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August 2019
Skagway (Nahku) Ore Terminal, Hazard ID #401

ANCHOR QEA

Remedial Action Options Analysis – DRAFT

Prepared for Alaska Department of Environmental Conservation
On behalf of White Pass & Yukon Route

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Project Number: 180159-02.03
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ABBREVIATIONS

ADEC	Alaska Department of Environmental Conservation
AIDEA	Alaska Industrial Development and Export Authority
AML	Alaska Marine Lines
BMP	best management practice
CAD	Confined Aquatic Disposal
cm	centimeter
COC	contaminants of concern
CSL	cleanup screening level
CSM	conceptual site model
cy	cubic yard
ENR	enhanced natural recovery
ESA	Endangered Species Act
ft	foot
Gateway Project	Municipality of Skagway Gateway Initiative Project
kg	kilograms
mg/kg	milligrams per kilogram
MLLW	mean lower low water
MMPA	Marine Mammal Protection Act
MNR	monitored natural recovery
MOS	Municipality of Skagway
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NCDF	Nearshore Confined Disposal Facility
NMFS	National Marine Fisheries Service
Objective	Remedial Action Objective
Options Analysis	Remedial Action Options Analysis
Ore Basin	Skagway Ore Basin
Ore Terminal	Skagway Ore Terminal
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
project	Skagway Ore Terminal Remediation project
QA/QC	quality assurance/quality control
RMC	residuals management cover
Services	National Marine Fisheries Service and the U.S. Fish and Wildlife Service
sf	square feet
site	Skagway Ore Terminal site
TCLP	toxicity characteristic leaching procedure

USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
Work Plan	Remedial Approach Work Plan
WPYR	White Pass & Yukon Route
WQC	water quality criteria

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Executive Summary

This Remedial Action Options Analysis (Options Analysis) report assesses potential remedial options to address historical sediment contamination associated with spillage from ore loading operations at the Skagway Ore Terminal site (site) located in Skagway, Alaska (Figure 1). This report also summarizes existing site sediment data and physical conditions, provides an overview of the conceptual site model, describes the regulatory framework for site remediation, delineates the remedial footprint, evaluates remedial options to address sediment contamination, and selects a preferred option that meets the site-specific Remedial Action Objectives (Objectives) for the Skagway Ore Terminal Remediation project (project).

Multiple investigations have investigated sediment quality at the site. These investigations have consistently shown that elevated metals concentrations, which are related to historical transfer and spillage of lead and zinc ore concentrates from the ore loader, are present in an area adjacent to the ore loader, and that metals concentrations decrease with distance from the structure.

A site-specific risk assessment was recently performed to evaluate the potential toxicity of elevated concentrations of ore-related metals to benthic organisms, the primary ecological receptor of concern, and assess potential hazards related to local shellfish consumption. The risk assessment concluded that elevated metals concentrations in Skagway Ore Basin (Ore Basin) sediments do not appear to be exerting direct toxicity on benthic organisms (Golder 2018). Removal of some proportion of the contaminant mass would be expected to further reduce the potential uptake of these metals by shellfish.

Despite the findings from the risk assessment that metal contamination in sediment does not pose an unacceptable risk, White Pass & Yukon Route (WPYR) understands that there is strong community interest in remediating site sediments. As such, WPYR is proposing to perform a remedial action, which has been evaluated and selected as part of this Options Analysis, to address legacy contamination in the Ore Basin and obtain closure for a majority of the basin.

As part of the options analysis process, remedial technology options were screened against the project Objectives and additional performance criteria common to remedial actions including effectiveness, permanence, implementability, compatibility with site use, and community acceptance.

The following remedial technology options were evaluated for site sediment:

- No Action
- Institutional Controls
- Removal
- Containment
- Treatment
- Disposal

A combination of technology options consisting of removal via mechanical dredging, ex situ treatment to stabilize the material, and disposal at a permitted upland disposal facility were retained as the preferred remedial option for addressing contaminated sediments associated with spillage from historical ore loading operations. These technologies have been effective in remediating contaminated sediments at other sediment cleanup sites with similar characteristics, and permanently eliminating contaminant mass from aquatic systems. Furthermore, the equipment and expertise for removal and disposal can be mobilized to the site, the technology does not encumber present and potential future site uses, and, based on feedback received during the June 26, 2019 Public Open House meeting in Skagway, removal of contaminated sediment is favored, relative to other options.

The remediation footprint was developed by comparing the relative benefits of removing contaminated sediment from progressively larger areas of the site in an effort to balance the adverse environmental impacts of dredging versus the ecological benefits of contaminant mass removal at the site. The Ore Basin Risk Assessment (Golder 2018) indicated that ore-related metals concentrations in Ore Basin sediments do not pose an unacceptable risk to benthic organisms. As such, the removal action recommended in this options analysis is being conducted in an effort to reduce the overall mass of contaminants in harbor sediment and gain community acceptance. The areas in front of the ore dock were the focus of the analysis because this area is where dredging is feasible without removing existing infrastructure. Contaminant concentrations are higher and accumulated contaminated sediment is observed to be thicker in front of the ore dock compared to under and behind the ore dock.

Based on the results of the contaminant mass removal analysis (Section 6.1), a remediation footprint of 15,000 square feet is recommended, which corresponds with removal of approximately 4,000 cubic yards of sediment. This would result in removal of approximately 79,000 kilograms (85%) of the total mass of lead from accessible areas of the Ore Basin. This removal action will achieve the Objectives by 1) removing the majority of lead from the site; 2) reducing potential human health risks (by reducing surface sediment concentrations); 3) reducing potential risks to benthic invertebrates (by reducing surface sediment concentrations); and 4) removing sediment that could potentially become a source to other areas, does not adversely impact site use, and can gain community and Alaska Department of Environmental Conservation (ADEC) acceptance.

Upon acceptance of the preferred remedial option by ADEC, design documents (i.e., specifications and design drawings) will be developed, project permits will be submitted, and ultimately the remedial action will be implemented.

1 Introduction

This Remedial Action Options Analysis (Options Analysis) report assesses remedial technology options to address historical sediment contamination associated with spillage from ore loading operations at the Skagway Ore Terminal site (site) located in Skagway, Alaska (ADEC Hazard ID #401; Figure 1). This report also summarizes existing site sediment data and physical conditions, provides an overview of the conceptual site model, describes the regulatory framework for site remediation, identifies the remedial footprint, evaluates remedial options to address sediment contamination, and selects a preferred option that meets the site-specific goals (i.e., the Remedial Action Objectives [Objectives]) for the Skagway Ore Terminal Remediation project (project).

This report is being completed on behalf of White Pass & Yukon Route (WPYR), who is taking the lead in addressing legacy ore-related sediment contamination at the site. This report was prepared in accordance with the Alaska Department of Environmental Conservation (ADEC)-accepted Remedial Approach Work Plan (Work Plan; Anchor QEA 2019).

1.1 Purpose

The purpose of this Options Analysis report is to identify, screen, and select a preferred remedial technology (e.g., natural recovery, dredging, capping, etc.) to address legacy sediment contamination in the Skagway Ore Basin (Ore Basin). Additionally, this Options Analysis documents available site information relevant to selecting a preferred remedial technology option, a summary of the project goals, the technical basis for defining the remedial footprint, and the rationale for selecting the preferred remedial option. Remedial technology options are screened against the project Objectives, as described in Section 3, and additional performance criteria common to sediment remedial actions (i.e., per 40 CFR §300.430(e)(7)), including: effectiveness, permanence, implementability, compatibility with site use, and community acceptance. For dredging technologies, contaminant mass removal scenarios are evaluated for currently accessible areas of the site (i.e., the areas where dredging is feasible without removing existing infrastructure). This report also provides the rationale for defining the extent of the remedial footprint to be addressed by the preferred remedial alternatives.

Upon acceptance of the preferred remedial option by ADEC, design documents (i.e., specifications and design drawings) will be developed, project permits will be submitted, and ultimately the remedial action will be implemented. By implementing the selected remedy, WPYR aims to address legacy sediment contamination at the site in a manner that is protective of human health and the environment and can be supported by ADEC, the Municipality of Skagway, the community, other potentially responsible parties, and project stakeholders.

2 Site Background

Several previous investigations have characterized sediment quality and environmental conditions at the site. These studies have documented existing site conditions, current and historical uses, bathymetry, existing structures, geotechnical and sediment transport conditions, the nature and extent of sediment contamination, and the risks to human health and the environment from sediment contamination. The following sections summarize these studies and the conceptual site model (CSM).

2.1 Site Setting and Use

Skagway is the city farthest north in the Southeast Alaska region (Figure 1) and provides the nearest access to tidewater for much of the neighboring Yukon Territory, Canada. The town is at the southwestern end of the 2.5-mile-long Skagway River valley; much of the valley lies between the Skagway River to the northwest and mountains to the southeast. The Skagway River empties into Taiya Inlet at the head of Lynn Canal, the northernmost fjord on the Inside Passage of the south coast of Alaska. Pullen Creek empties into the Ore Basin at the southeast corner of the basin (Figure 2). A municipal wastewater outfall is located within the Ore Basin near the end of the Broadway Dock (Figure 2).

The site is located in the Ore Basin, a deep-water port that transitions sharply from a limited nearshore area into deep marine waters of the Lynn Canal (Figure 1). The Skagway Ore Terminal (Ore Terminal) is located along the northern berth of the Ore Basin (Figure 2). The Ore Terminal is currently used to moor cruise ships and also for a variety of industrial purposes including cargo and petroleum transfer. Cruise ships, which frequently use the dock and walkways at the Ore Terminal for passenger debarkation and embarkation during the cruise season (e.g., from April to October), are a vital part of Skagway's local economy. Petro Marine Services operates a fuel depot on the ore dock, and Alaska Marine Lines (AML) operates a container facility at the northeastern end of the Ore Basin.

Historically, the Ore Terminal was used for transferring ore concentrate (primarily low-grade lead and zinc ore concentrates) from the Yukon Territory, Canada, to ore ships. Ore concentrate was transloaded, using the ore-loading conveyor system (the "ore loader"), to a variety of cargo vessels and barges. The original ore loader was an uncovered conveyor belt, which was enclosed in 1988 as part of Ore Terminal upgrades (Tetra Tech, Inc. 1990a).

The ore loader is not currently in use due to a lack of active mining operations; however, it may be used again, in some capacity, if active mining and shipment resume. The ore loader is owned and operated by Alaska Industrial Development and Export Authority (AIDEA), which is currently evaluating the ore loader structure for potential maintenance (AIDEA 2019). At the time of this report, the future of the ore loader and ore shipment operations are uncertain.

Future uses of the Ore Basin are anticipated to be similar to current uses. WPYR is not aware of any current or future operational dredging needs at the ore dock. No vessel restrictions have been communicated that would necessitate a deeper berth and no dredging to accommodate vessel operational requirements is being considered in conjunction with remedial design. There are numerous proposals to upgrade existing dock structures and modify mooring capacity, including replacing the cruise ship concrete dock (KPFF 2019). Future use of the ore loader is not well defined. WPYR is not aware of a plan to demolish the ore loader and adjoining dock.

2.2 Physical Site Conditions

The Ore Terminal was constructed between 1967 and 1969 by dredging Skagway Harbor and using the dredged material (typically coarse sand to gravel) as fill. As-built drawings are available from 1969 showing a basin-wide dredge depth of -42.5 feet mean lower low water (MLLW; Tippets 1969). As-built drawings also document the constructed riprap and sediment slopes along the perimeter of the Ore Basin, including under the ore loader and behind the existing docks. Current basin depths typically range from -45 to -34 feet MLLW, with a generally more-consistent elevation in the vicinity of the ore loader that ranges from -42 to -38 feet MLLW (TerraSond 2014).

Structures in the Ore Basin consist of numerous docks to support cruise ship operations, but also other local industrial and commercial operations. Structures present along the north side of the basin include a concrete cruise ship dock and dolphins that facilitate cruise ship berthing and the loading/unloading of cruise ship passengers, a timber dock, and the ore loader and walkways (Figure 2). Petroleum transfer are located adjacent to the ore loader through a series of pipelines that feed the adjacent tank farm. On the south side of the basin are the Broadway Dock (used for cruise ships) and the Alaska State Ferry Dock (Figure 2). At the head of the Ore Basin is the AML Dock, which is primarily used for cargo transfer to and from Skagway.

There is a municipal wastewater outfall located on the south side of the Ore Basin (Figure 2). According to discharge permit requirements, bathing and shellfish harvesting for raw consumption from Skagway Harbor are not permitted within the mixing zone, which encompasses most of the Ore Basin (National Pollutant Discharge Elimination System Permit No. AK002001-0).

The slope under the ore loader consists of riprap on the upper portion of the slope that terminates in a constructed keyway at an approximate elevation of -12 feet MLLW. Below the riprap, the slope has been characterized as deposited sediment overlying a constructed slope of 2.75 horizontal to 1 vertical (2.75H:1V) down to the basin floor (Tippets 1969). Due to the inaccessibility of this slope under and behind the ore loader and associated structures (collectively referred to here as "underpier") due to the high density of aging pilings, lack of supporting infrastructure, and unsafe underpier conditions for investigative sampling, minimal information exists regarding sediment conditions or quality in these areas.

A preliminary review of available structural (KPFF 2019) and geotechnical information (Hart Crowser 2019) was conducted to identify potential impacts of remediation on adjacent structures and provide supporting information for grain size and slopes. No detailed engineering analysis of existing structures has been performed; it is assumed that the remedial action will be confined to currently accessible areas of the Ore Basin and will not impact existing structures. If sediment removal is carried forward as the preferred remedial action, potential impacts to structures and the adjacent slope(s) will be evaluated during design.

A recent sediment transport analysis for the Ore Basin (Golder 2018, Appendix A) concluded that the Ore Basin is predominantly depositional and that fine-grained sediments from the Skagway River gradually accumulate in the Ore Basin over time, particularly in the area adjacent to the ore loader and along the toe of the slope. That conclusion is supported by changes in site bathymetry over time and recent subsurface sediment core logs that show a relatively thick (greater than 6 feet) unit of soft, fine-grained silt and sand over a dense gravelly sand, which is considered to be native harbor material, near the face of the ore dock. The sediment transport analysis also identified that vessel propeller wash scour is capable of resuspending and redistributing surficial sediments in some areas of the Ore Basin (Golder 2018, Appendix A). Propeller wash scour-like depression features were identified in three localized areas away from the face of the ore dock (Golder 2018, Appendix A).

Ore Basin sediment lithologies are characteristic of a depositional tidal environment that has replaced a high-energy fluvial and deltaic environment. Based on review of sampling logs from the *Sediment Characterization Report* (Anchor QEA 2015) and site *Risk Assessment* (Golder 2018), surface sediments in the Ore Basin typically consist of fine-grained silts with organic material overlying silty sand just below the surface that sits atop a thick sequence of dense gravelly sand that is considered to be native (i.e., deposited prior to construction of the harbor). The finer-grained surficial material is thickest adjacent to the face of the ore dock at the toe of the slope under the ore loader, with core logs showing deposition to be greater than 6 feet in some places.

In nearly all of the observed cores from the aforementioned two studies, contamination by ore-related metals was strongly associated with the finer-grained silt unit, although not necessarily at the surface. Golder (2018) found lower concentrations of ore-related metals in the upper 30 centimeters (cm) of sediment, and both Anchor QEA (2015) and Golder (2018) found only low metals concentrations in the deeper gravelly sand unit assumed to be native material. The nature and extent of sediment contamination is further described in Section 2.3.

Subsurface sediment conditions are not well understood for areas under and behind the ore dock and loader structures due to challenging access conditions and limitations of sampling techniques that can be deployed in these areas. Tetra Tech (2008) performed surface sediment sampling behind the ore dock in 2007 at multiple locations but was unable to collect subsurface core samples suitable for analysis in this area, despite multiple attempts, "due to the coarse substrate" encountered at many of the locations within the top 1 foot. One core sample (SH 8) was collected by Gubala (2013) to a reported depth of 4 feet (120 cm); however, no documentation of sediment conditions behind the ore dock was provided in the report, aside from general statements regarding a coarse sand layer that was reportedly encountered at the base (approximately 3 to 4 feet below the mudline) in some of the attempted core samples throughout the Ore Basin. Based on the bathymetry changes in the Ore Basin and conclusions from the sediment transport analysis performed by Golder (2018), it is assumed that substrate behind the ore dock and in the ore dock underpier is composed largely of accumulated sediments that overlie a native gravelly sand unit at unknown depth.

2.3 Existing Site Sediment Data Summary

Several previous investigations have characterized sediment quality at the site. These studies are divided into the following two categories based on data quality and recency:

- **Historical studies**, which are those completed more than 7 years ago, have been used to characterize harbor sediments and have questionable or low data quality (e.g., outdated sampling and/or analytical methods, uncertain sample locations/depths, and insufficient data quality assurance/quality control [QA/QC]).
- **Design-level studies**, which are those completed within the last 7 years, have high data quality, appear more representative of current conditions, and are considered usable for remedial design.

Sediment sampling locations from historical and design-level studies are shown in Figure 3.

2.3.1 Historical Sediment Studies

Multiple sediment investigations have been conducted throughout the Ore Basin and Skagway Harbor since the early 1980s. Table 2-1 provides a summary of the historical sediment studies and data types that have been reviewed as part of this report. Sediment sample locations from historical studies are shown in Figure 3. Surface sediment samples typically refer to samples collected from the top foot below the mudline, while subsurface samples are those that have been collected using a coring device or are from deeper than 1 foot below the mudline, although most historical subsurface core samples are from less than 2 feet below the mudline.

Table 2-1
Historical Sediment Investigations

Study	Sediment Chemistry		Toxicity Testing
	Surface	Subsurface	
Robinson-Wilson and Malinkey 1982	X		
Steffen, Robertson, and Kirsten, Inc. 1989	X	X	
Tetra Tech 1990a,b	X		
Dames & Moore 1995	X*	X*	
PND 1999	X		
PND 2005	X	X	
URS 2006	X*	X*	
Gubala 2007	X	X	
Tetra Tech 2008	X	X	X
Tetra Tech 2009	X*	X*	
Gubala 2011	X	X	
Gubala 2013	X	X	

Note:
* Studies with a limited list of analytes

These historical studies identified contaminants of potential concern in Ore Basin sediments, including metals associated with ore concentrates (e.g., lead, zinc, mercury, and copper), as well as polycyclic aromatic hydrocarbons (PAHs). Multiple studies observed that lead and zinc concentrations were highest adjacent to the ore loader and decreased with distance from the ore loader and ore dock. Only one historical study included sediment toxicity testing (Tetra Tech 2008); that study showed that adverse effects were not related to metal concentrations in sediment. According to Tetra Tech (2008), surficial sampling results from their 2007 investigation indicated a steady decrease in surficial metals concentrations over the past two decades in Skagway Harbor, likely as a result of natural attenuation.

Subsurface sediment quality in areas behind the ore dock is not well understood. Notably, Tetra Tech (2008) was unable to collect subsurface core samples suitable for analysis, despite multiple attempts, "due to the coarse substrate" encountered at many locations. One core sample (SH 8) was collected by Gubala (2013) to a reported depth of 4 feet (120 cm); the concentrations of ore-related metals exceeded the National Oceanic and Atmospheric Administration's Threshold Effects Levels at the deepest interval (approximately 3 to 4 feet), although no core logs, QA/QC samples, or further documentation are available to confirm or qualify the reported results. Only limited data are available (e.g., less than ten samples); however, surface sediment samples from behind the ore dock have elevated ore-related metals concentrations in the area surrounding the ore loader (Dames & Moore 1995; Tetra Tech 2008; Gubala 2013).

Although useful in understanding the nature and extent of contamination in the Ore Basin as well as data trends over time, the historical studies listed in Table 2-1 have questionable data quality (e.g., outdated sampling and/or analytical methods, uncertain sample locations/depths, and insufficient data QA/QC) and are therefore not considered acceptable for use in remedial design. For remedial design, which is the next step in the remediation process, a high level of detail and certainty in the data is needed, including analytical, field collection methods, and positioning accuracy. In many cases, the detailed analytical or core logs from these studies were not available for review. For the previous historical data sets, the chemistry and depth information has been relied upon as presented in the tables by the original authors but cannot be corroborated and may not match other, more recent results.

2.3.2 Design-Level Sediment Studies

The two investigations with data quality suitable for remedial design are the *Sediment Characterization Report* (Anchor QEA 2015) and the *Skagway Ore Basin Risk Assessment* (Golder 2018).

Table 2-2
Design-Level Sediment Investigations

Study	Sediment Chemistry		Toxicity Testing
	Surface	Subsurface	
Anchor QEA 2015	X	X	
Golder Associates 2018	X	X	X

In 2015, the Municipality of Skagway's (MOS) Gateway Initiative Project (Gateway Project) characterized sediments throughout the site to define the nature and extent of sediment contamination in the Ore Basin and identify a potential option for active remediation. That study, which was performed consistent with the ADEC-approved Gateway Sampling and Analysis Plan (Anchor QEA 2014), consisted of twenty subsurface sediment core locations throughout the Ore Basin that were sonic-driven to a maximum depth of 15 feet below the mudline and sampled in 2- to 4-foot intervals. Samples were analyzed for priority pollutant metals, PAHs, total solids, total organic carbon, and total sulfur. Several project-specific composite samples were additionally tested for tributyltin, polychlorinated biphenyl (PCB) Aroclors, and dioxins/furans. The results of that study (*Sediment Characterization Report: Skagway Ore Dock and Small Boat Harbor Dredging*; Anchor QEA 2015) were accepted by ADEC and indicated that a majority of Ore Basin sediments were below example risk-based cleanup levels (e.g., the cleanup screening level [CSL] from Washington State Sediment Management Standards), with the exception of metals-impacted sediments in a localized area adjacent to the ore loader (Anchor QEA 2015). The sediment impacts (primarily lead and zinc, and to a lesser degree mercury and PAHs) were typically observed in the top 4 feet below the mudline, were concentrated in the area adjacent to the ore loader (e.g., at stations SOD-01, -02, -03, and -05; Figure 3) and are bounded at depth by clean samples at the bottom of the core (i.e., samples with metals concentrations below the example screening levels discussed in Section 2.3.3) (Anchor QEA 2015).

Leachability testing was also conducted by Anchor QEA as part of the Gateway Project to provide input for dredged material disposal evaluations and because this testing is typically required by disposal facilities as part of characterization of the material. When compared against applicable waste thresholds, toxicity characteristic leaching procedure (TCLP) results exceeded the federal criterion (5.0 milligrams per liter) for lead. As a result, dredged materials from the Ore Basin (i.e., within the Gateway Project's preliminary dredge footprint) were not recommended for beneficial use as upland fill without treatment.

Golder conducted both surface and subsurface sediment core sampling throughout the Ore Basin as part of the Skagway Ore Basin Risk Assessment (Golder 2018). Numerous surface and subsurface sediment stations were sampled for analysis of metals, PAHs, total and fecal coliforms, and sewage indicators. Coring was completed to a maximum depth of 9 feet below the mudline using direct-push drilling methods (Golder 2018). Similar to the Anchor QEA (2015) study, this investigation found samples with ore-related metals (e.g., lead, zinc, mercury, silver, and copper) at concentrations exceeding the screening levels adjacent to the ore loader (Golder 2018; see Section 2.3.3 for a discussion of screening levels). Elevated concentrations were typically found in the organic silt unit (shallow subsurface samples) as well as some samples in the silty sand unit to a maximum depth of 7.7 feet below the mudline, with the highest concentrations occurring adjacent to the ore loader (Golder 2018). The locations with high concentrations of lead corresponded to those with high concentrations of zinc, mercury, and cadmium (Golder 2018). Samples from the majority of the Ore Basin had lead and zinc concentrations below the screening levels. Samples were also analyzed for PAHs, which were typically below screening levels with the exception of two samples near the ore dock. Golder (2018) noted that surface sediment concentrations were lower than those observed in multiple historical studies. Risk assessment conclusions from this study are discussed in Section 2.4.

2.3.3 Data Screening Criteria

The CSL is used in this Options Analysis as a screening tool for ore-related metals (e.g., lead and zinc) contamination in site sediments. The CSL is an example marine sediment cleanup level (from Chapter 173-204 Washington Administrative Code, 2013 revision) and were approved by ADEC as appropriate screening levels in the absence of an analogous state sediment standard.

Concentrations at or below the CSL are predicted to have minor adverse effects on benthic communities relevant to the Puget Sound in Washington (Barrick et al. 1988). There is not an analogous sediment cleanup value available in Alaska regulatory guidance. According to *Sediment Quality Guidelines Options for the State of Alaska* (ADEC 2001), in the absence of state sediment cleanup criteria, alternative screening/cleanup criteria, such as the above described marine sediment cleanup level from Washington State, may be used, as appropriate, in consultation with ADEC. However, although used for data screening purposes to perform the lead mass calculation described in Section 6.1, the CSL does not represent a site-specific risk-based threshold value (or cleanup level) for the Ore Basin. As such, exceedance of the CSL, by any chemical, does not mean that a risk is present. Results of the site-specific risk assessment are discussed in Section 2.4.

2.4 Risk Assessment Summary

A site-specific risk assessment (*Skagway Ore Basin Risk Assessment*, Golder 2018) was performed to evaluate the toxicity of elevated concentrations of ore-related metals (e.g., lead, zinc, and mercury) in Ore Basin sediments to benthic organisms and assess potential hazards related to shellfish consumption by humans and wildlife. The risk assessment, which was approved by ADEC, confirmed the presence of the elevated metals concentrations in a focused area adjacent to the ore loader, with most of the volume in the open-water area in front of the ore dock. The risk assessment concluded that elevated metals concentrations in Ore Basin sediments do not appear to be exerting direct toxicity on benthic organisms (Golder 2018). In addition, a sediment transport analysis performed by Golder (2018) concluded that the site is predominantly depositional and that fine-grained sediments from the Skagway River gradually accumulate in the Ore Basin over time, especially near the ore dock. This analysis suggests that cleaner river sediments are being deposited over historically contaminated sediments in the Ore Basin.

The risk assessment concluded that the concentrations of ore-related metals appeared to be decreasing over time. The current tissue concentrations in shellfish did not present a risk for wildlife consumption. A conservative screening of available tissue concentrations was also conducted with respect to consumption by humans. This screening was not able to conclusively determine that tissue concentrations were safe for unrestricted human consumption because of the limited number of samples available. The risk assessment concluded that ore-related metals were not presenting risks to benthic organisms or wildlife consuming shellfish. A detailed risk evaluation with respect to shellfish consumption by humans was described as an option but would require collaboration with stakeholders to understand risks in the context of both the natural background concentrations of metals, but more importantly, in the context of other contaminant inputs to the harbor. In the absence of that level of refinement, Golder (2018) acknowledged there were practical considerations regarding the need to dredge some parts of the Ore Basin. Removal of a portion of the mass of metals related to ore concentrates would be expected to further reduce uptake of these metals by shellfish.

2.5 Conceptual Site Model

The CSM for the Ore Basin is based on an interpretation of the site conditions, previous investigations, and risk assessment findings described in the previous sections. The CSM is provided here to summarize relevant information from previous site investigations that will influence remedial design choices.

Contaminants of potential concern in the Ore Basin include ore-related metals (e.g., lead, zinc, and mercury) and PAHs. This remedial options analysis is focused on addressing historical sediment contamination associated with ore-related metals. Numerous studies have confirmed the presence of metals in the Ore Basin, with the highest concentrations observed in the shallow subsurface sediments adjacent to the ore loader.

Sediment contamination in the Ore Basin has been associated with historical ore transfer operations at the Ore Terminal facility. The primary point sources of historical ore-related metals contamination in the harbor are considered to be periodic spills of ore concentrates from the ore loader (prior to its enclosure in 1988) during loading of ore concentrate material to barges and other vessels in the Ore Basin, as well as fugitive dust releases at the ore dock. These ore-related contaminants (e.g., lead and zinc) settled to the sediment surface. It appears that, based on their distribution at the site, these contaminants have not redistributed significantly and remain close to where they were originally deposited, creating "hot spots" of contamination in sediment near the point sources.

Based on the findings of a recent sediment transport analysis, clean sediment from the Skagway River is being deposited into the Ore Basin on top of the historical contaminated sediment; this clean sediment is contributing to natural recovery of Ore Basin sediments, especially near the ore dock (Golder 2018).

The *Ore Basin Risk Assessment* (Golder 2018) identified several receptors of potential concern. These include people (Skagway residents, seasonal residents, and recreational fishermen) who come into direct contact with site sediments or consume local fish or shellfish; local benthic and epibenthic invertebrates (e.g., crabs, shrimp, clams, and mussels) that live or forage in Ore Basin sediments; and fish and wildlife that consume these shellfish and fish. The risk assessment was performed to evaluate the toxicity of elevated concentrations of ore-related metals to benthic organisms, and assess potential hazards related to shellfish consumption by wildlife or humans. The risk assessment concluded that elevated metals concentrations in Ore Basin sediments do not appear to be exerting direct toxicity on benthic organisms or presenting risk to wildlife (Golder 2018). Ore-related metals are accumulating in shellfish, although concentrations appear to be declining over time. As such, removal of some proportion of the contaminant mass would be expected to further reduce the potential uptake of these metals by shellfish (Golder 2018).

3 Remedial Action Objectives

Based on community interest in performing a site cleanup to address legacy contamination in the Ore Basin and the understanding that the risk assessment indicates metals contamination does not pose an unacceptable risk, the following are WPYR's objectives for the proposed remedial action, as defined in the ADEC-accepted Work Plan (Anchor QEA 2019). These Objectives are used to guide selection of the preferred remedial option and will be used to inform subsequent design decisions and ultimately measure the success of the remedial action:

- **Objective 1:** Remediate the majority of the mass of sediment contamination associated with spillage of historical ore concentrates in areas of the Ore Basin where metals-contaminated sediment is accessible for remedial action
- **Objective 2:** Reduce potential human health risks associated with the consumption of resident Skagway shellfish by remediating the mass of legacy contaminants in Ore Basin sediments
- **Objective 3:** Reduce potential risks to benthic invertebrates by reducing the mass of legacy contaminants in Ore Basin sediments
- **Objective 4:** Remediate source areas of metals contamination that could potentially spread to adjacent areas that currently are not contaminated and/or have lower risks for benthic and human receptors
- **Objective 5:** Implement a remedial action that does not adversely impact existing or reasonably anticipated future harbor operational uses, including existing or reasonably anticipated infrastructure and cruise ship vessel calls
- **Objective 6:** Implement a remedy that can gain community and ADEC acceptance

4 Regulatory Considerations

Alaska does not have a framework for screening, assessment, and remediation of contaminated sediment. According to an ADEC Sediment Quality Guidelines Technical Memorandum (ADEC 2013), "In the absence of such a framework and for consistency within the Contaminated Sites Program, project managers should consult with their supervisors on when and how to evaluate sediment and/or sediment contamination." As such, WPYR has engaged ADEC regarding an approach to address sediment contamination associated with historical Ore Terminal operations. A Work Plan (Anchor QEA 2019) for the site was developed by Anchor QEA on behalf of WPYR and was reviewed and accepted by ADEC. That Work Plan provided a framework (i.e., the options analysis) for developing and selecting an appropriate remedial action for the site that can be reviewed and accepted by ADEC, the public, and other project stakeholders.

To date, ADEC has not adopted numeric sediment quality standards for the evaluation of impacts to aquatic life. However, ADEC Contaminated Sites Remediation Program developed the *Sediment Quality Guideline Options for the State of Alaska* (ADEC 2001), a technical report that recommends a range of potentially applicable sediment screening criteria (e.g., to determine if further studies are warranted). According to that ADEC report, the *Skagway Ore Basin Risk Assessment* (Golder 2018) would be considered a site-specific, second tier investigation, which effectively supersedes any example screening criteria (which are not site-specific). ADEC (2001) recommends that a "weight-of-evidence" approach be used for "final, site specific decisions in regards to sediment contamination." This options analysis is intended to provide this weight of evidence approach to decision making for addressing sediment contamination associated with historical Ore Terminal activities.

5 Identification and Screening of Remedial Technology Options

This section reviews available remedial technologies to address historical sediment contamination at the site, identifies and screens out those that are not applicable, and selects technologies to be carried forward in developing a preferred remedial option. The focus of this section is on remedial technologies that are feasible and could be applied to the site, based on experience with similar projects and best professional judgment.

5.1 No Action

No Action is a standard baseline comparison when remedial actions are proposed; however, No Action is not a feasible option to meet the project Objectives, particularly the intent to reduce both the mass of sediment contamination associated with historical ore dock operations (Objective 1) and reducing environmental risks by reducing the mass of legacy contamination (both to human health and to benthic organisms; Objectives 2 and 3). As such, No Action is not carried forward.

5.2 Institutional Controls

Institutional controls are legal or administrative tools or actions taken as part of a response action to reduce or minimize the potential for human health exposure to sediment contamination and ensure the long-term integrity of a remedy. Institutional controls may include, but are not limited to, the following:

- Proprietary controls, such as use restrictions and maintenance agreements, site access, and security measures, and operational controls to minimize the disturbance of sediments in active operational areas
- Informational devices, such as environmental monitoring requirements and notification of waterway users and seafood consumption advisories, public outreach, and education

Institutional controls alone are not considered to be a proven and reliable technology for achieving the project's Objectives and protecting human health and the environment. Institutional controls are most often used in the following situations:

- In conjunction with remedial technologies that isolate or leave contaminated sediments in place
- In locations where sediment contamination cannot be remediated through active measures due to site constraints
- In circumstances where potential uptake of contamination in fish and shellfish are expected to pose risks to human health for some time in the future

Such actions do not reduce the toxicity, mobility, or volume of contaminants; therefore, when using institutional controls alone, effectiveness is considered to be low. Costs are also expected to be low and are primarily related to administrative and legal costs, as well as potential long-term monitoring costs.

Institutional controls are retained as a remedial tool when applied in conjunction with other active remedial technologies, but the project would be designed in a way to minimize institutional controls, to the extent practicable, to limit potential impacts to future development at the ore dock. Based on discussions with ADEC, it is expected that institutional controls would be applied to areas of the site that are not currently accessible to facilitate site closure or until these areas can be addressed.

5.3 Natural Recovery

Natural recovery is the process by which contaminant concentrations in sediment are reduced through a combination of physical, biological, and chemical processes so that surface sediment concentrations reach acceptable levels within a reasonable timeframe (e.g., on the order of up to 30 years). Physical processes act to either bury surface sediment with newly deposited sediments or mix surficial sediment with deeper subsurface sediments through bioturbation, propwash, or other mixing influences. The two types of natural recovery (monitored natural recovery [MNR] and enhanced natural recovery [ENR]) are discussed below.

5.3.1 Monitored Natural Recovery

MNR refers to the beneficial effects of natural processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants of concern (COCs; USEPA 2005). These processes include biodegradation, diffusion, dilution, sorption, volatilization, chemical and biochemical stabilization of contaminants, and burial by natural deposition of cleaner sediments. The acceptability of using MNR as a remedial technology is highly dependent upon site physical processes, chemical makeup, potential for biodegradation, and ongoing natural deposition of clean off-site sediment that would support natural recovery.

Although MNR has been shown to be an effective remedial technology at many remediation sites, this site may not be a good candidate for MNR because MNR does not achieve all of the project Objectives, particularly the objective to reduce the mass of sediment contamination associated with historical ore dock operations (Objective 1) and reducing environmental risks by reducing the mass of legacy contamination (both to human health and to benthic organisms (Objectives 2 and 3).

The MNR technology is retained only for comparison with other remedial technologies, using specific evaluation criteria, to help select the preferred remedial option for the site (see Section 5.8). MNR may also be applicable in areas of the site where reduced levels of metals have been observed and deposition from the Skagway River is occurring.

5.3.2 Enhanced Natural Recovery

ENR is similar to MNR, but typically refers to placing a layer of clean material (usually sand) on top of sediments with relatively low contaminant concentrations to speed up (or enhance) the natural recovery process. This can occur through several processes, including mixing from bioturbation of the clean material with the underlying contaminants (USEPA 2005). This clean layer is not intended to provide complete containment of the underlying contaminated sediments but generally provides for a cleaner substrate and sufficient initial isolation that, along with future deposition of new material, reduces migration and physical contact with contaminants.

The degree of improvement depends on surface sediment concentrations prior to placement of the clean material, anticipated mixing that may occur through bioturbation, and erosive (e.g., propwash) and depositional (e.g., sedimentation) processes. In general, the clean material reduces average surface sediment concentrations and levels of exposure to organisms. However, there is no mass reduction in contaminants because the contaminants are left on site and, therefore, there is a potential for vessel propwash to scour portions of a placed ENR cover. Because ENR requires placing a layer of clean material over contaminated sediment, there is also a resulting reduction of water depth, which may not be suitable in areas of active vessel operations.

ENR has been shown to be an effective remedial technology at many remediation sites; for this site, however, ENR may not be a good candidate due to the elevated contaminant concentrations in some areas of the Ore Basin, no reduction in contaminant mass, and significant current and future anticipated vessel use with potential for mixing.

The ENR technology is retained only for comparison with other remedial technologies, using specific evaluation criteria, to help select the preferred remedial option for the site (see Section 5.8).

5.4 Removal

Removal of contaminated sediments is the most commonly applied sediment remediation technology, using either mechanical or hydraulic dredging equipment. Removal is always combined with some form of disposal option (e.g., upland disposal facility, aquatic ex situ containment, ex situ treatment with disposal, or ex situ treatment with beneficial use).

The effectiveness and accuracy of dredging depends upon many factors, including current velocities, dredged material characteristics, presence/abundance of debris, operator skill, positioning method and accuracy, and type of dredging equipment used. Because of the inherent inaccuracy in dredging, a remedial dredge plan will take into account uncertainties with the elevation of contamination and the ability of dredging equipment to remove sediment to a specified elevation or cut thickness. Equipment tolerance is typically built into a dredge plan by inclusion of an overdredge allowance, which increases the total actual volume of sediment removed as part of any dredge plan design. The overdredge allowance may vary but typically ranges from 6 inches to 1 foot for remedial dredging projects.

Regardless of the dredging method and use of dredging best management practices (BMPs), short-term water quality impacts and residual contamination post-dredging are inherent to the dredging process and need to be planned for. Dredging BMPs that are typically employed to help comply with water quality criteria include operational controls, barriers (such as silt curtains), specialized dredging equipment (such as closed buckets), and water quality monitoring.

All dredging projects result in some degree of resuspension, release, and residuals (NRC 2007). Residual contamination is defined as both contaminated sediment that remains un-dredged due to the inability to be 100% accurate in delineating all of the contaminated sediment (i.e., missed inventory), and contaminated sediment that was resuspended during dredging and that could not be fully captured (i.e., generated residuals) due to the limits of removal equipment in preventing loss of sediment during the action of dredging. The need to address residual contamination depends upon the concentrations and thicknesses of residuals that remain post-dredging. However, empirical data from numerous sediment remediation projects indicate that residual contamination is a common occurrence and that sites with high concentrations are unlikely to achieve their cleanup levels with dredge technology alone (Patmont and Palermo 2007).

As a result, residual management strategies are typically employed in conjunction with dredging activities. For this site, due to the presence of high concentrations of contaminants and anticipated residuals contamination, it is assumed that a clean sand layer, known as residuals management cover (RMC), will be a part of the remedial actions. RMC is a standard part of remedial dredging projects that will be placed on top of the dredged footprint after dredging is completed (see Section 7.1.1).

5.4.1 Mechanical Dredging

Common mechanical dredge types include barge-mounted cranes (often referred to as a clamshell dredge, due to its standard use of a clamshell bucket), backhoe excavator, dipper, dragline, and bucket ladder. Barge-mounted cranes (using various types of buckets) are frequently used in the United States. In shallower dredge depths, backhoe excavators outfitted with dredging buckets (often termed "instrumented backhoes") have also been used.

Mechanical dredges are designed to remove sediment at or near in situ density, although some amount of excess water is typically entrained in the dredge bucket as it closes and is lifted up through the water column. The quantity of water generated using mechanical dredging is orders of magnitude less than that generated with hydraulic dredging. Mechanical dredges are capable of effectively removing consolidated sediment, debris, and other materials, such as piling and riprap.

The barge-mounted crane can use different types of buckets or attachments to dredge or assist with demolition activities.

A typical construction sequence for mechanical dredging in the Ore Basin would be as follows (assuming upland disposal):

- Dredge contaminated sediment
- Place dredged sediment in a haul barge
- Transport dredged sediment to an off-site offloading facility and/or temporary stockpile/staging area
- Offload dredged sediment to a stockpile/staging area for either passive or active dewatering (dewatering methods may include working the sediment, mixing in additives, filter or belt presses, hydrocyclones, or other methods), as required. The contractor may elect to address this on the barge prior to transportation.
- Treat dredged sediment effluent from the stockpile and discharge to receiving waters or approved publicly owned treatment works
- Transport dredged sediment over land by truck or rail to disposal facility
- Dispose of dredged sediment at a permitted upland disposal facility

Mechanical dredging is expected to be successful at the site because of its effective removal of consolidated sediment, debris, and other materials, and the ability to relocate, thus reducing the potential impact to existing site operations (i.e., can be moved to not interfere with basin vessel traffic).

Mechanical dredging is retained for further consideration for comparison with other remedial technologies, using specific evaluation criteria, for the selection of the preferred remedial option for the site (see Section 5.8).

5.4.2 Hydraulic Dredging

Hydraulic dredges are barge- or float-mounted and typically use centrifugal pumps to "vacuum up" sediment. The most common types of hydraulic dredges are suction, cutterhead suction, or trailing suction hopper dredges. Hydraulic dredges create a slurry (i.e., mixture of sediment and water) that is pumped through the transport pipeline and discharged out of the pipeline, typically into a settling basin. A settling basin or other slurry retention structure is needed to allow the solids to settle out of the slurry, or to act as a buffer/holding area if active dewatering is used. Hydraulic dredging results in a large quantity of water that needs to be managed, typically requiring large upland areas suitable for use as settling basins (i.e., flat and contiguous) that have capacity to hold all of the dredge slurry generated during the time it takes for the first materials to settle. Alternatively, the slurry could be pumped into geotubes, which are large bags that contain the solids but allow the water to drain out, typically over the course of several weeks. The water is then collected, tested, and treated, if necessary.

Hydraulic dredges are less commonly used for contaminated sediment dredging than mechanical dredges, particularly in open-water accessible areas, due to having to manage large quantities of water that typically can be contaminated through the slurrying process that occurs during hydraulic dredging. Hydraulic dredges can generally dredge at a higher production rate than mechanical dredges if there are not limitations on production at the discharge end (e.g., settling basin flow-through rate) and if the site has minimal debris and low variability in bathymetry.

Debris presence is a significant issue due to a hydraulic dredge's inability to transport debris through a pipeline and because debris can damage or jam the cutterhead. A highly variable bed surface can also be difficult for a hydraulic dredge to work in because the hydraulic dredge typically swings side to side at a fixed elevation in order to remove the sediment.

Hydraulic dredging methods are ineffective at removing dense sediment. Based on sampling results, contamination extends into a dense sand unit in some areas of the Ore Basin. Successful removal of contaminants in dense sediments is not possible using hydraulic dredging methods.

Because hydraulic dredges transport the sediment through a pipeline (typically floating), hydraulic dredging can be difficult or impractical to use in active navigation areas where the floating pipeline may interfere with navigation. Pipeline pumping distance is also a factor in production rates and implementability; greater pipeline distances may require booster pumps and may be a greater impediment to navigation.

Hydraulic dredging, as a primary removal technology, is not considered practicable for this site due to the associated logistical challenges, water generation and management issues, and the widespread nature of mechanical dredging equipment that can address sediments in the open-water portions of the site with reduced logistical complications. Therefore, hydraulic dredging is not retained for comparison with other remedial technologies in Section 5.8 in the open-water portions of the site (out front of the ore dock). The next section addresses underpier considerations.

5.4.3 Underpier Dredging

Removing contaminated sediment from behind and under the ore dock and ore loader structures (i.e., underpier areas) presents significant engineering and construction technical challenges, high risk of structure damage, and higher safety risks to construction workers. Typically, the approach to address contaminated sediment under existing structures is to time the remedial action with future demolition and/or reconstruction of the existing structures in order to gain access to those inaccessible areas. This section considers the feasibility and risk for conducting underpier dredging at the Ore Terminal while the ore dock remains in place.

The feasibility to conduct underpier dredging by working around existing structures is dependent upon the pier design (e.g., pile spacing, deck elevation, and other obstructions), presence of debris and broken-off pilings, underpier slope geotechnical conditions, and ability of equipment to access the underpier area without potentially damaging the existing structure. Mechanical underpier dredging is not typically considered for underpier removal because it typically poses unacceptable risks (for damaging the existing structures or underpier riprap slopes) and environmental concerns (associated with sediment resuspension), as a result of dragging sediment from the underpier area downslope into the toe of slope where additional equipment can be used to re-dredge the sediment and lift it to a haul barge. Specialized equipment with long-reach capabilities would be needed to perform the dredging, given the overhead constraints of the ore dock structures. Such equipment may include a barge-mounted Gradall (an excavator with a telescoping boom), a barge-mounted long-reach excavator, or similar equipment, assuming this equipment would have sufficient reach to access sediments in harbor water depths (i.e., approximately 40 feet). In addition, assuming a contractor would be able to access underpier sediment through the current piling spacing, the contractor would then be required to use careful dredging techniques in underpier areas and within a specified structural offset from the structure and existing piling to avoid structural damage. If removal is conducted for the open-water portion of the site, it can be assumed that some amount of slough would occur naturally and would be removed as part of the remedial action, functionally addressing a portion of the underpier sediment without requiring direct access to that area.

Diver-assisted hydraulic dredging is an underpier dredging technique that has been implemented for limited contaminated sediment removal under piers (e.g., Esquimalt Graving Dock, Victoria, British Columbia, 2013 to 2014; Sitcum Waterway Remediation, Tacoma, Washington, 1995). However, diver-assisted dredging has significant issues, including extremely low production rates, inability to achieve depth of removal or to remove consolidated sediment, inability to remove debris, and diver safety concerns. Because the size of diver-assisted equipment is relatively small, the equipment has limited ability to dig materials and typically has only been used to remove surficial loose unconsolidated sediment. It is assumed that much of this material, if present, would slough into the dredge area upon completion of mechanical dredging and be removed through mechanical methods. Because of the low production rates associated with diver-assisted hydraulic dredging, dive time needed to complete underpier work can be very long. As such, diving risks associated with injury and death during construction would need to be carefully considered because commercial diving is a high-risk activity. This safety risk has to be weighed against the potentially low environmental benefit gained by removing only surficial sediment underpier, and the long-term risk of leaving contaminated sediment in the underpier areas. Underpier hydraulic dredging has many of the same considerations as standard hydraulic dredging, such as use of a hydraulic pipeline, extensive water management needs, and the need to dewater the sediment, but with significant additional technical and safety challenges.

Underpier dredging is not carried forward for the site as a remedial technology under or behind the ore dock, based on the lack of adequate access under the structure, the potential to damage the existing structures, and likely inability to effectively remove contaminated sediment under existing structures. However, hydraulic underpier dredging is retained for comparison with other remedial technologies, using specific evaluation criteria, to help select the preferred remedial option for the site (see Section 5.8).

5.5 Containment

Containment options isolate in situ contaminants from the marine environment and prevent direct contact with aquatic biota or humans. Engineered capping and sheetpile wall containment were considered as containment technologies for the site, as described below.

5.5.1 Engineered Capping

Engineered capping is an effective and proven remedial technology that involves designing and placing clean material on top of in situ contaminated sediments to effectively isolate the sediments from the aquatic environment in perpetuity. Engineered caps typically are at least several feet thick, and sometimes greater than 4 to 5 feet thick, due to the cap design requiring several layers of material to prevent potential erosive forces from vessel propwash and wind/waves, limit contaminant mobility, and address potential bioturbation on the cap. At sites where propwash or high current velocities or waves may impact the stability of the cap, a properly sized armor layer, developed as part of the engineered cap, is generally designed for the top layer of the cap to prevent cap erosion.

The primary objectives of in situ engineered caps are as follows:

- Stabilize the contaminated sediment and prevent contaminant resuspension and transport
- Reduce contaminant flux into the water column from contaminant mobility
- Physically isolate the contaminated sediment from benthic organisms

Engineered capping can result in site use constraints because it can reduce water depths, require institutional controls in vessel operational areas to avoid damaging the cap, limit future deepening or maintenance dredging of a site, and require long-term monitoring and maintenance. Variations of an engineered cap may include partial removal of contaminated sediment to minimize or eliminate impacts to navigation or use of innovative cap designs (USEPA 2005). While engineered capping has been successfully implemented throughout the world, its use at sites where active large-vessel navigation and berthing occurs is less frequent due to its inherent restrictions to navigation.

For open-water areas, an engineered cap may adversely impact the navigation depths for vessels (unless combined with dredging) and limit future deepening or maintenance dredging activities. Designing a stable engineered cap would require using armoring materials that may not be suitable for habitat substrate and could potentially be a risk factor for vessel hull damage if there is accidental grounding.

For underpier areas, several factors affect the ability to use engineered capping, including constructability and slope and structural stability. It is anticipated that, due to propwash forces, a large armor layer would be required to prevent potential erosion of the engineered cap. Placing an engineered cap typically requires careful placement of two or three discrete layers of materials. Also, due to the potential thickness and weight of an engineered cap (at least 2 to 3 feet thick), the effect on structural stability would need to be carefully analyzed. Capping sloped underpier sediments also requires building the slope up to gain sufficient layer thicknesses, which would impede navigational depths at the toe of the slopes, not to mention the ability to adequately place material under and behind structures to meet cap thickness requirements.

Although capping has been shown to be an effective remedial technology at many remediation sites, this site is likely not a good candidate for engineered capping because: 1) the source areas of contamination and mass of impacted sediment would remain in place and therefore would not meet several of the project Objectives; and 2) there may be adverse impacts to current vessel navigation and berthing uses.

The engineered capping technology is retained only for comparison with other remedial technologies, using specific evaluation criteria, to help select the preferred remedial option for the site (see Section 5.8).

5.5.2 Sheetpile Wall Containment

Sheetpile wall containment is an engineered containment approach that has been used to isolate contaminated sediments in situ or to create a disposal cell where contaminated sediments are placed within.

In the open-water area of the site, a sheetpile wall containment approach is not feasible due to water depth constructability issues and the obvious impact to vessel navigation. Placing a sheetpile wall containment structure around the existing Ore Terminal structure to isolate underpier contaminated sediment is also not considered practical and would result in significant loss of aquatic habitat. Therefore, sheetpile wall containment is not carried forward as a remedial technology for the site and is not retained for comparison with other remedial technologies in Section 5.8.

5.6 Treatment

Treatment is intended to immobilize, transform, or destroy COCs in sediment through the application of additives that reduce contamination to protective levels. In situ and ex situ treatment were considered as treatment technologies for the site, as described in the following sections.

5.6.1 *In Situ Treatment*

In situ treatment of sediment refers to technologies that immobilize, transform, or destroy COCs while leaving the sediment in place (i.e., without first removing the sediment). Generally, this technology involves biological, chemical, or physical treatment of sediment in place (USEPA 2005). It may include the use of reactive caps or additives that enhance biodegradation. For instance, small-scale treatment has been successfully performed on PCBs with additives; however, the development of an effective in situ delivery system to provide and mix the needed additives to the contaminated sediment is more problematic (USEPA 2005). Given the range of metals contaminants found at the site, there are no proven technologies to immobilize or treat the sediment while leaving it in place, outside of limited bench- or pilot-scale studies.

Due to the impractical nature of applying in situ treatment technologies in large-scale applications, and because they do not address the project Objectives related to removing a majority of the contaminant mass (Objective 1), in situ treatment is not carried forward as a remedial technology for the site and is not retained for comparison with other remedial technologies in Section 5.8.

5.6.2 *Ex Situ Treatment*

Ex situ treatment refers to technologies that immobilize, transform, or destroy COCs after first removing contaminated sediment from the site. Treatment processes may be classified as biological, chemical, physical, or thermal. The costs for ex situ treatment in some cases can be high depending on the types of treatment used, and the treated material typically still requires confined disposal; for this reason, the decision to include ex situ treatment often is driven by factors other than cost-effectiveness or environmental protectiveness, such as the regulatory requirement to treat hazardous waste level sediment. In some cases, ex situ treatment may help to reduce overall project costs if the costs of hazardous waste disposal options are high enough that the addition of ex situ treatment, plus a reduced category of disposal, is less expensive than disposal at a more restrictive disposal facility. As was noted previously, leachability testing conducted as part of previous sediment investigations (Anchor QEA 2015) indicated that the sediment exceeded the federal criterion for lead. From a disposal characterization perspective, this would require removed sediment to be disposed of as hazardous waste at a Subtitle C landfill. A cost-effective method to reduce the waste disposal classification to a non-hazardous waste classification (i.e., at a Subtitle D landfill) is ex situ treatment. Preliminary bench-scale treatment conducted as part of the Gateway Project (Anchor QEA 2016) indicates that mixing amendments would reduce the leachability of the sediment upon removal to levels that meet non-hazardous landfill disposal criteria.

For the above reasons, ex situ treatment (preferably through stabilization) is carried forward as a remedial technology (in conjunction with upland landfill disposal) for removed sediment where leachate upon removal is suspected to exceed hazardous waste thresholds and may be treated to reduce the concentrations for potential disposal at a non-hazardous (Subtitle D) facility. This technology is retained for comparison with other remedial technologies, using specific evaluation criteria, to help select the preferred remedial option for the site (see Section 5.8).

5.7 Disposal

After removal, contaminated sediment needs to be appropriately disposed of to meet ADEC and federal disposal requirements, which specifies standards for classifying materials for different land uses, or other requirements if taken out of place of origin. Several methods of disposal were considered for this site, including use of a Confined Aquatic Disposal (CAD) site, Nearshore Confined Disposal Facility (NCDF), or upland disposal at a permitted landfill following stabilization and/or ex situ treatment.

5.7.1 Confined Aquatic Disposal and Nearshore Confined Disposal

A CAD site is typically described as an aquatic disposal site where contaminated sediments from various sites are transported and consolidated into one area on the mudline (or in a pit in the mudline). The CAD site is then covered with clean material to fully isolate the contaminated sediment. CAD sites need to be designed to be stable against erosive forces, seismic, and underwater landslide considerations, bioturbation, and contaminant mobility through the cover. An NCDF is similar to a CAD site, and has similar design limitations, but refers to a facility that is built in the nearshore and which additionally results in new upland space by converting aquatic lands. CADs and NCDFs have been successfully implemented at many contaminated sediment sites, including regionally in the state of Washington at the Bremerton Naval Complex, and Ports of Tacoma, Seattle, and Everett in the Puget Sound.

Due to the lack of an identified location, uncertainties in permitting and required mitigation for constructing either a CAD or NCDF, as well as the significant time that would be required to site and permit either a CAD or NCDF), ex situ aquatic containment options such as CAD or NCDF will not be carried forward as remedial technologies and are not retained for comparison with other remedial technologies in Section 5.8. While a CAD or NCDF could be constructed as part of a larger port expansion, there are not currently plans for significant expansion or restructuring of the harbor that incorporates an area of fill. In the absence of a similar expansion project, a CAD or NCDF are not realistic for a project of this magnitude.

5.7.2 Upland Disposal Facility

A permitted upland disposal facility is an off-site engineered facility that provides permanent long-term isolation and disposal of waste material, thereby minimizing the potential for release of contaminants to the environment. Upland disposal facilities are designed to prevent the release of contaminants to groundwater, control runoff to surface water, and limit dispersion into the air.

Remediation and waste disposal contractors can arrange for transport (by barge, rail, and/or truck) and disposal of different waste types (including sediments and hazardous waste).

Disposal facilities can generally accept sediments/soils that comply with Resource Conservation and Recovery Act Subtitle D or C requirements. In the northwestern United States, the Roosevelt Regional Landfill near Goldendale, Washington, and Columbia Ridge Landfill near Arlington, Oregon, are the two upland regional landfills that have established services to receive wet sediments. These sites are licensed as Resource Conservation and Recovery Act Subtitle D commercial landfills in the states in which they operate, and both have the ability to receive wet dredged sediments. Neither facility currently has a barge offloading facility that could be used to provide barge-to-rail transloading; however, at least one commercial offload facility currently exists in Seattle that could transfer sediment from barges to rail cars. In addition to these two landfills, there may be other municipal landfills in the region that may also accept contaminated sediment. No upland disposal facilities exist in Alaska that are permitted to accept contaminated dredged sediment.

Upland disposal is carried forward as a potentially applicable remedial technology for the site and retained for comparison with other remedial technologies, using specific evaluation criteria, for the selection of the preferred remedial option for this site (see Section 5.8).

5.7.3 Beneficial Use

Beneficial use refers to situations where dredged materials are re-used in another environment (e.g., as roadbed fill). Beneficial use of contaminated dredged sediment is less common due to concerns with the liability of using contaminated sediments in other applications, but a typical example of beneficial use of contaminated sediment is upland construction backfill. For beneficial use to be approved, the contaminated sediment must meet beneficial use criteria associated with the proposed beneficial use, including both physical and chemical characteristics. In the context of this project, contaminated sediment would likely need stabilization to be suitable for use in most applications. If dredged material is proposed to be incorporated into a beneficial use project (e.g., as upland fill), a Letter of Non-Objection must also be obtained from ADEC's Contaminated Site program. An additional challenge in using contaminated sediment for beneficial use is in the ability to transfer ownership of future liabilities. Another beneficial use limitation is the likelihood that the material cannot be used as structural backfill, without physical amendment, due to the anticipated fine nature of the surficial sediment. No current potential beneficial use opportunities have been identified for this project. Therefore, beneficial use is not carried forward as a remedial technology for this site and is not retained for comparison with other remedial technologies in Section 5.8.

5.8 Technology Evaluation Criteria and Technology Selection

This section compares the retained remedial technologies described above and selects a preferred remedial technology for use at the site. The remedial technologies are compared based on effectiveness, permanence, implementability, compatibility with site use, and community acceptance. These evaluation criteria were selected for consistency with federal sediment cleanup guidance (USEPA 2005) and the project Objectives listed in Section 3. These evaluation criteria are described as follows for the site:

- **Effectiveness.** Effectiveness refers to the ability of the remedial technology to reduce human health and ecological risk at the site. Objectives 2 and 3 are associated with effectiveness.
- **Permanence.** Permanence refers to the ability of the remedial technology to reduce risks in the long term. For this site, permanence is related to mass removal of contamination (Objectives 1 and 4).
- **Implementability.** Implementability refers to the technical and administrative feasibility to implement the remedial technology.
- **Compatibility with site use**. Compatibility with site use refers to how the technology integrates with current site uses (vessel navigation and berthing) and the reasonably anticipated future site use (Objective 5).
- **Community acceptance.** Community acceptance refers to the ability of the technology to meet the needs of the community and ADEC (Objective 6).

Table 5-1 evaluates the retained remedial technologies based on these criteria, rated as poor, fair, good, or excellent. Dredging, ex situ treatment, and off-site upland disposal have been combined into a single technology option for this analysis because they would be used in conjunction with each other during a remedial action.

Table 5-1
Comparison of Remedial Technologies

Technology	Effectiveness	Permanence	Implementability	Compatibility with Site Use	Community Acceptance	Selection
Monitored Natural Recovery	**Fair.** Sedimentation has reduced surface sediment concentrations over time.	**Poor.** MNR does not remove site contaminants.	**Excellent.** MNR is highly implementable.	**Excellent.** MNR is compatible with site uses.	**Poor.** MNR is not likely to be acceptable as a stand-alone technology.	Eliminated as a primary remedial action.
Enhanced Natural Recovery	**Good.** ENR would further reduce site risks in surface sediment but may not be stable in the berthing area.	**Poor.** ENR does not remove site contaminants.	**Good.** ENR is readily implementable.	**Fair.** Material placement is not compatible with current or anticipated site uses.	**Poor.** ENR is not likely to be acceptable as a stand-alone technology.	Eliminated as a primary remedial action.
Mechanical Dredging, Ex Situ Treatment, and Off-site Upland Disposal	**Excellent.** Dredging will reduce site risks in combination with residuals management cover.	**Excellent.** Dredging will permanently remove site contaminants.	**Fair.** Dredging is implementable but would require equipment mobilization and material barge shipments to and from the contiguous United States. Dredging would require offsets from existing structures.	**Excellent.** Dredging is compatible with current and anticipated site uses.	**Excellent.** Dredging of contaminated sediment is likely to be favored by the community.	Preferred
Hydraulic Dredging in Underpier Areas	**Unknown, Poor to Good.** The effectiveness of this technology is uncertain due to lack of data regarding sediment material properties (e.g., density, grain size). This method is not effective in removing dense materials.	**Fair.** It is assumed that this method would only be partially effective; as such, additional measures may be required.	**Poor.** Implementability is considered poor due to anticipated challenges with access due to piling density, safety concerns with commercial diving over long periods of time (i.e., months) to complete the work, and compounding water management logistical limitations with dewatering.	**Fair.** There is the potential to cause some amount of structural damage due to removal of sediment supporting the structure and incidental strikes from equipment.	**Good.** Attempting underpier removal is likely to be favored by some members of the community; however, likely ineffective removal results and/or contractor safety considerations	Eliminated as a primary remedial action for underpier areas.

Technology	Effectiveness	Permanence	Implementability	Compatibility with Site Use	Community Acceptance	Selection
					may be a cause for concern.	
Engineered Capping	**Excellent.** Capping would further reduce site risks in surface sediment and could be armored to maintain stability.	**Good.** Capping does not remove site contaminants, but it could be engineered to be stable in the long term. Capping would isolate the contaminant from being taken up by crabs, shrimp, and mussels.	**Fair.** Capping is implementable but would require equipment mobilization and possible material barge shipments from the contiguous US.	**Poor.** Material placement is not compatible with current and anticipated site uses.	**Fair.** Capping anticipated to be somewhat favorable to the public.	Eliminated

As shown in Table 5-1, the preferred remedial option for addressing contaminated sediments associated with spillage from historical ore loading operations is removal via dredging, with ex situ treatment (solidification) to address leachable characteristics of the material after removal from the marine environment, and disposal at a permitted upland disposal facility. Removal, ex situ treatment, and disposal have been effective in remediating contaminated sediments at other sediment cleanup sites with similar characteristics (chemical and physical), and permanently eliminating contaminant mass from aquatic systems. Additionally, equipment and expertise for removal and disposal can be mobilized to the site, and the technology does not encumber present and potential future site uses. Removal of contaminated sediment through dredging is likely to be favored by the community, relative to other options, based on feedback received during the June 26, 2019 Public Open House meeting in Skagway. The costs of remedial design, permitting, and construction are not evaluated as selection criteria. However, overall remedial costs vary significantly starting at the very low cost of MNR, low cost for ENR, moderately high cost of engineered capping, and very high costs for dredging and disposal. The cost of dredging and disposal can be several orders of magnitude higher than the lowest cost of MNR.

6 Delineation of Removal Extents

As concluded in Section 5.8, removal (dredging), ex situ treatment, and upland disposal have been retained as the preferred remedial option for addressing contaminated sediments associated with spillage from historical ore loading operations. Removal, ex situ treatment, and disposal of contaminated sediment would likely consist of mechanical dredging followed by stabilization of the dredged material on the barge (i.e., following removal), and transport to a permitted upland landfill in the contiguous United States. Dredging residuals would then be managed by placing a thin layer of imported sand (e.g., 1 foot) as a residual management cover.

This section presents the rationale for developing the remediation footprint by comparing the relative benefits of removing contaminated sediment from progressively larger areas of the site in an effort to balance the environmental implications of dredging additional material versus the ecological benefits of contaminant mass removal at the site.

6.1 Contaminant Mass Removal Analysis

The purpose of this contaminant mass removal analysis is to identify a removal footprint that achieves the project Objectives and balances the benefits of removal versus adverse impacts during removal. This analysis focuses on mass removal rather than surface sediment concentrations and associated risks because the site-specific risk assessment (Golder 2018) did not lead to the development of specific cleanup threshold. Therefore, to meet the Objectives and address public concerns, a contaminant mass reduction approach is being proposed at this site. This approach is consistent with current site uses (e.g., vessel navigation and berthing) and optimizes the permanent removal of contamination from the site. Moreover, the remediation area developed using this mass-removal analysis also addresses the area of highest surface sediment concentrations and the greatest concentration of mass of metals in the Ore Basin. The following sections describe the steps employed to perform this analysis.

6.1.1 Screening Criteria and Indicator Chemicals

As previously noted, the Washington State CSLs were used as a screening level to determine sediment sample locations that were carried forward for further review as part of this analysis. The CSLs are based on a consistent methodology for 47 contaminants and represent the concentration above which toxicity has been found to occur to benthic organisms. The sediment area that exceeds the CSL for one or more contaminants is shown in Figure 4.

The CSL exceedance factor is a way to compare the relative impacts of contaminants on a common basis; the exceedance factor is calculated by taking the contaminant concentration and dividing it by the CSL. Consistent with the CSM, lead has the highest exceedance factor among all contaminants (exceedance factor of 79 times the CSL) and therefore has relatively larger impacts compared to other contaminants at the site. In addition, lead has the largest area that exceeds the CSL compared to other contaminants, and the lead exceedance areas encompass exceedances from all other contaminants. For these reasons, targeting the removal of lead was used as a surrogate for assessing the net contaminant removal of all ore-related metals at the site.

The area of lead CSL exceedances captures CSL exceedances for all other contaminants. In particular, zinc has the second highest exceedance factor at the site (exceedance factor of 77 times the CSL) and is considered a secondary indicator contaminant. However, as discussed in Section 6.1.4, zinc concentrations are co-located with elevated lead concentrations, so addressing lead would also address the areas of zinc contamination.

6.1.2 Mass Removal Extents

The mass of lead within the area of proposed remediation was estimated from sediment core data in the following six steps:

1. The maximum potential remediation area was calculated based on the accessible area in front of the ore dock with any sediment sample location that exceeded the CSL for lead in surface or subsurface sediment. For reference, the area behind and under the ore dock is discussed in Section 6.1.5.
2. The potential removal depth for each core was estimated based on the maximum sample depth that exceeded the CSL for lead.
3. The average concentrations of lead in each core were calculated based on the vertically weighted concentrations for each sampled interval of a sediment down to the removal depth. Core intervals without chemical data were assumed to have the concentration of the adjacent deeper sample interval.
4. The maximum potential remediation area was divided into areas representing each core using Theissen polygons. These polygons represent the estimated area associated with each core and are based on an analysis of halfway to the nearest adjacent sample location.
5. The dry-weight mass of sediment in each polygon was calculated based on the area of the polygon times the removal depth for the core for the polygon to determine a volume of sediment. This was then multiplied by the estimated dry-weight density of sediment.
6. The contaminant mass of lead for each polygon was calculated from the average concentration times the total mass.

Figure 5 shows the mass of lead in each polygon, which was calculated using the representative sample data from the corresponding sediment core location. As shown in Figure 5, the majority of lead mass is concentrated in the area adjacent to the ore loader, consistent with the location of the historical source.

6.1.3 Incremental Mass Removal Analysis

The incremental mass removal analysis evaluates the marginal effectiveness of removing successive polygons, starting with the polygon with the highest average concentration of lead and finishing with the polygon with the lowest average lead concentration. Figure 6 provides the mass removal information for each core and polygon (ordered from highest concentration to lowest concentration) and demonstrates the reduced effectiveness of removing successive volumes of material associated with the lower concentration sediment core locations. As demonstrated in the table, removing only the polygon associated with core station SED17-34 removes more than 40% of the mass of lead from the accessible areas of the Ore Basin that exceed the CSL. By removing the volume of material represented by the polygons associated with the cores with the four highest lead concentrations (SED17-34, SED17-40, SED17-35, and SOD-01), 85% of the lead mass would be removed from the accessible area of the Ore Basin.

Figure 6 depicts the mass of lead associated with each core location compared to the corresponding volume of sediment that would be removed. The curve shows that the majority of the mass of lead would be removed by targeting the highest concentration area, and minimal additional lead is removed by removing cores with lower concentrations. In particular, after the removal of SOD-01, there is appreciably less benefit in removing additional material to remove additional mass of lead.

The proposed remedial action footprint is shown in Figure 7. As a result of this analysis, a remediation footprint of approximately 15,000 square feet (sf) is recommended, corresponding with removal of approximately 4,000 cubic yards (cy) of sediment based on the volume estimation methods described in this section. Note this volume is in excess of the volumes provided in Figure 6 to account for design variables, such as slough from under the ore dock, which is not included in this preliminary analysis. This proposed remedial action footprint would result in removal of 79,000 kilograms (kg) or approximately 85% of lead from the accessible areas of the Ore Basin.

6.1.4 Mass of Zinc

As discussed previously, the area of lead CSL exceedances captures CSL exceedances for all other contaminants, including metals of concern such as zinc, mercury, and copper. In particular, zinc is considered the secondary indicator contaminant. An analysis of co-location of lead and zinc was performed to evaluate if addressing elevated lead concentrations would also address elevated zinc concentrations. The locations exceeding the CSL for lead and zinc were compared, demonstrating that all locations that exceed the CSL for zinc also exceed the CSL for lead. Lead and zinc concentrations were then plotted, showing that the concentrations are co-located. Based on this result, removal of lead mass will also address zinc contamination.

6.1.5 Sediment Under and Behind the Ore Dock

The area in front of the ore dock was the focus of the analysis because this area is currently accessible for remedial action. Contaminant concentrations are higher and accumulated contaminated sediment is observed to be thicker in front of the ore dock compared to under and behind the ore dock.

To put the sediment under and behind the ore dock in context relative to the amount of mass in the accessible areas of the Ore Basin, an order of magnitude estimate of the lead mass under and behind the ore dock was conducted. The lateral extents of contamination in the underpier area was estimated that exceeds the CSL based on the limited available historical data. This estimated extent of contamination was approximately 1.0 acre. Then, the volume of soft sediment on the slope within this area was estimated by comparing the most recent available bathymetry (TerraSond 2014) to the 1969 construction as-builts of the original constructed slope. The average depth of sediment was estimated to be 6.9 feet based on preliminary cross-sections. This is the full volume that would conservatively be assumed to be contaminated. The volume of sediment was then converted to mass by multiplying by a dry density of 45 kg/cubic foot, based on typical values for silty sands. Then, the average concentration of lead in sediment was calculated based on an arithmetic average of all historical samples within the area. Finally, the mass of lead was estimated by multiplying the average concentration by the mass of sediment.

The resulting order-of-magnitude estimate of lead mass that exceeds the CSL under and behind the ore dock is approximately 25% of the total mass of lead that exceeds the CSL in the Ore Basin, resulting in a total of 121,000 kg of lead. It should be noted that the 25% estimate of total mass exceeding CSL in the Ore Basin is considered to be conservatively high because this assumes that all of the sediment down to the original construction grades under and behind the ore dock is contaminated. Additionally, the two samples in the underpier area from the available data set that contain the highest concentrations of lead were both likely collected in front of the ore and timber docks; the original report (Dames & Moore 1995) notes that these samples were collected from a 50-foot vessel using a "dart sampler" and also states that coordinate certainty for the locations is limited. Removing these two samples from the weighted average reduces the percent of lead mass in the underpier areas to 10% of the Ore Basin, providing a lower bound estimate of the amount of lead mass in the underpier areas based on available data sources.

Note that this estimate of underpier mass of lead is based on older and surficial environmental data and rough estimates of sediment volume and should be considered an order-of-magnitude estimate only. Sampling under the ore dock to date has been limited by the available technologies and has not provided a complete picture of the lateral and vertical extents of contamination. This analysis requires a number of assumptions that could significantly affect the result. As such, until further additional information is available to validate these data, it should be used as an order-of-magnitude estimate. Still, this analysis does demonstrate that the majority of the lead mass in the Ore Basin is likely to be located in accessible areas and would be addressed by the proposed remedial footprint (Figure 7).

During removal (i.e., construction) of contaminated sediment from the front of the ore dock, some amount of sloughing of underpier material into the removal footprint could occur and would subsequently be removed during the remedial action. Depending on the nature of the material, this sloughing could include a significant volume of sediment from the underpier area; however, the limited information available does not allow for a reasonable estimate of slough at this time. Removal of underpier slough from the remedial footprint would effectively address a portion of the underpier sediment mass. This incidental removal of underpier sediments has not been accounted for in this analysis of underpier sediment mass.

6.2 Summary of the Recommended Removal Extents

The recommended removal extent consists of dredging an area of approximately 15,000 sf, corresponding with the removal of approximately 4,000 cy of sediment. This removal would be followed by backfill of approximately 1,000 cy of clean sand to address generated residuals (Section 7.1.1). The removal extent removes approximately 85% of lead mass from accessible areas in the Ore Basin. These volumes and area will be further refined during the remedial design process.

This removal footprint achieves the Objectives by removing the majority of lead from the site; reducing potential human health risks (by reducing surface sediment concentrations); reducing potential risks to benthic invertebrates (by reducing surface sediment concentrations); and removing sediment that could potentially become a source to other areas, does not adversely impact site use, and is anticipated to gain community and ADEC acceptance.

7 Remedial Design Considerations

This section summarizes design considerations associated with the preferred remedial option previously described in Section 5.8. Specifically, additional considerations are provided associated with remedial dredging, including a discussion of dredge residuals management, water quality impacts, and BMPs. This section also summarizes the anticipated schedule and discusses permit considerations associated with the remedial option.

7.1 Dredging Design Considerations

7.1.1 Dredge Residuals Management

Reliable characterization of sediment in advance of designing and conducting a remedial dredging action is a key element to the success of a remediation effort; however, complete removal of contaminated sediments within an aquatic environment is limited by the technical and logistical capabilities of the environmental dredging equipment and methods, and spatial heterogeneity of the sediment contamination.

Dredge residuals refer to the remaining contaminated sediments located at or below the constructed post-dredge surface, either within or adjacent to the dredging footprint (Figure 8). Additional action is often required when dredge residuals remain after completion of remedial dredging actions. As discussed in Bridges et al. 2008, dredge residuals are grouped into two categories: 1) missed inventory; and 2) generated residuals:

- **Missed inventory.** Also referred to as undisturbed residuals, these are contaminated sediments found at or below the post-dredge sediment surface that have been exposed but not fully removed as a result of the dredging operation. Missed inventory typically results from having imperfect information about the true vertical and/or horizontal extent of contaminated sediments that was predicted based on sediment sampling during or prior to the design process.
- **Generated residuals.** Generated residuals are contaminated post-dredge surface sediments that result from dislodged or suspended sediments generated by the dredging operation and ancillary activities (such as vessel movement) that are subsequently re-deposited on the mudline either within or adjacent to the dredge area. Generated residuals are typically deposited as a thin layer (e.g., several inches thick) and are inherent in dredging operations and, therefore, need to be accounted for and managed appropriately.

A decision-making framework will be developed prior to construction to establish protocols for managing dredge residuals. Standard methods that have been used to address residual contamination for mass removal projects typically include conducting contingency re-dredging to address missed inventory, or to remove generated residuals that exceed a specified concentration.

Another standard residuals management approach is to place a thin cover (thickness ranges from 12 inches to upwards of 20 inches) of clean sand after acceptance of required dredging. This thin cover is known as residual management cover (RMC) and is intended to provide clean surface sediment concentrations and additional stability to the contaminated sediment left in place. RMC acts in a similar manner as ENR and protects sediment quality should propwash or other disturbance resuspend sediments and covered residuals (i.e., by reducing volume-averaged contaminant concentration). RMC placement at similar remediation projects has been proven to be an effective method to address surficial residuals contamination immediately post-removal (Bridges et al. 2008).

7.1.2 Water Quality Impacts

Resuspension or discharge of suspended solids during sediments dredging can cause adverse water quality impacts. Therefore, it is anticipated that permit conditions (as described in Section 7.3) will likely limit the concentration of suspended solids that can be generated at specific locations near an operating dredge or a point of effluent discharge (i.e., dewatering barge).

Potential water quality impacts associated with dredging are expected to be temporary in nature and would be located at or close to the point of dredging. BMPs will be employed as discussed in Section 7.1.3 to reduce the degree of sediment resuspension and associated water quality impacts. No specific contaminant mobility testing or water quality modeling is anticipated to be conducted for this project; however, water quality management BMPs will build on best practices and experience with similar remediation projects.

Similar to potential water quality impacts during dredging, the potential water quality impacts during barge dewatering are expected to be temporary and confined to locations close to the barge. Some remediation areas may be suitable for passive barge dewatering; thus, a filtering system could be implemented to remove suspended solids prior to discharging effluent water back into the receiving waters within the dredge footprint. The project will be required to confirm that passive barge dewatering will be allowed.

During a remedial dredging program, water quality criteria apply at the discharge location, but a compliance boundary is commonly established to define the distance from operations that is the point of compliance. The compliance boundary is described as a theoretical mixing zone of water extending vertically from the mudline to the water surface, and horizontally for some established distance from the discharge location. It is anticipated that the application of the compliance boundary will be negotiated with the regulatory agency. A water quality monitoring plan will be developed to present the water quality objectives for the project.

7.1.3 Dredging Best Management Practices

BMP controls will be incorporated as part of the design specifications to minimize, to the extent practical, potential adverse construction impacts to the environment and the magnitude of residual contamination. The BMPs that may be implemented by the contractor during the dredging operations are described below.

7.1.3.1 Operational Controls

Operational controls are defined as modifications to standard operational practices implemented by a contractor that are intended to help minimize potential environmental impacts during remedial dredging and disposal operations. While operational controls are typically not written as explicit design requirements (although some controls will be specified), they are described as methods that the contractor can adjust in its operations to meet project environmental criteria performance requirements. Operational controls may include the following:

- **Real-Time Kinematic Positioning.** The contractor will be required to use real-time kinematic positioning controls, such as a differential global positioning system electronically displayed in the dredge operator's cabin, to provide real-time positioning control for the dredging operations.
- **Increasing Cycle Time.** For mechanical dredging operations, increasing the cycle time of the bucket can help reduce the rate of sediment loss to the water column, thus reducing potential water quality impacts. A longer cycle time generally means reducing the velocity of the descending or ascending bucket through the water column. However, limiting the velocity of the descending bucket in dredge operations may reduce the volume of sediment that is picked up by the bucket, thus requiring more total bites to remove the project material and increasing the overall project duration. This operational control is not expected to be a specification requirement but is available to the contractor to implement, if needed, particularly if the contractor is not meeting water quality objectives.
- **Eliminating Multiple Bites.** When the clamshell bucket hits the bottom, an impact wave of suspended sediment travels along the bottom away from the dredge bucket. When the clamshell bucket takes multiple bites before ascending to the surface, the bucket loses sediment as it is reopened for subsequent bites. The design specifications will prohibit taking multiple bites.
- **Modifying Dredging Operations During Peak Tidal Exchange Periods.** Dredging during peak tidal exchange periods (i.e., maximum ebb and flood tides) may increase downstream turbidity. The contractor may need to modify dredging operations (e.g., production rates) during these periods to minimize water quality impacts. This operational control is not expected to be a specification requirement but is available to the contractor to implement, if needed.

- **Eliminating Underwater Stockpiling.** Taking small dredge cuts and temporarily stockpiling material at the mudline creates a pile of loose sediment that could easily be resuspended and impact water quality. The contractor will be required to take complete dredge cuts (from the moment the bucket is closed at the mudline) and will be required to return the bucket to the surface and deposit dredged material onto the barge before returning the bucket back to the mudline.
- **Toe of Slope Removal and Slough Material.** Dredging at the toe of the slopes is expected to initiate some sloughing/slumping, which could temporarily resuspend sediments and impact water quality. The amount of potential resuspension is controlled by the amount of material that sloughs/slumps. The contractor will be required to perform multiple dredge passes along the toe of the slope, particularly at the toe of the ore dock slope where intentional sloughing will be initiated and subsequently removed to address contamination under the ore dock that is not accessible and in order to achieve the required dredge elevations or thicknesses. The contractor will be required to remove any slough material to meet final required dredge grades and may be required to perform the dredging in such a manner that dredging at the toe of the slope under the ore dock is conducted first to allow the maximum amount of time practicable for slough to occur during the contract period such that the contractor can remove as much slough as possible while still on site.
- **Eliminating Bucket Overloading.** When the dredge bucket impacts soft sediment, there is the potential for the bucket to penetrate beyond the designed digging depth of the bucket. When this occurs, the bucket returns to the surface with excess material at the bucket surface, which tends to fall back into the water before being placed into the material barge. If bucket overloading is observed, the contractor will be required to control the rate of descent on the bucket to prevent excess penetration of the bucket into the mud to reduce generated residuals and water quality impacts.
- **Eliminating Barge Overloading.** The contractor will be prohibited from overloading the material barge beyond the top of the side rails. When dredged material is heaped adjacent to and above the side rails, there is the potential for material to fall over the side rails. In addition, overloading the barge can lead to barge listing and instability, which could result in loss of sediment back to the surface water.

7.1.3.2 Specialized Equipment

Specialized equipment adopted by the contractor during dredging operations may include the following:

- **Silt Curtains.** A silt curtain is a constructed floating physical barrier that is positioned around the marine equipment (or the immediate area of dredging) to limit the spread of suspended sediment in the water column that is generated during dredging operations. Silt curtains are typically constructed of flexible, reinforced, thermoplastic material with flotation material in the upper hem and ballast material in the lower hem. The curtain is placed in the water surrounding the dredging area(s) to enclose, at a minimum, the area where the bucket enters and exits the water column. Because they are mostly impermeable, silt curtains are easily affected by tides and currents and their effectiveness can be adversely impacted by high current velocities, moderate to large wave conditions, or large tidal variation. Silt curtains are most effective if they can be deployed so that they extend from the water surface to the bottom or within a close distance (e.g., 5 feet) of the bottom, but this is not practical in the marine environment of Skagway due to the significant tidal fluctuation, water depths, and current velocities. When a silt curtain does not fully extend from the water surface to the bottom, there will remain a gap at the bottom where suspended sediment can be transported outside of the silt curtain area. Silt curtains may have limited effectiveness in an environment such as the Skagway Harbor due to the higher water depths (40+ feet) and hence the limited portion of the water column where a silt curtain would limit the spread of resuspended sediment. Local tidal exchange also creates currents that may cause billowing of the silt curtains, which has the potential to impede dredging operations and limit navigation in the dredging vicinity and would require significant maintenance for the silt curtain to remain functional. It is critical to consider their potential benefits and limitations before requiring a contractor to implement a silt curtain system and to what depth if the system is required. While a silt curtain may not be effective in Skagway Harbor, the contractor may choose to employ a silt curtain to help control potential water quality impacts.

- **Environmental or Closed Buckets.** This technology consists of specially constructed dredging buckets designed to reduce turbidity or suspended solids during dredging. In general, these buckets may help to minimize the loss of sediment out of the bucket when used properly. However, minimizing the loss of sediment out of the bucket does not necessarily mean reduced suspended sediment or lower turbidity. Closed buckets have not been proven to lower suspended sediments in all site conditions (Wang et al. 2002). Also, closed buckets have other limitations. Dense or compacted sediment and encountered debris must be removed with a digging style bucket (with teeth) since non-tooth buckets have a difficult time penetrating dense or compacted sediment and handling debris. A standard clamshell bucket will be effective at removing debris or dense substrate; closed buckets (without digging teeth) are generally ineffective at removing debris. Closed buckets are typically lightweight in construction and typically not suitable for digging denser materials. This BMP control will not be a specified requirement but is available to the contractor to implement, with the caveat that whichever bucket type they choose, they will be required to meet the water quality requirements and permit conditions.

7.1.4 Dredging Tolerances

During implementation of the remedy, dredging equipment accuracies and tolerances limit the ability of the contractor to remove the contamination to precisely the estimated neatline surface because the dredge generally works in a two-dimensional plane, either by dredging at a constant dredge elevation or a defined constant thickness over a specific area. Dredging equipment tolerances are built into a dredge plan by inclusion of an overdredge allowance, which increases the total volume of sediment removed to accommodate equipment capabilities to achieve a required dredge elevation. An overdredge allowance is defined in the dredge plan as additional material removed from below the required dredge elevation or cut thickness. Generally, a 1-foot overdredge allowance has been established for similar sediment remediation projects. This allowance is based on consideration of site conditions, regional dredging experience, and anticipated equipment types. With careful vertical control and modern positioning systems, it is feasible to limit the overdredge to a maximum of 1 foot.

7.2 Anticipated Schedule

Upon finalizing this Options Analysis report through review and response to comments from ADEC, the project will develop a preliminary dredge design that is intended to support development of permit documents. It is currently assumed that permit documents will be developed and submitted in fall 2019; based on Anchor QEA's experience permitting similar projects, the permits could take up to approximately 9 months to 1 year to be reviewed and approved by the permitting agencies (see Section 7.3). While permits are pending agency approvals, additional design documents will be developed to further refine the design. Upon receipt of project permits, design documents will be finalized with final permit conditions. At this point, the project will be tendered to determine a contractor. The tendering process for the project is currently estimated to begin in September 2020 with commencement of construction in November 2020. Construction is estimated to take 6 weeks to complete, assuming no weather delays, including mobilization and demobilization, with completion of construction in February 2021.

Anchor QEA understands there is an allowable work window in Skagway Harbor that would be provided as part of permit conditions. This work window coincides with the beginning of the cruise ship season (i.e., April to May) and therefore would not impact the project implementation schedule because the remedial work will be conducted outside of cruise ship season to avoid impacting vessels docking in the vicinity of the ore dock.

7.3 Permitting Considerations

This section identifies the environmental permits that may be required to implement the recommended remedial option. Some of the activities and environmental impacts that would potentially trigger various permits and regulatory approvals include the following:

- Dredging of contaminated sediments from the area adjacent to the ore dock
- Suspension of sediment and water quality impacts during dredging

- The potential to generate low levels of underwater noise (e.g., from dredge buckets hitting the seafloor)

Implementing the preferred remedial alternative requires applying for and obtaining permits and approvals. Coordination with applicable regulatory agencies will be conducted prior to permit application submittal to determine applicable project permit requirements.

Table 7-1 provides a list of permits and approvals that could be required for the project, including the issuing agencies, triggers (actions that create the requirement), as well as associated approval timeframes and notes regarding the process. Based on the anticipated remedial action (dredging), some of these permits may not be required. Prior to development and submission of project permitting documents, regulatory agencies will be consulted to determine the specific permits and approvals that will be required for the project.

Table 7-1
Permits and Approvals Potentially Required

Permit/Approval	Agency	Trigger	Timeframe/Notes
Clean Water Act Section 404 Permit	USACE	Dredging activities	An individual Section 404 permit can take approximately 1 year to obtain and includes a 30-day public notice period in which the public, regulatory agencies, or other parties can comment on the proposed project. The USACE will typically require the applicant to respond to and resolve comments. The USACE is also required to consult with Native American tribes with interests in the area. A Rivers and Harbors Act Section 10 Permit from the USACE is not expected to be required because the project does not involve the installation or removal of structures.
ESA/MSA Compliance	NMFS, USFWS	A USACE permit (i.e., Section 404/10 Permit)	ESA consultation is processed concurrently with the Section 404/10 permit, and MSA approval is concurrent with the ESA consultation process. The project will require the preparation of an ESA Biological Evaluation or Biological Assessment, depending on the anticipated level of effects to ESA-listed species.
MMPA	NMFS	Activities that may harm or harass marine mammals	The MMPA requires that an incidental take authorization be obtained for the unintentional “take” of marine mammals incidental to activities including construction projects. MMPA consultation can vary in duration based on the type of incidental take requested. The process can range from approximately 3 to 15 months. Based on the nature of the project and associated potential impacts to marine mammals, it is not expected that an identical take authorization will need to be obtained and a final determination as to the applicability of the MMPA to the project will be made in conjunction with the USACE and NMFS prior to permit submittal.

8 References

ADEC (Alaska Department of Environmental Conservation), 2001. *Sediment Quality Guideline Options for the State of Alaska*. Division of Spill Prevention and Response. Contaminated Sites Remediation Program. May 2001.

ADEC, 2013. Sediment Quality Guidelines. Technical memorandum prepared by ADEC Division of Spill Prevention and Response, Contaminated Sites Program. January 2013.

AIDEA (Alaska Industrial Development and Export Authority), 2019. Skagway Ore Terminal Fact Sheet. Accessed July 18, 2019. Available at: http://www.aidea.org/Portals/0/PDF%20Files/PFS_Skagway.pdf.

Anchor QEA (Anchor QEA, LLC), 2014. *Sampling and Analysis Plan, Gateway Intermodal Dock and Small Boat Harbor Dredging and Legacy Harbor Contaminant Mitigation Program*. Prepared for ADEC, USEPA and USACE on behalf of the Municipality of Skagway, Alaska. October 2014.

Anchor QEA, 2015. *Sediment Characterization Report, Skagway Ore Dock and Small Boat Harbor Dredging: Gateway Intermodal Dock Reconstruction Project and Legacy Harbor Contaminant Mitigation Program*. Prepared for Alaska Department of Environmental Conservation, U.S. Environmental Protection Agency and U.S. Army Corps of Engineers on behalf of the Municipality of Skagway, Alaska. June 2015.

Anchor QEA, 2016. *Laboratory Treatability Report, Gateway Intermodal Dock, Skagway, Alaska*. Prepared for Alaska Department of Environmental Conservation on behalf of the Municipality of Skagway, Alaska. July 2016.

Anchor QEA, 2019. *Skagway Ore Terminal Remedial Approach Work Plan*. Prepared for Alaska Department of Environmental Conservation, on behalf of White Pass & Yukon Route Railway. May 2019.

Barrick, R., S. Becker, L. Brown, H. Beller, and R. Pastorok, 1988. *Sediment-quality-values refinement. Volume 1. 1988 update and evaluation of Puget Sound AET (Apparent Effects Threshold)*. Final report. United States.

Bridges, T.S., S. Ells, D. Hayes, D. Mount, S.C. Nadeau, M.R. Palermo, C. Patmont, and P. Schroeder, 2008. *The Four 4s of Environmental Dredging: Resuspension, Release, Residual and Risk. Dredging Operations and Environmental Research Program*. U.S. Army Corps of Engineers, Engineer Research and Development Center/Environmental Laboratory TR-08-4. January 2008.

Dames & Moore (Dames & Moore, Inc.), 1995. *Final Environmental Site Assessment Report for the Skagway Ore Terminal for Alaska Industrial Development and Export Authority*. November 1995.

Golder (Golder Associates), 2018. *Skagway Ore Basin Risk Assessment*. Submitted to White Pass & Yukon Railway. Report Number: 1657231-006-R-Rev0. 25 January 2018.

Gubala (Gubala Consulting, Inc.), 2007. *Skagway Ore Terminal Phase II Environmental Baseline Study Report*. Prepared by Dr. Chad P. Gubala for Access Consulting Group. November 2007.

Gubala, 2011. *Skagway Harbor Baseline Study, Skagway (Nahku) Ore Terminal*. Prepared for ADEC on behalf of the MOS. November 2011.

Gubala, 2013. *2013 Skagway Harbor Gateway Pre-Engineering Assessment Analytical results from Sediment Coring Program*. Prepared for ADEC on behalf of the MOS. August 11, 2013.

Hart Crowser, 2019. *Draft 30 Percent Geotechnical Engineering Design Study, Skagway Ore Dock Improvements, Skagway, Alaska*. Prepared for KPFF Consulting Engineers. 19407-01. May 8, 2019.

KPFF, 2019. *Ore Dock Improvements, Skagway, Alaska, 30% Progress Submittal*. Prepared for Alaska Department of Environmental Conservation, on behalf of White Pass & Yukon Route Railway. March 11, 2019.

NRC (National Research Council), 2007. *Sediment Dredging at Superfund Megasites – Assessing the Effectiveness. Committee on Sediment Dredging at Superfund Megasites*. Board on Environmental Studies and Toxicology, Division of Life and Earth Studies. National Research Council of the National Academies. Washington, DC: The National Academies Press.

Patmont, C., and M. Palermo, 2007. *Case Studies of Environmental Dredging Residuals and Management Implications*. Paper D-066 presented in Remediation of Contaminated Sediments—2007, Proceedings of the Fourth International Conference on Remediation of Contaminated Sediments (Savannah, Georgia); January 2007.

PND Engineers, Inc. (PND), 2005. *Final Report: Dredge Material Characterization and Geotechnical Evaluation, Broadway Dock Expansion, Skagway, Alaska*. Report No. PND 034044.01. Prepared for Skagway Terminal Co.

Robinson-Wilson, E.F., and G. Malinkey, 1982. *Trace metal contaminants at an ore loading facility in Skagway, Alaska*. Report prepared for the U.S. Fish and Wildlife Service, Juneau, Alaska.

Steffen, Roberson, and Kirsten, Inc., 1989. *Skagway Ore Shiploading Terminal*, Report No. 60608/1.

TerraSond, 2014. *Engineering Design Survey Sheets. Gateway Intermodal Dock Reconstruction Project*. Prepared for Municipality of Skagway. October 28, 2014.

Tetra Tech, Inc. (Tetra Tech), 1990a. *Skagway Harbor Field Investigation*. Report No. TC4118-14. Prepared for U.S. Environmental Protection Agency and Alaska Department of Environmental Conservation.

Tetra Tech, 1990b. *Seafood Risk Assessment for Skagway Harbor*. Report No. TC 5155-03. Prepared for U.S. Environmental Protection Agency.

Tetra Tech, 2008. *Evaluation of Skagway Harbor and Pullen Creek Sediments and Surface Waters*. Prepared for Alaska Department of Environmental Conservation. February 25, 2008.

Tetra Tech, 2009. *Evaluation of Metals and Petroleum Derivatives in Skagway Harbor and Pullen Creek Sediments and Surface Waters*. Prepared for Alaska Department of Environmental Conservation and USEPA Region X. February 6.

Tippets (Tippets-Abbett-McCarthy-Stratton, Engineers and Architects), 1969. *Schedule of Drawings and Tide Data*. Ore Handling Terminal Phase 1, Skagway, Alaska. March 14, 1969.

URS Corporation (URS), 2006. *Environmental Monitoring Report, Skagway Ore Terminal, Skagway Alaska*. Prepared for Alaska Industrial Development and Export Authority (AIDEA). June 29.

USEPA (U.S. Environmental Protection Agency), 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. Office of Solid Waste and Emergency Response. U.S. Environmental Protection Agency, Washington, D.C. EPA-540-R-05-012, OSWER 9355.0-85. December 2005. Available at: http://www.epa.gov/superfund/health/conmedia/sediment/guidance.htm.

Wang, T.S., Larm, K., and D. Hotchkiss, 2002. *Evaluation of Closed Buckets for Remedial Dredging and Case Histories*. Proceedings – Third Specialty Conference on Dredging and Dredged Material Disposal, ASCE Dredging 2002 (Orlando, Florida); May 2002.

Figures

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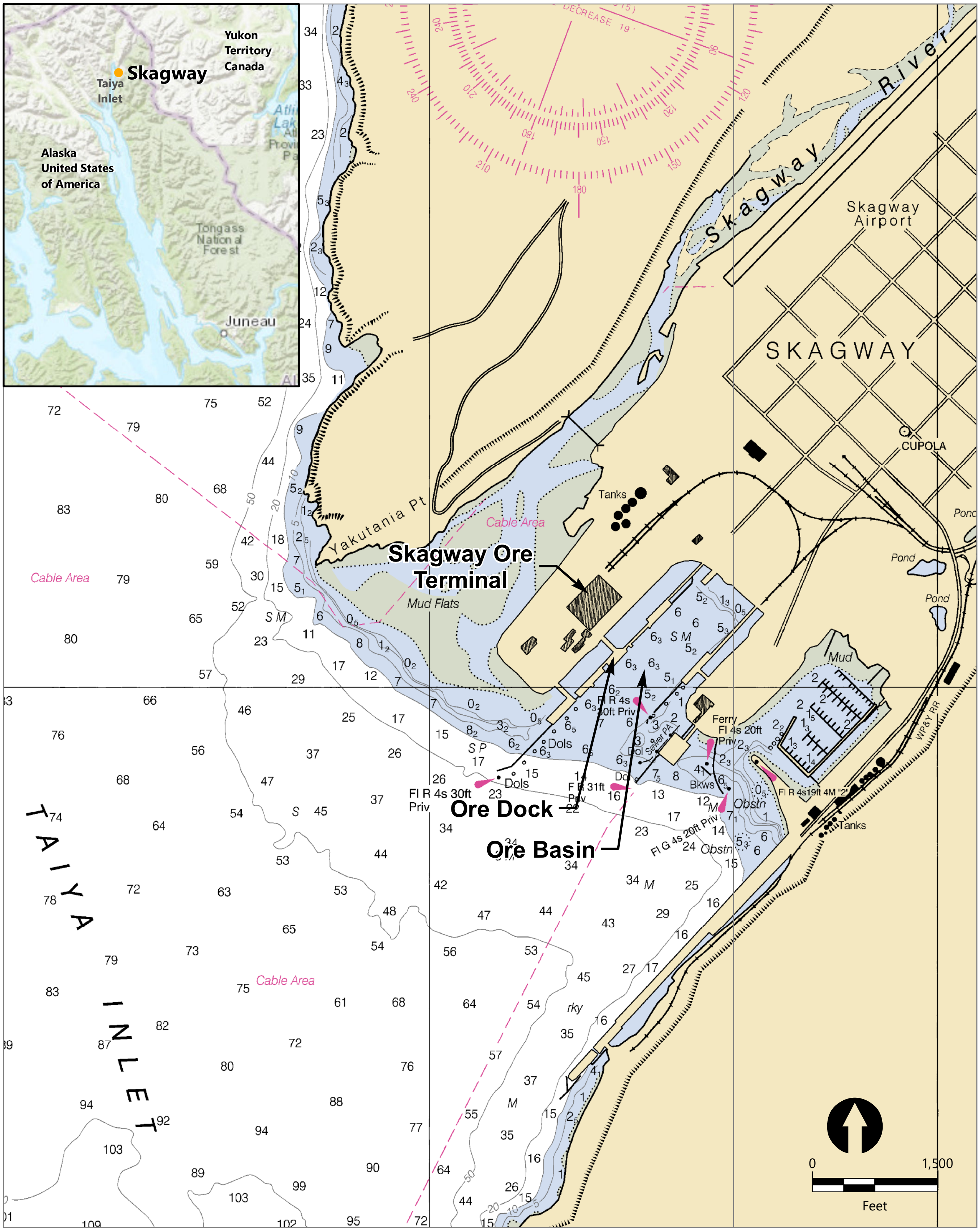

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ANCHOR QEA

Figure 1
Vicinity Map
Remedial Action Options Analysis
Skagway Ore Terminal

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Figure 2
Site Features
Remedial Action Options Analysis
Skagway Ore Terminal

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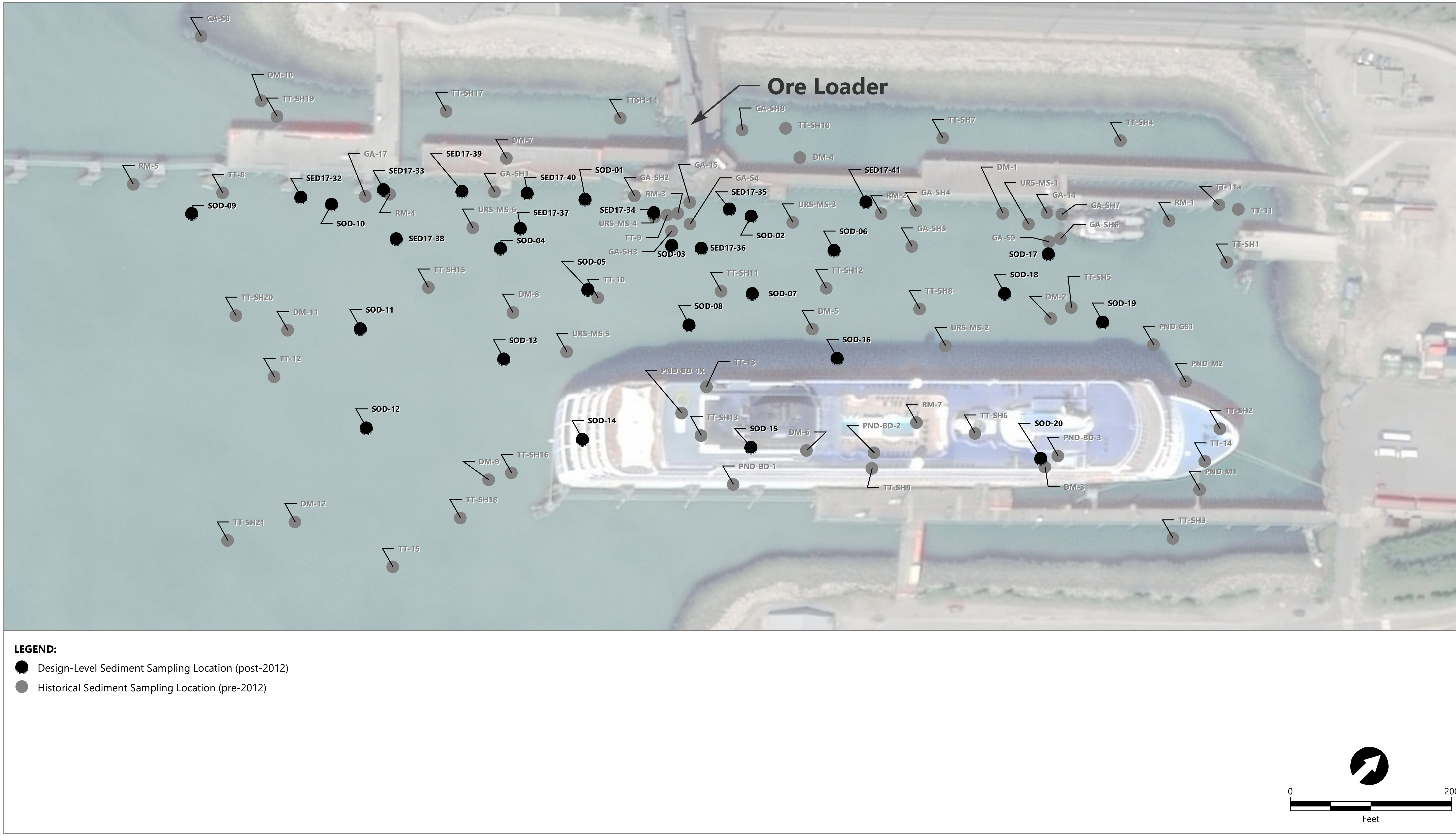

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Figure 3
Design-Level and Historical Sediment Sampling Locations
Remedial Action Options Analysis
Skagway Ore Terminal

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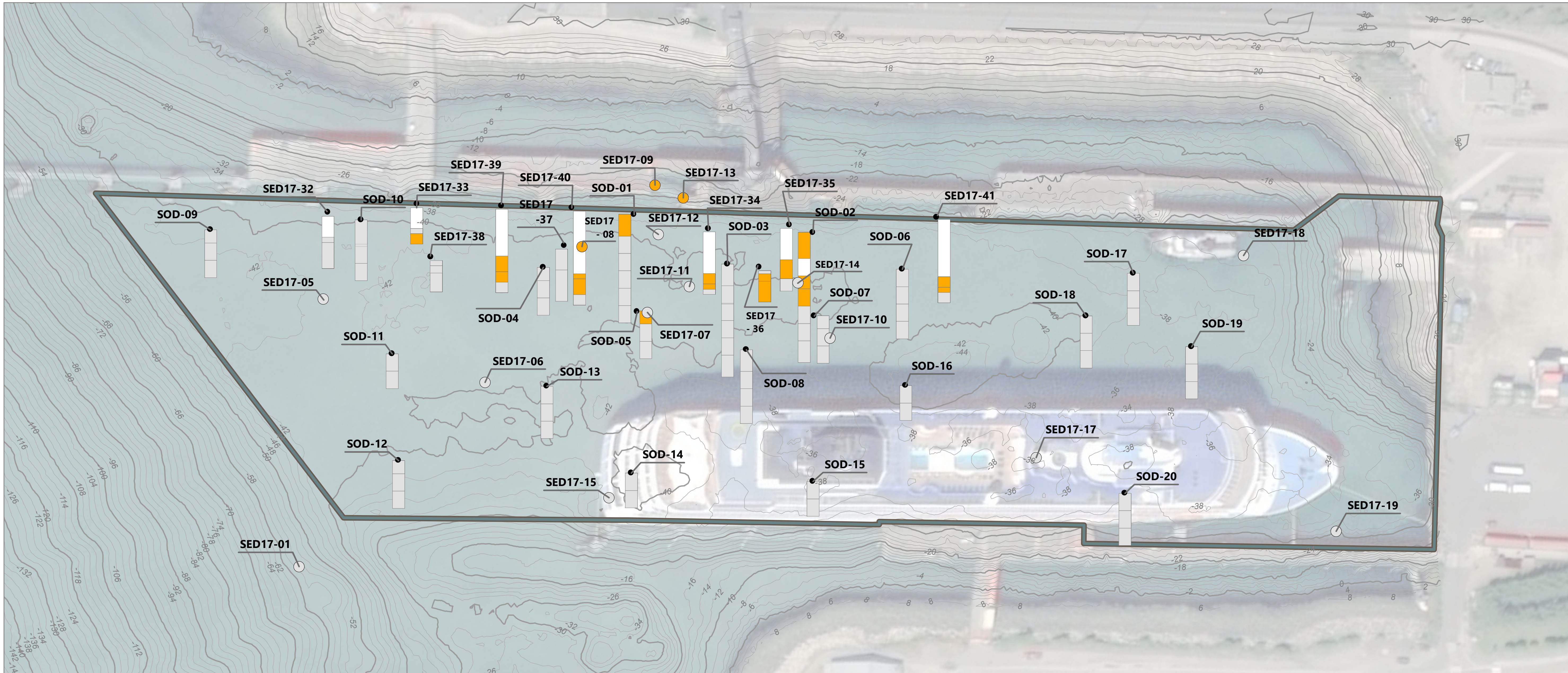

LEGEND:

Ore Basin

Bathymetry (feet MLLW)

Major Contour

Minor Contour

Subsurface Sediment Sampling Location

Surface Sediment Sampling Location

Subsurface Core Interval

Exceedance Criteria

Passes CSL for All Chemicals

Exceeds CSL for Any Chemical

No Data

NOTES:
1. MLLW: mean lower low water
2. CSL: cleanup screening level
3. Bathymetry from TerraSond, dated October 28, 2014
4. Design-level data include samples from Anchor QEA 2015 and Golder 2018.

0 200
Feet

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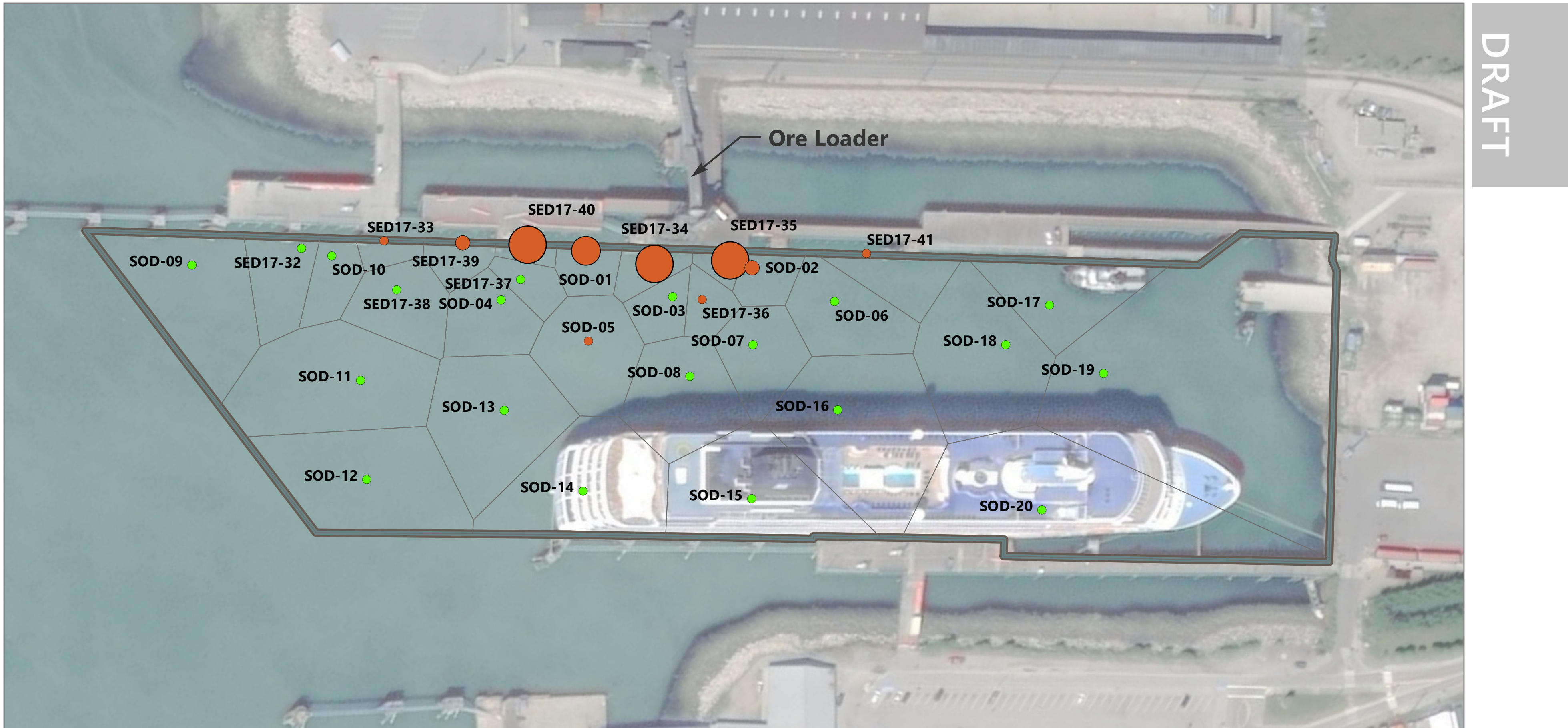
Figure 4
Summary of Design-Level Sediment Data
Remedial Action Options Analysis
Skagway Ore Terminal



LEGEND:

Mass of Lead per Area (pounds per square feet)

- 0.1 - 1.9
- 1.9 - 2.4
- 2.4 - 7.4
- > 7.4

- Lead Concentrations Below Screening Level
- Area Representative of Each Sample Location
- Ore Basin

0 200
Feet

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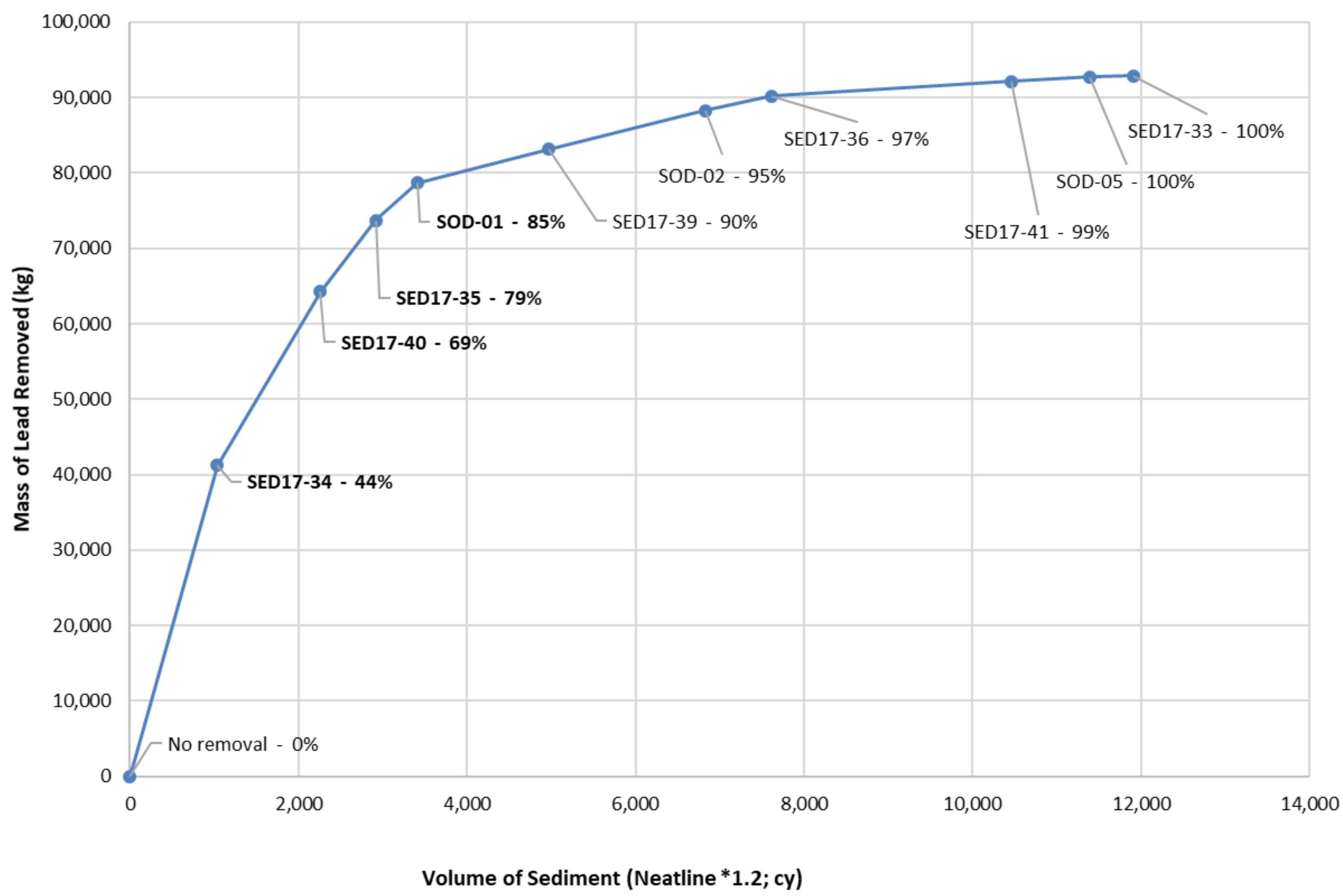
Figure 5
Lead Mass per Area in Sediment
Remedial Action Options Analysis
Skagway Ore Terminal

Figure 6 Mass and Percentage of Lead Removed with Incremental Removal of Core Polygons



Core and Polygon Information (Sorted by Concentration)							Cumulative Removal for Successive Cores Removed[a]			
Core	Dredge Depth (ft)	Average Lead Concentration (mg/kg)	Polygon Area (sf)	Sediment Neatline Volume (cy)	Sediment Neatline Mass (kg)	Lead Mass (kg)	Cumulative Number of Cores/ Polygons Removed	Cumulative Sediment Area Removed (sf)	Cumulative Sediment Volume Removed (neatline*1.2; cy)	Cumulative Mass Lead Removed (kg)
No removal	N/A						0	0	0	0
SED17-34	5.5	39,400	4,228	861	1,046,542	41,234	1	4,228	1,034	41,234
SED17-40	8.0	18,600	3,437	1,018	1,237,190	23,012	2	7,665	2,256	64,245
SED17-35	5.5	14,100	2,710	552	670,746	9,458	3	10,375	2,918	73,703
SOD-01	2.5	10,000	4,416	409	496,835	4,968	4	14,791	3,409	78,671
SED17-39	7.0	2,856	5,004	1,297	1,576,139	4,502	5	19,795	4,965	83,173
SOD-02	8.5	2,718	4,922	1,550	1,882,735	5,116	6	24,717	6,825	88,290
SED17-36	4.0	2,403	4,443	658	799,782	1,922	7	29,161	7,615	90,212
SED17-41	7.2	678	8,886	2,370	2,878,988	1,951	8	38,046	10,458	92,162
SOD-05	1.5	577	14,070	782	949,707	548	9	52,116	11,396	92,710
SED17-33	3.5	315	3,282	425	516,942	163	10	55,398	11,907	92,873

Notes:
a. The cumulative removal is the removal of the core associated with the row, plus the removal of the cores above in the table (i.e., all cores with higher concentrations).

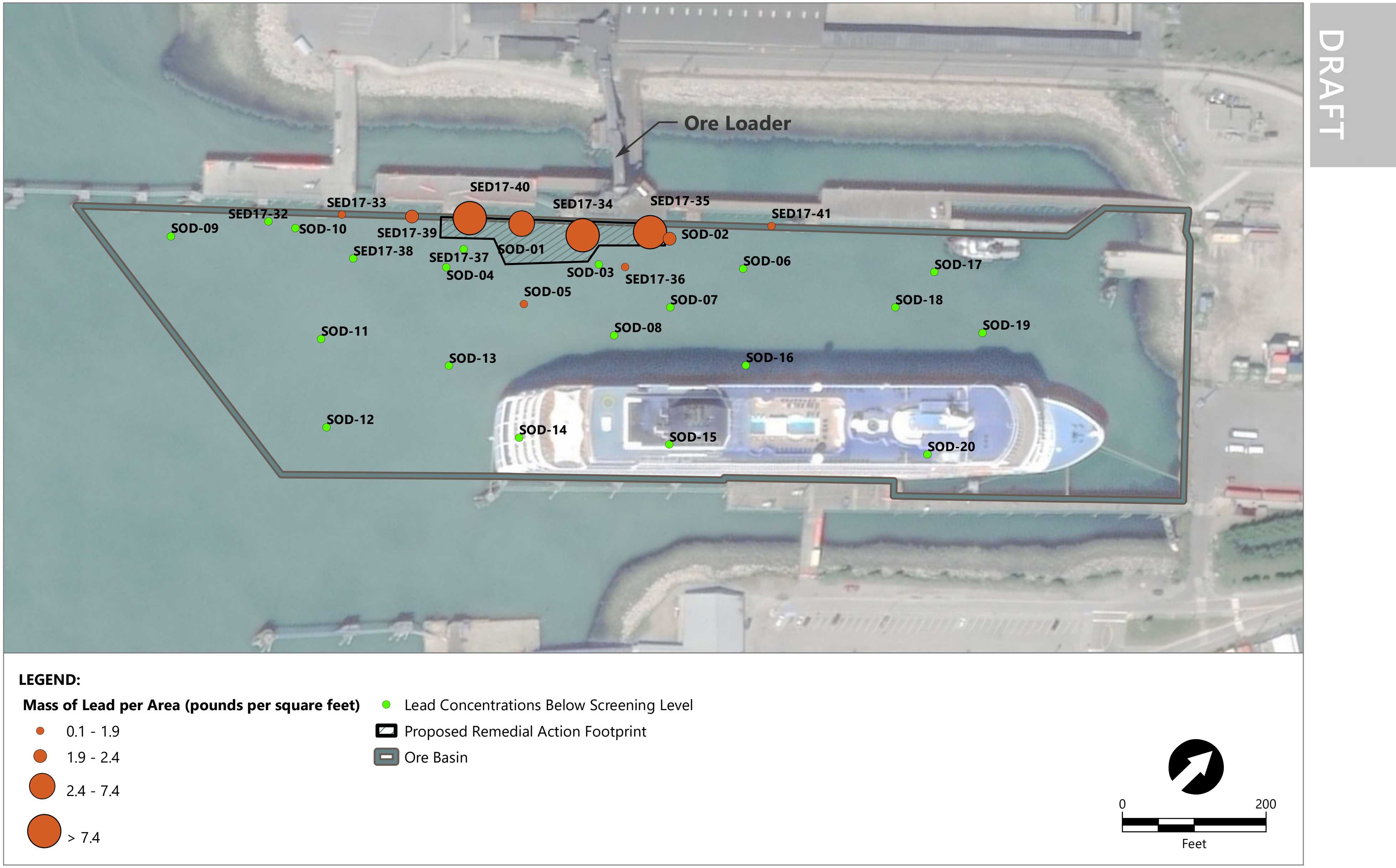


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Figure 7
Proposed Remedial Action Footprint
Remedial Action Options Analysis
Skagway Ore Terminal

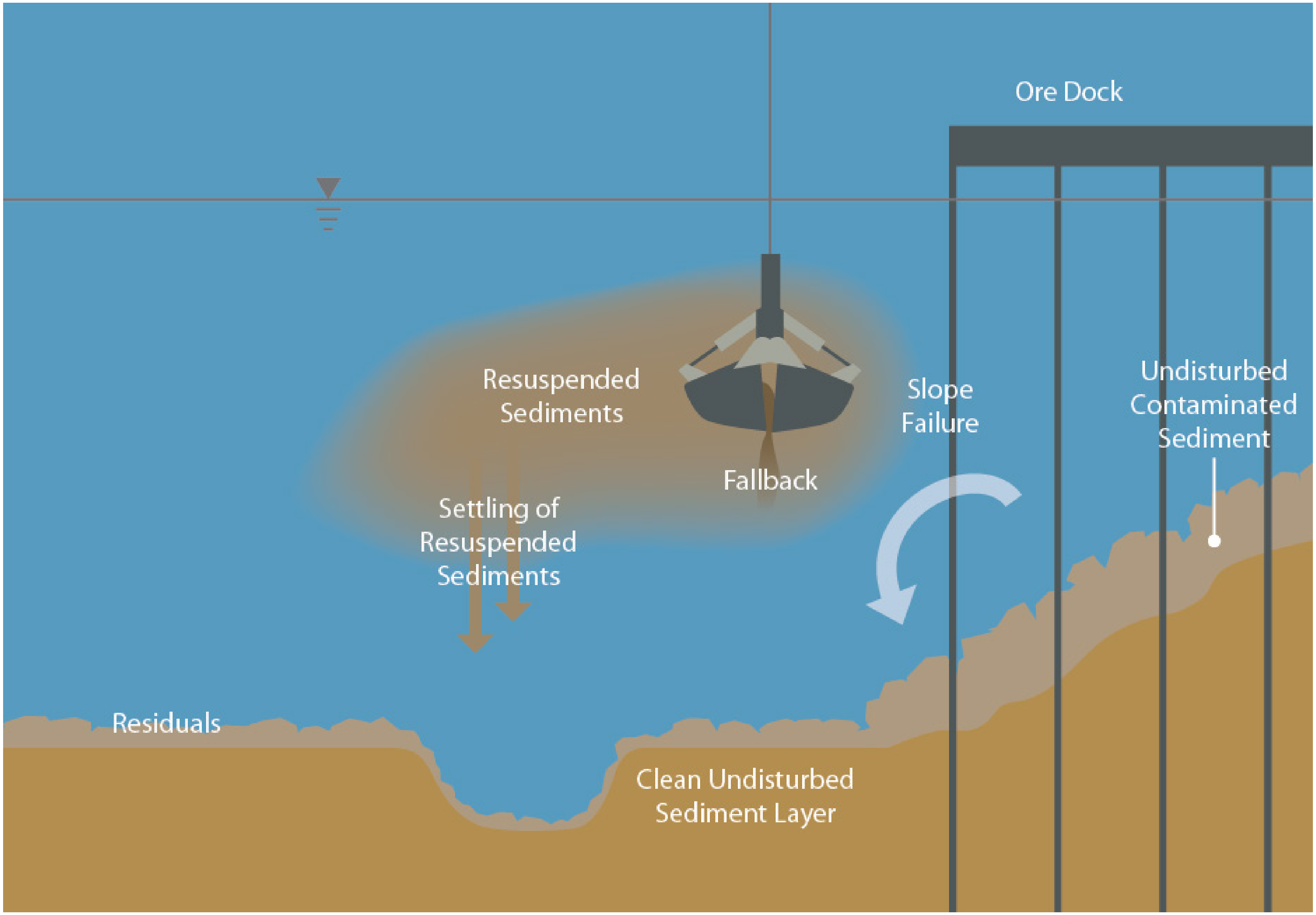

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Figure 8
Dredge Residuals Schematic
Remedial Action Options Analysis
Skagway Ore Terminal