gioud & R. Bonaparte; E&E
3	446.0	443.0	3.0	4.5	Loess	0.4	1.E-05	1.E-06	1.E-05	**1.E-05**	Freeze & Cherry[1, 2]
4	443.0	392.0	51.0	55.5	Mixed contaminated waste material	0.3	8.E-03	3.E-03	5.E-03	**5.E-03**	Geomean of grain size analysis results; Freeze & Cherry[2]
5	392.0	382.0	10.0	65.5	Native, very fine SAND and SILT	0.3	1.E-05	1.E-06	1.E-05	**1.E-06**	Freeze & Cherry[1, 2]
6	382.0	372.0	10.0	75.5	Weathered sandstone BEDROCK	0.25	1.E-03	1.E-04	1.E-03	**1.E-04**	Freeze & Cherry[1, 2]
7	372.0	362.0	10.0	85.5	Unweathered sandstone BEDROCK	0.25	1.E-05	1.E-06	1.E-05	**1.E-05**	Freeze & Cherry[1, 2]

Notes:
cm/sec - centimeters per second
Kv - vertical hydraulic conductivity
Water table assigned at base of layer 7 (depth = 85.5 feet)
Cap slope is 20% per E&E
1 - Freeze & Cherry, 1979 - page 29, Table 2.2
2 - Freeze & Cherry, 1979 - page 37, Table 2.4
3 - horizontal hydraulic conductivity (Kh)
NR - not required

TABLE A-2
SUMMARY OF HYDRAULIC CONDUCTIVITY BASED ON GRAIN SIZE ANALYSIS

Sample Designation	Depth of Sample (ft bgs)	D_{10} (mm)	D_{20} (mm)	D_{50} (mm)	D_{60} (mm)	Hydraulic Conductivity Based on Kozeny-Carmen (cm/sec)	Hydraulic Conductivity Based on Hazen (cm/sec)	Soil Description (USCS)
Surface Samples								
10SM12SS	0.5	0.003	0.01	0.049	0.11	1.5E-06	3.5E-06	GP-GM
10SM11SS	0.5	0.004	0.011	0.027	0.033	9.4E-06	1.6E-05	SM
10SM10SS	0.5	0.003	0.01	0.028	0.035	4.3E-06	8.3E-06	--
10MP62SS	0.5	0.008	0.032	0.75	2.3	1.4E-05	3.2E-05	GM
10MP60SS	0.5	0.006	0.045	1.7	3.3	8.7E-06	2.0E-05	GM
10MP36SS	0.5	0.036	0.098	0.25	0.3	6.5E-04	1.1E-03	SM
10MP34SS	0.5	0.033	0.09	0.25	0.3	5.0E-04	9.1E-04	SP
10MP32SS	0.5	0.012	0.042	0.16	0.21	4.0E-05	8.9E-05	MLS
10MP29SS	0.5	0.025	0.17	2.8	5.2	1.5E-04	3.5E-04	GPS
10MP17SS	0.5	0.022	0.12	1.3	2.4	1.2E-04	2.7E-04	GM
Subsurface Samples with grain size data less than 0.85 mm								
11MP12SB14	14	0.010	0.084	NA	NA	4.5E-05	1.0E-04	GM
11MP25SB30	30	0.010	0.037	NA	NA	4.3E-05	9.6E-05	GM
11MP25SB34	34	0.005	0.025	NA	NA	1.3E-05	2.9E-05	GM
11MP29SB18	18	0.021	0.160	NA	NA	2.0E-04	4.4E-04	GM
11MP29SB22	22	0.008	0.025	0.49	NA	2.7E-05	5.9E-05	GM/ML
11MP30SB14	14	0.011	0.025	0.22	0.59	2.9E-05	1.2E-04	MLS/GP-GM/SWG
11MP38SB12	12	0.009	0.042	NA	NA	3.6E-05	8.1E-05	SPG
11MP38SB14	14	0.015	0.075	NA	NA	1.0E-04	2.3E-04	GW-GM
11MP39SB10	10	0.009	0.033	NA	NA	3.9E-05	8.6E-05	GM
11MP40SB06	6	0.007	0.014	NA	NA	2.2E-05	4.9E-05	GM
11MP60SB24	24	0.007	0.019	NA	NA	2.3E-05	5.2E-05	GM

Notes:
mm = millimeters
cm/sec = centimeters per second
NA = data is not available
calculated K assuming n=0.3
GM=silty gravel
GPS=sandy gravel with silt
GW-GM=silty gravel with sand
ML=silt
MLS=silt with sand and gravel
SM=silty sand
SP=sand
SPG=sandy gravel with silt
SWG=gravelly sandy silt

Table A-3
Statistical Analysis for Metals Concentration - by Excavation Area
Red Devil Mine, AK
Vadoze Zone Geochemical Modeling

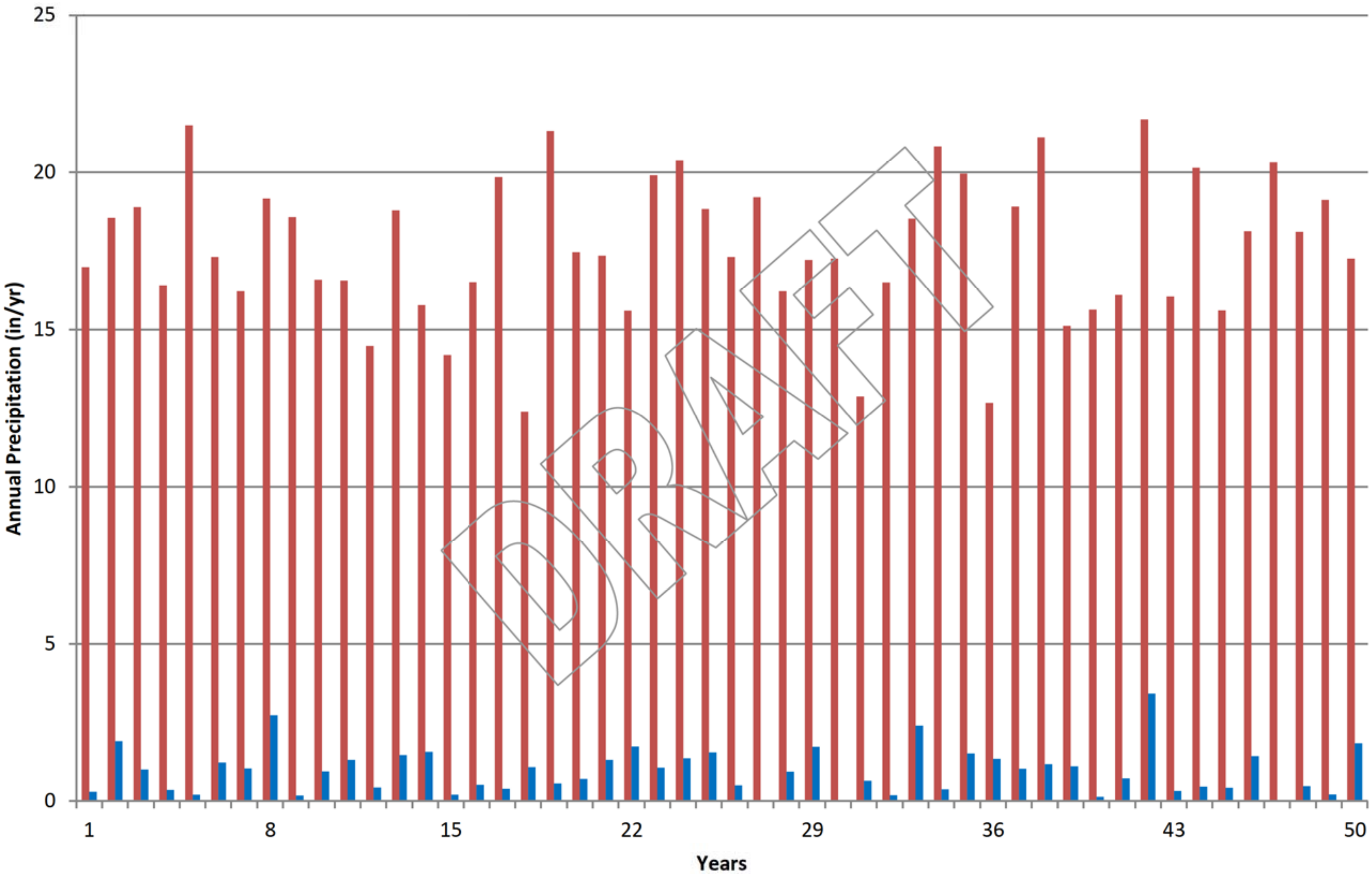
Excavation Area	Sampling Area	Proposed Excavation Volume		Reported Geomean Concentrations and Number of Samples (n)						Volume-weighted Reported Geomean Concentrations		
		Volume	Proportion of total	Total Antimony	n	Total Arsenic	n	Total Mercury	n	Total Antimony	Total Arsenic	Total Mercury
		Cubic Yard	%	*mg/kg*								
A	Pre-1955 Main	163,963	77%	594	186	906	74	103	74	455.0	693.9	78.7
B	Post-1955 Main Processing	7,279	3%	692	108	1118	108	96	108	23.5	38.0	3.2
C	Pre-1955 Main	1,056	0.5%	594	186	906	74	103	74	2.9	4.5	0.5
D	Red Devil Creek Downstream Alluvial Area and Delta	4,376	2%	243	16	408	16	31	16	5.0	8.3	0.6
E		6,689	3%	243		408		31		7.6	12.7	1.0
F		1,355	1%	243		408		31		1.5	2.6	0.2
G		2,023	1%	243		408		31		2.3	3.9	0.3
H		4,392	2%	243		408		31		5.0	8.4	0.6
I		10,271	5%	243		408		31		11.7	19.6	1.5
J		1,576	0.7%	243		408		31		1.8	3.0	0.2
K	Rice Sluice and Delta	4,296	2%	27	7	64	7	7	7	0.5	1.3	0.1
L	Dolly Sluice and Delta	471	0.2%	31	6	475	6	61	6	0.1	1.0	0.1
M		1,827	1%	31		475		61		0.3	4.1	0.5
Monofill	Post-1955 Main Processing	4,585	2%	692	108	1118	108	96	108	14.8	23.9	2.0
Totals		**214,159**	100%									
Weighted Average Geomean Concentrations (mg/kg)										**532**	**825**	**90**

Note:
For the purpose of the hydrogeologic analysis, it was assumed that 40% of the Monofill area (represented by the un-named rectangle) wiould be excavated and incorporated into the repository

Table A-4
Diesel Fuel Characterization (based on product analysis and Raoult's law)
Red Devil Mine, AK
Vadoze Zone Geochemical Modeling

Aromatics	Percent Mass	Coventional Kd	Weighted Kd	Weighted Average Kd
Benzene	0.0189%	5.89E+01	0.01	5.45E+09
Toluene	0.1940%	1.82E+02	0.35	
Ethylbenzen	0.1440%	2.78E+02	0.40	
Xylene	0.8210%	1.46E+03	11.99	
C_9-C_{10}	0.0589%	1.68E+03	0.99	
C_{10}-C_{12}	1.4327%	2.24E+03	32.09	
C_{12}-C_{16}	4.5750%	3.98E+03	182.09	
C_{16}-C_{21}	6.4975%	8.41E+03	546.44	
C_{21}-C_{35}	0.9934%	1.26E+05	1251.68	
Sub-total %	**14.7353%**			
Aliphatics				
C_5-C_6	0.0427%	8.04E+02	0.34	
C_6-C_8	0.4627%	3.80E+03	17.58	
C_8-C_{10}	5.2171%	3.02E+04	1.58E+03	
C_{10}-C_{12}	18.5755%	2.40E+05	4.46E+04	
C_{12}-C_{16}	34.8777%	5.37E+06	1.87E+06	
C_{16}-C_{21}	25.2764%	9.55E+08	2.41E+08	
C_{21}-C_{35}	0.8126%	1.07E+13	8.69E+10	
Sub-total %	**85.2647%**			

Source:
Geosphere and CH2MHill, 2006, Hydrocarbon characterization for use in the hydrocarbon risk calculator and example characterizations of selected Alaska fuels. Table 14



NOTES

Rain (in/yr)
Volume of Water from Snow (in/yr)

Precipitation data generated from the synthetic precipitation option in the Hydrologic Evaluation of Landfill Performance (HELP) Model for Anchorage, Alaska

in=inches
yr=year

Red Devil Mine
Red Devil, Alaska

ANNUAL PRECIPITATION TOTALS

August 2015 21-1-12509-001

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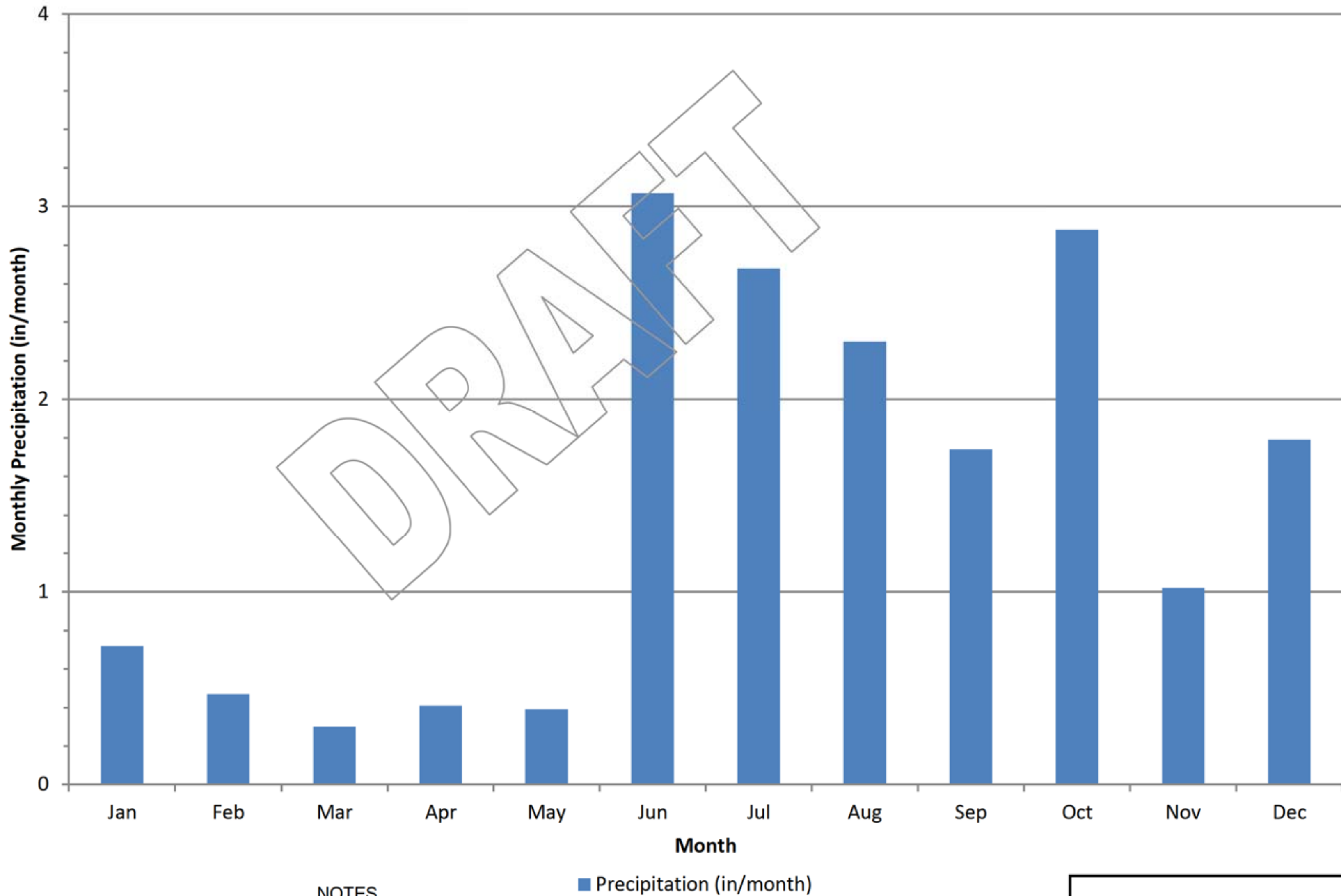
FIGURE A-1

FIG. A-1



NOTES

Precipitation data generated from the synthetic precipitation option in the Hydrologic Evaluation of Landfill Performance (HELP) Model for Anchorage, Alaska

in=inches

Red Devil Mine
Red Devil, Alaska

AVERAGE TOTAL MONTHLY PRECIPITATION

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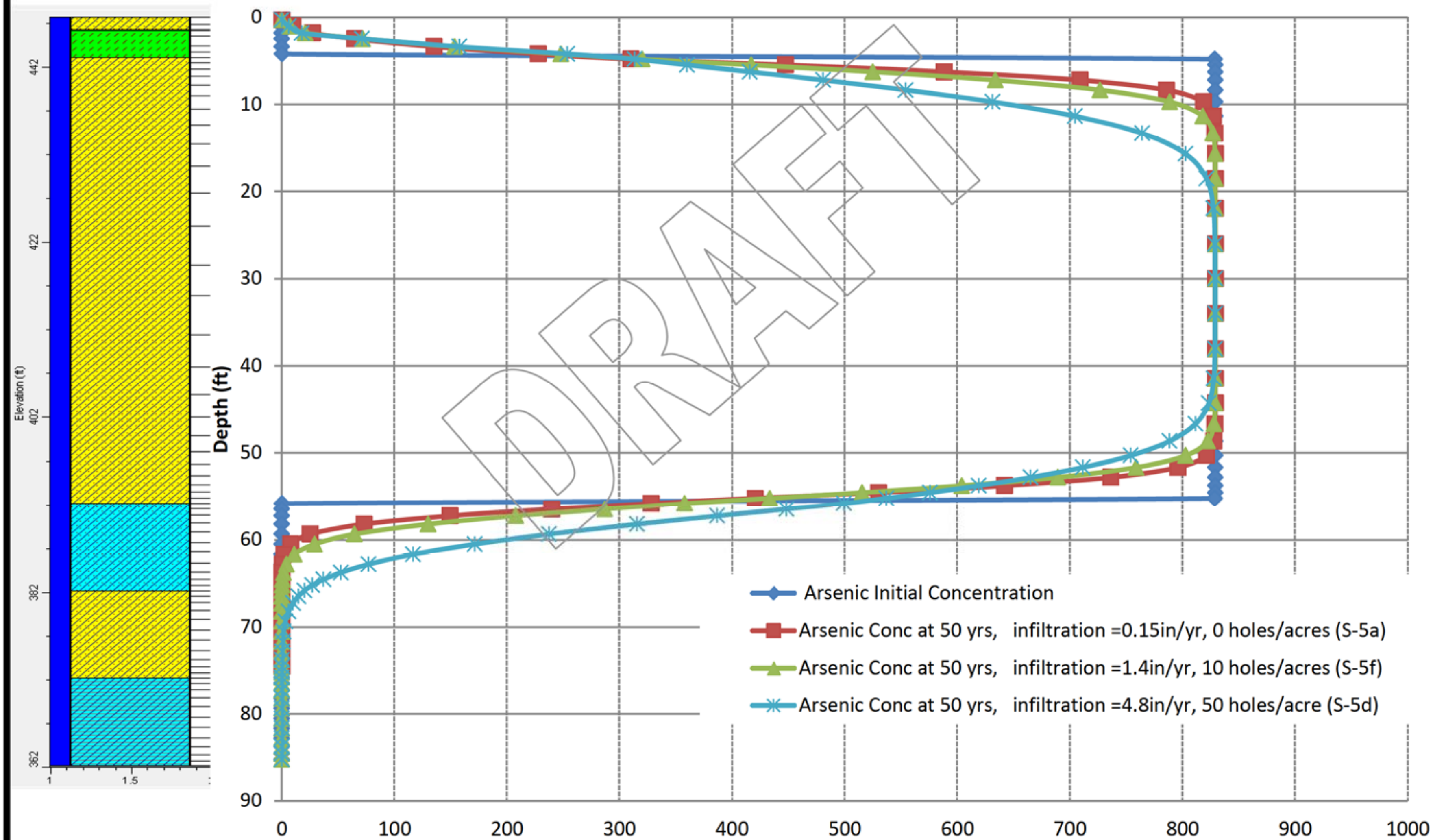
FIGURE A-2

FIG. A-2



NOTES

HELP=Hydrologic Evaluation of Landfill Performance

mg=miligrams

L=liters

Red Devil Mine
Red Devil, Alaska

HELP MODEL RESULTS
ARSENIC CONCENTRATIONS AFTER 50 YEARS

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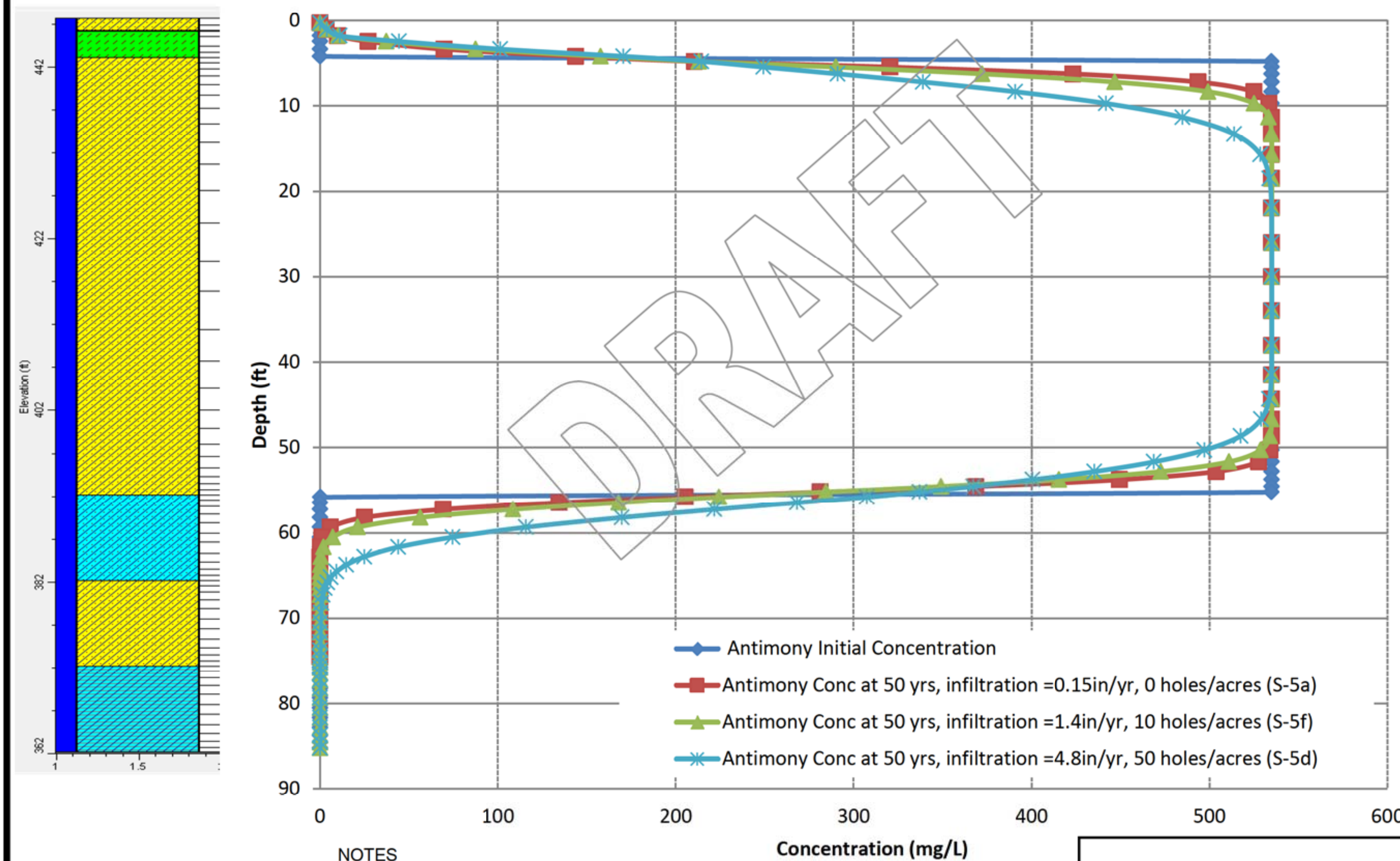
FIGURE A-3

FIG. A-3



NOTES

HELP=Hydrologic Evaluation of Landfill Performance

mg=miligrams
L=liters

Red Devil Mine
Red Devil, Alaska

HELP MODEL RESULTS
ANTIMONY CONCENTRATIONS AFTER 50 YEARS

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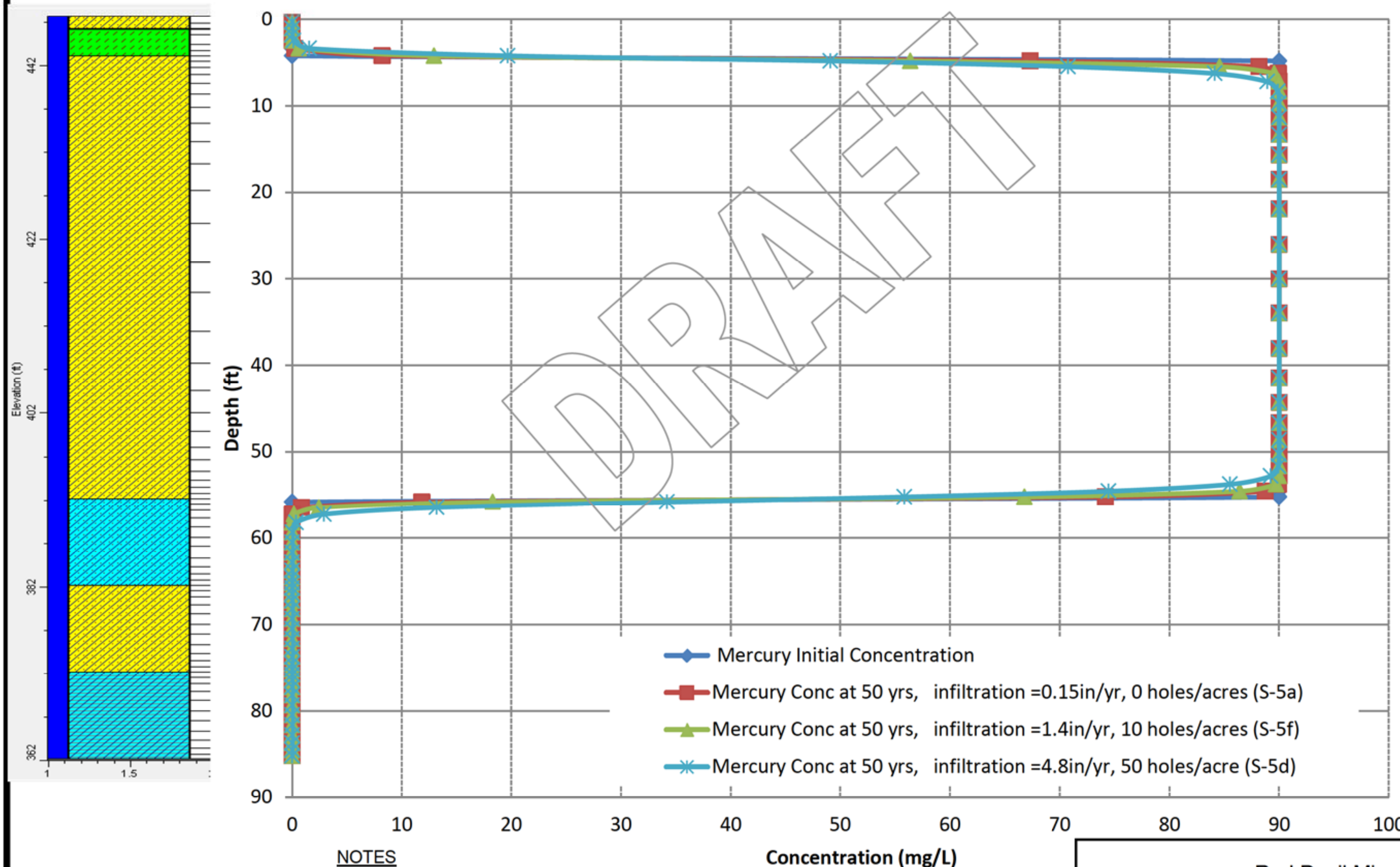
FIGURE A-4

FIG. A-4



NOTES

HELP=Hydrologic Evaluation of Landfill Performance

mg=miligrams
L=liters

Red Devil Mine
Red Devil, Alaska

HELP MODEL RESULTS
MERCURY CONCENTRATIONS AFTER 50 YEARS

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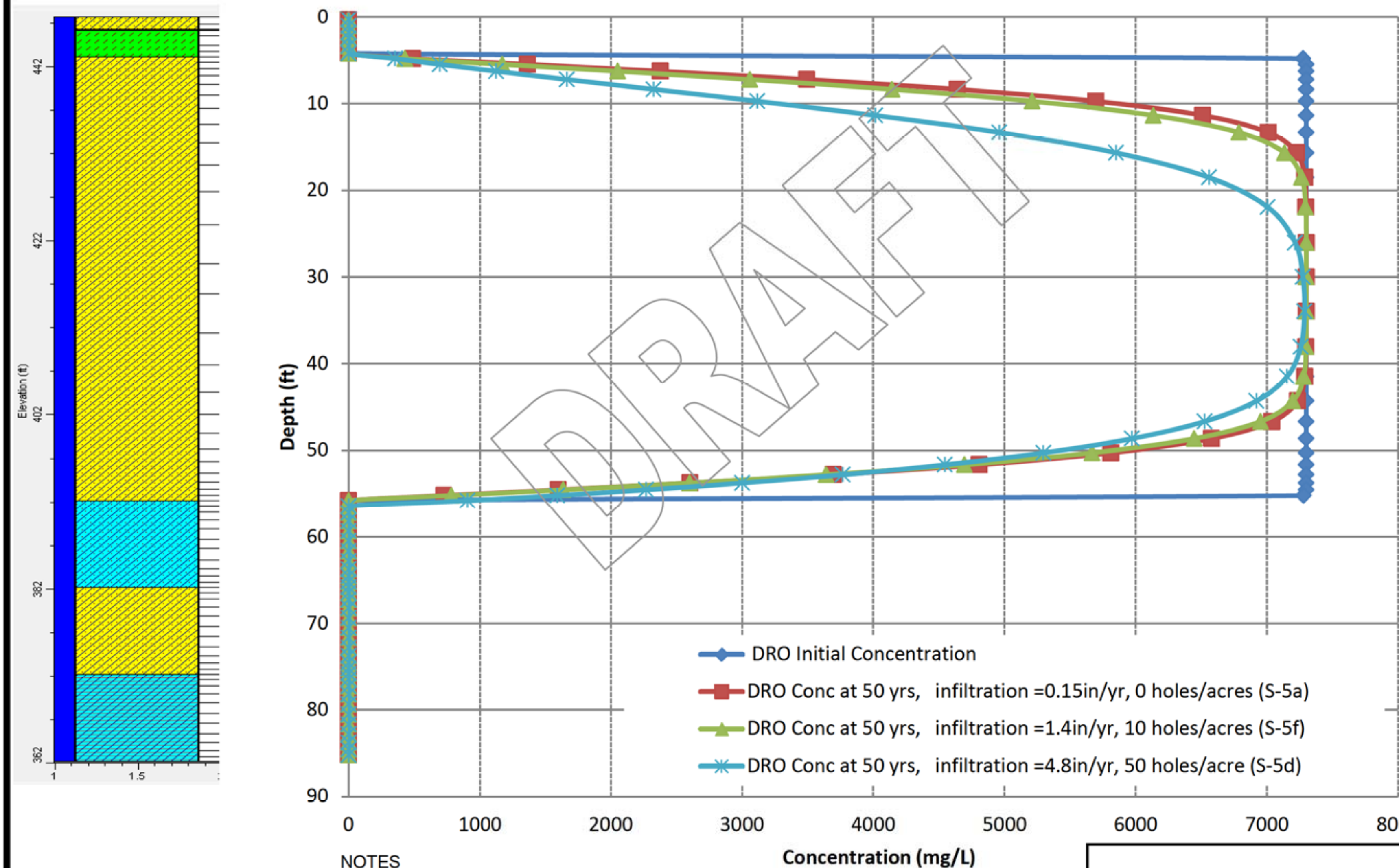
FIGURE A-5

FIG. A-5



NOTES

HELP=Hydrologic Evaluation of Landfill Performance

mg=miligrams
L=liters

Red Devil Mine
Red Devil, Alaska

HELP MODEL RESULTS
DRO CONCENTRATIONS AFTER 50 YEARS

August 2015 21-1-12509-001

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FIGURE A-6

FIG. A-6

APPENDIX B

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE MODEL DETAILS

Appendix B: HELP Model Details

Project : RDM HELP Model (revised profile)

Description: Revised profile

Model : HELP
An US EPA model for predicting landfill hydrologic processes and testing of effectiveness of landfill designs

Author : Li Ma, S&W

Client : Mark Longtine, E&E

Location : Red Devil, Alaska

Profile. RDM profile
Model Settings
[HELP] Case Settings

Parameter	Value	Units
Runoff Method	Model calculated	(-)
Initial Moisture Settings	User specified	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Initial Surface Water	0	(ft)
Vegetation Class	Good stand of grass	(-)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Fill	447.5033	446.0033	1.5000
Polyvinyl Chloride (PVC)	446.0033	446.0000	0.0033
Loess	446.0000	443.0000	3.0000
Waste Material	443.0000	392.0000	51.0000
Native soil	392.0000	382.0000	10.0000
Weathered Bedrock	382.0000	372.0000	10.0000
Bedrock	372.0000	362.0000	10.0000

2.1. Layer. Fill

Top Slope: 20.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.35	(vol/vol)
field capacity	0.105	(vol/vol)
wilting point	0.047	(vol/vol)
sat.hydr.conductivity	1e-4	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.12	(vol/vol)

2.2. Layer. Polyvinyl Chloride (PVC)

[HELP] Geomembrane Liner Parameters

Parameter	Value	Units
sat.hydr.conductivity	1E-14	(cm/sec)
pinhole density	2	(#/ha)
installation defects	0	(#/ha)
placement quality	4	(-)
geotextile transmissivity	0	(cm2/sec)

2.3. Layer. Loess

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.4	(vol/vol)
field capacity	0.222	(vol/vol)
wilting point	0.104	(vol/vol)
sat.hydr.conductivity	1E-5	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.12	(vol/vol)

2.4. Layer. Waste Material

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.3	(vol/vol)
field capacity	0.105	(vol/vol)
wilting point	0.047	(vol/vol)
sat.hydr.conductivity	5e-3	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.12	(vol/vol)

2.5. Layer. Native soil

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.3	(vol/vol)
field capacity	0.19	(vol/vol)
wilting point	0.085	(vol/vol)
sat.hydr.conductivity	1E-6	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.12	(vol/vol)

2.6. Layer. Weathered Bedrock

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.25	(vol/vol)
field capacity	0.105	(vol/vol)
wilting point	0.047	(vol/vol)
sat.hydr.conductivity	1e-4	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.12	(vol/vol)

2.7. Layer. Bedrock

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.25	(vol/vol)
field capacity	0.284	(vol/vol)
wilting point	0.135	(vol/vol)
sat.hydr.conductivity	1E-5	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.12	(vol/vol)

APPENDIX C

VARIABLY SATURATED 2D FLOW AND TRANSPORT MODEL DETAILS

Appendix C: VS2DT Model Details

Project : RDM VS2DT GW=85.6ft, S5, 50yr

New profile based E&E's instruction on 7/29/2015

Model : VS2DT
An USGS unsaturated zone model based on solution of Richard's equation

Author : Li Ma, S&W

Client : Mark Longtine, E&E

Profile. VS2DT Arsenic 5D

Model Settings
[VS2DT] Case Settings

Parameter	Value	Units
Transport Simulation	Langmuir Adsorption	(-)
Soil Hydraulic Function	van Genuchten	(-)
Initial Conditions: Water	Equilibrium Profile	(-)
Initial Conditions: Chemical	Nonuniform Concentration	(-)
Max. Simulation Time	18250	(days)
Evapotranspiration	No evapotranspiration	(-)

[VS2DT] Solver Settings

Parameter	Value	Units
Flow Closure Criteria	0.00328	(ft)
Relaxation	0.900	(-)
Weighting Hydr. Cond.	1.0	(-)
Transport Closure Criteria	0.100000000000000	(mg/l)
Min. Iterations	2	(-)
Max. Iterations	50	(-)
Space Differencing	Backward-in-Space	(-)
Time Differencing	Center-in-Time	(-)
Maximum Number of Time Steps	500000	(-)
Display Balance Every Time Step	yes	(-)

[VS2DT] Observation Times

#	Time	Balance summary (-)
1	**365**	yes
2	**3650**	yes
3	**18250**	yes

[VS2DT] Flow Upper Boundary

#	Start Time	End Time	Type	Value	Allowed Ponding (ft)
1	**0**	**18250**	Flux (in/year)	4.8	0.0

[VS2DT] Flow Lower Boundary

#	Start Time	End Time	Type	Value
1	**0**	**18250**	Pressure Head (ft)	0

[VS2DT] Transport Upper Boundary

#	Start Time	End Time	Type	Value	Inflow Concentration (mg/l)
1	**0**	**18250**	Concentration (mg/l)	0.000000000000000	0.000000000000000

[VS2DT] Transport Lower Boundary

#	Start Time	End Time	Type	Value	Inflow Concentration (mg/l)
1	**0**	**1**	Concentration (mg/l)	0.000000000000000	0.000000000000000

[VS2DT] Profile Initial Conditions

Parameter	Value	Units
Groundwater Depth	85	(ft)
Minimum Head for Equilibrium Profile	-4.5	(ft)

[VS2DT] Stress Period Defaults

Parameter	Value	Units
Initial Time Step	0.1	(days)
Time Step Multiplier	1.2	(-)
Maximum Time Step	20	(days)
Minimum Time Step	0.0100000	(days)
Reduction Factor	0.40	(-)
Maximum Head Change	3.28084	(ft)
Head Criterion	0.00328	(ft)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Loamy Sand1	447.6000	446.1000	1.5000
Geomembrane	446.0000	446.0000	-
Loess	446.0000	443.0000	3.0000
Mixed Waste	443.0000	392.0000	51.0000
Native Fine Sand1	392.0000	382.0000	10.0000
Weathered Bedrock1	382.0000	372.0000	10.0000
Bedrock	372.0000	362.0000	10.0000

6.1. Layer. Loamy Sand1

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.0001	(cm/sec)
Specific Storage	0.00000010	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.050	(vol/vol)
Alpha' (van Genuchten)	-145	(ft)
Beta' (van Genuchten)	6.00000	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	2	(ft)
Dm (Molecular Diffusion)	0.4700000	(cm2/day)
Decay Constant	0.00000000	(/hr)
Bulk density	1.400	(g/cu.cm)
K1 (Langmuir Isotherm)	25	(ml/g)
Q (Langmuir Isotherm)	0.0060	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

6.2. Layer. Geomembrane

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00000000003	(cm/sec)
Specific Storage	0.000001	(1/cm)
Porosity	0.49	(vol/vol)
Qr	0.15	(vol/vol)
Alpha' (van Genuchten)	-160	(cm)
Beta' (van Genuchten)	1.6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	1	(ft)
Dm (Molecular Diffusion)	0.1	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	25	(ml/g)
Q (Langmuir Isotherm)	0.025	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

6.3. Layer. Loess

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.4	(vol/vol)
Qr	0.09	(vol/vol)
Alpha' (van Genuchten)	-170	(cm)
Beta' (van Genuchten)	4	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	1	(ft)
Dm (Molecular Diffusion)	0.34	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	25	(ml/g)
Q (Langmuir Isotherm)	0.015	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

6.4. Layer. Mixed Waste

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.005	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.05	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.47	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	25	(ml/g)
Q (Langmuir Isotherm)	0.006	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	829	(mg/Kg)

6.5. Layer. Native Fine Sand1

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.000001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.07	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	5	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.4	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	25	(ml/g)
Q (Langmuir Isotherm)	0.007	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

6.6. Layer. Weathered Bedrock1

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.0001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.05	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.47	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	25	(ml/g)
Q (Langmuir Isotherm)	0.006	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

6.7. Layer. Bedrock

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.1	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	4	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.2	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	25	(ml/g)
Q (Langmuir Isotherm)	0.012	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

Profile. VS2DT Antimony

Model Settings

[VS2DT] Case Settings

Parameter	Value	Units
Transport Simulation	Langmuir Adsorption	(-)
Soil Hydraulic Function	van Genuchten	(-)
Initial Conditions: Water	Equilibrium Profile	(-)
Initial Conditions: Chemical	Nonuniform Concentration	(-)
Max. Simulation Time	18250	(days)
Evapotranspiration	No evapotranspiration	(-)

[VS2DT] Solver Settings

Parameter	Value	Units
Flow Closure Criteria	0.00328	(ft)
Relaxation	0.900	(-)
Weighting Hydr. Cond.	1.0	(-)
Transport Closure Criteria	0.100000000000000	(mg/l)
Min. Iterations	2	(-)
Max. Iterations	50	(-)
Space Differencing	Backward-in-Space	(-)
Time Differencing	Center-in-Time	(-)
Maximum Number of Time Steps	500000	(-)
Display Balance Every Time Step	yes	(-)

[VS2DT] Observation Times

#	Time	Balance summary (-)
1	**365**	yes
2	**3650**	yes
3	**18250**	yes

[VS2DT] Flow Upper Boundary

#	Start Time	End Time	Type	Value	Allowed Ponding (ft)
1	**0**	**18250**	Flux (in/year)	1.4	0.0

[VS2DT] Flow Lower Boundary

#	Start Time	End Time	Type	Value
1	**0**	**18250**	Pressure Head (ft)	0

[VS2DT] Transport Upper Boundary

#	Start Time	End Time	Type	Value	Inflow Concentration (mg/l)
1	**0**	**18250**	Concentration (mg/l)	0.000000000000000	0.000000000000000

[VS2DT] Transport Lower Boundary

#	Start Time	End Time	Type	Value	Inflow Concentration (mg/l)
1	**0**	**1**	Concentration (mg/l)	0.000000000000000	0.000000000000000

[VS2DT] Profile Initial Conditions

Parameter	Value	Units
Groundwater Depth	85	(ft)
Minimum Head for Equilibrium Profile	-6	(ft)

[VS2DT] Stress Period Defaults

Parameter	Value	Units
Initial Time Step	0.1	(days)
Time Step Multiplier	1.2	(-)
Maximum Time Step	20	(days)
Minimum Time Step	0.0100000	(days)
Reduction Factor	0.40	(-)
Maximum Head Change	3.28084	(ft)
Head Criterion	0.00328	(ft)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Loamy Sand1	447.6000	446.1000	1.5000
Geomembrane	446.0000	446.0000	-
Loess	446.0000	443.0000	3.0000
Mixed Waste	443.0000	392.0000	51.0000
Native Fine Sand1	392.0000	382.0000	10.0000
Weathered Bedrock1	382.0000	372.0000	10.0000
Bedrock	372.0000	362.0000	10.0000

1.1. Layer. Loamy Sand1

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.0001	(cm/sec)
Specific Storage	0.00000010	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.050	(vol/vol)
Alpha' (van Genuchten)	-145	(ft)
Beta' (van Genuchten)	6.00000	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	2	(ft)
Dm (Molecular Diffusion)	0.4700000	(cm2/day)
Decay Constant	0.00000000	(/hr)
Bulk density	1.400	(g/cu.cm)
K1 (Langmuir Isotherm)	45	(ml/g)
Q (Langmuir Isotherm)	0.0060	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

1.2. Layer. Geomembrane

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00000000003	(cm/sec)
Specific Storage	0.000001	(1/cm)
Porosity	0.49	(vol/vol)
Qr	0.15	(vol/vol)
Alpha' (van Genuchten)	-160	(cm)
Beta' (van Genuchten)	1.6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	1	(ft)
Dm (Molecular Diffusion)	0.1	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	45	(ml/g)
Q (Langmuir Isotherm)	0.025	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

1.3. Layer. Loess

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.4	(vol/vol)
Qr	0.09	(vol/vol)
Alpha' (van Genuchten)	-170	(cm)
Beta' (van Genuchten)	4	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	1	(ft)
Dm (Molecular Diffusion)	0.34	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	45	(ml/g)
Q (Langmuir Isotherm)	0.015	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

1.4. Layer. Mixed Waste

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.005	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.05	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.47	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	45	(ml/g)
Q (Langmuir Isotherm)	0.006	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	535	(mg/Kg)

1.5. Layer. Native Fine Sand1

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.000001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.07	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	5	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.4	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	45	(ml/g)
Q (Langmuir Isotherm)	0.007	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

1.6. Layer. Weathered Bedrock1

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.0001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.05	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.47	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	45	(ml/g)
Q (Langmuir Isotherm)	0.006	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

1.7. Layer. Bedrock

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.1	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	4	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.2	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	45	(ml/g)
Q (Langmuir Isotherm)	0.012	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

2. Profile. VS2DT Mercury 5F

Model Settings

[VS2DT] Case Settings

Parameter	Value	Units
Transport Simulation	Langmuir Adsorption	(-)
Soil Hydraulic Function	van Genuchten	(-)
Initial Conditions: Water	Equilibrium Profile	(-)
Initial Conditions: Chemical	Nonuniform Concentration	(-)
Max. Simulation Time	18250	(days)
Evapotranspiration	No evapotranspiration	(-)

[VS2DT] Solver Settings

Parameter	Value	Units
Flow Closure Criteria	0.00328	(ft)
Relaxation	0.900	(-)
Weighting Hydr. Cond.	1.0	(-)
Transport Closure Criteria	0.100000000000000	(mg/l)
Min. Iterations	2	(-)
Max. Iterations	50	(-)
Space Differencing	Backward-in-Space	(-)
Time Differencing	Center-in-Time	(-)
Maximum Number of Time Steps	500000	(-)
Display Balance Every Time Step	yes	(-)

[VS2DT] Observation Times

#	Time	Balance summary (-)
1	**365**	yes
2	**3650**	yes
3	**18250**	yes

[VS2DT] Flow Upper Boundary

#	Start Time	End Time	Type	Value	Allowed Ponding (ft)
1	**0**	**18250**	Flux (in/year)	4.8	0.0

[VS2DT] Flow Lower Boundary

#	Start Time	End Time	Type	Value
1	**0**	**18250**	Pressure Head (ft)	0

[VS2DT] Transport Upper Boundary

#	Start Time	End Time	Type	Value	Inflow Concentration (mg/l)
1	**0**	**18250**	Concentration (mg/l)	0.000000000000000	0.000000000000000

[VS2DT] Transport Lower Boundary

#	Start Time	End Time	Type	Value	Inflow Concentration (mg/l)
1	**0**	**1**	Concentration (mg/l)	0.000000000000000	0.000000000000000

[VS2DT] Profile Initial Conditions

Parameter	Value	Units
Groundwater Depth	85	(ft)
Minimum Head for Equilibrium Profile	-4.5	(ft)

[VS2DT] Stress Period Defaults

Parameter	Value	Units
Initial Time Step	0.1	(days)
Time Step Multiplier	1.2	(-)
Maximum Time Step	20	(days)
Minimum Time Step	0.0100000	(days)
Reduction Factor	0.40	(-)
Maximum Head Change	3.28084	(ft)
Head Criterion	0.00328	(ft)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Loamy Sand1	447.6000	446.1000	1.5000
Geomembrane	446.0000	446.0000	-
Loess	446.0000	443.0000	3.0000
Mixed Waste	443.0000	392.0000	51.0000
Native Fine Sand1	392.0000	382.0000	10.0000
Weathered Bedrock1	382.0000	372.0000	10.0000
Bedrock	372.0000	362.0000	10.0000

2.1. Layer. Loamy Sand1

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.0001	(cm/sec)
Specific Storage	0.00000010	(1/cm)
Porosity	0.3	(vol/vol)

Parameter	Value	Units
Qr	0.050	(vol/vol)
Alpha' (van Genuchten)	-145	(ft)
Beta' (van Genuchten)	6.00000	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	2	(ft)
Dm (Molecular Diffusion)	0.4700000	(cm2/day)
Decay Constant	0.00000000	(/hr)
Bulk density	1.400	(g/cu.cm)
K1 (Langmuir Isotherm)	1000	(ml/g)
Q (Langmuir Isotherm)	0.0060	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

2.2. Layer. Geomembrane

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00000000003	(cm/sec)
Specific Storage	0.000001	(1/cm)
Porosity	0.49	(vol/vol)
Qr	0.15	(vol/vol)
Alpha' (van Genuchten)	-160	(cm)
Beta' (van Genuchten)	1.6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	1	(ft)
Dm (Molecular Diffusion)	0.1	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	1000	(ml/g)
Q (Langmuir Isotherm)	0.025	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

2.3. Layer. Loess

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.4	(vol/vol)
Qr	0.09	(vol/vol)
Alpha' (van Genuchten)	-170	(cm)
Beta' (van Genuchten)	4	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	1	(ft)
Dm (Molecular Diffusion)	0.34	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	1000	(ml/g)
Q (Langmuir Isotherm)	0.015	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

2.4. Layer. Mixed Waste

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.005	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.05	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.47	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	1000	(ml/g)
Q (Langmuir Isotherm)	0.006	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	90	(mg/Kg)

2.5. Layer. Native Fine Sand1

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.000001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.07	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	5	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.4	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	1000	(ml/g)
Q (Langmuir Isotherm)	0.007	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

2.6. Layer. Weathered Bedrock1

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.0001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.05	(vol/vol)

Parameter	Value	Units
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.47	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	1000	(ml/g)
Q (Langmuir Isotherm)	0.006	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

2.7. Layer. Bedrock

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.1	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	4	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.2	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	1000	(ml/g)
Q (Langmuir Isotherm)	0.012	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

3. Profile. VS2DT DRO 5A

Model Settings

[VS2DT] Case Settings

Parameter	Value	Units
Transport Simulation	Langmuir Adsorption	(-)
Soil Hydraulic Function	van Genuchten	(-)
Initial Conditions: Water	Equilibrium Profile	(-)
Initial Conditions: Chemical	Nonuniform Concentration	(-)
Max. Simulation Time	18250	(days)
Evapotranspiration	No evapotranspiration	(-)

[VS2DT] Solver Settings

Parameter	Value	Units
Flow Closure Criteria	0.00328	(ft)
Relaxation	0.900	(-)
Weighting Hydr. Cond.	1.0	(-)
Transport Closure Criteria	0.100000000000000	(mg/l)
Min. Iterations	2	(-)
Max. Iterations	50	(-)

Parameter	Value	Units
Space Differencing	Backward-in-Space	(-)
Time Differencing	Center-in-Time	(-)
Maximum Number of Time Steps	500000	(-)
Display Balance Every Time Step	yes	(-)

[VS2DT] Observation Times

#	Time	Balance summary (-)
1	**365**	yes
2	**3650**	yes
3	**18250**	yes

[VS2DT] Flow Upper Boundary

#	Start Time	End Time	Type	Value	Allowed Ponding (ft)
1	**0**	**18250**	Flux (in/year)	0.16	0.0

[VS2DT] Flow Lower Boundary

#	Start Time	End Time	Type	Value
1	**0**	**18250**	Pressure Head (ft)	0

[VS2DT] Transport Upper Boundary

#	Start Time	End Time	Type	Value	Inflow Concentration (mg/l)
1	**0**	**18250**	Concentration (mg/l)	0.000000000000000	0.000000000000000

[VS2DT] Transport Lower Boundary

#	Start Time	End Time	Type	Value	Inflow Concentration (mg/l)
1	**0**	**1**	Concentration (mg/l)	0.000000000000000	0.000000000000000

[VS2DT] Profile Initial Conditions

Parameter	Value	Units
Minimum Head for Equilibrium Profile	-8	(ft)
Groundwater Depth	85	(ft)

[VS2DT] Stress Period Defaults

Parameter	Value	Units
Initial Time Step	0.1	(days)
Time Step Multiplier	1.2	(-)
Maximum Time Step	20	(days)
Minimum Time Step	0.0100000	(days)
Reduction Factor	0.40	(-)
Maximum Head Change	3.28084	(ft)
Head Criterion	0.00328	(ft)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Loamy Sand1	447.6000	446.1000	1.5000
Geomembrane	446.0000	446.0000	-
Loess	446.0000	443.0000	3.0000
Mixed Waste	443.0000	392.0000	51.0000
Native Fine Sand1	392.0000	382.0000	10.0000
Weathered Bedrock1	382.0000	372.0000	10.0000
Bedrock	372.0000	362.0000	10.0000

3.1. Layer. Loamy Sand1

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	2	(ft)
Dm (Molecular Diffusion)	0.4700000	(cm2/day)
Decay Constant	0.00000000	(/hr)
Bulk density	1.400	(g/cu.cm)
K1 (Langmuir Isotherm)	5.45e9	(ml/g)
Q (Langmuir Isotherm)	0.0060	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.0001	(cm/sec)
Specific Storage	0.00000010	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.050	(vol/vol)
Alpha' (van Genuchten)	-145	(ft)
Beta' (van Genuchten)	6.00000	(-)

3.2. Layer. Geomembrane

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00000000003	(cm/sec)
Specific Storage	0.000001	(1/cm)
Porosity	0.49	(vol/vol)
Qr	0.15	(vol/vol)
Alpha' (van Genuchten)	-160	(cm)
Beta' (van Genuchten)	1.6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	1	(ft)
Dm (Molecular Diffusion)	0.1	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	5.45e9	(ml/g)
Q (Langmuir Isotherm)	0.025	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

3.3. Layer. Loess

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.4	(vol/vol)
Qr	0.09	(vol/vol)
Alpha' (van Genuchten)	-170	(cm)
Beta' (van Genuchten)	4	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	1	(ft)
Dm (Molecular Diffusion)	0.34	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	5.45e9	(ml/g)
Q (Langmuir Isotherm)	0.015	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

3.4. Layer. Mixed Waste

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.005	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.05	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.47	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	5.45e9	(ml/g)
Q (Langmuir Isotherm)	0.006	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	7300	(mg/Kg)

3.5. Layer. Native Fine Sand1

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.000001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.07	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	5	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.4	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	5.45e9	(ml/g)
Q (Langmuir Isotherm)	0.007	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

3.6. Layer. Weathered Bedrock1

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.0001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.05	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	6	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.47	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	5.45e9	(ml/g)
Q (Langmuir Isotherm)	0.006	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

3.7. Layer. Bedrock

[VS2DT] Soil Parameters

Parameter	Value	Units
Saturated Hydraulic Conductivity	0.00001	(cm/sec)
Specific Storage	0.0000001	(1/cm)
Porosity	0.3	(vol/vol)
Qr	0.1	(vol/vol)
Alpha' (van Genuchten)	-145	(cm)
Beta' (van Genuchten)	4	(-)

[VS2DT] Transport Parameters

Parameter	Value	Units
Alpha L	5	(ft)
Dm (Molecular Diffusion)	0.2	(cm2/day)
Decay Constant	0.0	(/day)
Bulk density	1.4	(g/cu.cm)
K1 (Langmuir Isotherm)	5.45e9	(ml/g)
Q (Langmuir Isotherm)	0.012	(-)

[VS2DT] Initial Conditions

Parameter	Value	Units
Concentration	0	(mg/l)

APPENDIX D

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental/water resources report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland

C Cost Information

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Derived Cost DCIC1 - Mobilization/Demobilization (Alt 2)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Front End Loader	1	each	$538	$538	2013 RSMeans, 01 54 36.5 0020	
Diesel Generator	1	each	$372	$372	2013 RSMeans, 01 54 36.50 1150	
Barge Delivery Cost	1	each	$57,600	$57,600	Vendor Quote, Crowley Maritime Corp	
			DCIC1 Subtotal	*$58,510*		

Derived Cost DC1a - Mobilization/Demobilization (Alt 3a,b,c,d)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Backhoe	2	each	$538	$1,076	2013 RSMeans, 01 54 36.5 0020	
Dozer	2	each	$538	$1,076	2013 RSMeans, 01 54 36.5 0020	
Front End Loader	3	each	$538	$1,614	2013 RSMeans, 01 54 36.5 0020	
Boom Crane	1	each	$538	$538	2014 RSMeans, 01 54 36.5 0020	
Dump Truck	3	each	$538	$1,614	2014 RSMeans, 01 54 36.5 0020	
Pugmill/Chemical Spreader	1	each	$538	$538	2014 RSMeans, 01 54 36.5 0020	
Diesel Generator	2	each	$372	$744	2013 RSMeans, 01 54 36.50 1150	
Lodging Trailer Transport	1	each	$37,803	$37,803	Vendory Quote, AATCO Structures and Logistic	
Barge Delivery Cost	2	each	$990,000	$1,980,000	Vendor Quote, Crowley Maritime Corp	
			DC1a Subtotal	*$2,025,003*		

Derived Cost DC1b - Mobilization/Demobilization (Alt 4)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Backhoe	2	each	$538	$1,076	2013 RSMeans, 01 54 36.5 0020	
Dozer	2	each	$538	$1,076	2013 RSMeans, 01 54 36.5 0020	
Front End Loader	3	each	$538	$1,614	2013 RSMeans, 01 54 36.5 0020	
Dump Truck	3	each	$538	$1,614	2014 RSMeans, 01 54 36.5 0020	
Diesel Generator	2	each	$372	$744	2013 RSMeans, 01 54 36.50 1150	
Boom Crane	1	each	$538	$538	2013 RSMeans, 01 54 36.5 0020	
Lodging Trailer Transport	1	each	$37,803	$37,803	Vendory Quote, AATCO Structures and Logistic	
Barge Delivery Cost	2	each	$1,209,600	$2,419,200	Vendor Quote, Crowley Maritime Corp	Changed uniat cost back from 990k
			DC1bSubtotal	*$2,463,665*		

Derived Cost DCIC2 - Field Overhead and Oversight (Alt 2)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Superintendent	1	month	$12,400	$12,400	2013 RSMeans, 01 31 13.20 0260	
Clerk	1	month	$3,100	$3,100	2013 RSMeans, 01 31 13.20 0020	
Trailer	1	month	$209	$209	2013 RSMeans, 01 52 13.20 0350	
Porta John (2)	1	month	$366	$366	2013 RSMeans, 01 54 33 40 6410	
Field Office Expenses	1	month	$220	$220	2013 RSMeans, 01 52 13.40 0100	
Pressure Washer for Deconning	1	month	$465	$465	2013 RS Means, 01 54 33 5450	
3/4 Ton Pickup Rental	2	each	$3,000	$6,000	Vendor Quote, ABC Motorhome & Car Rentals	
Diesel-Engine-Driven Generators	1	month	$4,950	$4,950	Vendor Quote, Craig Taylor Equipment	50-65 kW. $2,475/unit. Assume two generators are
Diesel Fuel For Generators and Pickup Trucks	1	month	$10,450	$10,450	Engineer Estimate	Estimate based on ~2500 gallons/month @ $4.18/gallon (current average $/gal for diesel in Alaska)
Lodging Trailer Rental	2	each	$4,350	$8,700	Vendor Quote, Adventures in Alaska Rentals	Assume 5 people total.
Lodging Trailer Transport	1	each	$37,803	$37,803	Vendory Quote, AATCO Structures and Logistic	
Propane for Lodging Trailers	1	montth	$405	$405	Engineer Estimate	Assume 225lbs of propane used/trailer/month @ $0.90/lb.
Per Diem	1	month	$48,600	$48,600	Engineer Estimate	Assume $108/person/day. Assume 15 people
			DCIC2 Subtotal	*$133,668*		

Derived Cost DC2 - Field Overhead and Oversight (Alts 3a, b, c, and 4)

Description	Quantity	Unit	Unit Cost	Cost/Month	Reference	Notes
Superintendent	1	month	$12,400	$12,400	2013 RSMeans, 01 31 13.20 0260	
Clerk	1	month	$3,100	$3,100	2013 RSMeans, 01 31 13.20 0020	
Trailer	1	month	$209	$209	2013 RSMeans, 01 52 13.20 0350	
Porta John (2)	1	month	$366	$366	2013 RSMeans, 01 54 33 40 6410	
Field Office Expenses	1	month	$220	$220	2013 RSMeans, 01 52 13.40 0100	
Air Monitoring Instrument Rental	1	month	$8,100	$8,100	Vendor Quote, Field Environmental	Assume four DataRam 4000s @ $1,350/unit/month, and four Personal DataRams @ $675/unit/month
Pressure Washer for Deconning	1	month	$465	$465	2013 RS Means, 01 54 33 5450	
3/4 Ton Pickup Rental	5	each	$3,000	$15,000	Vendor Quote, ABC Motorhome & Car Rentals	Assume 5 trucks required for the site.
Diesel-Engine-Driven Generators	1	month	$4,950	$4,950	Vendor Quote, Craig Taylor Equipment	50-65 kW. $2,475/unit. Assume two generators are needed for duration of field activity.
Diesel Fuel For Generators and Pickup Trucks	1	month	$12,540	$12,540	Engineer Estimate	Estimate based on ~3000 gallons/month @ $4.18/gallon (current average $/gal for diesel in Alaska)
Lodging Trailer Rental	4	each	$4,350	$58,000	Vendor Quote, ATCO	each Unit houses 6 people. 12'x54', 3 moth lease: assume 15 people total
Lodging Trailer Transport	1	each	$37,803	$37,803	Vendory Quote, AATCO Structures and Logistic	
Propane for Lodging Trailers	1	montth	$810	$810	Engineer Estimate	Assume 225lbs of propane used/trailer/month @ $0.90/lb.
Per Diem	1	month	$48,600	$48,600	Engineer Estimate	Assume $108/person/day. Assume 15 people
			DC2 Subtotal	*$202,563*		

Derived Cost DC3a - Site Preparation (Alt 3a, b)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Silt Fencing	4,000	linear foot	$1.02	$4,060	2013 RS Means, 31 25 14.16 1000	Assume average of adverse and ideal conditions.
Hay Bales	4,000	linear foot	$10.55	$42,200	2013 RSMeans, 31 25 14.16 1250	
Staging Area Geotextile	1,111	square yard	$2.33	$2,589	2013 RSMeans, 31 32 19.16 1500	Assumed 100' X 100'
Staging Area Aggregate Base	10,000	square foot	$8.05	$80,500	2013 RSMeans, 32 11 23.23 0100	
Dewatering Pad Geotextile	1,111	square foot	$2.33	$2,589	2013 RSMeans, 31 32 19.16 1500	Assumed 100' X 100'
Dewatering Pad Aggregate Base	10,000	square foot	$8.05	$80,500	2013 RSMeans, 32 11 23.23 0100	
Dewatering Pad Liner	10,000	square foot	$1.35	$13,500	2013 RSMeans, 33 47 13.53 1100	30 mil thickness
Temporary Barge Mooring Construction	1	lump sum	$200,000	$200,000	Engineer Estimate	
River Access Structure Construction	1	lump sum	$51,500	$51,500	Engineer Estimate	
Excavate Borrow Material for Haul Road Construction	3,911	cubic yard	$1.79	$7,017	2013 RSMeans, 31 23 16.42 0305	Bulk bank measure, add 15% for loading onto truck
Haul Borrow Material for Haul Road Construction	3,911	cubic yard	$7.85	$30,702	2013 RSMeans 31 23 23.20 5050	Assume average 2 mile cycle to borrow source.
Haul Road Construction	17,600	square yard	$14.75	$259,600	2013 RSMeans, 01 55 23.50 0100	Gravel fill, 8" gravel depth, Assume 1 mile of haul road, 30 ft. wide to allow two-traffic of 22 cy off-road haul trucks (ea ~10 feet wide).
Haul Road Dust Control	260	day	$1,000	$260,000	2013 RSMeans, 31 23 23.20 2500	
			DC3a Subtotal	*$1,034,757*		

Derived Cost DC3b - Site Preparation (Alt 4)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Silt Fencing	4,000	linear foot	$1.02	$4,060	2013 RS Means, 31 25 14.16 1000	Assume average of adverse and ideal conditions.
Hay Bales	4,000	linear foot	$10.55	$42,200	2013 RSMeans, 31 25 14.16 1250	
Staging Area Geotextile	1,111	square yard	$2.33	$2,589	2013 RSMeans, 31 32 19.16 1500	Assumed 100' X 100'
Staging Area Aggregate Base	10,000	square foot	$8.05	$80,500	2013 RSMeans, 32 11 23.23 0100	
Dewatering Pad Geotextile	1,111	square foot	$2.33	$2,589	2013 RSMeans, 31 32 19.16 1500	Assumed 100' X 100'
Dewatering Pad Aggregate Base	10,000	square foot	$8.05	$80,500	2013 RSMeans, 32 11 23.23 0100	
Dewatering Pad Liner	10,000	square foot	$1.35	$13,500	2013 RSMeans, 33 47 13.53 1100	30 mil thickness
Temporary Barge Mooring Construction	1	lump sum	$200,000	$200,000	Engineer Estimate	
River Access Structure Construction	1	lump sum	$51,500	$51,500	Engineer Estimate	
Excavate Borrow Material for Haul Road Construction	1,956	cubic yard	$1.79	$3,508	2013 RSMeans, 31 23 16.42 0305	Bulk bank measure, add 15% for loading onto truck
Haul Borrow Material for Haul Road Construction	1,956	cubic yard	$7.85	$15,351	2013 RSMeans 31 23 23.20 5050	Assume average 2 mile cycle to borrow source.
Haul Road Construction	8,800	square yard	$14.75	$129,800	2013 RSMeans, 01 55 23.50 0100	Gravel fill, 8" gravel depth, Assume 0.5 mile of haul road, 15 ft. wide.
Haul Road Dust Control	182	day	$1,000	$182,000	2013 RSMeans, 31 23 23.20 2500	
			DC3b Subtotal	*$808,097*		

Derived Cost DCIC4 - Install Access Controls

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Install Fencing	5,000	linear foot	$28.50	$142,500	2013 RSMeans, 32 31 13.20 0800	6 ga. wire, 6' high, galv steel
Install Fence Gates	6	each	$1,100	$6,600	2013 RSMeans, 32 31 13.20 5060	6' high, 12' opening, in concrete
Install Warning Signs on Fencing	50	each	$95	$4,750	Engineer Estimate	Assume one for every 100 feet of fencing.
			DCIC4 Subtotal	*$153,850*		

Derived Cost DC4a - Excavate Contaminated Material (Alt 3a, b, c)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Excavate Contaminated Material and Load Haul Trucks	204,500	cubic yard	$4.29	$877,305	2013 RSMeans, 31 23 16.42 0305	
Confirmation Sampling	20	each	$200	$4,090	Engineer Estimate	Assume 1 sample every 10,000 s.f.
Haul Contaminated Material to Repository Site or Solidification Staging Area	204,500	cubic yard	$3.93	$803,685	2013 RSMeans 31 23 23.20 5000	
Spread dumped material, by dozer, no compaction	204,500	cubic yard	$2.26	$462,170	2013 RSMeans, 31 23 23.17 0020	
Compaction- riding, vibrating roller, 12" lifts, 2 passes	204,500	cubic yard	$0.26	$53,170	2013 RSMeans, 31 23 23.23 5060	
Water truck-soil wetting	204,500	cubic yard	$2.38	$486,710	2013 RSMeans, 31 23 23.23 9000	
			DC4a Subtotal	*$2,687,130*		

Derived Cost DC4b - Excavate Contaminated Material (Alt 4)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Excavate Contaminated Material and Load Super Sack	204,500	cubic yard	$6.79	$1,388,555	2013 RSMeans, 31 23 16.42 0305 + Vendor Quote $2.50/cy ($10/4cy), B.A.G. Corp	
Confirmation Sampling	20	each	$200	$4,090	Engineer Estimate	Assume 1 sample every 10,000 s.f.
Haul Super Sacks to Staging Area	204,500	cubic yard	$1.87	$382,415	2013 RSMeans, 31 23 23.14 5400	
			DC4b Subtotal	*$1,775,060*		

Derived Cost DC5a - Solidification (Alt 3a,b,c,d)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Cement Soil Stabilization/Solidification	30,675	cubic yard	$70	$2,147,250	USEPA Technology Performace Review: Selecting and Using Solidification/Stablilzation Treatment for Site Remediation (2009)	Assumes large scale ex-situ treatment using pugmill to inject cement solidier/stabilizer.
Confirmation Sampling	148	each	$200	$29,662	Engineer Estimate	Assume 1 sample every 2,500 s.f.
Haul treated material to Repository	30675	cubic yard	$3.93	$120,553	2013 RSMeans 31 23 23.20 5000	
			DC5a Subtotal	*$2,297,465*		

Derived Cost DC5b - Monofill #2 Seperation, Excavation, Solidification, hauling and backfilling (Alt 3c &3d)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Excavate Contaminated Material and Load Haul Trucks	4,585	cubic yard	$4.29	$19,670	2013 RSMeans, 31 23 16.42 0305	26,040 CY x 15%
Haul Contaminated Material to Repository Site or Solidification Staging Area	4,585	cubic yard	$3.93	$18,019	2013 RSMeans 31 23 23.20 5000	
Spread dumped material, by dozer, no compaction	4,585	cubic yard	$2.26	$10,362	2013 RSMeans, 31 23 23.17 0020	
Compaction- riding, vibrating roller, 12" lifts, 2 passes	4,585	cubic yard	$0.26	$1,192	2013 RSMeans, 31 23 23.23 5060	
Water truck-soil wetting	4,585	cubic yard	$2.38	$10,912	2013 RSMeans, 31 23 23.23 9000	
Seperation of Material Not Suitable for Repository	459	cubic yard	$4.29	$1,967	2013 RSMeans, 31 23 16.42 0305	10% of excavated material
Decontamination of Material Not Suitable for Repository	459	cubic yard	$53	$24,301	Remediation Technoligies screening matrix and reference guide, Version 4.0	
Purchse Super Sacks	306	each	$14.30	$4,371	vendor quote	
Load Super Sacks	459	cubic yard	$2.33	$1,068	2013 RSMeans, 31 23 16.42 0305 + $2.50/cy ($10/4cy)	
Load Super Sack Containers on to River Barge	459	cubic yard	$1.87	$857	2013 RSMeans, 31 23 23.14 5400	
Barge Transport from Red Devil to Seward	459	cubic yard	$172	$78,679	Vendor Quote, Crowley Maritime Corp	
Load Super Sack Containers from Barge to Train	459	cubic yard	$4	$1,898	2013 RSMeans, 31 23 16.13 1346	
Train Transport	459	cubic yard	$153	$69,930	Vendor Quote, Alaska Railroad	
Disposal of Material Not Suitable for Repository	596	ton	$230	$137,092	Vendor Quote, Waste Management	
Excavate Borrow Material for Backfilling	4,585	cubic yard	$1.79	$8,225	2013 RSMeans, 31 23 16.42 0305	
Haul Backfill Material to Excavation Areas	4,585	cubic yard	$7.85	$35,992	2013 RSMeans 31 23 23.20 5050	
Compaction- riding, vibrating roller, 12" lifts, 2 passes	4,585	cubic yard	$0.26	$1,192	2013 RSMeans, 31 23 23.23 5060	Assumes 5% of total excavated area
Grade Backfill Areas to Match Existing Topography	229	square yard	$0.20	$12,397	2013 RSMeans, 31 22 16.10 3300	Assumes 5% of total excavated area
			DC5b Subtotal	*$438,125*		

Derived Cost DC6a - Backfill Excavated Areas (Alt 3a,b,c,d)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Excavate Borrow Material for Backfilling	204,500	cubic yard	$1.79	$366,873	2013 RSMeans, 31 23 16.42 0305	
Haul Backfill Material to Excavation Areas	204,500	cubic yard	$7.85	$1,605,325	2013 RSMeans 31 23 23.20 5050	
Compaction- riding, vibrating roller, 12" lifts, 2 passes	204,500	cubic yard	$0.26	$53,170	2013 RSMeans, 31 23 23.23 5060	Assumes 5% of total excavated area
Grade Backfill Areas to Match Existing Topography	61,986	square yard	$0.20	$12,397	2013 RSMeans, 31 22 16.10 3300	Assumes 5% of total excavated area
			DC6 Subtotal	*$2,037,765*		

Derived Cost DC6b - Backfill Excavated Areas including Monofill #2(Alt 4)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Excavate Borrow Material for Backfilling	204,500	cubic yard	$1.79	$366,873	2013 RSMeans, 31 23 16.42 0305	
Haul Backfill Material to Excavation Areas	204,500	cubic yard	$7.85	$1,605,325	2013 RSMeans 31 23 23.20 5050	
Compaction- riding, vibrating roller, 12" lifts, 2 passes	204,500	cubic yard	$0.26	$53,170	2013 RSMeans, 31 23 23.23 5060	Assumes 5% of total excavated area
Grade Backfill Areas to Match Existing Topography	61,986	square yard	$0.20	$12,397	2013 RSMeans, 31 22 16.10 3300	Assumes 5% of total excavated area
			DC6 Subtotal	*$2,037,765*		

Derived Cost DC7a - Excavate Remaining Portion of Red Devil Creek and haul to Repository (Alt 3a,b,c,d)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Coffer Dam for Red Devil Creek Diversion	4	each	$3,100	$12,400	Vendor Quote, Aqua Barrier	Assume 4' high x 30' long. Price Includes Shipping to Bethel
Pump Rental for Red Devil Creek Diversion	2	each	$25,339.25	$50,679	Vendor Quote, Rain For Rent	300 gal/min pump with hoses and shipping for 10 months. Includes shipping costs from Kenai to Bethel.
Red Devil Creek Excavation	4,500	cubic yard	$4.29	$19,305	2013 RSMeans, 35 20 23.13 0500	
Load Sediment onto Haul Trucks	4,500	cubic yard	$0.66	$2,970	2013 RS Means, 31 23 23.15 4070	Material cost not included
Haul Contaminated Material to Repository Site	4,500	cubic yard	$3.93	$17,685	2013 RSMeans 31 23 23.20 5000	22 CY off-road, 15 min, 5 mph , cycle 2000 ft.
Spread dumped material, by dozer onto Repository, no compaction	4,500	cubic yard	$2.26	$10,170	2013 RSMeans, 31 23 23.17 0020	
Compaction- riding, vibrating roller, 12" lifts, 2 passes	4,500	cubic yard	$0.26	$1,170	2013 RSMeans, 31 23 23.23 5060	
Water truck-soil wetting	4,500	cubic yard	$2.38	$10,710	2013 RSMeans, 31 23 23.23 9000	3000 gal. truck
			DC7a Subtotal	*$125,089*		

Derived Cost DC7b - Excavate Remaining Portion of Red Devil Creek

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Coffer Dam with shipping	4	each	$3,100	$12,400	Vendor Quote, Aqua Barrier	Assume 4' high x 30' long
Pump Rental with shipping	2	each	$10,568.25	$21,137	Vendor Quote, Rain For Rent	300 gal/min pump with hoses and shipping for 3 months. Includes shipping costs from kenai to Bethel.
Creek Excavation	4,500	cubic yard	$17.55	$78,975	2013 RSMeans, 35 20 23.13 0500	
Load Sediment into Super Sacks	4,500	cubic yard	$6.79	$30,555	2013 RSMeans, 31 23 16.42 0305 + $2.50/cy ($10/4cy)	
			DC7b Subtotal	*$143,067*		

Derived Cost DC8 - Transportation

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Purchase Super Sacks	139,333	each	$14.30	$1,992,467	Vendor Quote	
Load Super Sack Containers on to River Barge	209,000	cubic yard	$1.87	$390,830	2013 RSMeans, 31 23 23.14 5400	
Barge Transport from Red Devil to Seward	209,000	cubic yard	**$172**	$35,864,400	Vendor Quote, Crowley Maritime Corp	
Load Super Sack Containers from Barge to Train	209,000	cubic yard	$4	$865,260	2013 RSMeans, 31 23 16.13 1346	
Train Transport	209,000	cubic yard	$153	$31,876,680	Vendor Quote, Alaska Railroad	
			DC8 Subtotal	*$70,989,637*		

Derived Cost DC9 - Disposal (Alt 4)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Hazardous Waste Disposal	45,728	ton	$230	$10,517,325	Vendor Quote, Waste Management	
Non-Hazardous Waste Disposal	237,673	ton	$31	$7,367,848	Vendor Quote, Waste Management	
			DC9 Subtotal	*$17,885,173*		

Derived Cost DC10a - Repository Construction (Alt 3a, 3b, 3c, 3d)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Excavate Borrow Material for Bedding Layer	4,938	cubic yard	$1.79	$8,859	2013 RSMeans, 31 23 16.42 0305	Bulk bank measure, add 15 % for loading onto truck
Haul Bedding Material to Repository Site	4,938	cubic yard	$7.85	$38,765	2013 RSMeans 31 23 23.20 5050	Assume 2 mile cycle to borrow source. Loess Layer Thickness = 8"
Finish grading- slopes, steep	22,222	s.y.	$0.25	$5,556	2013 RSMeans, 31 22 16.10 3310	Assume 200,000 square foot area for repository.
Water truck-soil wetting	4,938	cubic yard	$2.38	$11,753	2013 RSMeans, 31 23 23.23 9000	3000 gal. truck
Geotextile	200,000	square foot	$0.21	$42,200	Vendor Quote, Alaska Tent & Tarp	Non Woven
Geomembrane Liner	200,000	square foot	$1.65	$330,000	Vendor Quote, Alaska Tent & Tarp	XR5 liner - 30 mil.
Install Geotextile and Geomembrane Liner	1	lump sum	$60,600	$60,600	Vendor Quote, Alaska Tent & Tarp	
Excavate Vegetative Cap Material for Bedding Layer	2,469	cubic yard	$1.79	$4,430	2013 RSMeans, 31 23 16.42 0305	Bulk bank measure, add 15 % for loading onto truck
Haul Vegetative Cap Material to Repository Site	2,469	cubic yard	$7.85	$19,383	2013 RSMeans 31 23 23.20 5050	Assume 2 mile cycle to borrow source. Loess Layer Thickness = 18"
Fill, spread dumped material, by dozer, no compaction	4,938	cubic yard	$2.26	$11,160	2013 RSMeans, 31 23 23.17 0020	
Water truck-soil wetting	2,469	cubic yard	$2.38	$5,877	2013 RSMeans, 31 23 23.23 9000	3000 gal. truck
Seeding	5	acre	$1,250	$5,739	2013 RSMeans, 32 92 19.13 0020	
Excavate Perimeter Ditch	333	cubic yard	$1.56	$520	2013 RSMeans, 31 23 16.42 0305	Assume 900 ft long. Cross Sectional Area = 10 s.f.
Excavate Riprap Material from Borrow Source	500	cubic yard	$1.79	$897	2013 RSMeans, 31 23 16.42 0305	Bulk bank measure, add 15 % for loading onto truck. Assume 18" deep, 9 ft wide, 900 ft long.
Haul Riprap Material to Repository Site	500	cubic yard	$7.85	$3,925	2013 RSMeans 31 23 23.20 5050	Assume 2 mile cycle to borrow source.
Spread dumped material, by dozer	500	cubic yard	$2.26	$1,130	2013 RSMeans, 31 23 23.17 0020	
			DC10a Subtotal	$550,794		

Derived Cost DC10b - Leachate Liner Construction (Alt 3b &3d)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Compact Subgrade	4,033	cubic yard	$3.78	$15,245	2015 RSMeans, 31 23 23.23 6030	towed sheepsfoot, 6" lifts, 4 passes, 5 acre footprint
Spread primary composite loess liner	16,133	cubic yard	$7.18	$115,835	2015 RSMeans, 31 23 23.17 0170	spread fill from stockpile w/ 1-1/2 CY Front End loader, 5 acre footprint, 2' deep layer
Compact loess liner	16,133	cubic yard	$3.78	$60,983	2015 RSMeans, 31 23 23.23 6030	towed sheepsfoot, 6" lifts, 4 passes, 5 acre footprint
Bottom Liner	230,000	square foot	$1.65	$379,500	Vendor Quote	30 mil. XR5, 200,000 sf x 15%
12" drainage layer	8,066	cubic yard	$77	$621,082	2015 RSMeans, 31 05 16.10 0360	spread fill, no compaction w/ 200 HP dozer, 5 acre footprint, 1' deep layer
6" granular protective soil	4,033	cubic yard	$7.18	$28,957	2015 RSMeans, 31 23 23.17 0170	spread fill from stockpile w/ 1-1/2 CY Front End loader, 5 acre footprint, 6" deep layer
Top and Side Liners	250,000	square foot	$1.65	$412,500	Vendor Quote	30 mil. XR5, 212,300 x 15%
Install Top and Bottom Liner	1	lump sum	$121,200	$121,200	Vendor Quote	
Leacahte Collection System	1	lump sum	$69,000	$69,000	Municipal Solid Waste Landfills, Economic Impact Analysis for the Proposed New Subpart to the New Source Performance Standards, U.S. Environmental Protection Agency, June 2014	$12,000 per acre for 5 acre footprint + 15%
leachate collection system QAQC	1	lump sum	$287,500	$500,000	Municipal Solid Waste Landfills, Economic Impact Analysis for the Proposed New Subpart to the New Source Performance Standards, U.S. Environmental Protection Agency, June 2014	$100,000 per acre for 5 acre footprint
Leacahte transfer pipe trench	1,650	foot	$4.44	$7,326	2015 RSMeans, 31 23 16.14 0750	Utility Trenching, with 12HP chain trencher, 8" wide, 36" deep
Leachate transfer pipe	1,650	foot	$220	$363,000	2015 RSMeans, 22 66 53.60 1140	Corrosion resistant pipe, 4"
			DC10b Subtotal	*$2,694,627*		

Derived Cost DC11a - Monofill Concrete Cloth Cover (Alt 3a and b)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Concrete Cloth Shipping	1	Lump	$20,000	$20,000	Vendor Quote, Milliken Concrete Cloth	
Concrete Cloth Materials	30,000	square foot	$7.77	$233,100	Vendor Quote, Milliken Concrete Cloth	Includes all materials including stakes
Concrete Cloth Cover Construction	30,000	square foot	$1.55	$46,500	Vendor Quote, Milliken Concrete Cloth	20% of product cost; assume material
Water truck-cover wetting	7,500	cubic yard	$2.38	$17,850	2013 RSMeans, 31 23 23.23 9000	3000 gal. truck; assume 1/4" thinkness
Excavate Perimeter Ditch for drainage control	333	cubic yard	$1.56	$520	2013 RSMeans, 31 23 16.42 0305	Assume 900 ft long. Cross Sectional Area = 10 s.f.
Excavate Riprap Material from Borrow Source for drainage ditch	500	cubic yard	$1.79	$897	2013 RSMeans, 31 23 16.42 0305	Bulk bank measure, add 15 % for loading onto truck. Assume 18" deep, 9 ft wide, 900 ft long.
Haul Riprap Material to Surface Mined Area for drainage ditch	500	cubic yard	$7.85	$3,925	2013 RSMeans 31 23 23.20 5050	Assume 2 mile cycle to borrow source.
Spread dumped material, by dozer in drainage ditch	500	cubic yard	$2.26	$1,130	2013 RSMeans, 31 23 23.17 0020	
			DC11 Subtotal	$323,922		

Derived Cost DC11b - Remove and offsite disposal of Monofill #2 (Alt 4)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Excavate Contaminated Material and Load Haul Trucks	4,500	cubic yard	$4.29	$19,305	2013 RSMeans, 31 23 16.42 0305	26,040 CY x 15%
Haul Contaminated Material to Repository Site or Solidification Staging Area	4,500	cubic yard	$3.93	$17,685	2013 RSMeans 31 23 23.20 5000	
Spread dumped material, by dozer, no compaction	4,500	cubic yard	$2.26	$10,170	2013 RSMeans, 31 23 23.17 0020	
Compaction- riding, vibrating roller, 12" lifts, 2 passes	4,500	cubic yard	$0.26	$1,170	2013 RSMeans, 31 23 23.23 5060	
Water truck-soil wetting	4,500	cubic yard	$2.38	$10,710	2013 RSMeans, 31 23 23.23 9000	
Purchase Super Sacks	3,000	each	$14.30	$42,900		
Load Super Sacks	4,500	cubic yard	$171.60	$772,200	2013 RSMeans, 31 23 16.42 0305 + $2.50/cy ($10/4cy)	
Load Super Sack Containers on to River Barge	4,500	cubic yard	$1.87	$8,415	2013 RSMeans, 31 23 23.14 5400	
Barge Transport from Red Devil to Seward	4,500	cubic yard	$0	$0	Vendor Quote, Crowley Maritime Corp	
Load Super Sack Containers from Barge to Train	4,500	cubic yard	$4	$18,630	2013 RSMeans, 31 23 16.13 1346	
Train Transport	4,500	cubic yard	$153	$686,340	Vendor Quote, Alaska Railroad	
Hazardous Waste Disposal	910	ton	$230	$209,300	Vendor Quote, Waste Management	
Non-Hazardous Waste Disposal	2,600	ton	$31	$80,600	Vendor Quote, Waste Management	
Excavate Borrow Material for Backfilling	4,500	cubic yard	$1.79	$8,073	2013 RSMeans, 31 23 16.42 0305	
Haul Backfill Material to Excavation Areas	4,500	cubic yard	$7.85	$35,325	2013 RSMeans 31 23 23.20 5050	
Compaction- riding, vibrating roller, 12" lifts, 2 passes	4,500	cubic yard	$0.26	$1,170	2013 RSMeans, 31 23 23.23 5060	Assumes 5% of total excavated area
Grade Backfill Areas to Match Existing Topography	225	square yard	$0.20	$12,397	2013 RSMeans, 31 22 16.10 3300	Assumes 5% of total excavated area
			DC11b Subtotal	*$1,934,390*		

Derived Cost DC12 - Site Restoration (Alt 3a, b, c, d, and 4)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Regrade excavated areas to match existing topography	30000	square yard	$0.20	$6,000	2013 RSMeans, 31 22 16.10 3300	
Seeding	6	acre	$1,250	$7,748	2013 RSMeans, 32 92 19.13 0020	
			DC12 Subtotal	*$13,748*		

Derived Cost DC13a - Construction Completion (Alt 3a, b, c, d)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Erosion and Sediment Controls Removal	4,000	linear foot	$1	$4,400	2013 RSMeans, 31 25 14.16 1000, 31 25 14.16 1250	
Haul Road Removal	1,956	square yard	$9.20	$17,991	2013 RSMeans, 02 41 13.17 5050	
Staging Area Removal	1,111	square yard	$9.20	$10,222	2013 RSMeans, 02 41 13.17 5050	
Dewatering Pad Removal	1,111	square yard	$9.20	$10,222	2013 RSMeans, 02 41 13.17 5050	
Temporary Barge Mooring Removal	1	each	$42,954	$42,954	Engineer Estimate	
River Access Structure Removal	1	each	$32,216	$32,216	Engineer Estimate	
Equipment Decontamination	1	lump sum	$3,189	$3,189	2013 RSMeans, Crew B-1D	1 Laborer + 1 Pressure Washer. $531.41/day. Assume 6 days.
			DC13a Subtotal	*$121,195*		

Derived Cost DC13b - Construction Completion (Alt 4)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Erosion and Sediment Controls Removal	2,000	linear foot	$1	$2,200	2013 RSMeans, 31 25 14.16 1000, 31 25 14.16 1250	
Haul Road Removal	978	square yard	$9.20	$8,996	2013 RSMeans, 02 41 13.17 5050	
Staging Area Removal	1,111	square yard	$9.20	$10,222	2013 RSMeans, 02 41 13.17 5050	
Dewatering Pad Removal	1,111	square yard	$9.20	$10,222	2013 RSMeans, 02 41 13.17 5050	
Temporary Barge Mooring Removal	1	each	$42,954	$42,954	Engineer Estimate	
River Access Structure Removal	1	each	$32,216	$32,216	Engineer Estimate	
Equipment Decontamination	1	lump sum	$3,189	$3,189	2013 RSMeans, Crew B-1D	1 Laborer + 1 Pressure Washer. $531.41/day. Assume 6 days.
			DC13b Subtotal	*$109,999*		

Derived Cost DC14a - Groundwater Monitoring Wells (Alt 3a and b)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Install Groundwater Monitoring Wells	6	ea	$10,000	$60,000	Engineer Estimate	50' depth through bedrock or difficult drilling
			DC14a Subtotal	*$60,000*		

Derived Cost DC14b - Groundwater Monitoring Wells (Alt 3c and d)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Install Groundwater Monitoring Wells	3	ea	$10,000	$30,000	Engineer Estimate	50' depth through bedrock or difficult drilling
			DC14b Subtotal	*$30,000*		

Derived Cost DC15 - Loess cover in surface mining area (Alt 3a, b, c, d, and 4)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Haul Loess Material to Surface Mining Site	8,067	cubic yard	$7.85	$63,326	2013 RSMeans 31 23 23.20 5050	Assume 2 mile cycle to borrow source. 5 acre footprint, Loess Layer Thickness = 12"
Spread loess surface material to surface mining site	8,067	cubic yard	$7.18	$57,921	2015 RSMeans, 31 23 23.17 0170	spread fill from stockpile w/ 1-1/2 CY Front End loader, 5 acre footprint, 1' deep layer
Compact loess material to surface mining site	4,033	cubic yard	$3.78	$15,245	2015 RSMeans, 31 23 23.23 6030	towed sheepsfoot, 6" lifts, 4 passes, 5 acre footprint
			DC15 Subtotal	*$136,492*		

Derived Cost OM1 - Operation and Maintenance Costs (Alt 2)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Mobilization and Demobilization	2	lump sum	$2,000	$4,000	Engineer Estimate	Travel/Lodging/Per Diem
Fence Inspection	2	lump sum	$2,050	$4,100	2013 RSMeans, 01 31 13.20 0120	Assume 1 week. Average rate for field engineer.
Fence Maintenance	1	lump sum	$5,000	$5,000	Engineer Estimate	
Annual Report	1	lump sum	$10,000	$10,000	Engineer Estimate	
			OM1 Subtotal	*$23,100*		

Derived Cost OM2a - Operation and Maintenance Costs (Alt 3)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Mobilization and Demobilization	2	lump sum	$2,000	$4,000	Engineer Estimate	Travel/Lodging/Per Diem
Repository Inspection	2	lump sum	$2,050	$4,100	2013 RSMeans, 01 31 13.20 0120	Assume 1 week. Average rate for field engineer.
Repository Maintenance	1	lump sum	$10,000	$10,000	Engineer Estimate	
Annual Report	1	lump sum	$20,000	$20,000	Engineer Estimate	
			OM2a Subtotal	*$38,100*		

Derived Cost OM2b - Leachate Collection, Offsite Transportation, and Disposal (Alt 3b and 3d)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Leachate Collection	2	lump sum	$4,100	$8,200	2013 RSMeans, 01 31 13.20 0120	Assume 1 week. Average rate for field engineer.
Leachate Transportation	605	Cubic Yard	$330	$199,729	Vendor Quote	Addition of all transportation costs
Leachate Disposal	90,000	gallons	$7	$639,900	Vendor Quote, Waste Management	
			OM2b Subtotal	*$847,829*		

Derived Cost OM3a- Sampling and Analysis (Alt 3a and b)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Mobilized 2 man field crew & expences	1	lump sum	$10,000	$10,000		
Sample and Analyze 10 groundwater samples for metals and TPH	1	lump sum	$4,100	$4,100	2013 RSMeans, 01 31 13.20 0120	Assume 1 week. Average rate for field engineer.
			OM3a Subtotal	*$14,100*		

Derived Cost OM3b- Sampling and Analysis (Alt 3c and d)

Description	Quantity	Unit	Unit Cost	Cost	Reference	Notes
Mobilized 2 man field crew & expences	1	lump sum	$10,000	$10,000		
Sample and Analyze 5 groundwater samples for metals and TPH	1	lump sum	$2,050	$2,050	2013 RSMeans, 01 31 13.20 0120	Assume 1 week. Average rate for field engineer.
			OM3b Subtotal	*$12,050*		