FINAL
January 2011

Andrew Bay Data Collection Assessment Technical Memorandum

Former Naval Air Facility
Adak Island, Alaska

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ES060210114454SEA

Document Identification

Revision Number	Final
Document Title	Andrew Bay Data Collection Assessment Technical Memorandum
Site Name	Former Naval Air Facility, Adak, Alaska
Contract Task Order	KR-01
Report Coverage	This technical memorandum presents the results of a historical records review for military munitions activities and for physical site information related to munitions and explosives of concern (MEC) located within and offshore of the Andrew Lake Seawall (Operable Unit B-2, Area of Concern ALSW-01). Conceptual site model data gaps are identified. The feasibility and estimated costs of resolving them are discussed. Conceptual remedial strategies are also discussed in the course of identifying further data gaps.
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Final Document Approved for Release

Date: January 31, 2011

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Executive Summary

Background

The U.S. Navy has completed a Draft Final Remedial Investigation (RI) Report for 24 areas of concern (AOCs) located in Operable Unit (OU) B-2 at the former Naval Air Facility on Adak Island, Alaska (U.S. Navy, 2009c). During the course of the RI, it was recognized that there were insufficient data to evaluate the nature and extent of munitions and explosives of concern (MEC) present at one of the AOCs known as "the Andrew Lake Seawall" (ALSW-01). The Andrew Lake Seawall is located in the northern part of OU B-2 and divides Andrew Lake from Andrew Bay. ALSW-01 was originally designated as a munitions response area based on historical and continuing observations of accumulated MEC on the seawall and adjacent tidelands.

ALSW-01 comprises a naturally occurring barrier beach that may have been extended or built up to close and control Andrew Lake. The tideland area is composed of cobbles and boulder material with an estimated average size of 4 to 10 inches in diameter, although larger boulders are also present. The elevation of the seawall rises to 30 feet above sea level. The setting is dynamic, with significant movement and accumulation of rock on the seawall, especially during winter storm events. Andrew Bay is north of the seawall, with bottom conditions observed to be cobbles and boulders centrally in the bay and kelp present to the west and, in particular, to the east in the bay. Sea conditions can be very aggressive in Andrew Bay, such that no known fishing, recreational boating, or diving occurs in this area.

Navy Explosive Ordnance Disposal (EOD) teams periodically perform visual and detector-aided inspections (seawall sweeps) to recover and dispose of MEC from the seawall and tidelands. Seawall sweeps of record have been conducted periodically since 1962 and annually since 2004. MEC items that have been found have been reported as a variety of discarded military munitions (DMM) presumed to have been disposed in the waters of or near Andrew Bay during or after World War II. The location, contents, and extent of the offshore disposal area are unconfirmed.

In response to these uncertainties, the Navy agreed to collect available historical information about possible offshore munitions disposal near ALSW-01 and to support decision-making about remediation by evaluating the feasibility of collecting MEC-related data of known and usable quality from the marine source area at ALSW-01. Conceptual remedial approaches were developed in concert with the review and evaluation to identify any further data gaps to be addressed, to aid in developing data quality objectives, and to aid in framing questions for upcoming decision-making about remediation. Finally, the practicability, costs, and long-term effectiveness of a potential data collection effort and remedial action were evaluated.

Summary of Findings

The findings relevant to the objectives of this technical memorandum (TM) are summarized in the subsections below.

Historical Document Review

The review of historical documents did not reveal specific instances of munitions disposal in or near Andrew Bay. Historical record anecdotal reports from one veteran stationed at Adak referenced the abandonment of munitions in the terrestrial area of ALSW-01, as well as munitions disposal in shallows near the Andrew Lake Seawall and on the north side of Mount Adagdak. No dumping locations or shoreline accumulations of MEC were found in these areas during attempts to corroborate the anecdotal reports with visual field investigations conducted in July and August of 2010.

MEC Data Review

A wide range of munitions types were found at the Andrew Lake Seawall, including bombs, mortars, fuzes, grenades, projectiles, bursters, flares, and small arms ammunition. Although the materiel recovered to date has been classified as DMM, the possible presence of unexploded ordnance (UXO) cannot be categorically eliminated because training range firing positions existed along the Andrew Lake Seawall. Most items found were highly deteriorated, likely the result of abrasion in heavy wave action, surf, and surge activity in the rugged marine environment. The advanced deterioration of the items makes conclusive determination of explosive status (UXO versus DMM) difficult. Munitions are referred to as "MEC" in this TM for these reasons.

More than 1,400 individual items have been recovered and identified, with approximately 15 to 20 items recovered from the seawall each year. However, information has not been reported consistently. Data on quantities, munitions type, category, condition, and specific location vary considerably. Reliable trending analysis for these data is not possible.

Underwater MEC Presence and Transport

Most of the MEC found at ALSW-01 likely has been mobilized and transported from waters shallower than about 300 feet deep, and none is likely to have been mobilized from depths in excess of 600 feet. There are no records or indications of the lateral limits of the source area along the shoreline. Lateral deposition limits recorded during 2001, 2002, and 2003 seawall sweeps are at approximately 300 yards west and 800 yards east of the Andrew Lake Spillway. These limits were verified during the July and August 2010 site visits.

Conceptual Site Model

The primary contaminant release mechanism at the site is assumed to be offshore dumping, although no records concerning disposal in Andrew Bay have been found. Munitions would also have been deposited in the bay through use of the target ranges, which were operational between 1943 and 1945. Speculation about additional potential and unconfirmed release mechanisms has included a sunken barge, a former pier, discarding items on the beach, and erosion from the seawall. In the absence of any physical evidence or documentation, these mechanisms are considered less plausible or likely.

The human receptor exposure pathway for MEC is complete along the intertidal area of ALSW-01. Access to the beach, and, therefore, to munitions that may be deposited there, is possible and has been known to occur. The human receptor exposure pathway to MEC in the marine area is not complete.

The principal data gaps to be addressed for impending remedial decision-making include the summary items listed below:

- **The location, specific identity, and verifiable quantity of MEC items collected from ALSW-01.** This gap prevents quantifiable deposition trends from being developed that could be useful in projecting the expected type and length of time MEC will continue to be deposited on the seawall.
- **The quantity of MEC currently present in Andrew Bay that might still migrate to the Andrew Lake Seawall.** This gap also prevents quantifiable deposition trends from being developed that could be useful in projecting the expected nature and duration of deposition.
- **The general configuration and extent of the MEC source area.** MEC might exist as a point source such as mounded munitions on the seafloor, as an area source (from training range deposition or migration from a point source), or some combination of point and area sources. If a concentrated group or grouping of MEC were identified, then the quantity of such items could be useful in estimating an approximate deposition duration.

Data Collection Assessment

A conceptual approach to addressing the data gaps under appropriate data quality objectives was developed. A combination of the most reliable and appropriate survey methods was selected. The cost for this approach was estimated at $6.4 million. This cost represents a rough-order-of-magnitude estimate. The basis for this cost estimate is provided in **Appendix C**.

Remedial Action Alternatives Assessment

Conceptual remedial approaches were developed based on best professional judgment and current information about MEC presence. The conceptual remedial options considered included diving, electromagnets, mechanical rakes, entombment, and dredging. Dredging was established as the most viable remedial approach and is the most protective of human health and the environment of the alternatives identified. The estimated cost of dredging was $136 million, and represents a rough-order-of-magnitude estimate. The basis for this cost estimate is provided in **Appendix D**.

Conclusions

A critical decision point in establishing goals for data collection and remedial efforts was to determine how successful the overall effort would be as a complete remedial strategy. Success was found to be unlikely based on the conclusions discussed below.

In the best professional judgment of the Project Team and the subject matter experts consulted, there is no combination of data collection effort and remedial action that could ensure annual seawall sweeps would not continue to be required for the long term.

Site conditions and the likely wide distribution of MEC pose unresolved obstacles to a successful investigation and remedial effort. Andrew Bay bottom conditions have been documented as smaller, more mobile rocks in the center of the bay with more boulders and kelp to the east and west. Regardless of whether the original deposition of materials in Andrew Bay was from dumping, or training, or both, wave forces and the passage of approximately 65 years since release have likely thoroughly mixed MEC with rocks and boulders throughout the bay floor leading up to the beach.

Any assessment effort that would quantify MEC for removal must identify individual items among cobbles, boulders, and kelp, as well as below cobbles. Munitions must be identified below the cobbles based on the dynamic nature of the seafloor. The extent of cobble and boulder transport is such that approximately 20 to 30 feet of the Andrew Lake Spillway is blocked by new rock deposition each winter.

A successful remedial effort must remove all the transportable items from the same setting. However, based on site conditions and the limitations of any removal approach, MEC would still be present and would migrate. Therefore, in the absence of confidence in the remedial strategy, seawall sweeps would continue to be a requirement for the long term.

Table ES-1 summarizes projected costs over a 75-year period under the scenario that the data collection and remedial efforts are and are not undertaken.

TABLE ES-1
Cost Comparison of Remedial Effort with Seawall Sweeps
Former Naval Air Facility, Adak Island, Alaska

	Data Collection, Remedial Action, and Continued Seawall Sweeps	Seawall Sweeps
Data collection effort	$6,400,000	--
Remedial action	$136,000,000	--
Seawall sweeps (75 years)	$3,750,000	$3,750,000
Total (75 years)	$146,150,000	$3,750,000

Note: Seawall sweeps are shown at the present $50,000 per year with no escalation factor (present worth).

Recommendations

Overall, approximately 15 to 20 MEC items are recovered from the Andrew Lake Seawall each year. A bathymetric survey is likely to confirm the cobble and boulder composition of the seafloor with limited magnetometer access to depths that allow individual items to be identified. Removal could be successful for large piles but not for individual or widely distributed items currently under and interspersed with mobile rock in the dynamic marine environment of Andrew Bay. Factors that affect the success of a removal effort relate to the inability to collect data with enough discrimination, the depth from which information must be collected, the mobile status of materials on the seafloor, the character of the seafloor itself, and the multi-year effort required for the work.

The approach of not fully characterizing or removing all munitions that may be present is consistent with that applied at other Adak munitions response sites where exposure pathways are not complete. In particular, this approach has also been implemented on the terrestrial areas where slopes exceed 30 degrees.

Based on the conclusions of this TM as discussed by the Project Team in October 2010, seawall sweeps (and maintenance of institutional and engineering controls such as access restrictions and community outreach) would need to continue whether or not the effort was spent on the additional investigation and/or response action. The cost of additional investigation and/or response action would be more than 37 times that of the 75-year present-worth cost of $3.75 million for seawall sweeps, but would produce no quantifiable expectation of reduced risk or reduced requirements for seawall sweeps.

Given the continued requirement for seawall sweeps in any future site management case, no significant gain in risk reduction or environmental protection is likely to be realized through the data collection and/or response action effort because it is unlikely that all the individual items could be located and removed in this dynamic marine environment. In view of the lack of identifiable improvement in protection of human health and the environment and the strong likelihood that remedial goals will not be realized, the Project Team recommends that the data collection effort and potential remedial action not be undertaken. The Project Team further recommends that site management include the program of continued beach sweeps coupled with the existing institutional and engineering control program. Five-year reviews will be conducted as required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to monitor the protectiveness of this remedy.

Contents

Appendix

Table

Figure

Acronyms and Abbreviations

AATC	Anti-Aircraft Training Center
ADCP	Acoustic Doppler Current Profiler
ADEC	Alaska Department of Environmental Conservation
ALDA-01	Andrew Lake Disposal Area
ALSW-01	Andrew Lake Seawall
AOC	area of concern
BOSS	buried object scanning sonar
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHIRP	compressed high-intensity radar pulse
cm	centimeter
COPC	contaminant of potential concern
CSM	conceptual site model
CWM	chemical weapons materiel, chemical warfare materials, chemical weapons material
DMM	discarded military munitions
EOD	explosive ordnance disposal
EMI	electromagnetic inductance
EPA	U.S. Environmental Protection Agency
ESHA	Explosives Safety Hazard Assessment
ESTCP	Environmental Security Technology Certification Program
FDEM	frequency-domain electromagnetic
FM	frequency modulation
FS	feasibility study
g	gram
GPS	global positioning system
IAS	initial assessment study
LORAN	Long-range Navigation
MBE	multibeam echosounder
MEC	munitions and explosives of concern
mm	millimeter
nmi	nautical mile
NOAA	National Oceanic and Atmospheric Administration

OU	Operable Unit
QA	quality assurance
QC	quality control
RI	remedial investigation
ROM	rough order of magnitude
ROV	remotely operated vehicle
RTK	real-time kinematic
SAS	synthetic aperture sonar
SBP	sub-bottom profiling
SI	site investigation
TDEM	time-domain electromagnetic
TM	technical memorandum
USACE	U.S. Army Corps of Engineers
USBL	ultra-short baseline positioning
USFWS	U.S. Fish and Wildlife Service
UXO	unexploded ordnance
WHG	Woods Hole Group
WWII	World War II

1.0 Introduction

The U.S. Navy has completed a Draft Final Remedial Investigation (RI) Report for 24 areas of concern (AOCs) at Operable Unit (OU) B-2 at the former Naval Air Facility on Adak Island, Alaska (U.S. Navy, 2009c). **Figure 1-1** shows the facility's location. The OU B-2 RI assesses hazards posed by munitions and explosives of concern (MEC), as well as potential risks to human health and the environment from exposure to munitions constituent (MC) contamination. During comment resolution for the OU B-2 RI, the U.S. Environmental Protection Agency (EPA) and the Alaska Department of Environmental Conservation (ADEC) expressed concern that the RI addressed only the terrestrial portion of the Andrew Lake Seawall (ALSW-01) AOC, which is located on the northern part of OU B-2 adjacent to Andrew Bay (**Figure 1-1**).

The seawall isolates Andrew Lake from Andrew Bay, and consists of boulders, cobbles, and some metal debris. The seawall was included in OU B-2 as an AOC primarily because MEC regularly washes up along the seawall. The MEC source is presumed to be offshore munitions disposal in and around Andrew Bay and might include munitions from former firing points associated with a training area located on the seawall. There was also some concern that MEC had been buried among the materials used to construct the seawall. This possibility was explored during the 2008 field investigation for the OU B-2 RI, and no MEC was found at depth within the seawall.

The RI for OU B-2 did not investigate the offshore marine portions of the AOC, which serve as the presumed source area and transport zone for MEC that washes up along the seawall. The location, content, and extent of the MEC source area is unknown, as are the specific physical environmental conditions that govern the movement and deposition of MEC across ALSW-01. This lack of information restricts decision-making about the types of remedial action alternatives that might be appropriate to address MEC hazards at ALSW-01.

The EPA and ADEC requested that information regarding in-water disposal be included in the RI and that the OU B-2 feasibility study (FS) address remedial strategies for both the terrestrial and marine areas of ALSW-01. The Navy acknowledged in discussions with the EPA and ADEC that only limited data exist for the potential disposal areas, and that the development of remedial alternatives for areas with little characterization data may not be feasible. Furthermore, it was noted that additional investigation into the extent of the marine disposal areas is impractical given the high-energy environment, limited data on disposal activities, technologies available for assessment, and water depth of the presumed disposal areas.

In response to these uncertainties, the Navy agreed to collect available historical information about possible offshore disposal of munitions near ALSW-01 and to evaluate the feasibility of collecting data of known and usable quality from the marine source area at ALSW-01 to support decision-making about remediation. Additionally, the Project Team agreed to develop remedial strategies and projected costs based on the assumed conceptual site model (CSM) as a means of furthering the site evaluation while acknowledging that these approaches and costs could be further refined following a data collection effort.

For the purposes of this Data Collection Assessment Technical Memorandum (TM), munitions in Andrew Bay and depositing on the seawall are referred to as MEC. They have historically been referred to and classified as discarded military munitions (DMM), but the possibility that unexploded ordnance (UXO) might be present cannot be eliminated from consideration because of the presence of the training school and firing points on the seawall.

1.1 Objectives

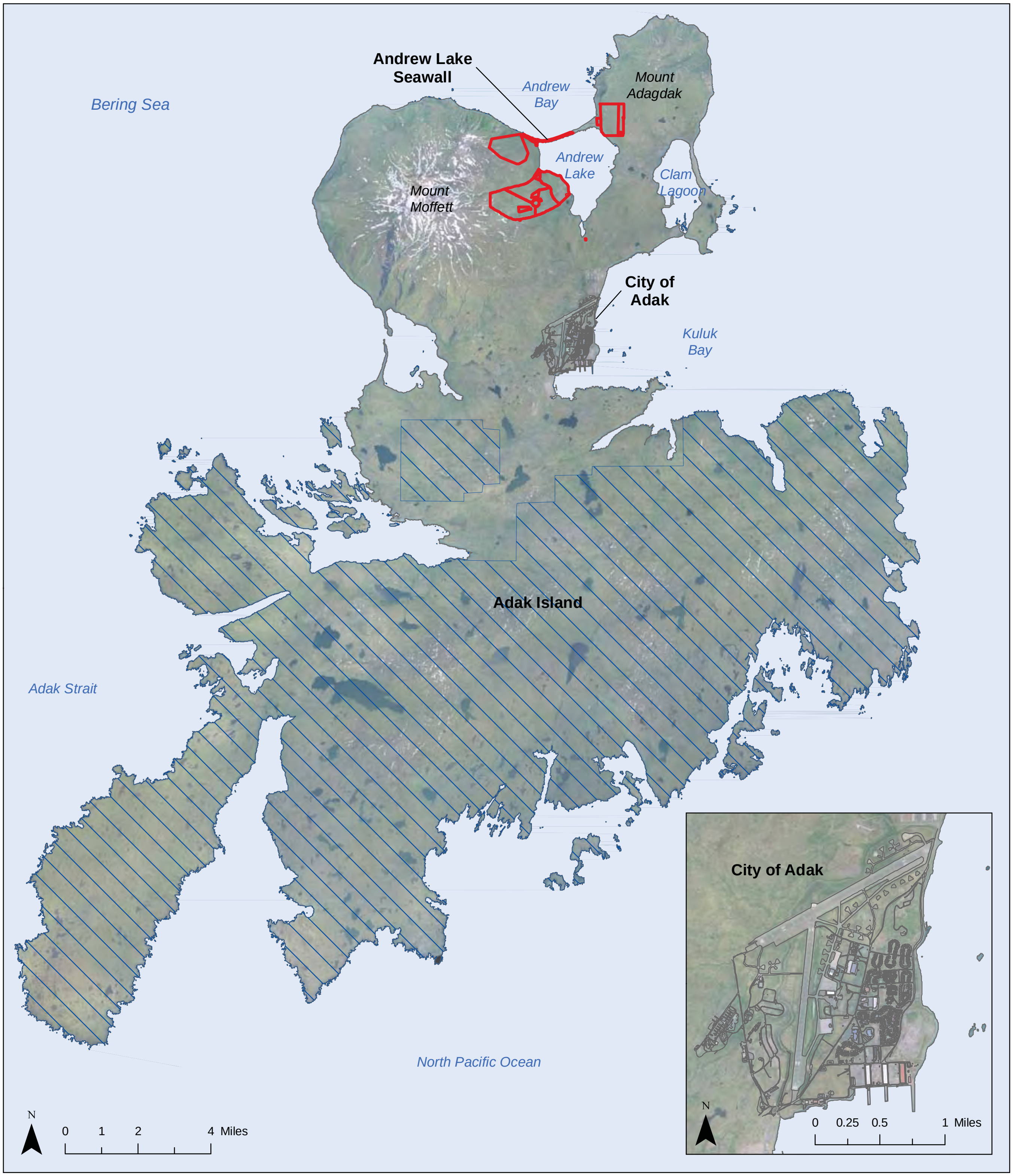
Following are the specific objectives of this TM:

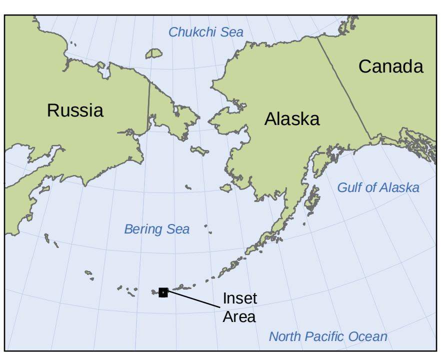
- Procure, consolidate, and review historical and other documents that might provide useful information about MEC activities in and around Andrew Bay.
- Evaluate available data on the number and types of MEC found and reported during annual surface sweeps and other activities at ALSW-01.
- Report on the nature and extent of MEC present in the offshore area to the extent possible, as well as on the nature of MEC transport within and from it.
- Develop an updated CSM for the depositional and offshore portions of ALSW-01 to better understand potential risks posed by MEC and MC in these zones.
- Review the applicability of data collection methods implemented for other projects at other locations to the CSM developed for Andrew Bay.
- Investigate and report on the feasibility and cost of collecting data of sufficient quality from the marine environment to fill data gaps to be addressed for decision-making about remediation.
- Summarize potential remedial approaches and general costs based on assumed depositional and transport scenarios, as well as the likely outcome of the data collection effort.

1.2 Document Organization

This TM consists of an Executive Summary, this introduction, and the following additional sections:

- **Section 2.0, Site Background,** summarizes the background and physical characteristics of ALSW-01.
- **Section 3.0, Data Review**, discusses the findings of previous studies conducted at ALSW-01 and of a historical records review.
- **Section 4.0, Conceptual Site Model**, provides the CSM developed for ALSW-01. The CSM describes possible exposure pathways and how contaminants might be transported from their sources to receptors.
- **Section 5.0, Data Collection Assessment**, discusses the feasibility and cost of collecting usable data for characterizing the nature and extent of munitions washing up at ALSW-01.





Source: Aerial photography (2008) USA Environmental; City of Adak (2009) CH2M HILL; AMNWR (2010) Critigen; Land and Graticules (2006) ESRI.

Legend

- Operable Unit B-2 Sites
- City of Adak
- Alask Maritime National Wildlife Refuge (AMNWR)

FIGURE 1-1
Adak Island Overview Map
Former Naval Air Facility
Adak Island, Alaska

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Section 6.0, Remedial Action Alternatives, discusses potential remedial action approaches based on the current CSM and includes projected costs for the effort.

- **Section 7.0, Conclusions**, summarizes the findings of this TM.
- **Section 8.0, References and Bibliography**, lists the documents cited in and reviewed for this TM.
- **Appendix A, Summary of Terrestrial Data**
- **Appendix B, Marine Survey Information**
- **Appendix C, Basis of Cost Estimate and Data Collection**
- **Appendix D, Remedial Action Alternatives Assessment**

2.0 Site Background

Andrew Lake Seawall, looking southwest from Mount Adagdak toward the base of Mount Moffett.

This section provides an overview of the physical setting and summary regulatory background of Andrew Lake Seawall (ALSW-01). The operational and regulatory history of Adak Island is provided in the OUB-2 RI (U.S. Navy, 2009c).

Three areas of ALSW-01 are relevant to this TM. The first is the terrestrial area of study addressed by the RI for OU B-2 (**Figure 2-1**). The second includes tidelands (intertidal areas, or areas between mean high and mean low tide elevations) along the seawall where most MEC has historically been deposited (**Figure 2-2**). The third is the marine or submerged lands presumed to be the source and transport area for MEC appearing on tidelands and occasionally on uplands areas (also shown in **Figure 2-2**). General physical characteristics and historical details specific to these areas are provided in the subsections below.

2.1 Terrestrial Area of ALSW-01

ALSW-01 includes upland elevations (above the high tide elevation) of terrestrial areas along the western portion of the seawall located along the north shoreline of Andrew Lake, as shown in **Figure 2-1**. The boundaries of ALSW-01 form a long, narrow shape that is roughly 150 feet wide and follows the contour of the seawall for approximately one mile. The Andrew Lake Spillway crosses ALSW-01 near the western end of the site. The terrestrial portion of ALSW-01 is bordered by Andrew Lake Disposal Area (ALDA-01) to the west, Andrew Lake to the south, the adjacent intertidal and marine areas of ALSW-01 to the north, and non-OU B-2 areas to the east.

ALSW-01 was designated a munitions response area based primarily[1] on historical and continuing observations of accumulated MEC along the tidal and upland zones of the AOC. Navy explosive ordnance disposal (EOD) personnel periodically perform visual and detector-aided inspections and removal of MEC (seawall sweeps). Eighteen years of EOD beach sweep recovery efforts conducted from 1962 through 2009 were reviewed for this TM. Sweeps have been conducted annually since 2004. The presumed source area for these items is the marine area to the north.

[1] There was some concern during the RI that MEC had been buried among the materials used to construct the seawall. This possibility was explored in the 2008 RI field investigation and no MEC was found at depth within the seawall.

2.1.1 Physical Characteristics

The seawall itself is narrow and elongated, similar to a dike, and has a narrow, flat top with steep sides. The seawall separates the freshwater lake from Andrew Bay to the north, which is an embayment of the Bering Sea. Elevations in the upland portion of the AOC range from about 10 to 30 feet above sea level. The following summarizes the physical characteristics of the terrestrial portion of ALSW-01:

Andrew Lake Seawall viewed from tideland toward spillway area in July 2010. Cobbles plug the spillway over winter storm seasons.

Area. Total area approximately 10 acres.

Access. Access by unimproved road originating on the east side of Andrew Lake. A locked steel gate is located on this road to deter public access. Access is also possible on foot from the main access road running along the western shore of Andrew Lake. This road is gated near the south end to deter general access.

Terrain. Transitions from generally flat atop the seawall to very steep along the sides (north and south) of the seawall. The ground surface in the depositional area west of the spillway is hummocky.

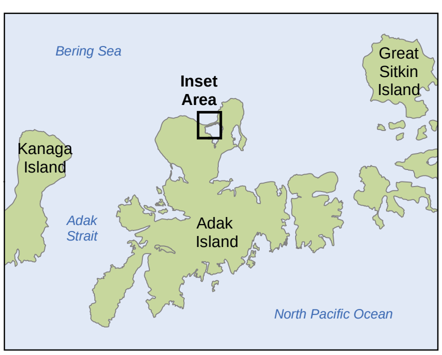
Vegetation. Short, relatively sparse grass atop the wall and tussocks of taller grass along the sides where adequate soil is present.

Ecology. Large rock and cobble habitat with sparse vegetation and low diversity of wildlife. The beach areas provide foraging opportunities for several species of birds, including the bald eagle, several species of gulls, and the rock sandpiper.

Andrew Lake Seawall viewed from spillway toward tidelands after clearing conducted in September 2009.

Hydrology/Surface Water. Natural spillway at the northwest corner of Andrew Lake (see **Figure 2-1**) allows some flow of freshwater into Andrew Bay. At times, the spillway is obstructed and discharge is limited to water flowing through the cobble substrate of the seawall to Andrew Bay.

Geology. Natural berm constructed of moderately sorted rounded to well rounded boulder and cobble gravel that may have been reinforced during World War II (WWII) by the addition of metal debris and wood.



Source: Aerial, AOC, Countours (2008) USA Environmental; Slopes Greater Than 30 Degrees (2009) Critigen; Land (2006) ESRI.

Legend

- Area of Concern (AOC)
- 100-ft Contour
- Slopes Greater Than 30 Degrees

FIGURE 2-1
Andrew Lake Seawall
Former Naval Air Facility
Adak Island, Alaska

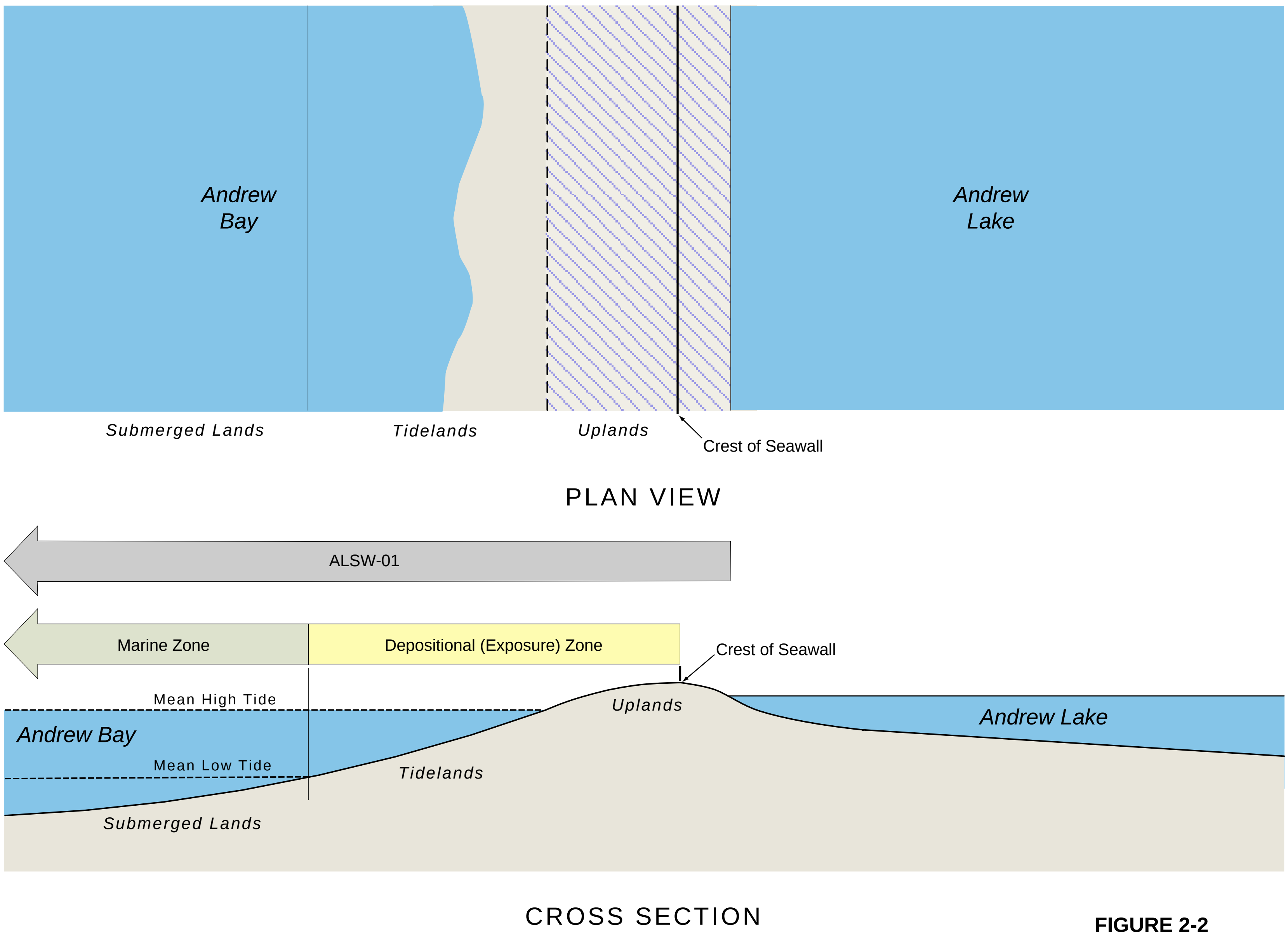


FIGURE 2-2
ALSW-01 Marine and Depositional Zones
Former Naval Air Facility
Adak Island, Alaska

Use. Navy Exclusion area. Future identified uses include subsistence, recreation, or wildlife management.

The surface geology of the Andrew Lake Seawall area reflects the high-energy nature of the Andrew Bay coastline, with large rocks and cobbles making up the steeply sloped beach and nearby areas. The portion of ALSW-01 west of the spillway, inclusive of portions of the Andrew Lake disposal area (ALDA-01), is covered with rocks and cobbles that were washed into the area during storms.

Andrew Lake Seawall areas east of spillway showing steepness of tidelands. Note size of cobbles transported to both tidelands and upland areas by wave energy and storm surge.

2.1.2 Past Investigations

A 2008 investigation at ALSW-01 focused on possible subsurface MEC along upland portions of the seawall and the upland portion of the AOC west of the spillway; the study included the following:

- A geophysical survey and limited intrusive investigation along transects that followed the top and sides of the seawall east of the spillway
- A detector-aided visual inspection west of the spillway
- A 100 percent geophysical survey and limited intrusive investigation of a 30-meter by 30-meter grid at the expected location for a small arms burial area west of the spillway

The intrusive investigations were limited by the extremely rough and cobbly nature of the seawall, as well as the high density of anomalies caused by the apparent use of metal debris in seawall construction. No MEC was found in the areas addressed during the 2008 investigation.

2.1.3 Explosives Safety Hazard Assessment Results for ALSW-01

Overall site conditions and the nature and extent of MEC at each OU B-2 site, including ALSW-01, were inputs to the Adak-specific Explosives Safety Hazard Assessment (ESHA) tool that was used to assess explosive hazards as part of the OU B-2 RI. The ESHA tool analyzes the results of the MEC portion of the RI and determines the potential magnitude of the risk/hazard present. This methodology was developed as part of the overall framework for assessing and managing potential MEC threats on Adak Island and reflects the following conclusions about MEC risk on Adak:

- Areas where MEC is known or indicated to be present create more potential for explosive hazards than areas where MEC has been purposefully searched for and have not been found or where all known MEC has been removed.
- Different types of MEC present different potentials to detonate if disturbed, and, if detonated, can produce a range of adverse consequences.

- The potential for explosive hazards is created when MEC is located where it is likely to be disturbed by current or future land use activities.
- There is greater potential for explosive risk where public exposure is greatest (for example, increased contact or easier accessibility).

The ESHA assigned relative scores to qualitative estimates of the MEC but did not define quantitative measures of known MEC risk. A score of "A" corresponds to the lowest relative hazard level, while a score of "E" corresponds to the highest relative hazard level. From the ESHA, RI outcomes ranked sites as either (1) Adak no further action with institutional controls (for example, educational awareness) for sites with A or B scores, or (2) further evaluation in the FS for sites with C or D scores. The ESHA methodology considers only human exposure to MEC on land; there is no provision for possible in-water exposure.

The surface of ALSW-01 received a score of C, indicating that further evaluation and/or response actions are needed to reduce the risk to the public. **Table 2-1** summarizes the site characteristics relevant to the ESHA scoring.

TABLE 2-1
ESHA Results for ALSW-01
Former Naval Air Facility, Adak Island, Alaska

Hazard Factor	Site-specific Characteristics
Ordnance presence (MEC)	MEC present, as determined from annual surface sweeps
Ordnance hazard category	Critical
Amount of energetic material	1 to 10 pounds (81 mm projectile: 2.05 pounds)
Depth of ordnance	Surface (found)
Access to area	Restricted (locked gate)
Current (and likely near-term future) land use	Access Restricted Navy Exclusion Area
Future land use	Subsistence, recreation, or wildlife management

Note: Previous (2004) Explosives Safety Hazard Assessment (ESHA) Score: C. The current ESHA Score: C. Disposition: Further evaluation is needed—forward to the Feasibility Study.
MEC = munitions and explosives of concern
mm = millimeter

2.2 Intertidal and Marine Zones of ALSW-01

ALSW-01 includes the intertidal areas bordering, and the submerged lands offshore of, the seawall. The marine portion of ALSW-01 is the presumed source, transport, and deposition area for MEC. The nature and extent of MEC in the marine portion of ALSW-01 have not been determined. Andrew Bay is a marine environment with a high-energy beach susceptible to heavy surf. The shoreline along the Andrew Lake Seawall reflects the geology and high-energy nature of the Andrew Bay coastline, with large rocks and cobbles making up the steeply sloped beach and nearby areas.

2.2.1 Past Investigations

Information on the seabed composition is limited. An EOD report (U.S. Navy, 2000) noted that the rocky conditions along the shoreline persist well offshore. Depth soundings made along about 2.5 miles of the shore indicated that the 100-foot contour was approximately 1,000 yards from the shoreline, consistent with available nautical charts. Navy policy states that the explosive risk of munitions exists only in waters shallower than 120 feet. This depth is based on the estimated limit at which recreational diving is likely to occur (U.S. Navy, 2005a). Water depth contours and other marine area information are shown in **Figure 2-3**.

Andrew Lake Seawall depositional area to the west of the Andrew Lake spillway.

Included in the work effort offshore of the ALSW was a surface and underwater visual survey. Navy personnel performed surface swims and identified munitions on the sea bottom in the vicinity of the Lake Andrew Spillway along a 550-yard traverse at a water depth of approximately 15 feet. The munitions observed included 40 millimeter (mm) projectiles to 81 mm mortars and an unconfirmed occurrence of a depth charge. The surveyors reported that many munitions may have been present but were obscured by the large diameter of boulders. The composition of the bottom through the tidelands and into submerged lands was reported as a solid layer of boulders out to a water depth of approximately 50 feet. Mixed sand and rock were noted at depths of 50 to 100 feet. The presence of kelp was observed as minimal by Navy personnel in August 2000 (U.S. Navy, 2000).

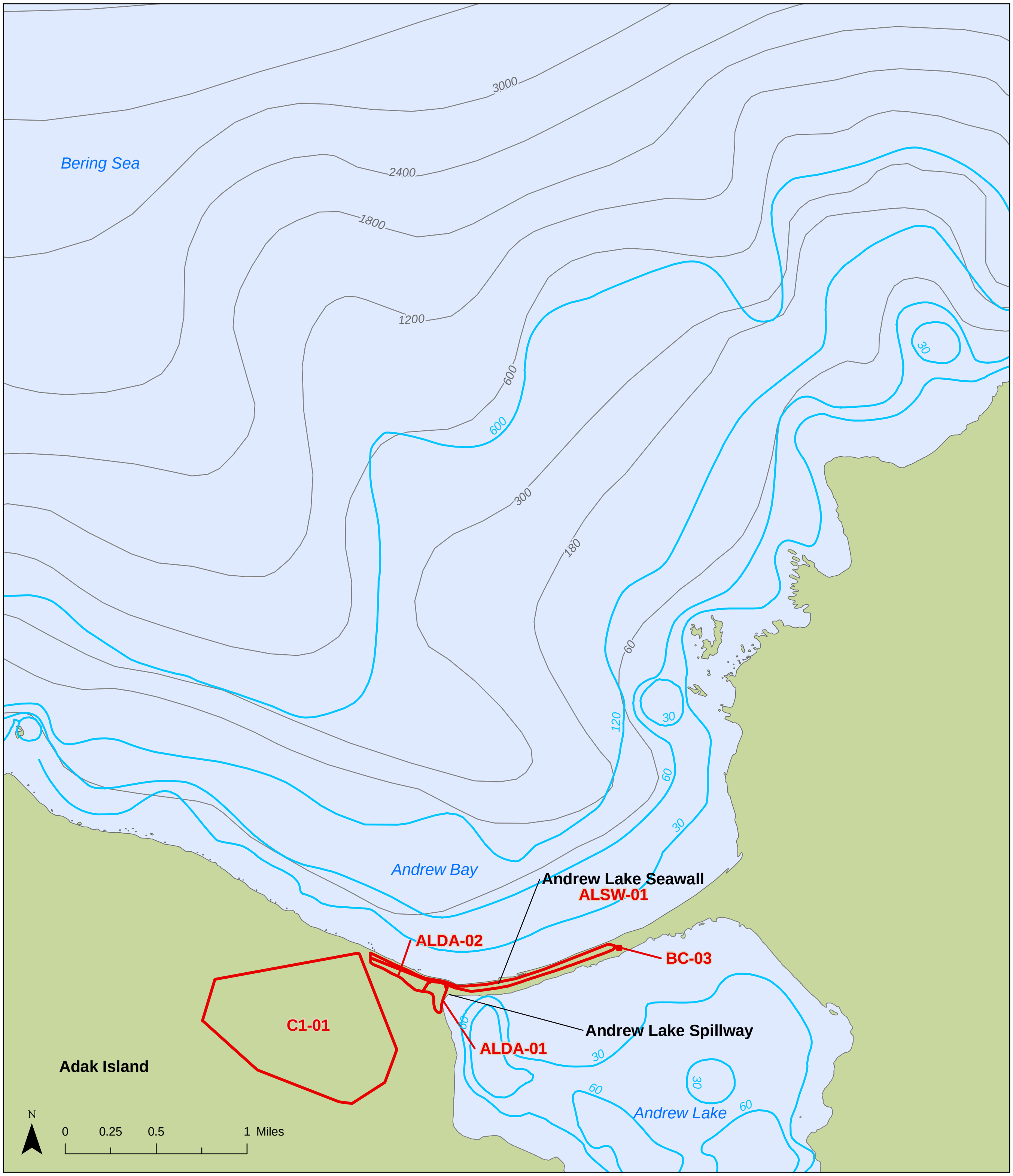
A modeling study was conducted by the Woods Hole Group (WHG) to identify conditions under which significant munitions motion would be expected to occur (WHG, 2002). The study results are presented in Section 3.

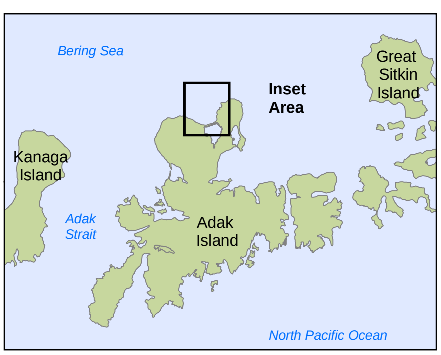
Andrew Lake Seawall depositional area to the east of the Andrew Lake spillway. Note kelp formations extending out into Andrew Bay in background.

2.2.2 Ecological Considerations

Vegetation in this area is limited to rockweed and kelp along the rocky segments of the beach (U.S. Fish and Wildlife Service [USFWS], 1995a). WHG (2002) indicated that kelp beds extend out hundreds of meters from the beach. The presence of kelp beds typically varies throughout the year, with kelp thickest in the late summer and early fall, and much reduced during the winter, as large winter storms tend to tear kelp from the seabed.

As discussed in Section 2.7.2 of the OU B-2 RI (U.S. Navy, 2009c), marine mammals found in the bays and harbors of Adak Island, both year-round and on a migratory basis, include the harbor seal, orca, northern harbor porpoise, Dall's porpoise, sperm whale, Baird's beaked whale, goosebeaked whale, gray whale, minke whale, fin whale, humpback whale, right whale, sea otter, and Steller's sea lion. Marine aquatic resources are abundant in Andrew Bay. These include several species of crustacea, mollusks, echinoderms, bivalves, and fish that inhabit the area. Additionally, USFWS reports that three streams on the west side of Andrew Lake, including Moffett Creek, support several species of anadromous fish (for example, coho salmon) that are expected to migrate through Andrew Bay.





Source: NOAA Bathymetry Coastal from US Chart 16460 (2001); NOAA Approach bathymetry from US Chart 16465 (2009); USA Environmental AOCs (2008).

Legend

NOAA Approach Bathymetry Contours in Feet (Chart 16465)

NOAA Coastal Bathymetry Contours in Feet (Chart 16460)

Area of Concern (AOC)

FIGURE 2-3
Bathymetry and Areas of Concern
Former Naval Air Facility
Adak Island, Alaska

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3.0 Data Review

This section presents the review of available data for the terrestrial and marine portions of ALSW-01.

3.1 Historical Data Review

The objective of the site information assessment was to review previous studies and historical documents to gather information about the source, nature, and extent of MEC found at ALSW-01. A detailed search for and review of historical documents was conducted by CH2M HILL and Navy personnel.

3.1.1 Munitions Investigation Activities near ALSW-01

Multiple munitions response AOCs near ALSW-01 are identified and documented in the OU B-2 RI (U.S. Navy, 2009c). **Figure 3-1** shows the location of ALSW-01 and other nearby AOCs including ALDA-01, Andrew Lake Beach Crater Area (ALDA-02), and Blind Cove/Camper's Cove Firing Point 1 (BC-03). Combat Range 1 Mortar Impact Area (C1-01) is also shown in the figure, but it is located well above the elevation of the seawall, so activities there are unlikely to have influenced the seawall area. Munitions activities and MEC investigation findings as documented in the RI for OU B-2 at these AOCs, including ALSW-01, are summarized in **Table 3-1**.

3.1.2 Archive Search

A series of documents were obtained to provide information about past munitions-related operations near ALSW-01, locations of ammunition disposal areas in or near Andrew Bay, and types and frequency of munitions found in the intertidal area of ALSW-01. A historical document archive review was conducted by a Navy archivist to provide information for this TM (U.S. Navy, 2010e). This effort included the review of documents at the repositories listed below:

- Naval History and Heritage Command (Photographic Section, Aviation History and Operational Archives), Washington Navy Yard, Washington, D.C.
- Navy Library, Washington Navy Yard, Washington, D.C.
- National Archives and Records Administration (National Archives I), Pennsylvania Avenue, Washington, D.C.
- National Archives and Records Administration (National Archives II), Adelphi Road, College Park, Maryland
- National Archives and Records Administration (Regional Branch), Anchorage, Alaska
- Online Web sources

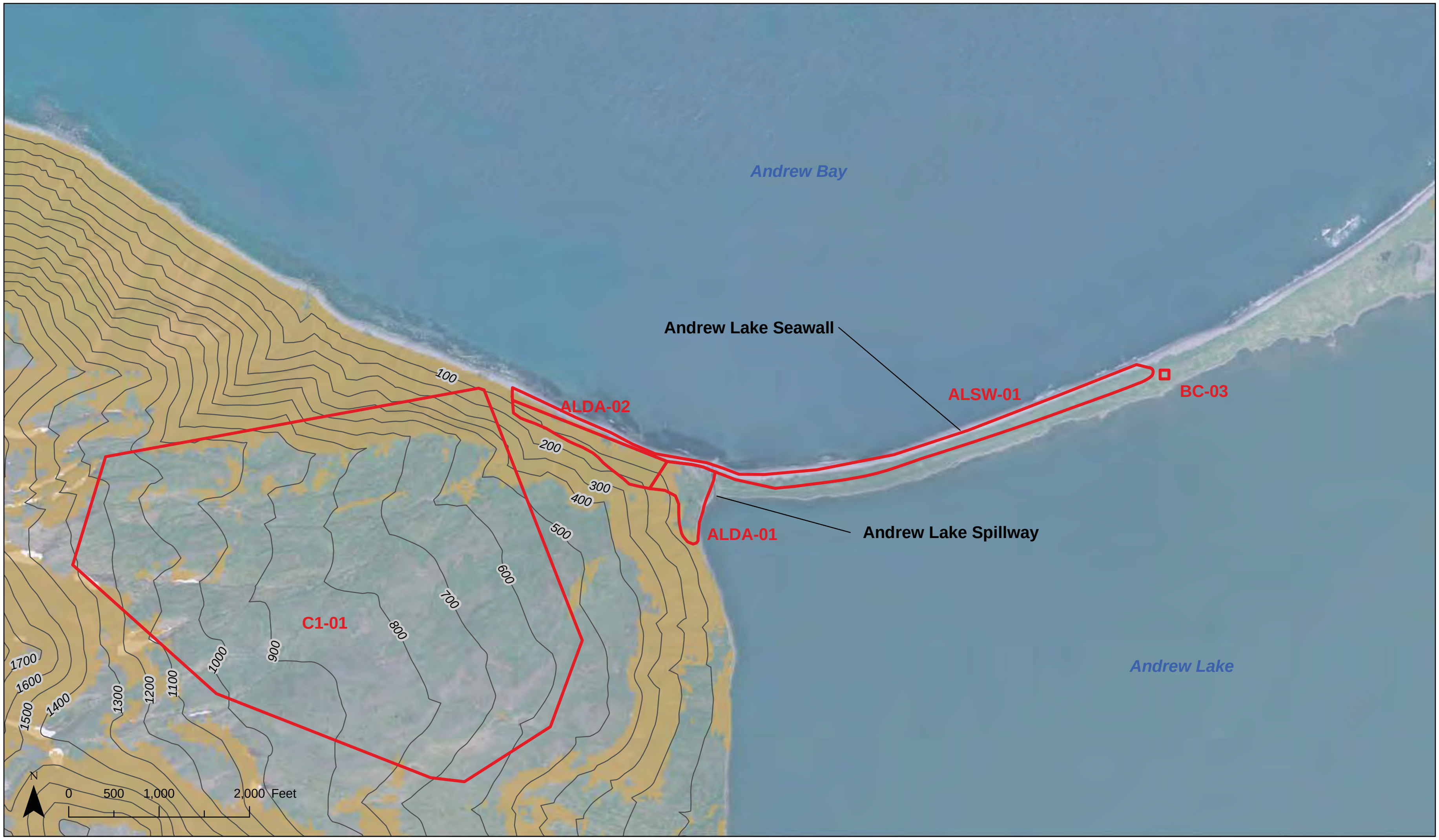
TABLE 3-1
Munitions Found at and in the Vicinity of the Andrew Lake Seawall
Former Naval Air Facility, Adak Island, Alaska

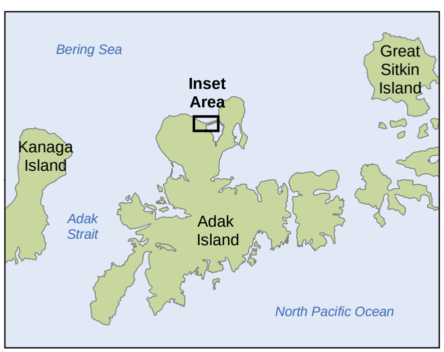
AOC	AOC Name	Munitions Activities	Summary of MEC Findings
ALDA-01	Andrew Lake Disposal Area	Potential burial area with possible wash-up of MEC from offshore disposal area	MEC, including 60 mm and 81 mm mortar casings, 40 mm MK11, M47A2 incendiary bomb, metal fragments including 0.50 caliber bullet. MEC found from the surface down to 2 feet bgs.
ALDA-02	Andrew Lake Beach Crater Area	Potential aerial bombing range	No MEC finds to date; however, heavy bomb fragmentation has been identified.
ALSW-01	Andrew Lake Seawall	Wash-up area for disposal at sea and potential disposal area.	MEC, including 40 mm cartridge, 60 mm and 81 mm mortars, various fuzes, thermite bomblets, thermite grenades, M52 incendiary bomb, and small arms. All found at the surface.
BC-03	Blind Cove/ Camper's Cove Firing Point 1	Firing point for 155 mm projectiles	No MEC found.
C1-01	Combat Range 1 Mortar Impact Area	Combat range and/or maneuver area	UXO, including 60 mm and 81 mm mortars, 20 mm projectiles, 37 mm projectiles, 40 mm projectiles, M100 series bomb fuze. No MEC found. Some metal fragments found. UXO and metal fragments found from the surface down to 4 feet bgs.

Note: Information obtained from OU B-2 Remedial Investigation report (U.S. Navy, 2009c).
AOC = area of concern
bgs = below ground surface
MEC = munitions and explosives of concern
mm = millimeter
UXO = unexploded ordnance

Additional documents from Navy regional files were also reviewed, including those listed below.

- **U.S. Army Corps of Engineers (USACE) Historical Analysis—Adak, Alaska CWM Search.** Historical aerial photographic analysis of an area between Clam Lagoon and Andrew Lake (USACE, 2002b).
- **USACE Archives Search Summary Report**. Archive search report for munitions and explosive waste chemical warfare materiel at Adak Naval Air Station (USACE, 1993).
- **U.S. Navy Follow-up Archives Search Report**. Archive search report for chemical warfare materiel at Adak Naval Air Station (U.S. Navy, 1997).
- **Foster Wheeler Archive Search Summary Report: Volumes 1 and 2**. Summary of archive search reports conducted for Adak Island. Includes appendix with EOD incident reports at Adak Island from the 1940s through the early 1990s (Foster Wheeler, 1998).
- **U.S. Navy After-Action Reports**. Documentation of EOD trip recoveries between 2004 and 2009. Includes documentation of munitions recovered from Andrew Lake Seawall munitions sweeps (U.S. Navy, 2004a, 2005b, 2006, 2007a, 2008, 2009a).





Legend

100-ft Contour

Area of Concern (AOC)

Slopes Greater Than 30 Degrees

Source: Aerial, AOCs, Contours (2008) USA Environmental; Slopes Greater Than 30 Degrees (2009) Critigen; Land (2006) ESRI.

FIGURE 3-1
Topography and AOCs
Andrew Bay Seawall Area
Former Naval Air Facility
Adak Island, Alaska

\\JAFAR\PROJ\ADAK_335753\MAPFILES\TECHMEMO\ANDREWSEAWALL_TOPOGRAPHYAOC.MXD AYOST 6/14/2010 11:29:39

3.1.3 Historical Document Review Findings

The historical documents obtained provide information about WWII-era military activities, as well as operations in the Aleutian Islands, on Adak Island, and near Andrew Bay. Various military training activities occurred in the vicinity of Andrew Lake during and just after WWII. **Figure 3-2** illustrates the historical military activities conducted in the Adak Island area. These activities and training ranges include the following:

- U.S. Army coastal artillery placements
- Small arms firing ranges
- Anti-aircraft defense artillery
- U.S. Navy Anti-Aircraft Training Center
- U.S. Naval Ships gunnery exercises

The historical document review did not find any conclusive evidence of munitions having been disposed of in Andrew Bay. The possibility exists that obsolete or unserviceable ammunition was disposed of in the shallow waters of Andrew Bay; however, no specific documentation of disposal or the facilities to support disposal was located.

Figure 3-3 shows some of the specific activities near the Andrew Lake Seawall. Anti-aircraft artillery guns were mounted near and along Andrew Lake Seawall during WWII. The purpose of the anti-aircraft artillery positions was to provide local defense against low-flying enemy aircraft. In addition, the U.S. Navy Anti-Aircraft Training Center (AATC) was established in February 1944 near Andrew Lake. Courses of instruction and firing at the AATC were provided on 50 caliber machine guns, 20 millimeter (mm) guns, and 3-inch/50 caliber dual-purpose guns. Targets included towed sleds, rockets, balloons, and sleeves in or near Andrew Bay. A restricted Danger Zone (see **Figure 3-3**) was established in 1944 to prohibit unauthorized traffic within the firing area during AATC hours of operation. Additionally U.S. naval ships conducted gunnery exercises and practice in the Bering Sea north of Andrew Bay during WWII. Targets included towed sleds, sleeves, and balloons.

3.1.3.1 Munitions Disposal Activities

The historical documentation did not provide conclusive evidence of specific offshore munitions disposal near Andrew Bay (for example, barge records). Anecdotal references to nearshore disposal in Andrew Bay were found. Numerous records allude to general munitions disposal practices at Adak and disposal areas in the Aleutian Island chain during WWII and immediately following the war. The items listed below are the more notable of those observed during the historical document review.

- Extensive open-air magazines for a wide variety of aircraft, naval, artillery, and infantry munitions were located throughout the island as referenced and observed in multiple WWII-era operational reports and photographs.

- Photographs reference gunnery positions and open-air magazines at the east end of the Andrew Lake Seawall; however, some of these contain contradictory references for areas around Clam Lagoon to the east and not all photographs are of sufficient quality to determine location reference points (Foster Wheeler, 1998).

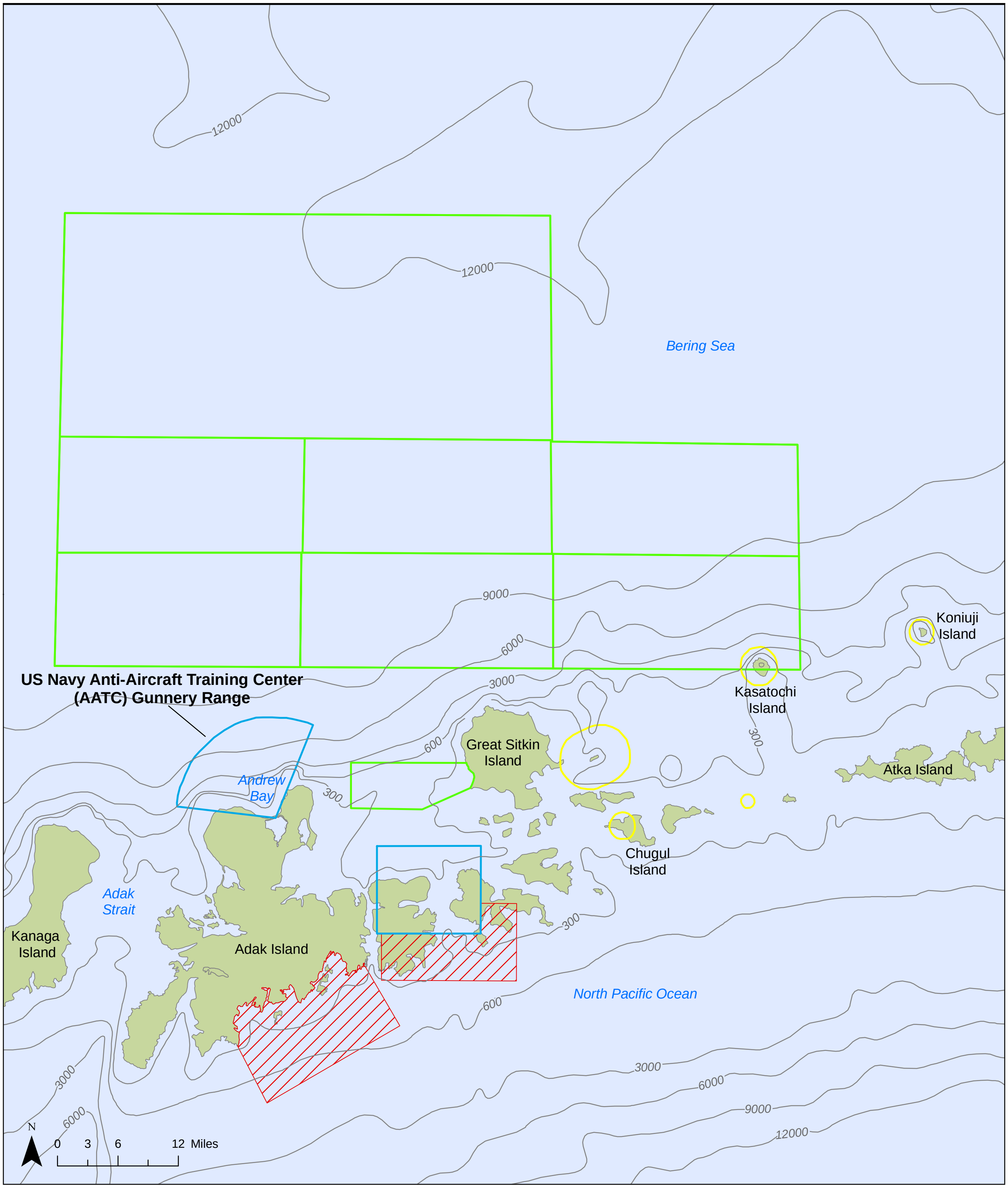
On July 11, 1945, the Commandant of the 17th Naval District established three disposal areas for explosives, ammunition, and chemicals. They included areas near Kodiak Island, Atka Island, and Sitka Island (U.S. Navy, 2010e).

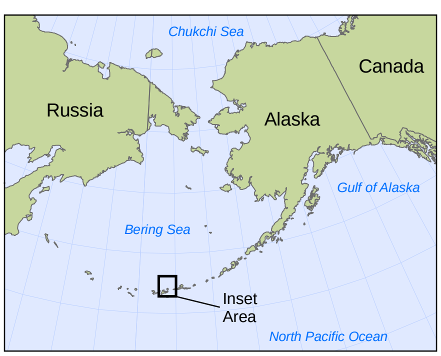
- A Navy Staff Conference report dated August 2, 1946, discusses ammunition disposal at sea. The report states that there were three disposal sites being used near Sitka, Kodiak, and Adak islands (consistent with the documentation of disposal areas discussed above). The exact locations of disposal areas are not provided. A request was made to authorize additional disposal areas that would be a minimum of 10 miles offshore and a minimum of 6,000 feet deep (USACE, 1993).
- Multiple references have been made to a chemical and possibly non-chemical munitions disposal area 10 to 13 miles north of Adak Island. Mustard gas and lewisite chemical munitions are referenced in multiple documents, as are incendiary bombs, smoke grenades, incendiary grenades, and a variety of materials associated with these chemical munitions (Foster Wheeler, 1998).
- One operational report states that 65 tons of ammunition was disposed of at Adak in June 1946 and 130 tons remained to be destroyed. The report did not specify the method or area of disposal (USACE, 1993).
- 1947 reports discussed an inventory of 530 tons of unserviceable ammunition and general references to disposal on Adak Island and at sea (Foster Wheeler, 1998).
- The background section of a 1962 Ordnance Disposal Operations report contains the text below (Foster Wheeler, 1998). No documents or reports supporting these specific statements were found.

  > "The ordnance is assumed to have been scattered by attempts to destroy large quantities with insufficient counter charges, prior to departure of the U.S. Army in 1949. Exact information as to the responsibility is not available in EOD files."

- The background section of a 1963 Ordnance Disposal Operations report contains the text below (Foster Wheeler, 1998). No documents or reports supporting these specific statements were found.

  > "The bulk of the unexploded ordnance (UXO) on Adak is presumed to be abandoned U.S. Army owned ammunition dating back to 1943-1945. From observations it appears that the ammunition was disposed of within the five fathom curve or left on the beaches to be disposed of by the elements. The area used as heavy weapons firing range shows indiscriminate use in that firing was not localized and no real effort put forth on range clearance of duds. In general, this ammunition is becoming more hazardous with age (rounds being pounded on rocks in beach areas and chemical rounds rusting through and igniting spontaneously)."



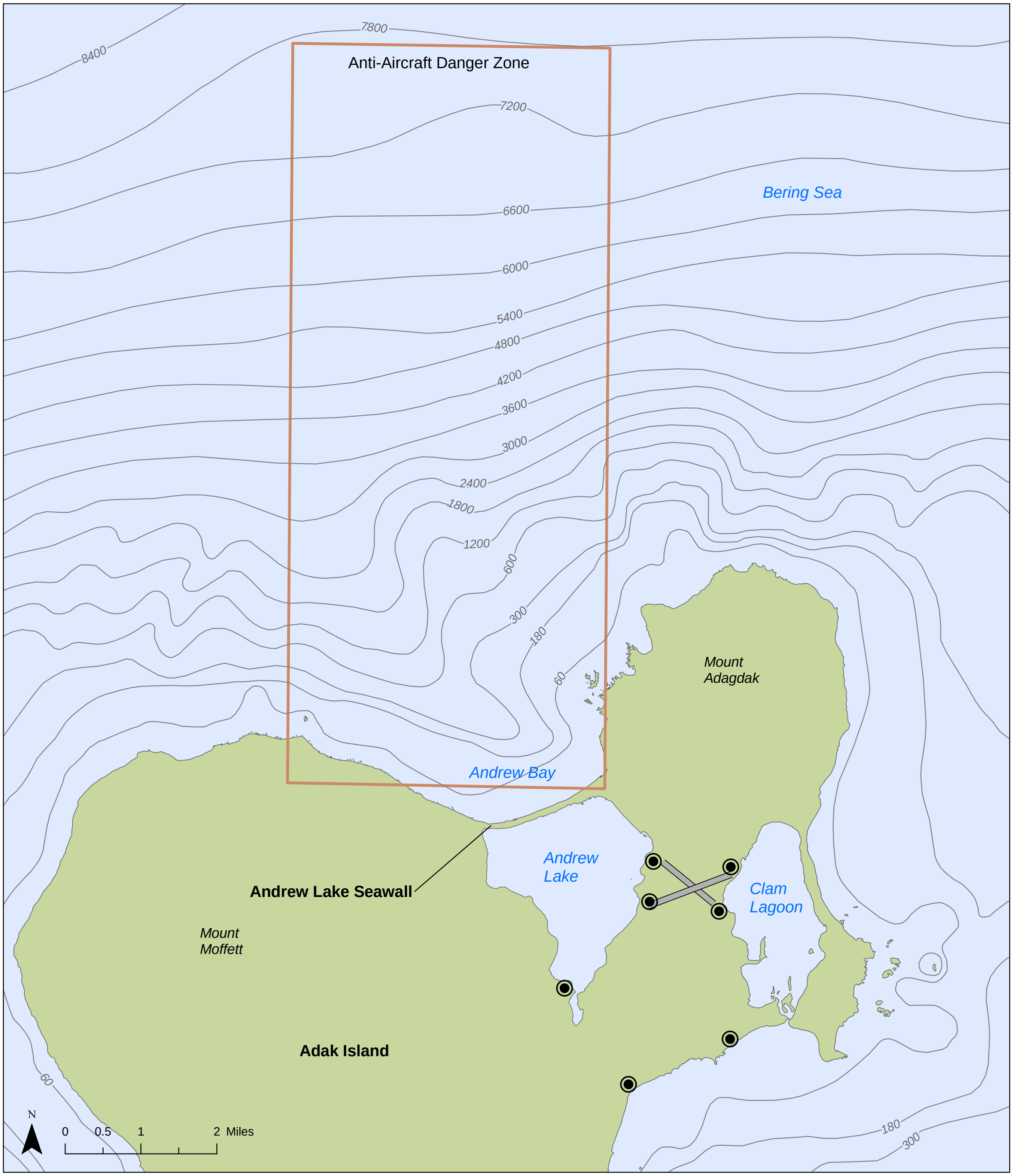


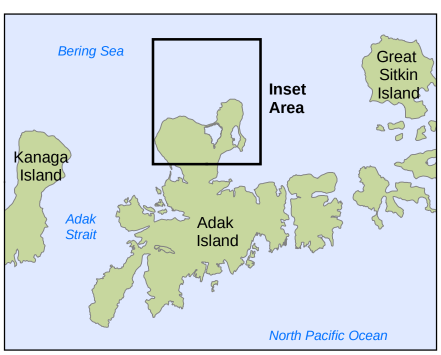
Source: General Bathymetry (2005) NOAA; Military Activities (2010) Critigen; Land and Graticules (2006) ESRI.

Legend

- General Bathymetry Contours in Feet
- Aerial Fighter Gunnery Range
- Anti-Aircraft Gunnery Range
- Bombing Target
- Navy Ships Gunnery Exercise Areas

FIGURE 3-2
Adak Area WWII Era Military Activities
Former Naval Air Facility
Adak Island, Alaska





Source: Coastal Bathymetry (2001) NOAA; Military Activities (2010) Critigen; Land and Graticules (2006) ESRI.

Legend

- Anti-Aircraft Artillery Positions
- Coastal Bathymetry Contours in Feet
- Former Airfield
- Anti-Aircraft Danger Zone

FIGURE 3-3
Andrew Bay WWII Era Military Activities
Former Naval Air Facility
Adak Island, Alaska

Later the report discusses observations at Andrew Bay:

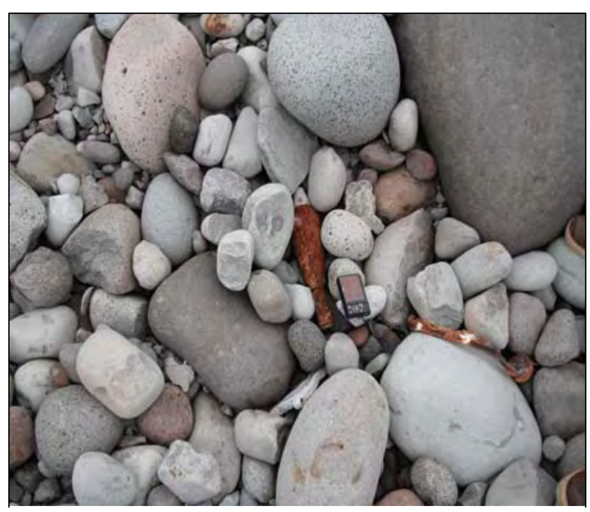
> "Andrew Bay, area extending west of Lake Andrew Spillway approximately one mile, [and] east approximately 500 yards. This area is cordoned by barbed wire and marked by metal and wooden signs. It is impossible to state amounts and types of UXO in this area, but should range upward into tons. An underwater search extending to the 10 fathom curve in this area will be conducted as time and weather permit. For the beach area it is recommended that EOD personnel can be trained as a bulldozer operator to remove large quantities of metal scrap which are hampering operations and move heavy rocks for a more thorough search."

No dive report as referenced above was identified. Chemical munitions referred to in WWII operational documentation includes incendiary, smoke, flare, tear gas, mustard gas, and similar materiel.

- A 1998 interview of Bomb Disposal Unit veterans visiting the island noted the construction of roads to transport bombs, projectiles, mortars, and fuzes in large quantities to a location on the north side of Mount Adagdak. The material reportedly was disposed of over the cliffs into the water on the north side of the mountain. The individual did not recall other specific disposal sites, other than a reference to disposing of four torpedoes off the Lake Andrew Seawall (interview between D. Fetzer, veteran of U.S. Army S Bomb Disposal Unit assigned to 32nd Infantry, and D. Keller, Foster Wheeler Environment, Memorandum of Record Document 3757, June 4, 1998 [Foster Wheeler, 1998]). Visual reconnaissance was conducted along the roadways on the north portion of Adak in July and August 2010 with no evidence of dumping areas that accessed the ocean, munitions dumpsites off roads, or MEC on beaches outside of ALSW-01 found.

3.1.3.2 ALSW-01 MEC Removal Trends

The Archive Search Summary Report (Foster Wheeler, 1998) provides documentation of EOD incident reports and some documentation of Andrew Lake Seawall munitions sweeps from the 1960s through the mid-1990s. This includes documentation of munitions that had been found near the Andrew Lake Seawall. In addition, Navy EOD After-Action Reports (U.S. Navy, 2004a, 2005b, 2006, 2007a, 2008, 2009a) from 2004 through 2009 document munitions sweeps of the Andrew Lake Seawall. Specific information on the locations of items retrieved is not provided. **Table A-1** in **Appendix A** summarizes the types and quantities of munitions that washed up and were discovered on or near the Andrew Lake Seawall as documented in historical documents. The munitions were grouped into general types, as shown in **Table A-2** in **Appendix A**, because of the variability in the EOD incident reports and other historical documents.



Mortar observed among cobbles, Andrew Lake Seawall intertidal area, July 2010.

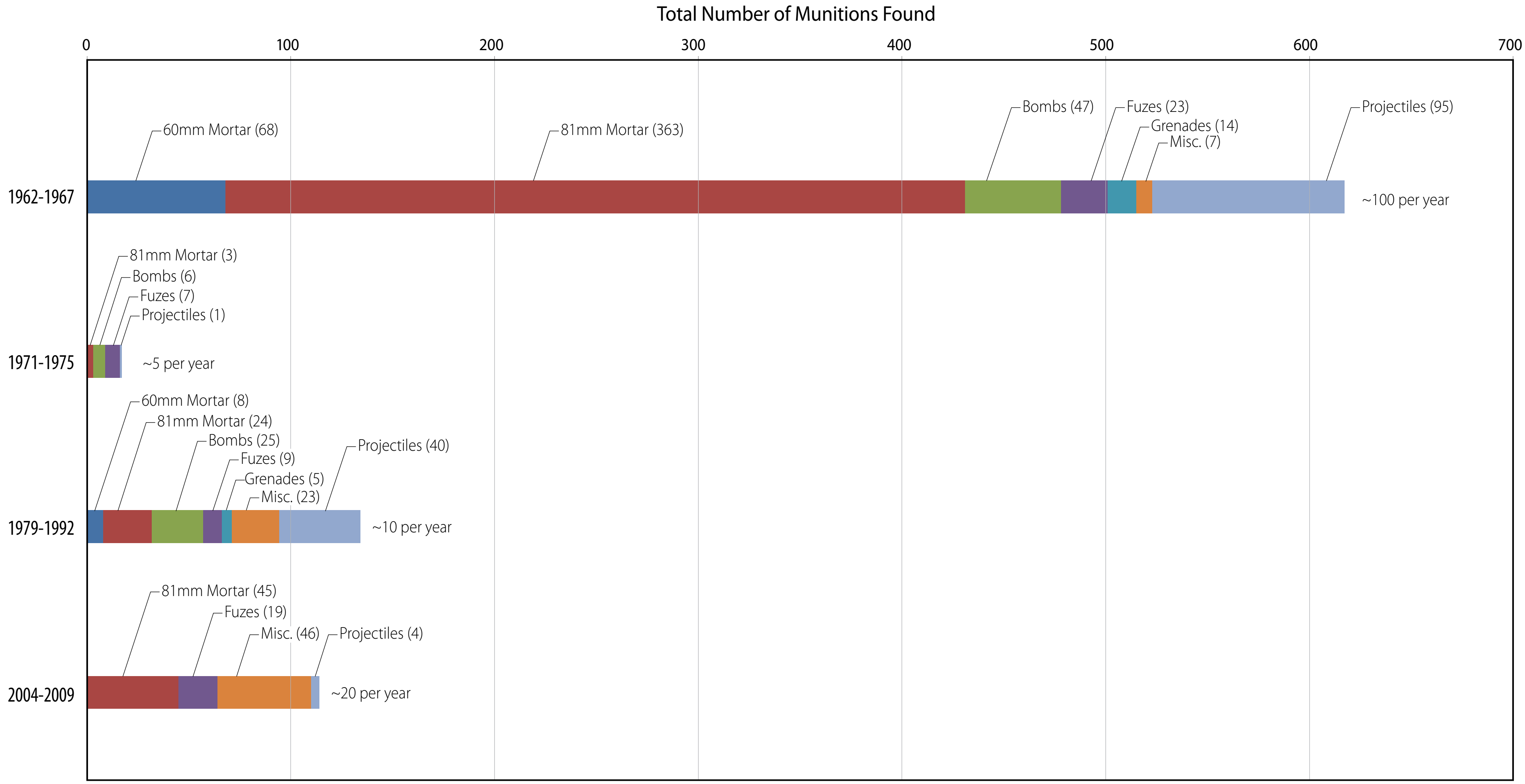
Standard munitions designations are not given in many of the documents. The EOD incident reports range from detailed descriptions of the munitions found (mortar, 81 mm HE, and WP M43 Light) to general descriptions (small arms ammunition). Quantities of munitions have not been documented consistently. For example, some documents report the exact number of specific items collected (for example, 4 each 81 mm HE), while other reports list quantities more generally (for example, 6 mortars). These discrepancies are magnified for small arms ammunition because the quantities vary greatly. In some instances, small arms ammunition is reported in pounds—in other reports, as number of items without the type of small arms ammunition being specified. There are lengthy gaps in the historical documentation. For example, documentation of Andrew Lake Seawall munitions sweeps between 1992 and 2004 was not available at the time of this report.

The munitions found at Andrew Lake Seawall include a wide range of types from 1,000-pound bombs to small arms ammunition. **Figure 3-4** shows the results of these munitions sweeps by timeframe. The data are organized into four time periods based on the gaps in EOD reports. Highlights for the various munitions types include the following:

- The greatest quantity of small arms ammunition, 238 casings and other small arms items, was found on September 22, 2009. Discovery of small arms ammunition was relatively consistent from 1962 through 2009.
- 81 mm mortars are documented relatively consistently in EOD incident reports between 1962 and 1992. The maximum number of 81 mm mortars (128 in total) was found on April 3, 1963.
- Bombs that were discovered ranged from a 1,000-pound bomb found on April 1, 1963, to thermite bomblets. The greatest quantities of bombs were found in 1962 and 1963.
- Fuzes have also been discovered fairly consistently during all time periods.
- Grenades were found in 1962 and 1963 during beach sweeps, but rarely found afterwards.
- Projectiles were consistently present at relatively low quantities. The greatest quantity of projectiles (45 in total) was found on April 3, 1963.
- Miscellaneous munitions items were found throughout at various times between 1979 and 2009. These miscellaneous munitions include items such as bursters, an unknown firing device, a parachute flare, and other items.

Inconsistencies in the EOD incident reports and the relatively long time periods for which no records are available do not allow for the quantification of trends. As shown in **Figure 3-4**, the generalized qualitative trends listed below can be made.

- The largest amounts of munitions were recovered from Andrew Lake Seawall between 1962 and 1967. This activity includes extensive beach sweeps conducted in 1962 and 1963.
- 81 mm mortars, projectiles, and fuzes were found during all time periods. 81 mm mortars were consistently discovered on Andrew Lake Seawall throughout the available EOD incident reports.



Notes:
1. Data not collected during the years 1968 to 1970, 1976 to 1978, and 1993 to 2003.
2. Small arms ammunition quantities not included.
3. MEC recovery quantities and rates are limited to the historical EOD reports available and approximate due to inconsistent item descriptions.

FIGURE 3-4
Summary of Munition Type Results by Time Frame
Former Naval Air Facility
Adak Island, Alaska

- Grenades and 60 mm mortars were encountered only sporadically and in relatively low quantities.
- In general, bombs show a decreasing trend in washing up on Andrew Lake Seawall.
- Small arms items were approximately 80 percent of the more than 500 items recovered from 2004 through 2009.
- No information regarding any seasonal variation in deposition rates has been recorded.

Depositional trends show approximately 15 to 20 items deposited per year, as estimated within the context of the accuracy of the MEC descriptions. Deposition of munitions items occurs along ALSW-01 from approximately 300 yards west to 800 yards east of the Andrew Lake Spillway.

Figure 3-5 summarizes the total quantity of each munitions type found between 1962 and 2009. As previously discussed, it is difficult to make a conclusive statement about the munitions deposition trends at ALSW-01.

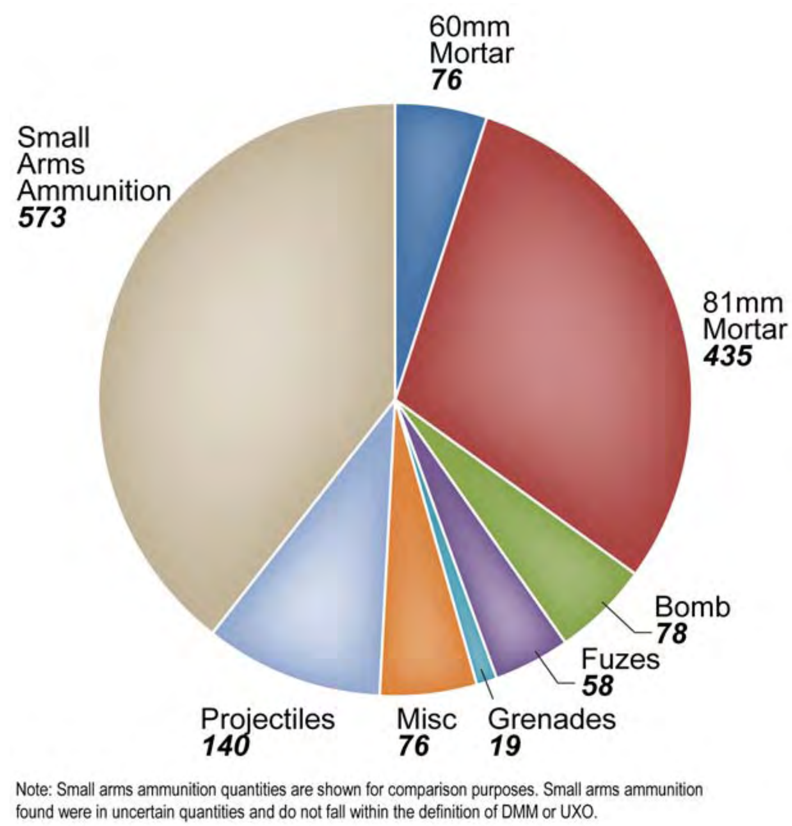


FIGURE 3-5
Total Munitions Found at ALSW-01
Former Naval Air Facility, Adak Island, Alaska

3.1.4 Source Area Findings

The historical document review did not reveal specific documentation of munitions having been disposed of in or near Andrew Bay or ALSW-01. Anecdotal reports reference abandonment of munitions in the terrestrial area of ALSW-01, the disposal of munitions in shallows and on the north side of Mount Adagdak, and disposal of torpedoes in Andrew Bay. However, the anecdotal reports contain inconsistencies when compared with other records and reports, and could not be confirmed with field reconnaissance efforts.

3.2 Marine Data Review

Munitions removal data and historical documents were reviewed to collect site data and munitions information. A 2002 report addressing possible UXO and DMM migration mechanisms and properties was provided by the Navy for review. This information was used to determine the site-specific nature of transport for the various munitions in an effort to confirm the nature of possible transport zones and source areas. The sections below summarize the documents reviewed and the findings of the data evaluation.

3.2.1 Document Review

Of the historical documents reviewed, a study performed by WHG (2002) was the most relevant in identifying conditions under which significant munitions motion would be expected to occur. Another document that provides limited information about sea-bottom characteristics and MEC observations in an area offshore of the Andrew Lake Seawall is a surface and underwater visual survey conducted by Navy personnel in 2000 (U.S. Navy, 2000). Surface swimmer and small vessel observations identified munitions on the sea bottom in the vicinity of the Andrew Lake Spillway along a 550-yard traverse at a water depth of approximately 15 feet. The munitions observed included 40 mm projectiles to 81 mm mortars and an unconfirmed occurrence of a depth charge. The surveyors reported that many munitions may have been present but were obscured by the large diameter of boulders present. The composition of the bottom through the tidelands and into submerged lands was reported as a solid layer of boulders out to a water depth of approximately 50 feet. Mixed sand and rock were observed at depths of 50 to 100 feet. The presence of kelp was observed as minimal by Navy Personnel in August 2000 (U.S. Navy, 2000), and as extending hundreds of meters from the beach and bordering the east and west side of the beach during the summer months in another report (WHG, 2002).

Public domain records, public domain databases, and historical documents were also reviewed to update information about site-specific physical conditions relevant to transport. This information includes waves and currents, bathymetry, tidal elevations, and seabed composition.

3.2.2 Conditions Affecting Transport

Factors that affect the transport of munitions across submerged lands within ALSW-01 include waves, currents, bathymetry, tidal elevations, and seabed composition. Waves and currents contribute to near-bottom water velocities that can act to dislodge and move munitions along the sea bottom. Bathymetry determines the water depths at given locations. Near-bottom water velocities are affected by surface wave action and will be smaller in deep water than in shallow water. As waves move into shallow water, the changes in bathymetry affect wave propagation and transformation. Wave heights also increase in some areas and decrease in others because of the shape and depth of the seafloor, which has refraction and diffraction effects on the waves.

Tidal elevations affect wave propagation. Waves that move into the bay during high tides will have less effect on sea-bottom conditions because the water is deeper; however, the deeper water also allows larger waves to penetrate and break closer into the island. Seabed composition can affect the potential for mobilization of munitions. Mobilization potential would be expected to be different for munitions buried under a layer of sand or rock than if they were lying on the surface of a more solid bottom. In addition, the size and nature of seafloor rock and sediment can affect the forces that would be required to mobilize individual munitions.

3.2.3 Wave Characteristics

Andrew Bay faces north and is exposed to waves generated in the Bering Sea. Local wave measurements are not available. Regional wave data were obtained from National Oceanic and Atmospheric Administration (NOAA) buoys 46035 and 46073, which are positioned at the locations shown in **Figure 3-6**. Buoy 46035 is approximately 310 nautical miles (nmi) north of Andrew Bay and buoy 46073 is approximately 250 nmi northeast of Andrew Bay. Periods of coverage for these buoys are shown in **Table 3-2**. Both of these buoys provide hourly data related to wave height and duration; they do not measure wave direction. More localized data relevant to Andrew Bay were not identified.

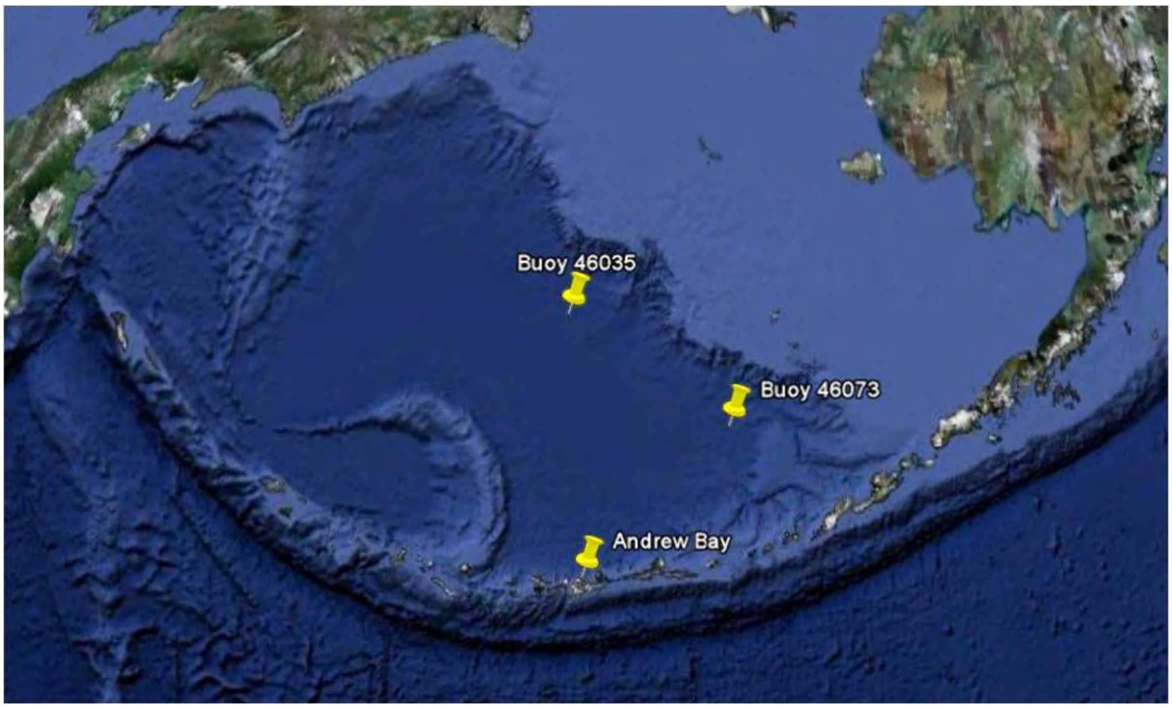


FIGURE 3-6
NOAA Wave Buoy Locations in the Bering Sea Relative to Andrew Bay
Former Naval Air Facility, Adak Island, Alaska

TABLE 3-2
Wave Buoy Coverage
Former Naval Air Facility, Adak Island, Alaska

Station No.	Station Name	Coverage [a]
46035	Bering Sea 310 nautical miles north of Adak, Alaska	September 1985 through April 2010
46073	Southeast Bering Sea	May 2005 through April 2010

[a] Coverage as of May 2010; some periods of interruption occur in each record as a result of buoy repair and relocation.

WHG (2002) uses buoy 46035 data from 1985 through 2000 to define boundary conditions for a wave transformation model of nearshore wave conditions at the site. Propagation directions were assumed to be from the north and north-northwest. Based on the available data, model runs were performed for a maximum wave height of 38 feet, an overall average wave height of 8.3 feet, and for wave heights representing average conditions during July and November. Additional wave growth between the buoy and the site was not considered because no data were available.

To evaluate the appropriateness of data from Buoy 46035 for other locations in and around the Bering Sea, available data were obtained from Buoy 46073 and compared with data from Buoy 46035 for the same time period (May 2005 to December 2009). The wave height data from Buoy 46073 tracked well with, but were generally lower than, the data from buoy 46035. Statistical representations of the data for Buoy 46073 were within about 10 percent of the same representations of the data for buoy 46035. A review of the data for Buoy 46035 revealed incidents of significant wave heights greater than 38 feet (used as a bounding case in WHG [2002]) and as high as 49.2 feet. This suggests a possible greater potential for mobilization of munitions during extreme events.

The lack of directional wave data from the NOAA buoys, as well as the lack of wave data closer to the site, makes characterization of waves at the site difficult. For purposes of this TM, it was assumed that data from Buoy 46035 would be appropriate for a preliminary assessment of potential munitions mobilization and transport depths and distances, and that an extreme significant wave height of 49.2 feet would provide a reasonable upper bound for conditions at the site.

3.2.4 Currents

NOAA tidal current prediction stations in the vicinity of Adak Island are shown in **Figure 3-7**. Three stations are located to the west of the island in Adak Strait and two are located to the east in Kagalaska Strait. Average maximum flood currents range from 1.9 to 2.8 knots in Adak Strait to 2.5 to 3.9 knots in Kagalaska Strait. Maximum ebb currents range from 1.4 to 2.2 knots in Adak Strait to about 3 knots in Kagalaska Strait.

Current data for north of Andrew Bay were not identified. Currents in Andrew Bay can be expected to have both tidal and wind-driven components. Tidal components in Andrew Bay should be considered to be significantly less than those observed within the straits between islands. Wind-driven currents are strongest at the surface and will decrease with depth. For purposes of this TM, it was assumed that near-bottom wind currents would be small compared with currents generated by extreme waves (assumed to be negligible); therefore, near-bottom wind currents are omitted from the assessment.

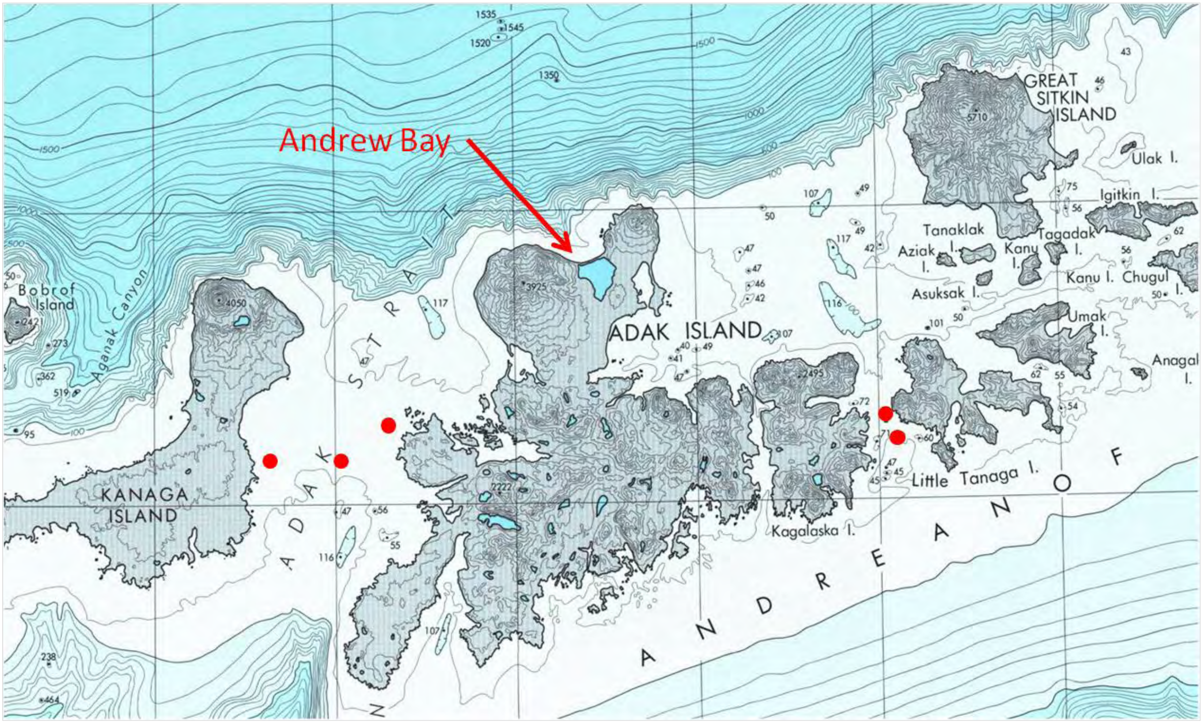
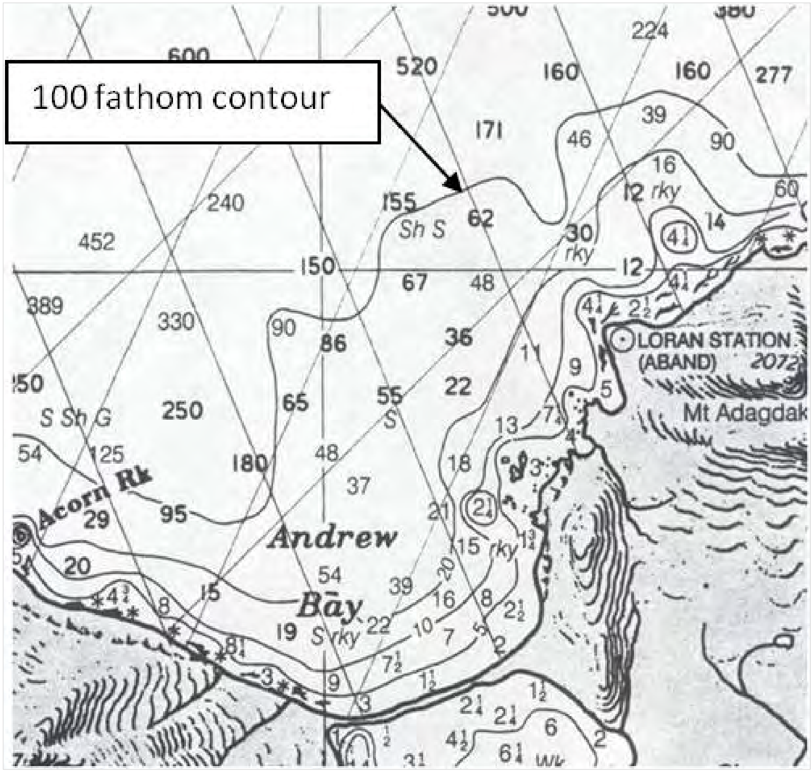


FIGURE 3-7
Tidal Current Station Locations
Former Naval Air Facility, Adak Island, Alaska

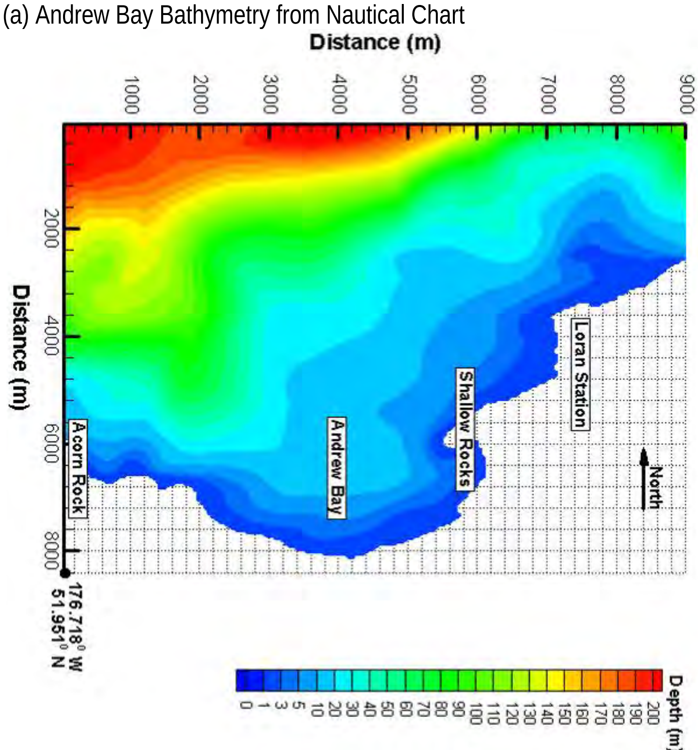
3.2.5 Bathymetry

Bathymetric information was obtained for the area around Adak Island and north of Andrew Bay from current National Ocean Service nautical charts, historical bathymetric maps, and historical survey data obtained from the National Geophysical Data Center (NOAA, 2010). **Figure 3-8** shows bathymetric contours in the area of Andrew Bay from (a) NOAA Nautical Chart 16471, *Andreanof Islands – Atka Pass to Adak Strait*, and (b) model bathymetry presented in WHG (2002). Water depths on the nautical chart, **Figure 3-8(a)**, are shown in fathoms (1 fathom = 6 feet) with the 100-fathom contour called out in the figure. Water depths in the model bathymetry shown in **Figure 3-8(b)** are presented in meters.

During this review, discrepancies were found when information on the available charts was compared with the bathymetric contours used in WHG (2002) as a basis for modeling wave conditions and munitions mobilization in Andrew Bay. **Figure 3-9** shows the two figures from **Figure 3-8** superimposed. As shown in **Figure 3-9**, the 100-fathom (183-meter) contour from the nautical chart appears to lie within about the 65.6- to 98.4-foot (20- to 30-meter) contour from the model bathymetry. From this comparison, it appears that the nautical chart bathymetry may have been assumed to be presented in feet rather than fathoms, and therefore the model bathymetry in WHG (2002) may be too shallow by a factor of about 6. If this is the case, wave modeling propagation performed in WHG (2002) would not be valid and the results would be expected to overpredict the area in which waves could mobilize munitions and move them toward the beach.



(a) Andrew Bay Bathymetry from Nautical Chart



(b) Model Bathymetry Presented in WHG (2002)

FIGURE 3-8
Comparison of Nautical Chart with Model Bathymetry
Former Naval Air Facility, Adak Island, Alaska

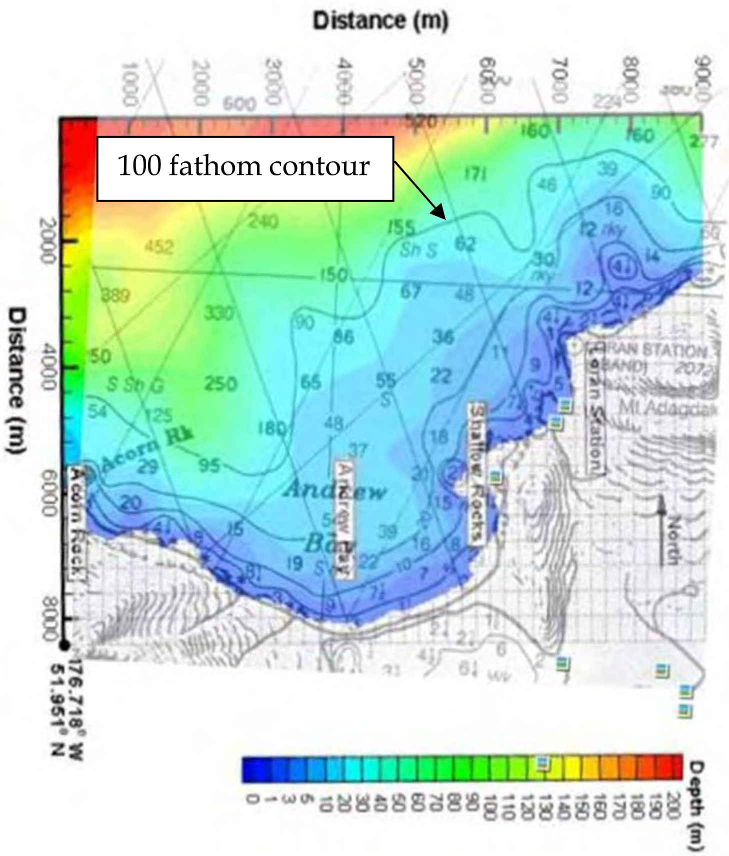


FIGURE 3-9
Overlay of Contour Plots
Former Naval Air Facility, Adak Island, Alaska

3.2.6 Tides

Tides around Adak Island are mixed, with spring tides exhibiting diurnal (one high and one low tide per day) characteristics, which then evolve to semi-diurnal tides (two high and two low tides per day), with a marked diurnal inequality during neap tides. The mean tidal range (the difference between mean high water and mean low water), based on tides in Sweeper Cove, is 2.9 feet with a great diurnal range (difference between mean higher high water and mean lower low water) of 3.7 feet.

3.2.7 Seabed Composition

Information on seabed composition is limited. WHG (2002) indicates that the beach in the central portion of Andrew Bay is composed primarily of cobble- and boulder-sized material with an estimated average size of 3.9 to 9.8 inches and large boulders. The EOD dive report (U.S. Navy, 2000) notes rocky bottom conditions with minimal kelp at about 15- to 20-foot water depths off the Andrew Lake Spillway in August 2000. Depth soundings made along about 2.5 miles of the seawall indicated that the 100-foot contour was approximately 1,000 yards from the shore, consistent with information from available nautical charts. It was also noted that the bottom transitioned to rock and sand at about the 50-foot contour.

3.2.8 Munitions Characteristics

Characteristics that will affect an individual munition's potential for mobilization under the influence of waves and currents include the size, shape, and weight of the item. **Table 3-3** of WHG (2002) lists typical types of munitions recovered on the beach since 1962 by EOD personnel based on EOD incident reports. Physical characteristics of each munition were based on information in the ORDATAII Version 1.0 database.

TABLE 3-3
Characteristics of Typical Munitions Recovered from the Beach at Andrew Bay
Former Naval Air Facility, Adak Island, Alaska

Type	Diameter[a] (cm)	Length[b] (cm)	Weight[a] (kg)	Calculated Volume (cm^3)	Calculated Density (g/cm^3)
81 mm mortar	8.1	28.2	4.9	1453	3.37
75 mm HE M41A1	7.5	24.8	6.2	1096	5.66
60 mm mortar M721	6.0	36.1	2.0	766[b]	2.61[b]
60 mm mortar	6.1	12.2	2.0	357	5.61
Grenade rifle M17	5.7	5.7	0.7	145	4.81
40 mm HEI	4.0	18.0	1.0	226	4.42
20 mm HE M97	2.0	8.3	0.1	26	3.84
1,000-pound bomb	47.2	177.0	420.0	309,704	1.36

[a] Dimensions and weights from WHG (2002).
[b] M721 mortar volume and density are adjusted to account for small-diameter tail fin section.
cm = centimeter
cm^3 = cubic centimeter
g/cm^3 = grams per cubic centimeter
kg = kilogram

Volume and density calculations were made based on the given dimensions and weight. These calculations assume that the munition is cylindrical with the dimensions given. This is not necessarily the case and will likely overestimate the volume and underestimate the density of each munition to the extent that this assumption is not true. Initial density estimates for the 60 mm M721 mortar (1.96 grams [g] per cubic centimeter [cm^3]) appeared unreasonably low. Closer review of the 60 mm M721 mortar characteristics show a much smaller-diameter tail fin section that accounts for about a third of its overall length. The volume and density calculated for this munition is based on an assumed effective length that is approximate three-quarters of the total length. Calculations were made based on the physical characteristics presented in **Table 3-3**; however, results are qualified in the discussion accordingly.

3.2.9 Transport Potential

The transport factors and methodology for calculating boundary transport conditions presented in the study performed by the WHG (2002) were found to be sound and useful given the information available, with the exception of the discrepancy in water depth noted in Section 3.2.5. Mathematical sediment and munitions item transport models are also available to estimate various aspects of seafloor transport. However, insufficient weather, wave, current, seafloor composition, bathymetric data, or information on munitions quantities, characteristics, and locations is available to engage the use of these models. As confirmed in a review of the literature and coastal sediment transport theory, the potential for mobilization and transport of munitions on the seabed to the beach at Andrew Bay depends on the exposure of the munitions to waves and currents, bathymetry, seabed composition and features, and the physical characteristics of the munitions.

Exposure of munitions to waves and currents subjects munitions to shear stresses arising from near-bottom water flow across the seabed. Shear forces of sufficient magnitude can dislodge or mobilize and transport the munitions toward the beach. Forces are sufficient to dislodge, transport, and deposit cobbles on the seawall such that explosives are required annually to reopen the drainage from Andrew Lake. The photos in Section 2.1.1 show the condition of the spillway after clearing in 2009 and the extent of accumulation present by the following summer. Burial of the munitions under the seabed or armoring of munitions with rock can result in the requirement of greater magnitudes of shear stresses for exposure, release, and transport.

The transport potential of munitions was evaluated by estimating the critical shear stress necessary to mobilize various categories of munitions, and then by calculating the maximum water depth, which, under extreme wave conditions, would generate sufficient bottom shear to mobilize the munitions. This process produced a series of water depths at which various munitions types would be expected to move under extreme, storm-related wave amplitudes. These depths were then compared to the bathymetric contours to produce general zones of possible movement, and thus regions of ALSW-01 adjacent to the tidal zone from which munitions would move along the seafloor. The movement of munitions at lesser wave heights would still occur at depths and distances within the zones identified. Therefore, the extent of the area offshore from Andrew Bay with potential to move munitions up to the beach is bounded by the bathymetric contour equal to the maximum water depth calculated, and by the shoreline along ALSW-01.

3.2.9.1 Critical Shear Stress

The approach taken by WHG (2002) to estimate the critical shear stress for mobilization of munitions was based on work performed by Komar (1987) related to selective entrainment of sediment particles from a natural sediment bed consisting of a range of sediment sizes. Komar presented a formulation for the critical shear stress to selectively mobilize sediment of up to diameter D_i as:

$$\tau_c = 0.045(\rho_s - \rho)\, g\, D_{50}^{\ 0.6} D_i^{\ 0.4}$$

The ρ_s is the sediment density and ρ is the density of water (both in g/cm^3), g is the acceleration caused by gravity (980 cm/s^2), D_{50} is the median particle diameter in the bed in centimeters (cm), and D_i is the diameter of the largest individual particle that would be entrained from the bed in cm. This relationship was used as a basis for the assessment conducted for this TM.

The bottom composition offshore from ALSW-01, and, therefore, the value of D_{50}, is unknown. Diver observations indicate a transition from cobble- and boulder-sized material at the beach to rock and sand-sized material at about the 50-foot water depth contour; however, a more rigorous characterization of the bottom conditions around the bay has not been performed. A range of median particle sizes for the seabed was assumed for the purposes of this assessment with values for D_{50} of 1, 5, 10, and 20 cm. Previous estimates of critical shear stress (τ_c) from WHG (2002) were based on a median seabed particle size of 10 cm based on shore observations of beach material.

The value of D_i was calculated based on the volume of the munitions and was assumed to act as a sphere with the same volume. The sediment density was assumed to be equal to the calculated density of the munitions presented in **Table 3-3**. Critical shear stresses calculated to mobilize the munitions listed in **Table 3-3** are presented in **Table 3-4**.

3.2.9.2 Calculation of Maximum Bottom Depths for Mobilization

Calculation of bottom shear generated by waves was performed based on procedures presented in USACE (2002a) for calculation of combined wave-current bottom shear stress. A spreadsheet was set up to calculate bottom shear based on the significant wave height, peak period, and water depth. The water depth in the spreadsheet was varied until the calculated bottom shear was approximately equal to the critical shear for the selected munition. This depth was taken as the maximum depth at which the munition would be mobilized.

Resulting maximum water depths consistent with the critical stresses in **Table 3-4** are presented in **Table 3-5**. Values shown in bold red font are depths at which sufficient shear to move the munitions item due to wave action is predicted, but where incoming waves would have already broken and begun to dissipate. Munitions residing at these depths and bottom sediment diameter would not be expected to move because the peak energy of waves would have dissipated before crossing the depth indicated.

TABLE 3-4
Calculated Critical Shear Stresses for Mobilization of Typical Munitions with Varying Bottom Characteristics
Former Naval Air Facility, Adak Island, Alaska

				Critical Shear Stress (Pa)			
				Sediment D_{50}			
Munition Type	**Munition Volume (cm^3)**	**Effective Diameter (cm)**	**Density (g/cm^3)**	**1 cm**	**5 cm**	**10 cm**	**20 cm**
81 mm mortar	1,453	14.1	3.37	29.8	78.3	118.7	179.9
75 mm HE M41A1	1,096	12.8	5.66	56.7	148.9	225.7	342.1
60 mm mortar M721	1,021	11.3	2.61	18.5	48.6	73.7	111.7
60 mm mortar	357	8.8	5.61	48.3	126.9	192.3	291.4
Grenade rifle M17	145	6.5	4.81	35.4	93.0	141.0	213.6
40 mm HEI	226	7.6	4.42	33.7	88.4	134.0	203.2
20 mm HE M97	26	3.7	3.84	20.9	54.9	83.2	126.0
1,000-pound bomb	30,9704	83.9	1.36	8.6	22.6	34.2	51.9

cm = centimeter
cm^3 = cubic centimeter
g/cm^3 = grams per cubic centimeter
HE = high explosive
HEI = high explosive incendiary
kg = kilogram
mm = millimeter
Pa = Pascals

TABLE 3-5
Maximum Water Depths for Mobilization of Typical Munitions
Former Naval Air Facility, Adak Island, Alaska

Munition Type	Maximum Depth for Mobilization of Munitions by Waves (feet) Sediment D_{50} 1 cm	5 cm	10 cm	20 cm
81 mm mortar	250	125	85	**55**
75 mm HE M41A1	160	65	**40**	
60 mm mortar M721	310	175	130	90
60 mm mortar	160	65	**40**	
Grenade rifle M17	180	80	**50**	
40 mm HEI	195	90	**60**	
20 mm HE M97	220	110	75	**50**
1,000-pound bomb	515	415	365	305

Note: Based on a 49.2-foot, 16-second significant wave. Numbers shown in **bold red** font indicate that the water depth required to generate sufficient shear to mobilize the given munition is less than the breaking depth of the extreme wave. Waves at the given depth would be reduced by wave breaking and would not be sufficient to mobilize the munition.
cm = centimeter
cm^3 = cubic centimeter
g/cm^3 = grams per cubic centimeter
HE = high explosive
HEI = high explosive incendiary
kg = kilogram
mm = millimeter

3.2.9.3 Mobility Evaluation

The equation used to calculate critical shear stresses for mobilizing a variety of types of munitions on the seabed under the influence of waves was originally developed to estimate the potential of a river to selectively remove sediments up to a given size. The equation used is an empirical relationship that indicates that the tendency of a given sized particle to be mobilized from a sediment mixture is dependent on the size of particles in the mixture as a whole. Although the mechanisms that underlie this tendency were not discussed in Komar (1987), it was assumed that this tendency was attributable to the ability of sediment with a larger grain size to better resist scour and to provide a greater measure of support and armoring to the given sized particle.

Because the equation was developed for natural sediments, the ability to represent mobilization of munitions is limited by differences between characteristics of the munitions and the natural sediments, in particular their shape and density. Given the data available and the uncertainties inherent in any sediment transport calculation, this approach is appropriate for providing an estimate of mobility potential of the munitions; however, the resulting numbers should be viewed qualitatively, based on an understanding of the limitations of the calculations and uncertainties in the munitions characteristics.

Potential Effect of Munitions Shape on Mobility Potential

The munitions shown in **Table 3-3** have lengths that are 2 to 6 times their diameters. Natural sediments will be closer to spherically shaped with the length of the long axis of the particle similar in length to that of the small axis.

Representing long cylindrical objects as spheres is likely conservative in that it over-represents mobility, and thus may generate larger estimated zones of transport. Spherical objects would tend to "roll" up onto the bed under the influence of shear stress more readily than a long, narrow object would, and, therefore, would likely be more easily mobilized.

Potential Effect of Munitions Density on Mobility Potential

Calculated densities of the munitions range from less than that of typical sediments to as much as two times as dense. The assumption that the sediment is the same density as munitions would likely be conservative for munitions with densities less than that for the surrounding sediments. Using this assumption would under-represent the density of the surrounding material and, therefore, over-represent the potential for removal of this material, resulting in a greater amount of exposure of the munitions item to bottom flows. These munitions include 1,000-pound bombs and possibly the 60 mm M721 mortar. For munitions with densities greater than that of the surrounding sediments, assuming the density of surrounding sediments to be the same as that for the munitions would result in an assumed bed that is denser and, therefore, more stable than the actual surrounding sediments would be; therefore, the shear stress needed to mobilize the munitions may be over-represented. These include the remaining munitions in **Table 3-3**.

The practice of modeling munitions as cylinders based on their maximum diameters and lengths likely under-represents the actual density of the individual munitions. Materials with greater densities would generally require greater shear stress to mobilize; however, as discussed above, using the calculated munitions densities for the majority of the munitions types would result in overestimation of the density of the surrounding material, likely resulting in a reduction of the calculated potential for scour and removal of this material. This likely underestimates the actual density of the munitions and overestimates the mobility potential of the munitions if the characteristics of the surrounding material are not considered. To some extent, these two tendencies will tend to counter each other.

Results

The results in **Tables 3-4** and **3-5** illustrate the effects that bottom composition has on the potential for mobilizing the various types of munitions. For example, the shear stress required to mobilize a given munitions type in sediment with a median grain size of 5 cm is calculated to be about 2.6 times greater than for sediment with a 1-cm median grain size, 4 times greater for sediment with a median grain size of 10 cm, and 6 times greater for sediment with a median grain size of 20 cm.

In **Table 3-5**, the numbers in a red bold font indicate that the water depth required to mobilize the munition was less than the breaking depth of the wave. In these cases, the munitions would not be expected to be mobilized under the conditions assumed. For example, an 81 mm mortar would not be expected to mobilize if the seabed consisted of material with a median grain size of 20 cm, assuming that the mortar was a part of this sediment mixture. The munition could, however, be mobilized if it were partially buried in a sediment mixture with smaller grain size or if it were sitting on top of the seabed.

Additionally, once mobilized, the munition could continue to be transported over the seabed regardless of the composition of the bed sediment.

With the exception of the 1,000-pound bomb, the deepest water predicted to be able to mobilize the munitions for the conditions assumed was on the order of 300 feet or less for sand/gravel bed material and less for seabed material with larger grain size distributions. These limits are based on extreme wave conditions. Mobilization by smaller waves would be limited to shallower water.

3.2.10 Source Area Findings

Based on the results of the calculations documented above, the majority of the munitions that have been found on the beach at Andrew Bay likely have been mobilized and transported from waters shallower than about 300 feet deep (**Figure 2-3)**. Because of their large size, the 1,000-pound bombs could have initially been mobilized and transported from deeper waters (depths up to about 500 feet).

Water depths drop off fairly rapidly outside Andrew Bay, and it is unlikely that any munitions at or beyond the 600-foot depth line could be mobilized and transported toward the beach. The potential to transport munitions from inshore deep water toward the beach in Andrew Bay will be a function of the size and direction of approaching waves. Munitions deposited in shallow enough waters off the northern end of Adak Island could be mobilized by waves from the north generated in the Bering Sea, transported to the shore, and transported along the shore to the beach.

It is unlikely that any munitions that may reside off the eastern or western shores of Adak Island could be mobilized and moved into Andrew Bay. Waves approaching these areas from the Bering Sea could potentially mobilize munitions in these areas, but transport would be to the south, away from Andrew Bay.

The eastern and western shores of the northern portion of Adak Island are sheltered by adjacent islands from most of the wave energy generated in the Pacific Ocean approaching from the south. This limits the potential for wave-induced transport of munitions along these shorelines to Andrew Bay on the north. Therefore, the potential source areas are limited to the northern shores of the island, where transport toward Andrew Bay could occur because of waves generated in the Bering Sea.

Because of the lack of directional wave data near the site, it is not possible to identify any single source or better define lateral limits to the area that could define a specific source of munitions that could make their way onto the beach at Andrew Bay.

3.3 Munitions Constituents

While potential MC concentrations in environmental media at Andrew Bay have not been sampled, the quantity of MC and the environmental conditions in Andrew Bay are such that accumulation of MC to the extent that ecological exposure point concentrations would be exceeded is considered unlikely. Following is evidence supporting this evaluation:

- With the highly energetic conditions, the long duration of time since sources were deposited, the gradual rate of release of MC from breached munitions, and the large volume of water for dilution, MC concentrations within Andrew Bay are likely to have attenuated significantly and are therefore unlikely to pose meaningful risk.

- Benthic infauna are not expected in shallow water areas in Andrew Bay because survey data indicate that there is limited or no sediment in shallow areas (less than 50 feet).
- Bioaccumulation potential for MC is low. The types of contaminants of potential concern (COPCs) likely to be released are not notably bioaccumulative, and significant movement into a food web is unlikely. [1]
- Biomagnification in the food web is not expected to occur, based the low potential for bioaccumulation and the effect of attenuation discussed above.
- MC exposure was evaluated as part of the terrestrial RI in the OB/OD area (assumed to be the area of highest possible exposure). No MC risk was determined to be present. Contaminant sources (munitions types) as documented during beach sweeps are similar to those evaluated as part of the RI.
- Extensive data have been collected for the Baseline Ecological Risk Assessment at OU 2 at the Jackson Park Housing Complex site in Bremerton, Washington, to determine risks posed by MC. These data include analysis of COPCs for tissue samples (U.S. Navy, 2010c) and analysis of COPCs in sediments (U.S. Navy, 2010b). The Baseline Ecological Risk Assessment concluded that ecological risks were estimated to be negligible for all ecological receptors.

Therefore, it is reasonable to conclude that MC exposure to marine receptors is not significant. MCs are, therefore, not addressed further in this TM.

3.4 Data Review Conclusions

After the review of historical documents, EOD recovery records, and marine mobilization mechanisms, no conclusions can be made about specific source areas or types, migration pathways, or definitive trends of munitions deposition on ALSW-01. Information useful in moving forward with further investigations in the area has been identified. Some notable items are listed below.

- The munitions removed from ALSW-01 are likely migrating from offshore areas that are either dumpsites associated with former training ranges, or a combination of both dumpsites and training ranges. Other disposal mechanisms that have been considered but are not confirmed and are considered less likely include dumping from a former pier, release from a sunken barge, or having been left onshore to be carried by the tide.
- The munitions might include DMM in the form of abandoned or surplus ammunition, or UXO from aircraft, anti-aircraft, infantry, and artillery training activities, although no reports of fused and fired munitions were found. Munitions debris in the form of targets, spent casings, and other items may also be included.
- Small arms ammunition may continue to be the prevalent munitions type deposited at ALSW-01.

[1] An ecoscoping form for the OU B-2 AOCs is provided in Attachment E-1 of the RI (U.S. Navy, 2009c). The ecoscoping conducted for the RI for OU B-2 indicated that, based on the criteria for bioaccumulative compounds described in ADEC guidance (ADEC, 2009b), none of the COPCs is considered bioaccumulative. This is further supported by a recent study of bioaccumulation of MC in the marine environment, *Bioaccumulation of Explosive Compounds in the Marine Mussel*, Mytelus galloprovinciallis (Rosen and Lotufo, 2007b). The authors confirmed that the bioaccumulation potential is low for explosive compounds (TNT, HMX, and RDX), which are known to be weakly hydrophobic. This suggests that munitions-related COPCs are not likely to biomagnify in the food chain.

- It is likely that the majority of munitions recovered from ALSW-01 have migrated from waters shallower than about 300 feet deep.
- It is unlikely that any items recovered have migrated from waters deeper than 600 feet.
- There are no indications of lateral limits of source or migration areas parallel to the orientation of the Andrew Lake Seawall beyond the current intertidal and terrestrial depositional area.

4.0 Conceptual Site Model

This section describes the updated CSM for ALSW-01. The CSM is a simplified, schematic diagram of possible exposure pathways and the means by which contaminants are transported from the primary contaminant source(s) to receptors. The CSM includes receptors and potential exposure pathways appropriate to plausible scenarios and provides the basis for identifying and evaluating potential risks. The elements of a complete exposure pathway and CSM include the following:

- Source media
- Contaminant release mechanisms
- Contaminant transport pathways
- Receptors
- Exposure pathways

In the absence of any one of these components, an exposure pathway is considered incomplete and, by definition, there is no risk or hazard. **Figure 4-1** presents the CSM schematic for the site. The following sections summarize the nature of the CSM components.

4.1 Site Characteristics, Release Mechanisms, and Transport Pathways

The Andrew Lake seawall east of the spillway is narrow and elongated, similar to a dike with a narrow, flat top and steep sides. The seawall appears to have been a naturally occurring barrier beach or spit that may have been extended and built up. Materials used appear to have been almost entirely local rock and cobbles; however, some soil, wood, and scrap metal appear to have also been used in filled areas. Elevations in the upland portion of the seawall range from about 10 to 30 feet above sea level. The seawall separates the freshwater lake from Andrew Bay to the north, which is an embayment of the Bering Sea. The area below the mean higher high water mark on the Andrew Bay side of the seawall is owned by the Alaska Department of Natural Resources (U.S. Navy, 2009c).

The tideland or beach area near the seawall is comprised of primarily cobble and boulder material with an estimated average size of 4 to 10 inches in diameter; the beach also contains many larger boulders. The composition of the sea bottom through the tidelands and out into submerged lands was reported as a solid layer of boulders out to a water depth of approximately 50 feet. Mixed sand and rock were observed at depths of 50 to 100 feet (U.S. Navy, 2000). The presence of kelp in submerged areas of ALSW-01, is reported as minimal in one report (U.S. Navy, 2000), and as extending hundreds of meters from the beach and bordering the east and west side of the beach during the summer months in WHG (2002).

The primary contaminant-release mechanism at the site is assumed to be offshore munitions disposal rather than firing of munitions at training ranges. There were anecdotal reports of dumping, but no confirming documentation has been identified and no visual indications of shoreline access for marine dumpsites have been found. The location and amount of offshore munitions are unknown. ALSW-01 has become a depositional area for munitions.

The Navy periodically performs sweeps along the seawall and west of the Andrew Lake Spillway to remove MEC that has been deposited through wave action. About 15 to 20 munitions items are recovered each year from an area extending about 300 yards west and 800 yards east of the Andrew Lake Spillway.

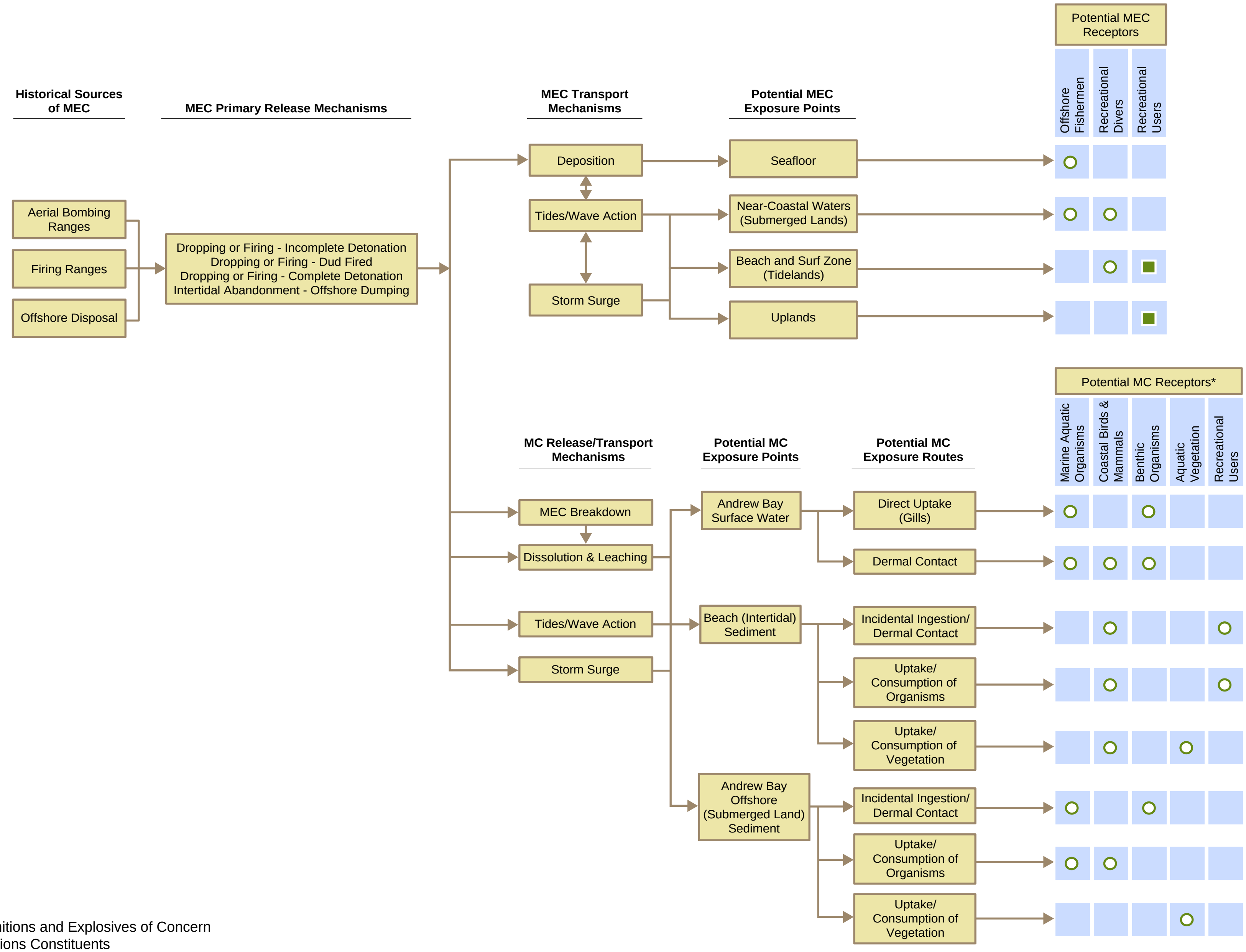
Based on the records reviewed and the OU B-2 RI, MEC found at ALSW-01 appears to consist of unfuzed and unfired munitions (classified as DMM) and small arms ammunition (not considered MEC), rather than UXO, although the possible presence of UXO cannot be eliminated from consideration. Potential contaminant transport pathways for MEC are depicted in **Figure 4-1**. The pathways include deposition on the seafloor and subsequent transport from the disposal area to the beach and upland areas by tides, wave action, and storm surges.

4.2 Site Access and Receptors

Engineering controls (locked gates, fences, and posted signs) have been installed to deter people from accessing the site. These access restrictions are assumed to be required regardless of whether the data collection and site remediation strategies are implemented. Institutional controls such as community awareness outreach and distribution of education materials are also in place. These efforts are planned to continue at Adak Island, including ALSW-01. The location of gates, roadway closures, and fencing may change with the completion of remedial efforts in particular areas on Adak Island. The site is no longer used for training and is accessed approximately annually by Navy EOD personnel to remove MEC from the beach at ALSW-01. Therefore, plausible receptors under the current land use scenario are the occasional site worker and recreational site users who trespass onto the site.

The anticipated future land use at the site is as a wildlife refuge/subsistence/recreation area. Plausible receptors under the future land use scenario are future recreational users. There are no access restrictions to the offshore portions of the site, and offshore fishing or recreational diving could presumably take place in the area although no offshore fishing or recreational diving is known to ever have occurred in the area and is presumed unlikely. Encounters with MEC through recovery in fishing nets or contact during diving are considered very unlikely.

Ecological receptors at the site and adjacent marine area include terrestrial and aquatic wildlife. Marine aquatic receptors and shorebirds using the area are considered to have the highest potential for exposure and risk to site-related contaminants. Marine aquatic receptors likely include marine birds, marine mammals, fish, and invertebrates. Upland terrestrial receptors may include several species of birds, including the bald eagle, several species of gulls, and the rock sandpiper. A summary of relevant contaminant release and transport mechanisms, sources and exposure media, receptor scenarios, and exposure pathways for this site is provided in **Figure 4-1**.



Notes:
MEC = Munitions and Explosives of Concern
MC = Munitions Constituents
UXO = Unexploded Ordnance
DMM = Discarded Military Munitions
■ = Potentially complete pathway
○ = Pathway considered potentially complete, however exposure is likely insignificant
Blank = Incomplete pathway

*Exposure pathways for MC receptors are based on professional judgement as no data has been collected for biota or sediments in Andrew Bay

FIGURE 4-1
Conceptual Site Model for MEC and MC at ALSW-01
Former Naval Air Facility
Adak Island, Alaska

ES052810062740SEA Fig. 4-1 ConceptSiteModel_v3.ai

4.3 Contaminant Nature and Extent

Items found at the surface of ALSW-01 during periodic surface sweeps have included a wide variety of MEC, small arms ammunition, and non-munitions-related metal debris. Most items found during these sweeps are highly weathered and appear to have originated offshore, as there are no known current or recent land-based activities that could reasonably have resulted in the deposition of MEC along the seawall.

In the submerged zone of ALSW-01, surface swimmer and small vessel EOD survey observations identified munitions on the sea bottom in the vicinity of the Lake Andrew Spillway along a 550-yard traverse at a water depth of approximately 15 feet. The munitions observed included 40 mm to 81 mm projectiles and a possible occurrence of a depth charge. The surveyors reported that many more munitions may have been present, but were obscured by the large diameter of boulders present along the sea bottom (U.S. Navy, 2000).

It is likely that most munitions recovered from ALSW-01 migrated from waters shallower than about 300 feet deep. It is unlikely that any recovered items have migrated from waters deeper than about 600 feet. The lateral limits of source and migration areas along or beyond the alignment of the Andrew Lake Seawall have not been determined.

If there are dumpsites offshore (or materials were left on the beach), then they would likely have initially been piles on the seafloor (or beach). The materials would have spread through wave action across the seafloor and are assumed to be on, among, and beneath cobbles. Whether residual piles remain on the seafloor cannot be estimated. If the munitions source also includes target areas, then these materials would be spread across the seafloor. Items spread across the seafloor would be moving progressively toward shore from the mobility depth for that item and would be located on, among, and below seafloor cobbles at the mobility depth and shallower.

No samples of sediment or other environmental media have been collected for MC analysis at the site. However, the need for such samples has not been established because of the high energy nature of the site—meaning that there is very little sediment to which possible receptors might be exposed. In addition, it is expected that any MC discharged to surface water in Andrew Bay would be immediately diluted beyond the limits of detection.

4.4 Data Gaps

Information on types of munitions disposed of offshore in Andrew Bay is limited to items found during surface sweeps of ALSW-01. Fundamental data gaps remain as obstacles to making progress under conventional regulatory decision-making processes. These data gaps involve both site and MEC presence characteristics, and include the following:

- Accurate and detailed data on bathymetric elevations and contours
- Wave direction, height, and frequency data specific to Andrew Bay
- Current direction and velocity data specific to Andrew Bay
- Data on the location, areal extent, nature, and depth of the offshore source area(s)

- Data on the variation in sea-bottom character and burial depth of MEC across the source area
- Data on the expected trends in quantity, type, and other characteristics of future MEC deposition at ALSW-01

5.0 Data Collection Assessment

This section examines the feasibility and cost of collecting usable data of sufficient quality to characterize the nature and extent of MEC in the marine portion of ALSW-01. Section 5.1 describes the data needed and quality requirements. Section 5.2 describes the investigation methods and technologies that might be used to acquire the necessary data and evaluates the usefulness of the technologies relative to data needs and site-specific conditions. Section 5.3 provides information about Marine MEC Data Collection case studies. Section 5.4 identifies the recommended technologies and work approaches for conducting the investigations, and Section 5.5 presents the estimated costs for conducting the investigations as recommended.

5.1 Investigation Objectives and Quality Criteria

The objective of the investigation contemplated for Andrew Bay is to gather data of sufficient quality to characterize the physical setting and determine the nature and extent of MEC. The approach to the investigation must account for the difficulty in working offshore in the Bering Sea environment at a location remote from essential resources such as labor, equipment, fuel, medical facilities, and others.

The types of information needed to fill the existing data gaps include data for both site characteristics and the nature and extent of munitions present. The types of data needed to fill the gaps related to site characteristics include detailed bathymetry, wave and current information, and seabed composition and thickness. In general, these data are needed at a level of quality comparable to that required for marine construction projects. Such projects have been conducted in the vicinity of Kuluk Bay on the east side of Adak Island. Therefore, it is assumed in this TM that it is possible to gather the necessary data in Andrew Bay.

The fundamental MEC data quality requirement for Andrew Bay is to identify clusters and discrete munitions at definable and reproducible locations in a bottom composition that varies from sand to large boulders. MEC source area groupings that may have once existed have likely been subject to mobilizing conditions for approximately 65 years. Some amount of the MEC present in the marine portion of ALSW-01 is widely dispersed and also under seafloor cobbles because individual munitions and cobbles are known to be dynamic in Andrew Bay.

5.2 Identification and Screening of Technologies

The challenges of underwater site characterization and munitions detection include the properties of water, the need to maintain safe working conditions, and the ability to accurately locate and possibly retrieve the detected items (EPA, 2005). These challenges are further complicated in Andrew Bay by often-harsh weather, strong ocean currents and waves, kelp beds, presence of boulders on the seafloor, and ongoing movement of the items. This section describes the investigation methods and technologies to consider using to acquire the necessary data, and evaluates the usefulness of the technologies relative to data needs and site-specific conditions.

5.2.1 Sediment and Particle Movement Modeling

Several mathematical models are available to estimate the transport characteristics of sediments and particles along the sea bottom. Identification and selection of these models can be conducted when more detailed bathymetric, current, wave, and MEC information is available. Estimation of potential for mobilization and transport of munitions in the marine environment to Andrew Bay requires an adequate representation of wave and current conditions along the northern shoreline of Adak Island. A wave propagation modeling study that would simulate propagation and wave transformation from deep water to the Adak Island shoreline would provide information about the site-specific wave conditions that are needed to better assess potential munitions source locations.

A site-specific wave propagation model would require deep-water boundary conditions. Wave data from existing buoys lack directional data and the buoys are too far away to provide data that can be directly applied at Adak Island. A focused hindcast modeling study could be performed for the Bering Sea area based on historical meteorological information. Data from such a study would provide offshore boundary conditions for a nearshore wave propagation modeling study. Results of nearshore wave and current modeling could then be fed into a model for calculating transport of munitions. Numerous mathematical models are available to estimate the transport characteristics of sediments and particles along the sea bottom. Identification and selection of these models can be conducted when more detailed bathymetric, current, wave, and munitions information is available.

5.2.2 Offshore Munitions Assessment Methods

Munitions assessments need to incorporate multiple methods to effectively record the detection, location, condition, and type of objects within an offshore area. This can be accomplished by remote methods and human methods.

5.2.2.1 Visual Dive Surveys

Human assessment methods would be employed under favorable weather and diving conditions to avoid the great difficulty and high degrees of safety risk arising from the large and undefined boundaries of the study area, unknown nature of MEC hazards, rarity of acceptable weather and diving conditions, visibility, and remoteness of the site. The Offshore Environmental Survey (U.S. Navy, 2000) conducted by Navy personnel did note that visibility and calm surface conditions during the survey were acceptable for diving operations. The report recommends the following:

> "Subsequent reconnaissance/clearance operations should incorporate multiple dive teams to search and clear such a large area. This will require detailed planning and logistics. Maximum operational safety and effectiveness will be achieved by conducting small boat operations from a larger support platform. This platform should be capable of launching and recovering multiple dive boats, as well as berthing and messing both support and diving personnel. Emergency medical services and an onsite recompression chamber will be required for personnel safety."

These recommendations identify general resources required for such a survey, but do not constitute a practical, implementable approach to conducting one. The rarity of suitable weather conditions as noted in anecdotal reports from previous investigations makes realistic planning impracticable for the visual survey of the area. In addition, one of the conclusions of the October 2007 Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) Workshop on Technology Needs for the Characterization, Management, and Remediation of Military Munitions in Underwater Environments (SERDP, 2007) was that "the use of divers is not cost effective or efficient for investigation of anomalies on the bottom and is potentially hazardous to the diver."

Data quality is also likely to be unacceptable. The prevailing presence of large boulders that likely obscure munitions greatly reduces the reliability of identifying individual munitions, as does the probability that munitions are also present under cobbles. Close inspection of suspect MEC would appear to be both unworkable under safety requirements and inefficient in reducing the rate of survey operations. Finally, the management of visual observations to produce reliable location information for use by geographic information system applications is unlikely to provide reliably reproducible MEC locations given the dynamic bottom conditions.

Diving represents a significant labor hours and cost commitment for the coverage obtained and has the highest safety risk of all the investigative approaches considered. Direct observation and mapping of MEC by divers is not considered as a primary data collection effort in this TM because the feasibility of this method of investigation cannot be reliably evaluated without first addressing the data gaps identified in Section 4.4 with other technologies. Other technologies could initially be used as a primary method to further define and pinpoint the MEC source areas with the use of dive surveys to further refine the data and provide up close identification of munitions, associated fuzing, and explosive hazards.

5.2.2.2 Underwater Cameras

Current technology ranges from handheld digital cameras with underwater housing and memory cards to tethered high-resolution video cameras with panel displays on support craft. Systems are also available for incorporating infrared light technology to assist in low light/low visibility scenarios and for laser scaling. Benefits of using underwater cameras to detect munitions in sediment include the low cost and ease of use. Cameras can be mounted to a surface vessel or tethered to a towed depressor wing, sled, or remotely operated vehicle (ROV). Some video systems use global positioning system (GPS), depth sensors, altimeters, cable counters, and/or acoustic ultra-short baseline positioning system (USBL) to track the position of the camera in two- or three-dimensional space. General positioning uses vessel-mounted GPS or a Smart Tether™ system (a real-time navigation system that uses GPS and sensors embedded within the tether to accurately navigate an ROV from a moving point). The effectiveness of underwater cameras decreases with loss of visibility, which occurs in high turbidity water environments. Underwater cameras cannot detect objects buried beneath the sediment or cobble surface. Marine survey contractor staff members have reported that general visibility conditions are relatively good in the area of Adak Island when compared to other locations throughout the Alaska region.

5.2.2.3 Magnetometer and Electromagnetic Inductance Surveys

The two most common geophysical technologies for detecting munitions presence that have been adapted for underwater use are magnetometry and electromagnetic inductance (EMI). Magnetometry involves the use of a passive sensor that measures minor variations in the earth's magnetic field. Ferrous objects create irregularities in the earth's magnetic field and may contain remnant magnetic fields of their own that are then detected by magnetometers. The two most common magnetometry systems used to detect munitions are cesium vapor and fluxgate. Cesium vapor magnetometers measure the magnitude of a magnetic field and produce digital system output. The fluxgate systems measure the relative intensity of the gradient in the earth's magnetic field. A third type, Overhauser effect magnetometers, is also being used for marine construction, mineral exploration, and MEC survey applications. These devices offer high sensitivity and are much less affected by orientation relative to the earth's magnetic field than cesium vapor sensors.

EMI makes use of an active sensor that induces electrical currents in conductive objects. Conductivity readings of the secondary magnetic field created by the electrical currents are used to detect both ferrous and nonferrous objects. EMI systems operate in time and frequency domains. Time-domain electromagnetic (TDEM) systems operate by transmitting a magnetic pulse that induces currents in and near conducting objects. These currents produce secondary magnetic fields that are measured by the sensor after the transmitter pulse has ended. Frequency-domain electromagnetic (FDEM) instruments operate in much the same way as TDEM instruments in that they actively send electromagnetic energy into the ground; however, they do so by transmitting continuous electronic signals and measuring the resulting eddy currents.

For either system to detect individual munitions underwater or buried in the seafloor, the closer the detector is to the marine sea bottom the better. For current best available magnetometer systems, an acceptable distance for reliable detection of individual munitions is 3 to 6 feet. Electromagnetic systems generally have shorter detection ranges, but may work better for those items made up of a large percentage of nonferrous metal. Larger items and clusters of small items can be detected at proportionately longer ranges. The two most common operational platforms for deploying this type of underwater detection sensor are a diver using a handheld instrument and a towed array. Towed arrays contain one or several magnetometers, EMI sensors, or a combination of both that can be pulled along or slightly above the bottom behind a vessel. Arrays can be suspended from an underwater mast or towed by cable and "flown" along, either at a fixed distance below the surface of the water or at a fixed distance above the bottom surface, bathymetry permitting. Towed arrays generally employ positional calculations originating from real-time kinematic (RTK) GPS, which are then merged with USBL acoustic positioning systems or layback calculations that estimate the position of towed equipment to mark anomaly positions.

Munitions "detectability" is dependent on numerous factors, but the general rule is, the larger the munition, the deeper (or farther away from the sensor[s]) it can be detected. Many factors must be considered when evaluating whether a given geophysical system or technique can detect a given specific munition, including munition type, length, diameter, surface area, volume, weight, and orientation with respect to the geophysical sensor. For EMI sensors, additional factors of the geophysical systems that are relevant to the detection depths of munitions include the physical size of the instrument's transmitter and receiver coils, the operating power of the transmitter coil, the sensitivity of the receiver(s), the measurement/sampling densities, the speed of the survey platform, the distance of the sensor(s) from the item, the geologic/environmental conditions at the site, and the signal loss caused by the electrical conductivity of sea water. For magnetometers, the additional relevant factors include the sensitivity of the magnetometer, the measurement/sampling densities, the distance of the sensor(s) from the item, and the geologic/environmental conditions at the site.

As discussed above, these systems can detect individual munitions that are on or below the bottom surface and can be positioned with a reasonable degree of accuracy (typically within 3 to 6 feet in the x-y-z directions). The advantage of using these systems is that they are able to detect metallic items buried in the shallow sediment, or that might be out of sight between or beneath boulders. Both magnetometer and EMI systems are capable of digital geophysical mapping (recording data for subsequent data processing and interpretation) for a large survey area. For large survey areas offshore of ALSW-01, these applications may be most appropriate for identification of concentrations of metallic anomalies (such as munitions debris fields) rather than selecting individual items. Emerging sensor equipment configurations include multiple sensor arrangements, which form sensor arrays that significantly increase the single-pass areal coverage of a towed sensor.

Disadvantages associated with underwater geophysical surveys are that the sensors must be maneuvered and towed along the area of investigation and are susceptible to snagging, and the sensor platform may be unstable because of currents or protruding objects. Water surface (or near water surface) towed magnetometers and EMI systems have a much lower detection capability than those towed near or along the bottom surface and are, therefore, typically used only in very shallow water or when searching for very large targets. Weather conditions, currents, and tides can also severely affect the stability of the sensor platform. As depth of water increases, so does the complexity of the geophysical survey operation.

Currently available geophysical systems cannot discriminate between munitions and other metallic debris. Deposits such as volcanic magnetite sands, rocks, and boulders can create widespread anomalies that mask or distort magnetic anomalies resulting from munitions. Given the relatively recent volcanic origin of Adak Island, magnetic interference is very likely to be a factor affecting data quality. As an example, magnetic interference for magnetometer surveys has proven to be a factor affecting data quality and the ability to detect items during marine surveys on the Olympic Peninsula, a much more mature geologic setting (U.S. Navy 2007b).

5.2.2.4 Side-scan Sonar

Side-scan sonar is an acoustic system that can be used to detect objects on the seafloor. All acoustic systems transmit sound energy and analyze the return signal (echo) that has bounced off the seafloor or other objects that protrude from or are on the surface of the seafloor. The strength of the return echo is continuously recorded creating a "picture" of the seafloor. The advantage of using acoustic technologies is that, when compared to the other technologies, a very large area can be surveyed in a relatively short amount of time with a very high image resolution. Currents, tides, and weather conditions can adversely affect acoustic technologies if the survey vessel on which they are mounted or the towfish in which they are installed are not stable or instrumented to correct for motion (for example, heave, pitch, roll, and yaw). Use of digital data and positional recording allow real-time visualization of underwater topography and positive location of objects.

This sonar technology is applicable to searching and mapping the condition of the seafloor and in areas where the seafloor is relatively smooth, potentially locating munitions. Digital images are recorded and positioned with GPS and other positioning technologies. Some objects may be easily identifiable with a degree of discrimination between munitions and clutter. In addition, side-scan sonar systems can be used in both clear and turbid waters. Side-scan sonar cannot differentiate between metallic and nonmetallic objects and cannot detect items buried in the sediment. The system can, however, provide an indication of sediment type and relative hardness by measuring variations in the acoustic return backscatter. Seafloor composition and habitat can be inferred from these variations. If a high-data-density survey is to be completed, the time and cost of the survey would be proportional to the amount of data that must be collected. Many munitions located under and around large-diameter boulders would not be detected by this technology. Discriminating between munitions and scrap items may not be possible or reliable, although a high-quality, high-frequency conventional side-scan sonar can discriminate between objects with compact geometry down to a nominal cm size. Developing systems that use multibeam echosounder (MBE) focused-array technologies can achieve very high resolution at longer ranges, can allow higher survey speeds, and can increase detection along track coverage.

5.2.2.5 Multibeam Sonar

An MBE sonar system provides bathymetric and often imagery data over a swath between 120 to 150 degrees wide below the survey vessel. The system transmits a fan-shaped beam that is very wide across the course of instrument track and very narrow along-track. The system generates a large number of very narrow beams across-track. Each time the sonar pings, it derives a depth measurement for each beam. Transmission of more than 250 beams tens of times per second is typical.

This technology, when combined with appropriate vessel attitude, heading, and position sensors, can generate a full-coverage map of the seafloor. A high-resolution system can accurately map even very small features (20 cm or less) in shallower depths, while providing swath coverage of three to four times the water depth. Maintaining accurate measurements of the survey vessel’s three-dimensional attitude is important for generating data of acceptable quality. Similar to side-scan sonar, an MBE sonar system can measure variations in the acoustic return backscatter, from which the seafloor composition and habitat can be inferred. Similar surveys have been conducted successfully in the area of Kuluk Bay off the eastern shore of Adak Island.

This technology is useful to searching and detecting objects that are lying on or protruding above the seafloor surface, but cannot differentiate between metallic and nonmetallic objects and cannot detect items buried in the sediment. Many munitions located under and around large-diameter boulders would not be detected by this technology. The probability of detection can be increased, however, by increasing sounding density. Sounding density can be increased by reducing the line spacing or by increasing the ping rate or the total number of beams transmitted per pulse.

Distinguishing between munitions and scrap items may not be possible or reliable using multibeam bathymetry alone; however, this technology can provide critical information for the safe operation of towfish. High-resolution bathymetry data that is integrated with side-scan imagery and magnetometer/gradiometer/EMI data can provide the basis for a much better definition of site conditions, differentiation of ferrous and nonferrous objects, and also discrimination of buried items. The successful combination of this information can provide much better indications of possible MEC distribution than the individual use of these technologies.

5.2.2.6 Synthetic Aperture Sonar

Synthetic aperture sonar (SAS) combines a number of acoustic pulses to form an image with much higher resolution than is possible with conventional sonar. SAS moves the sonar along a line and illuminates the same spot on the marine floor with several pulses from a different origin. By coherent reorganization of the data from all the pulses, a synthetic aperture image is produced. This technology requires a very high-quality navigation system on the towfish and advanced processing techniques to be effective. SAS cannot discriminate between individual munitions and other debris. Many munitions located under and around large-diameter boulders are unlikely to be detected by this technology.

This sonar technology is applicable to searching and detecting objects that are lying on or protruding above the seafloor surface. Digital images are recorded and positioned with RTK GPS. In addition, SAS systems can be used in both clear and turbid waters. As depth of water increases, so does the complexity of the survey operation. If a high-data-density survey is to be completed, the time and cost of the survey would be proportional to the amount of data that must be collected.

5.2.2.7 Buried Object Scanning Sonar

Buried object scanning sonar (BOSS) is an acoustic technology developed to generate images of objects buried in sediments using reflection tomography. BOSS is a relatively new, emerging technology that transmits frequency modulation (FM) pulses over a wide frequency band. These pulses “illuminate” buried targets and the return pulses are then measured with an array of hydrophones. The resulting reflection-generated topographic images provide target shape information useful for target classification.

A BOSS system can be used in both clear and turbid water, and can be used to locate individual munitions that are on or just below the sediment surface. However, the system needs to be used in conjunction with a magnetometer or electromagnetic system in order to differentiate between metallic and nonmetallic objects.

5.2.2.8 Sub-bottom Profiling

Sub-bottom profiling (SBP) systems are acoustic systems that are typically used to identify and characterize sediment layers on or under the seafloor. SBP systems essentially use the principle of seismic reflection to image various layers of the seafloor. Active SBP systems can be either high-frequency or mid- to low-frequency, compressed high-intensity radar pulse (CHIRP) systems. High-frequency systems achieve relatively high resolution; however, their bottom penetration depth is significantly less than that obtained by lower frequency systems. SBP data can be used to locate changes in thicknesses in the near surface stratigraphic layers as well as providing information on sediment types.

SBP systems are acoustic systems that are potentially capable of detecting large concentrations of munitions in a homogeneous environment, and are effective in turbid waters. SBP can be used to identify soft or hard sediment or rock and therefore can be used to determine whether munitions are likely or unlikely to be buried in a certain location. The digital images collected in the SBP systems are recorded and positioned with RTK GPS.

SBP is a poor technology for locating small, isolated individual objects on the marine floor or subsurface. This technology cannot differentiate between metallic and nonmetallic objects, and is adversely affected by sea and weather conditions. SBP is not a standalone munitions detection technology, but it could be useful to assess depth of burial of dense objects. However, SBP could not differentiate cobbly to bouldery ALSW offshore seafloor areas from munitions accumulation areas.

5.2.2.9 Instrument Platforms

"ROV" is the commonly accepted name for an unmanned, submersible vehicle that is tethered to a vessel on the surface by a means of a cable. ROVs have thrusters that generally provide three-dimensional maneuverability and are operated by a person (or persons) aboard the surface vessel. The surface operator(s) are linked to the ROV by a tether that contains cables carrying electrical signals back and forth between the operator(s) and the vehicle. Most ROVs are equipped with a video camera and lights. Additional equipment is commonly added to expand the vehicle's capabilities, including sonars, a still camera, manipulator or cutting arm(s), and other instruments.

ROVs are capable of being used in deep water, in conjunction with magnetometers and EMI sensors, and capable of video-recording and establishing the position of objects protruding from or on the seafloor depending on the technology used. Because of these factors, ROV technology is potentially applicable for munitions detection if used in conjunction with other detection technologies. ROVs are significantly less effective in rougher waters with strong currents, which can easily be the conditions found in the ALSW offshore areas.

Towed pods, fish, or bottom towed arrays are much like the ROVs in that they may carry one or more types of remote sensors. The platform is tethered to the surface ship by a strong cable or fixed tow bar and its communications links. A tethered system's depth and trajectory is controlled by the speed and direction of travel of the surface vessel, with less ability to control lateral movements. Towed fish are generally lighter and more portable than ROVs, which tend to be used with smaller, more maneuverable surface vessels. Additionally, fish are less likely to be tangled in plants or other organic snags; however, a fish would be just as susceptible to loss or snags in rigid debris fields. Debris fields are a hazard, as indicated by subsurface surveys performed by others who discovered antisubmarine nets, sunken vessels, and submerged vehicles during geotechnical surveys in Kuluk Bay (Golder Associates, 2004).

Fixed arrays are attached to the underside or the side of the hull of a surface vessel. With attached arrays, a greater number of remote sensing instruments can be deployed simultaneously to perform area surveys. However, the resolution of the data will change as the surface vessel moves from shallow to deeper water because the fixed deployment depth of the equipment does not change with location or time. Advantages are that precise survey locations can be recorded since the navigation/GPS equipment is on a stable platform on board the ship and that the equipment is less likely to be damaged or lost. The size of the surface vessel also affects the ability to conduct surveys in a nearshore environment.

For the relatively shallow waters typically surveyed for MEC, much of the equipment may be installed on the survey vessel. This is especially true for the multibeam sonar system, and frequently true for the SBP system. Magnetometer and EMI systems, when used in very shallow water (less than 3 meters), can often be floated and towed behind a vessel with enough separation to avoid interference from the metal, motor, and electronics on the vessel. The typical minimum operating depth for a small survey launch is approximately 3 feet. Maximum depths are limited by local weather conditions and the distance of the vessel from shore.

Fixed-wing and helicopter aircraft platforms are also used for geophysical data collection, but their use is extremely limited for underwater environments because of the large standoff distance between the sensors and the sea bottom.

5.2.3 Comparisons of Detection Technologies

This section provides a summary comparison of the detection technologies presented in Section 5.2.2. The primary function, secondary function, advantages, and disadvantages of each technology are presented in **Table 5-1,** along with information about the various instrument platforms.

TABLE 5-1
Comparison of Munitions Investigation Approaches
Former Naval Air Facility, Adak Island, Alaska

Primary Function	Secondary Function	Advantages	Disadvantages
Archival Research			
Offshore bathymetry, anecdotal or verifiable evidence of disposal	Confirmation of munitions disposal quantities and timeframe	Acquire concise information about munitions in Andrew Lake Seawall offshore area.	Lack of written record yields no information, archival search to date yields little useful information about Andrew Bay disposal areas.
Dive Survey			
Identify area, types, and locations of munitions	Identify substrate conditions, confirm conditions determined using other investigative methods, confirm MEC presence using handheld devices	Direct data gathering, reliable observations based on visually seeing items, can be used in shallow water to confirm results of other data collection methods.	Very high safety risk; high labor and cost for area covered; not a SERDP- and ESTCP-recommended data-gathering method; limited by sea conditions, depth, and visibility; low rate of survey coverage; limited integration with geographic information systems unless divers tracked with acoustic positioning systems.
Underwater Camera			
Identify area, types, and locations of munitions	Identify substrate conditions, confirm conditions determined using other investigative methods	Simple systems are inexpensive and easily procured, require low skill level to deploy and operate. Many underwater systems available that are good for investigating geophysical anomalies or specific sea-bottom characteristics. Integrate with geographic information systems via time synchronization and position overlays.	Requires low turbidity and limited standoff distance to acquire high-quality video. Towed video sleds require active “flight” to avoid striking the sea bottom or debris. Addition of scaling lasers, multiple cameras, and altimeter increases system cost.

TABLE 5-1
Comparison of Munitions Investigation Approaches
Former Naval Air Facility, Adak Island, Alaska

Primary Function	Secondary Function	Advantages	Disadvantages
Magnetometer			
Locate area of ferrous munitions presence	Locate areas of scrap ferrous presence or other metallic objects	Portable, proven technology, able to survey large areas quickly; waterproof and rugged equipment; equipment is readily available; can be operated simultaneously with other equipment.	Requires experienced personnel for marine use, depth needs to be within 3 to 6 feet of seafloor for required data quality; susceptible to geologic conditions; may be affected by water conditions; severely oxidized steel not strongly magnetic; cannot distinguish between munitions and other ferrous debris.
Electromagnetic Inductance			
Locate area of nonferrous and ferrous munitions occurrences	Locate areas of nonferrous and ferrous scrap metal presence or other metallic objects	Portable, proven technology, able to survey large areas quickly; waterproofed and rugged equipment; equipment readily available; can be operated simultaneously with other equipment except magnetometers in most circumstances; affected by geology significantly less than magnetometers.	Requires experienced personnel for marine use; altitude-dependent for detection of small targets (needs to be closer to seafloor for increased probability of detection); current systems have limited ability to distinguish between munitions and other metallic debris.
Side-scan Sonar			
High-resolution imagery of seafloor	Evaluate seafloor conditions, locate/define large munitions or groupings	Inexpensive, portable proven technology, able to survey large areas quickly, waterproof and rugged equipment, readily available, not affected by water conditions, low skill level to implement, can be operated simultaneously with other equipment, can obtain data in shallower water, can be integrated with sub-bottom profiling.	Seafloor image quality may be poor in areas of kelp (kelp will block acoustic signals), not able to discriminate munitions from rocks on seafloor if similar in size or shape or larger than munitions.
Multibeam Sonar			
High-resolution bathymetry	Evaluate seafloor conditions, locate/define large munitions or groupings	Surveys large areas quickly; waterproof and rugged equipment; not affected by water conditions; can be operated simultaneously with other equipment; mature technology capable of very high resolution and accurate full bottom coverage; three-dimensional mapping of the bottom.	Seafloor image quality may be poor in areas of dense kelp (kelp blocks acoustic signals); unable to discriminate munitions targets from rocks on seafloor if similar in size or shape to munitions and data density is low; equipment more expensive than side-scan sonar; moderate skill level to operate and process.

TABLE 5-1
Comparison of Munitions Investigation Approaches
Former Naval Air Facility, Adak Island, Alaska

Primary Function	Secondary Function	Advantages	Disadvantages
Synthetic Aperture Sonar			
High-resolution imagery	Evaluate seafloor conditions, locate/define large munitions or groupings	Able to survey large areas quickly; waterproof and rugged equipment; not affected by water conditions; can be operated simultaneously with other equipment.	Seafloor image quality may be poor in areas of kelp (kelp will block acoustic signals); not able to discriminate munitions targets from rocks on seafloor if similar in size or shape to munitions; emerging technology for commercial applications; equipment more expensive than side-scan sonar and not readily available; moderate to high skill level to operate.
Sub-bottom Profiling			
Bathymetry survey, substrate evaluation	Identify debris areas and depth of burial (good from several to tens of feet depth penetration), characterize bottom sediments	Relatively inexpensive, portable, easily procured, proven technology; able to survey large areas quickly; waterproof and rugged equipment; available equipment; not affected by water conditions; low skill level to implement; can be operated simultaneously with other equipment; most equipped with positioning software.	Will not discriminate small munitions from rocks; may be able to detect 500- to 1,000-pound bombs. Moderate to high levels of skill required for data interpretation.
Buried Object Scanning Sonar			
Locate area of buried possible munitions occurrences	Evaluate seafloor conditions, locate/define large munitions	Able to detect munitions and other objects in both clear and turbid water, able to survey large areas quickly, waterproof.	Seafloor image quality may be poor in areas of kelp (kelp will block acoustic signals), not able to discriminate MEC targets from rocks on seafloor if similar in size or shape to munitions.
Instrument Platforms			
Handheld Instruments			
Gather data and locate area of nonferrous and ferrous munitions occurrences	Locate areas of nonferrous and ferrous scrap metal presence or other metallic objects	Limited requirement for support resources; low skill level to implement, small craft are easily available; direct data gathering by divers or small craft crew operating from surface.	Limited by sea conditions, depth, and visibility; low rate of survey coverage; limited integration with geographic information systems unless divers tracked with acoustic positioning systems.

TABLE 5-1
Comparison of Munitions Investigation Approaches
Former Naval Air Facility, Adak Island, Alaska

Primary Function	Secondary Function	Advantages	Disadvantages
Survey Vessel			
Gather data from maneuverable survey vessel operating from surface	Not applicable	Small (approximately 20 to 50 feet plus) launch vessel can be configured to work with all sensors listed in this Technical Memorandum, either mounted to the vessel hull, on a pole mount, or towed behind the vessel; properly configured, these systems can be operated in water depths down to about 3 to 12 feet.	Operations limited by sea conditions, depending on the specific design and capabilities of the survey launch.
Fixed Array			
Gather data from maneuverable survey vessel operating from surface	Not applicable	Adaptable for multiple instruments and lighting, not limited to size of device, good for surface-based surveys, less susceptible to loss/damage of equipment.	Fixed instrument array attached to boat, only as maneuverable as boat, inability to change operational depth of instrument platform, cannot operate in shallow nearshore environment, moderate or specialized personnel required for deployment.
Remotely Operated Vehicles			
Gather data from maneuverable adaptable multi-instrument platform at varying depths		Adaptable for multiple instruments and lighting, maneuverable, moderate skill level to operate, operational depth can be more precisely controlled than other towed devices, with clear water and limited sediments, a very cost-effective alternative to diving.	Can be a heavy, bulky instrument platform that requires larger boat to deploy and operate, moderate or specialized personnel required for deployment, operational depth in shallow water dependent on size of boat, can snag on debris/plants.
Towed Fish or Bottom-towed Array			
Gather data from towed platform operating at surface or at depth		Adaptable for multiple instruments and lighting, not limited to size of device, useful for surface-based surveys or at depth	Limited on number of technologies deployed at one time, can snag on debris/plants, susceptible to loss or damage from contact with bottom, rocks, debris.

ESTCP = Environmental Security Technology Certification Program
MEC = munitions and explosives of concern
SERDP = Strategic Environmental Research and Development Program

5.3 MEC Case Studies for Marine Data Collection

This section provides case studies for collecting marine data to determine the extent of underwater MEC. The case studies include Ostrich Bay near Bremerton, Washington; Ordnance Reef near Wai'anae, Hawai'i; and MRP Site 100 in San Diego Bay, California.

5.3.1 Ostrich Bay, Bremerton, Washington

The U.S. Navy evaluated Ostrich Bay for DMM. This evaluation included a geophysical survey of portions of Ostrich Bay and diving on selected targets to ensure the data collected adequately defines the nature and extent of DMM. The geophysical investigation consisted of the following technologies:

- High-resolution MBE system
- Bottom-penetrating imagery systems (sub-bottom sonar)
- Surface towed time-domain electromagnetic induction (TDEMI) array

The MBE system provides high-resolution bathymetry and can detect and identify features on the order of 0.5 to 3 feet and greater in size (water depth and range dependent) above the surface of bottom sediments. After the MBE survey was performed, the entire site was surveyed with bottom-penetrating imagery systems (sub-bottom sonar) and a bottom-towed TDEMI array to determine ferrous and nonferrous metal anomaly density. In addition, diving was conducted on selected targets identified through several data collection efforts. A total of 822 targets were selected and investigated over approximately four months. Targets were located using RTK GPS navigation. Underwater metal detectors were used to identify potential metallic items buried in sediment (U.S. Navy, 2010a).

Several considerations arise in applying Ostrich Bay investigation technologies to Andrew Bay. Ostrich Bay is a shallow, protected inlet with little exposure to wind, waves, and storm surge. The deepest diving in the central portion of the bay was to 40 feet. A barometric chamber was accessible and the dive site bordered a hospital. Towing a wing from a boat was not affected by wave action or underwater obstructions. These conditions do not exist at Andrew Bay, where the remoteness, underwater obstructions, and poor weather, and high levels of wave energy all detrimentally affect the quality of data collected and level of safety hazard exposure.

5.3.2 Ordnance Reef, Wai'anae, Hawai'i

The main thrust of the Ordnance Reef Project was to independently collect data to define the extent of a DMM sea disposal site off O'ahu, Hawai'i, that is locally referred to as "Ordnance Reef" and determine the presence or absence of MC (for example, explosives and/or metals) through biological, sediment, and water sampling. These data supported the U.S. Department of Defense evaluation of potential risks posed to human health and the environment from the DMM at Ordnance Reef.

NOAA conducted a side-scan sonar survey to identify locations of possible military munitions and determine their extent within the study area. NOAA surveyed an 81.7-linear-mile area using side-scan sonar. A Benthos C3D High Resolution 200 kHz Side Scan Imaging System (C3D) with bathymetry and a Benthos 1624 dual-frequency, 123 kHz and 383 kHz side-scan sonar were used to determine the extent of munitions within the study area. The C3D system was towed alongside the survey vessel and continuously collected acoustic images of the shallow water study area. Minimum height above the seafloor for C3D was 5 to 10 meters (10 to 20 percent of sonar range). ROVs and divers were used to confirm the presence of munitions targets detected by the side-scan sonar. The shallow water study area is a very active geologic area and is a mixture of hard bottom and coral heads producing multiple targets acquired by the side-scan sonar. Divers and an ROV were sent to targets that had similar sonar returns. The purpose of this was to distinguish geologic and biologic features from possible munitions. The ROV and divers were able to rule out many targets acquired during the shallow water survey as either geologic or biologic (coral heads).

The project was confined to a maximum depth (approximately 300 feet) based on equipment limitations. Clusters (nine) of military munitions not previously identified were found near shore. DMM present within the study area ranges from small arms ammunitions to large caliber projectiles and naval gun ammunition. Identifying the specific munitions proved difficult because these munitions have blended into the marine environment and were often encrusted with marine life growing off the munitions. In addition, fish and sediment samples were also analyzed for explosives. Water samples were collected and processed for salinity, dissolved oxygen, pH, and temperature. Overall trace metal enrichment in sediments from the study area is very low. This observation suggests that little contamination of the Ordnance Reef area is derived from DMM. Areas where high metals were detected were located at the outfall from the on-shore Wai'anae Wastewater Treatment Plant (WWTP) and attributed to natural land drainage from adjacent road surfaces and volcanic rock minerals (NOAA, 2007).

Several considerations arise in applying Ordnance Reef project investigation technologies to Andrew Bay. These include the differences in proximity to critical resources, the physical setting, and the energy state of the marine environment. The Wai'anae Coast area studied is located near populated areas where diving support and medical resources are readily available. Kelp, large boulders, and scrap metal were not noted in the Wai'anae Coast seabed, which is predominantly sand, macroalgae, and uncolonized hardbottom. While the Wai'anae study area is exposed to high-energy wind waves from the open ocean, dry trade winds are the prevailing weather influence, a distinct difference from the polar front convergence zone present at Adak Island. Suitable conditions for operating small craft and for diving are available throughout the year along the Wai'anae Coast.

As with the comparison made with Ostrich Bay in Section 5.3.1, the remoteness, underwater obstructions, poor weather, and high levels of wave energy at Andrew Bay all detrimentally affect the quality of data collected and level of safety hazard exposure.

5.3.3 MRP Site 100 Site Investigation, San Diego Bay Primary Ship Channels

Site 100, located in San Diego Bay adjacent to San Diego, California, is approximately a 12-mile-long, 1-mile to 3-mile-wide crescent-shaped bay. A site investigation (SI) plan has been developed and includes geophysical investigation of the site using various geophysical techniques, including side-scan sonar to detect items above the sediment surface and underwater magnetometers to detect ferrous metallic items both at the sediment surface and subsurface. This case study provides an example of an approved work plan approach for underwater MEC data collection. A multi-tiered technical approach will be employed during the Phase 2 SI field investigation as follows:

- **1st-tier technology: Side-scan sonar.** This technology involves using a sonar device towed by operations vessel emitting sonar waves to map bay floor topography; it is utilized to identify potential entanglement issues for follow-on technologies (underwater magnetometer array and ROV) and potential munitions items that protrude from the surface.

- **2nd-tier technology: Marine-towed underwater magnetometer array.** This technology involves passive detection equipment that detects ferrous items and is towed by an operations vessel; it is used to detect magnetic anomalies on the surface and within the subsurface of the bay floor.
- **3rd-tier technology: ROV.** This technology is a compact, submersible vehicle equipped with a video camera with high-intensity lighting operated from the deck of the operations vessel. ROV will be utilized to further investigate magnetic anomalies identified by the underwater magnetometer array (U.S. Navy, 2010g).

Several considerations arise in applying MRP Site 100 project investigation technologies to Andrew Bay. These include the physical setting and the energy state of the marine environment. Kelp, large boulders, and scrap metal were not noted in the MRP Site 100 study area seabed. Kelp and large boulders may pose significant obstacles in maneuvering to attain full traverse coverage of the site, and in maintaining suitable magnetometer array standoff from the seabed. Scrap metal presence is likely to generate sufficient quantities of false positive data that may prove difficult to resolve given the weather and sea state conditions prevalent at Andrew Bay. While the MRP Site 100 study area is exposed to high-energy wind waves from the open ocean, prevailing weather is classified as semi-arid, similar to that of the Mediterranean Sea region. Suitable conditions for operating small craft and for diving are available throughout the year, while they are not at Andrew Bay.

As with the comparison made with Ostrich Bay and Ordnance Reef, the remoteness, underwater obstructions, and high levels of wave energy at Andrew Bay all detrimentally affect the quality of data collected and level of safety hazard exposure.

5.4 Conceptual Field Investigation Approach

Both site characteristic and munitions information need to be collected to address data gaps. In this section, the most reliable and available methods are identified and incorporated into a sequence of survey operations. It is not possible to consider all permutations for collecting the information necessary; however, this approach has been verified as conceivable during discussions with qualified staff members of a marine survey subcontractor and subject matter experts, as well as through discussions with the Project Team. Should any field investigation be conducted, additional data might become available that would significantly change the data gathering approach and associated costs.

The collection of underwater site information is relatively mature and there have been long-standing operations in the area. Reliable technologies, systems, and firms are contracted by government agencies, engineering firms, and marine construction companies for a variety of purposes. Conventional data-gathering approaches are appropriate to acquire the bathymetric, wave, current, and sea-bottom information needed.

The collection of reliable data on the occurrence of underwater munitions, however, is an emerging area of study and operations. In the past decade, numerous research studies have been conducted that identify technologies, quality assurance (QA) and quality control (QC) issues and methods, and operational characteristics. Given the remote location of the site, limited duration of acceptable survey conditions, and large area of study, the best approach appears to involve the most proven data sensors and platforms. Extensive research, planning, design, and contingency development are needed at multiple stages of such an investigation to meet safety, regulatory, and quality requirements.

Because of the remote location and working conditions at Adak Island, the greatest number of instruments possible should be deployed during each mobilization in order to capitalize on available work platforms, good weather, and good seas. The survey methods and technologies should be combined and sequenced for the safe, efficient, accurate, and precise collection of data. Each successive survey and data set provided by the various types of instruments can be used to compare information for specific features and anomalies continuously while the survey is conducted. Ample personnel should be allotted for the ongoing processing and comparison of survey data from multiple sources, and these data should be discussed with the survey crew and investigation oversight staff on an ongoing basis.

The conceptual field investigation approach developed for this TM is summarized below and presented in the following subsections:

Phase 1

- Conduct a combined noninvasive site data collection of Andrew Bay to gather the following data:
  - Site geodetic control and local tide datum elevations
  - High-resolution bathymetry
  - ADCP tidal, wave amplitude, frequency, and directional data
- Conduct a combined multisensor geophysical surveys to concurrently gather data using the following technologies:
  - Side-scan sonar
  - Magnetometer
  - SBP

Phase 2

- Conduct a geophysical survey using towed magnetometer and high-resolution bathymetry to close data gaps identified during the Phase 1 effort (such as mapping over-winter changes to identify seafloor and depositional features as a means of validating transport modeling) and identify anomalies for investigation.
- Deploy an ROV equipped with a magnetometer, shovelhead, and camera to gather further site data at the seafloor that might be needed in selected areas based on the survey methodology employed above; recover wave and current data collected by deployed sensors.

5.4.1 Site Geodetic Control and Quality Control Survey

Prior to marine site data collection, local geodetic control needs to be established across multiple terrestrial monuments to ensure appropriate survey location control. Local tide datum elevations also need to be established under acceptable criteria for multibeam and other surveys.

Demonstrating the proper function of geophysical systems is vitally important for any geophysical survey. The additional challenges and difficult operations involved with underwater geophysical surveys make it even more important to design, construct, implement, and document effective and reliable geophysical verification systems. A marine instrument verification strip would be required to confirm equipment detection function and positional accuracy, as well as near-term migration forces.

5.4.2 Bathymetric Survey

The ALSW-01 offshore area should have a bathymetric survey performed either simultaneously with another remote-sensing survey or preceding all other work. The bathymetric survey could be accomplished with the multibeam instruments described in vendor information from TerraSond Limited provided in **Appendix B.**

High-resolution bathymetry would provide the site information needed to plan future survey traverses with other instruments and might identify large groupings of debris that protrude above the surrounding seafloor. Detailed bathymetric data for the entire area of study would help to define safe passage areas for the survey vessel and survey instruments, and would be the primary source of information for managing vessel safety and equipment damage risks. The primary safety risks for Andrew Bay underwater survey operations are underwater obstructions that the vessel or survey equipment might come into contact with, including bottom, shoals, rocks, kelp, debris, and munitions.

High-resolution bathymetry would improve the reliability of MEC mobility estimates and might provide information on the lateral boundaries of movement. This information could also be useful with site-specific wave and current data for transport modeling, and it could help to delineate the extent of MEC presence by refining likely zones of mobility in Andrew Bay.

5.4.3 ADCP Tide and Current Data Collection

Site-specific wave amplitude, frequency, and directional data would improve the reliability of MEC mobility estimates and may provide information on the lateral boundaries of movement along the northwest shoreline of Adak Island and Andrew Bay. This information could be used with high-resolution bathymetry and other wave and current data for transport modeling, and it could help to delineate the extent of MEC presence by refining likely zones of mobility in Andrew Bay.

Fixed array Acoustic Doppler Current Profiler (ADCP) sensors could be used to collect current and wave data continuously in parallel with other data collection during the course of survey operations. Remote ADCP sensors would be deployed with acoustic recovery couplers at locations selected after the multibeam survey to collect wave data during the survey duration. These sensors would be retrieved before demobilization, data would be downloaded, and the sensors would be redeployed with accessory batteries and other preparations for a year-long residence time and recovery during the next survey season.

5.4.4 Side-scan Sonar, Magnetometer, and Sub-bottom Profiling

The second survey pass would likely best be performed with concurrent side-scan sonar, magnetometer, and sub-bottom survey equipment. These surveys would generate maps of magnetic anomalies, further high-resolution representations of the sea-bottom surface, and variations in sea-bottom and sub-bottom sediment characteristics (typically consolidated and unconsolidated materials). Magnetometer arrays would be used to assess the sea bottom at the deepest possible safe operating depths. Electromagnetic sensors were determined to not be useful, given the anticipated seafloor standoff requirements.

It is unlikely that MEC identification data quality as defined in Section 5.1 can be obtained. Given that detailed bathymetry is not available to assess survey pathways through the site, the likelihood of attaining and maintaining instrument-sea bottom standoff in the range of 3 to 6 feet (required to reliably detect medium-size individual MEC) cannot be reliably determined. The likely presence of kelp, scrap metal, rocks, and debris poses further obstacles to maintaining survey coverage and depth without significant risk of equipment damage or loss. Significant wave action introduces serious obstacles to instrument position and maneuver control, which could greatly reduce available survey time depending on weather conditions at the time of the survey.

The presence of ferromagnetic minerals is likely to obscure the identification of individual MEC (U.S. Navy 2007b). Ferromagnetic minerals would create remnant magnetic background noise, but the occurrence of steel materials (munitions casings) would also create perturbations in the local magnetic field. The closer the sensor is to the magnetic source, the more likely the detection will be, and the better the resolution of the resulting magnetometer survey. Based on observations to date of the boulder seafloor conditions, the success in positioning a magnetometer close to the bottom is questionable.

5.4.5 Anomaly Category Investigation

If suitable conditions are present after the foregoing survey operations are completed, time might be available to further investigate anomalies or categories of anomalies as a QC effort. Anomalies could be identified during and after the planned foregoing surveys are conducted and when preliminary onsite data processing is complete. Prevalent or recurring types of anomalies that have been identified and examined through the various instruments could be classified for further investigation. Based on weather conditions and remaining survey duration, specific sites representative of widespread or recurring types of anomalies could be reexamined for further study by available instruments for resolution as possible.

5.4.6 Data Processing, Reporting, and Future Investigation Planning

After demobilization, data processing, and transmittal of survey data and reports, analysis should be conducted to identify remaining data gaps, munitions hazards, and other issues to be resolved for completing the CSM.

5.4.7 Follow-on and ROV Survey

A second survey would be conducted the following summer season to recover ADCP sensors and investigate specific areas of interest or high anomaly density using methods selected from those used during the first survey. In addition to closing data gaps, key features (both stratigraphic and metallic) identified during the first season’s efforts can be remapped to estimate over-winter movement potential and validate transport modeling assumptions.

A tethered ROV equipped with a video camera, positioning equipment, and a magnetometer could be used to examine geophysical anomalies or to characterize features identified by the multibeam, side-scan sonar, and sub-bottom profile surveys. Using an ROV is assumed to be effective in areas with adequate visibility and access to the same degree as divers at less cost and safety risk; however, it would not be effective in kelp beds, probing sediments, or in moving underwater obstructions. As reported by EOD swimmers, bottom conditions are assumed to be cobbles and boulders with limited sandy areas (U.S. Navy 2000).

The ROV coverage of an area is also slow (although faster than divers), which is an important factor considering the sea conditions north of Adak Island. For this reason, the ROV is a confirmatory investigation method and not a primary investigation method.

5.5 Data Quality and Usability

As discussed in Section 5.1, the fundamental criterion for data quality in defining the nature and extent of MEC presence in Andrew Bay is to locate clustered and individual munitions. The chief obstacles to achieving the required data quality are listed below.

- MEC is known to be in motion across the site and its position is likely to change after it is located. Items successfully located within the 300-foot depth curve are likely to move. Munitions recovered from ALSW-01 are likely to have mobilized from within this depth curve under the conditions identified in Section 3.2. As shown in **Figure 2-3**, this contour as identified in navigational charts encompasses most of the underwater lands in Andrew Bay, an area of roughly 2,700 acres, using the Long-range Navigation (LORAN) Station and Acorn Point as lateral boundaries. The source area for the munitions is likely much smaller than the 2,700-acre potential based on the approximately 1-mile-wide depositional zone of munitions along the seawall.

- Large- and moderate-sized rocks in the shallower underwater lands of Andrew Bay obscure visual and acoustic acquisition of munitions. These conditions severely limit the investigation of geophysical anomalies in the area and their discrimination from scrap metal or ferrous geologic deposits. Additionally, based on the dynamic environment, munitions are likely also present below cobbles on the seafloor. The visual swimmer survey conducted in 2000 indicated the presence of large-diameter boulders that are likely to obscure many munitions. These boulders were reported at depths of 50 feet and shallower. This contour traverses Andrew Bay roughly parallel to the seawall approximately 700 yards off the Andrew Lake Seawall according to navigational charts. As shown in **Figure 2-3**, this depth contour encompasses a large portion of the underwater lands in Andrew Bay, with an upper limit of roughly 1,000 acres, using the LORAN Station and Acorn Point as lateral boundaries.

- Underwater obstacles are likely present that would interfere with acoustic and geophysical surveys. Kelp, scrap metal, debris, rocks, and interfering bottom contours are likely to be significant obstacles to the safe transit of surface and submerged towed instruments. The presence of these items is also likely to obscure acquisition of data using acoustic means in localized or widespread areas to an unknown degree.

- Seafloor standoff requirements are such that reliable electromagnetic data are not likely to be obtained, while magnetometers are able to collect useful data at a greater distance from the seafloor. However, ferrous and/or magnetic deposits have been reported around Adak Island that, if present in Andrew Bay, pose a significant obstacle to identifying geophysical anomalies where such deposits are located.
- QC and QA of underwater geophysical data for the detection of MEC are emerging topics of study and operational practices are not fully developed. Developing conceivable measures for such a distant site and under the robust and challenging site conditions present at Andrew Bay may be possible, but their effectiveness will not be fully known until the survey has been conducted and data evaluated. The precision of geophysical survey information would typically be measured by reviewing data collected over emplaced QC seed items or previously established or known items in the survey areas with known locations; however, because of the challenging operational environment, precision would likely be measured through review of the same instrument-specific QC and instrument validation data and data quality objectives used to validate accuracy. The prospects for establishing and maintaining seed items in the survey area bring a series of unresolved concerns to bear. Seed items must remain in a fixed position that is located with a high degree of precision and accuracy. This would likely require sea-bottom penetration to achieve. The high-energy conditions in Andrew Bay also pose challenges in maintaining such items over multiple seasons of investigation work. Similar challenges apply to the design and construction of geophysical prove-out systems near the site. Suitable sheltered waters near the site are not known to be available, and transit to other parts of the island to access them would further reduce the brief operational schedule available in summer months.

5.6 Estimated Cost

Rough-order-of-magnitude (ROM) costs were established for a marine survey using a series of fundamental assumptions. Although the scope and cost of any future investigations conducted may be significantly different from those developed here, these costs can be used for discussion and comparison purposes and for determining cost reasonableness to achieve the potential protectiveness of remedial measures that might be performed after a comprehensive RI. The basis of the cost estimates with further scope assumption and component cost items is provided in **Appendix C**.

The cost of the two-season marine survey was estimated to be $6.4 million. The range of this ROM estimate is $4.5 million to $9.7 million. The marine survey includes allotments to address the data quality and usability issues identified in Section 5.5; however, the effectiveness of these measures is not reliably known. The marine survey costs include estimates of a minimal yet undefined effort required to prepare RI/FS documents for ALSW-01.

6.0 Remedial Action Alternatives

This section screens conceptual approaches to underwater MEC remedial actions that could be used in Andrew Bay and evaluates the most likely remedial action that would be implemented in Andrew Bay, based on the Project Team's best professional judgment of the nature and location of munitions in the bay at this time.

These approaches, or alternatives, were developed in the absence of definitive data on the nature and extent of MEC present. For the purposes of developing general level of effort and costing information, however, remedial actions were considered, and the most likely method chosen considering the assumed dispersal of munitions, location, sea and seafloor conditions, and technological capabilities. **Appendix D** includes a detailed narrative and supporting costs.

6.1 Depositional and Transport Model

The location, content, and extent of the MEC source area are unknown, as are the specific physical conditions that govern MEC movement and deposition across the AOC. This lack of information restricts decision-making about the types of remedial actions that might be appropriate to address MEC hazards at ALSW-01. However, based on the information reviewed to date and knowledge of site conditions, the following depositional and transport model can be constructed:

- The seafloor consists of cobbles and boulders, with some sandy areas to the center of Andrew Bay and kelp density increasing to the east and west of the bay.
- Sea conditions can be very aggressive, with periods when no on-water work is possible. In addition, no sheltered areas are present on the north side of the island for on-water staging of equipment during periods of foul weather.
- Most MEC is present and mobile off the Andrew Lake Seawall out to a depth of 300 feet.
- MEC is assumed present in a primary source area of 250 acres using an area bounded by the deposition along the seawall and extending 0.5 miles into Andrew Bay. This area encompasses water depths to approximately 100 feet, while encompassing water depths to the 300-foot transport potential expands the area to 1,440 acres or 2.25 square miles.
- MEC may be present in concentrated source areas (piles) and/or individually spread along the seafloor, both on and below cobbles, among boulders, and potentially in kelp beds.
- MEC identified during the data collection effort is likely to have moved during the time duration between data collection and remedial efforts.

6.2 Conceptual Remedial Actions

This section identifies remedial action techniques and technologies that could be used for underwater MEC recovery in Andrew Bay. The goal of remedial actions in Andrew Bay would be to remove MEC from the source area so that deposition no longer occurs along the seawall. In the event that not all transportable MEC is removed from Andrew Bay, annual seawall sweeps would be continued. Furthermore, consistent with Navy goals for all of Adak Island, the Navy would maintain community awareness on the residual explosive safety risk from MEC and define the response process to be used if MEC were to be encountered by the public.

The underwater environment poses additional challenges for MEC removal above that for terrestrial munitions response sites. These challenges include safety issues associated with the generally more unstable underwater environment from factors such as waves, tides, currents, low visibility, temperature, and sedimentation. Safety must be of the highest priority in regard to divers and all other personnel for underwater MEC response actions. The sections below discuss individual approaches for underwater MEC remedial actions. **Appendix D** discusses each remedial action in detail. Dredging was carried forward as the most reasonable remedial approach of the conceptual approaches listed below.

- **Divers.** EOD or UXO-qualified divers could be used to conduct visual and handheld instrument-guided searches to detect and remove MEC in water depths of 120 feet or less.
- **Magnets and electromagnets.** Large industrial magnets operated by cranes have been used successfully by dredging, salvage, and marine construction companies to remove metal debris and to lift other metallic objects from underwater (motor vehicles). Magnets could be dragged along the bottom surface to recover ferrous objects on or slightly below the seafloor.
- **Mechanical rake.** A mechanical rake with large tines could be used to scrape sediment in an attempt to recover MEC that is on and just below the seafloor.
- **Entombment.** MEC entombment might be an acceptable approach if it could be demonstrated that it can permanently isolate the MEC source.
- **Dredging.** Hydraulic or mechanical dredging could be used to remove bottom material from designated underwater locations. Dredge spoils could be screened to separate MEC and other metallic debris for handling in an adjacent barge.

6.3 Remedial Alternative Assessment: Dredging

Considering the technological applications, assumptions, and limitations presented in **Appendix D**, dredging was determined to be the underwater MEC removal approach with the greatest chance of success. Dredging has been used to recover underwater MEC at locations such as Jackson Park and Mare Island. Assuming that the extensive technical feasibility issues are resolved and the project could be successfully implemented, dredging would be the most protective of human health and the environment of the alternatives identified.

The net present value rough order-of-magnitude cost for dredging is $136 million. The cost basis for this estimated cost is provided in **Appendix D. Table 6-1** presents the advantages and disadvantages of the dredging alternative along with the estimated costs.

TABLE 6-1
Summary of Remedial Action Assessment: Dredging
Former Naval Air Facility, Adak Island, Alaska

Alternative	Advantages	Disadvantages	Total Cost (net present value)
Dredging	Removes MEC item source if successfully implemented.	Significant implementation issues with safety and habitat damage risks. Application at Adak is unlikely to remove all items such that no future deposition occurs on the Andrew Lake Seawall. Considerable logistical issues to overcome.	$136 million

MEC = munitions and explosives of concern

7.0 Conclusions and Recommendations

This section summarizes the conclusions developed in this TM.

7.1 Nature and Extent of Contamination

No definitive mapping or investigation of specific source areas showing types, migration pathways, or definitive trends of munitions deposition on ALSW-01 has been conducted. Information and assumptions useful in moving forward with further investigations in the area has been identified and developed. Notable items include the following:

- The historical document review did not reveal specific documentation of munitions disposal in or near Andrew Bay. Anecdotal reports from one veteran stationed at Adak referenced the abandonment of munitions in the terrestrial area of ALSW-01, as well as munitions disposal in shallows near the Andrew Lake Seawall and on the north side of Mount Adagdak. No dumping locations or shoreline accumulations of MEC were found in these areas during visual field investigations conducted in July and August 2010.
- The human receptor exposure pathway for MEC is complete along the intertidal area of ALSW-01. Access to the beach, and, therefore, to munitions that may have been deposited there is possible and has been known to occur. The human receptor exposure pathway to MEC in the marine area is not complete. There is no known recreational swimming or diving in the area and sea conditions are not compatible with fishing in this area. The ecological receptor exposure pathway for MEC in the marine area is potentially complete; however, exposure was found likely insignificant.
- The munitions removed from ALSW-01 are likely migrating from offshore areas that are either dumpsites associated with former training ranges, or a combination of both dumpsites and former training ranges. Other less likely depositional scenarios considered include dumping off a pier that may have been present, release from a barge that may have sunk in Andrew Bay, or surface disposal on the beach.
- The munitions might include DMM in the form of abandoned surplus ammunition and munitions from aircraft, anti-aircraft, infantry, and artillery training activities. Munitions debris in the form of targets, spent casings, and other items are also included. UXO may also be present, based on the known locations of former training areas.
- Most of the munitions recovered from ALSW-01 have likely migrated from waters shallower than about 300 feet deep. It is unlikely that any items recovered have migrated from waters deeper than 600 feet.
- There are no records or indications of the lateral limits of the source area in Andrew Bay. The current lateral deposition limits along the Andrew Lake Seawall are at approximately 300 yards west and 800 yards east of the Andrew Lake Spillway. These limits were verified during the 2010 site visits.

- Using the area bounded by the deposition along the seawall and extending 0.5 miles into Andrew Bay as a primary potential source area results in a preliminary investigation area of 250 acres. This encompasses water depths to approximately 100 feet. Encompassing water depths to the 300-foot transport potential expands the area to approximately 1,440 acres or 2.25 square miles.

Data gaps identified in producing a completed CSM include the following:

- Accurate and detailed bathymetric elevations and contours
- Wave direction, height, and frequency data specific to Andrew Bay
- Current direction and velocity data specific to Andrew Bay
- Data on the location, areal extent, and depth of the offshore disposal source area(s)
- Data on preferential migration pathways or zones along the shoreline and/or out into Andrew Bay
- Data on the variation in areal density, type, and condition of munitions across the source area
- Data on the variation in sea-bottom character, sediment thickness, and burial depth of munitions across the source area
- Data showing the expected trends in quantity, type, and other characteristics of future munitions deposition at ALSW-01

7.2 Data Collection Feasibility Assessment

The most reliable technologies for geophysical and site data gathering addressing the CSM data gaps identified in Section 4 were identified and evaluated in Section 5.

Recent and ongoing data collection efforts conducted at Ostrich Bay (Bremerton, Washington), Ordnance Reef (Wai'anae, Hawaii), and MRP Site 100 (San Diego, California) were evaluated as case studies. The data collection technologies used at these sites have been generally successful at these locations; however, in all cases, the physical setting, energy, and depths were more amenable to a successful data collection effort than at Andrew Bay.

Given the remote site location, limited duration of acceptable survey conditions, and large study area, the best approach appears to involve the most proven data sensors and platforms. Conventional data-gathering approaches appear to be appropriate to acquire the bathymetric, wave, current, and sea-bottom information needed. In addition, because of the remote location and working conditions at Adak Island, the greatest number of instruments should be deployed during each mobilization in order to capitalize on available work platforms, good weather, and good seas.

The preferred approach would include the following:

Phase 1

- Conduct a combined noninvasive site data collection of Andrew Bay to gather the following data:
  - Site geodetic control and local tide datum elevations
  - High-resolution bathymetry
  - ADCP tidal, wave amplitude, frequency, and directional data
- Conduct a combined multisensor geophysical surveys to concurrently gather data using the following technologies:
  - Side-scan sonar
  - Magnetometer
  - SBP

Phase 2

- Conduct a geophysical survey using towed magnetometer and high-resolution bathymetry to close data gaps identified during the Phase 1 effort (such as mapping over-winter changes to get seafloor and depositional features as a means of validating transport modeling) and identify anomalies for investigation.
- Deploy an ROV equipped with a magnetometer, shovel head, and camera to gather further site data at the seafloor that might be needed in selected areas based on the survey methodology employed above; recover wave and current data collected by deployed sensors.

The data collection effort was developed to encompass two field seasons. Tidal and wave amplitude frequency recorders would operate over a year-long window to allow appropriate modeling of transport potential. Additionally, a follow-on magnetometry effort and ROV operations would be used to refine data following analysis and review of the initial data set concerning bottom conditions.

It is conceivable that such a survey could be conducted to collect information to fill the identified data gaps. However, the feasibility of conducting such an investigation while obtaining data that reliably identify individual MEC is very low. The ongoing movement of munitions over most of the likely extent of MEC, the prevalence of large rocks and kelp that obscure much of this same area, the likely presence of multiple underwater obstacles, the possible presence of ferrous and/or magnetic sea-bottom deposits, and the emerging nature of QA/QC methods for underwater geophysical investigations all combine to pose significant obstacles to the collection of good, usable data.

Practical scope and schedule issues also may significantly reduce the feasibility of such an investigation. Because of the remote location, short field season, underwater environment, and other site-specific characteristics, working conditions at ALSW-01 are expected to be extremely difficult. As a contingency, multiple MEC detection technologies could be deployed in phases to successfully acquire the data needed for decision-making about remediation. These contingencies were included in the Section 5.4 field investigation plan;

however, they would be subject to the data quality issues identified in the previous paragraph.

7.3 Remedial Action Alternatives Assessment

Section 6 and **Appendix D** evaluate potential approaches for underwater MEC remedial actions that could be used in Andrew Bay. The approaches were developed based on the Project Team's best professional judgment on the nature and location of munitions in the bay because of the absence of definitive data on the nature and extent of the MEC. To develop a general level of effort and costing information, remedial alternatives were considered and the most likely method chosen in consideration of the assumed dispersal of munitions, location, sea and seafloor conditions, and technological capabilities.

The remedial goal was established as removing MEC from the source area so that deposition no longer occurs along the seawall and annual seawall sweeps are no longer required. Options considered included using divers, industrial electromagnets, mechanical rakes, entombment, and dredging. Given all the factors associated with the CSM and project implementation at Adak, dredging was established as the remedial action with the greatest chance of success. Material sorting would occur on the deck of support barges with rock returned to the source areas. An ROV would be used in concert with the dredge to ensure that metallic materials are removed. The effort is anticipated to require 7 years to complete.

7.4 Conclusions

A critical decision point in establishing goals for data collection and remedial efforts was to determine how successful the overall effort would be as a complete remedial strategy. Success was found to be unlikely based on the conclusions discussed below.

In the best professional judgment of the Project Team and the subject matter experts consulted, there is no combination of data collection effort and remedial action that could ensure that annual seawall sweeps would not continue to be required for the long term. Annual seawall sweeps are used to mitigate MEC exposure risk and may be used in the future to also identify deposition trends indicating the expected duration of deposition.

Site conditions and the wide distribution of MEC pose obstacles to a successful investigation and remedial effort. Andrew Bay bottom conditions have been documented as smaller, more mobile rocks in the center of the bay with more boulders and kelp to the east and west. Regardless of whether the original deposition of materials in Andrew Bay was from dumping, or training, or both, wave forces and the passage of approximately 65 years since release have likely thoroughly mixed MEC with rocks and boulders throughout the bay floor leading up to the beach.

Any assessment effort that would quantify MEC for removal must identify individual items among cobbles, boulders, and kelp, as well as below cobbles. Munitions must be identified below the cobbles based on the dynamic nature of the seafloor. The extent of cobble and boulder transport is such that approximately 20 to 30 feet of the Andrew Lake Spillway is blocked by new rock deposition each winter.

A successful remedial effort must remove all the transportable items from the same setting. The work must be accomplished safely in at a remote site location in an aggressive climate with commonly unfavorable seas. In the absence of confidence in the remedial strategy, seawall sweeps would continue to be a requirement for the long term.

Both the near- and long-term costs of the data collection, remedial action, and beach sweeps far exceed the cost of the beach sweeps alone, yet confidence in remedy performance is low. **Table 7-1** summarizes projected costs over a 75-year timeframe under the scenarios in which the data collection and remedial efforts are and are not undertaken. The 75-year timeframe was established by the Project Team for this TM based on the approximately 65 years elapsed since the munitions were deposited in the bay, and the lack of apparent downward trending of deposited item quantity. As indicated in the **Table 7-1**, both the near- and long-term costs of the data collection, remedial action, and beach sweeps far exceed the cost of the beach sweeps alone.

TABLE 7-1
Cost Evaluation Remedial Effort with Seawall Sweeps
Former Naval Air Facility, Adak Island, Alaska

	Data Collection, Remedial Action, Continued Seawall Sweeps	**Seawall Sweeps**
Data collection effort	$6,400,000	--
Remedial action	$136,000,000	--
Seawall sweeps (75 years)	$3,750,000	$3,750,000
Total (75 years)	**$146,150,000**	**$3,750,000**

Note: Seawall sweeps are shown at the present $50,000 per year with no escalation factor (present worth).

7.5 Recommendations

Overall, approximately 15 to 20 MEC items are recovered from the Andrew Lake Seawall each year. A bathymetric survey is likely to confirm the cobble and boulder composition of the seafloor with limited magnetometer access to depths that allow individual items to be identified. Removal could be successful for large piles but not for individual or widely distributed items currently under and interspersed with mobile rock in the dynamic marine environment of Andrew Bay. Factors that affect the success of a removal effort relate to the inability to collect data with enough discrimination, the depth from which information must be collected, the mobile status of materials on the seafloor, the character of the seafloor itself, and the multi-year effort required for the work.

The approach of not fully characterizing or removing all munitions that may be present is consistent with that applied at other Adak munitions response sites where exposure pathways are not complete. In particular, this approach has also been implemented on the terrestrial areas where slopes exceed 30 degrees.

Based on the conclusions of this TM as discussed by the Project Team in October 2010, seawall sweeps (and maintenance of institutional and engineering controls such as access restrictions and community outreach) would need to continue whether or not the effort was spent on the additional investigation and/or response action. The cost of additional investigation and/or response action would be more than 37 times the 75-year present-worth cost of $3.75 million for seawall sweeps but would produce no expectation of reduced risk or reduced requirements for seawall sweeps.

Given the continued requirement for seawall sweeps in any future site management case, no significant gain in risk reduction or environmental protection is likely to be realized through the data collection and/or response action effort because it is unlikely that all the individual items could be located and removed in this dynamic marine environment. In view of the lack of identifiable improvement in protection of human health and the environment, as well as the strong likelihood that remedial goals will not be realized, the Project Team recommends that the data collection effort and potential remedial action not be undertaken. The Project Team further recommends that site management include the program of continued beach sweeps coupled with the existing institutional and engineering control program. Five-year reviews will be conducted as required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to monitor the protectiveness of this remedy.

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Appendix A
Summary of Terrestrial Data

TABLE A-1
Munition Descriptions and Types
Former Naval Air Facility, Adak Island, Alaska

Year	Month	Day	Qty[1]	Item Description from EOD Reports[2]	Munition Type
1962	Sept	10	73	Mortar, 81mm, HE and WP M43, Light	81mm Mortar
1962	Sept	10	3	Mortar, 81mm, HE and WP M56, Heavy	81mm Mortar
1962	Sept	10	21	Mortar, 60mm	60mm Mortar
1962	Sept	10	8	40mm, HEI (complete round)	Projectiles
1962	Sept	10	8	40mm, HEI (projectiles)	Projectiles
1962	Sept	10	4	Grenades, rifle, HEAT	Grenades
1962	Sept	10	2	Grenades, frag.	Grenades
1962	Sept	10	1	Bomb, Incendiary, 4 lb.	Bomb
1962	Sept	10	8	Fuse, Bomb AN/M-100 A1	Bomb
1962	Sept	10	8	Fuse, Bomb AN/M-103 A1	Bomb
1962	Sept	10	1	Projectile, 90mm	Projectiles
1962	Sept	10	1	Small arms ammo, various cal. [3]	Small Arms Ammo.
1962	Sept	11	72	Mortar, 81mm, HE and WP M43, Light	81mm Mortar
1962	Sept	11	3	Mortar, 81mm, HE and WP M56, Heavy	81mm Mortar
1962	Sept	11	10	Mortar, 60mm	60mm Mortar
1962	Sept	11	1	40mm, HEI (complete round)	Projectiles
1962	Sept	11	14	40mm, HEI (projectiles)	Projectiles
1962	Sept	11	1	Grenades, rifle, HEAT	Grenades
1962	Sept	11	2	Fuse, Bomb AN/M-100 A1	Bomb
1962	Sept	11	2	Fuse, Bomb AN/M-103 A1	Bomb
1962	Sept	11	1	Small arms ammo, various cal. [3]	Small Arms Ammo.
1962	Sept	12	76	Mortar, 81mm, HE and WP M43, Light	81mm Mortar
1962	Sept	12	1	Mortar, 81mm, HE and WP M56, Heavy	81mm Mortar
1962	Sept	12	16	Mortar, 60mm	60mm Mortar
1962	Sept	12	1	40mm, HEI (complete round)	Projectiles
1962	Sept	12	13	40mm, HEI (projectiles)	Projectiles
1962	Sept	12	2	Grenades, rifle, HEAT	Grenades
1962	Sept	12	1	Grenades, frag.	Grenades
1962	Sept	12	1	Bomb, Incendiary, 4 lb.	Bomb
1962	Sept	12	15	Fuse, Bomb AN/M-100 A1	Bomb
1962	Sept	12	7	Fuse, Bomb AN/M-103 A1	Bomb
1962	Sept	12	1	Projectile, 90mm	Projectiles
1962	Sept	12	1	Parachute Flare MK5	Misc
1962	Sept	12	1	Small arms ammo, various cal. [3]	Small Arms Ammo.
1963	Apr	1	1	1000 lb. G.P. Bomb M-65 Unfused	Bomb
1963	Apr	1	1	750 lb., SAP Bomb M-58 Unfused	Bomb
1963	Apr	3-5	36	81mm Mortar Rounds (heavy) H.E. or W.P Fused	81mm Mortar
1963	Apr	3-5	92	81mm Mortar Rounds (light) H.E. Fused	81mm Mortar
1963	Apr	3-5	14	2.36" Rockets HEAT, Fused	Projectiles
1963	Apr	3-5	3	Grenades, rifle, HEAT, Fused	Grenades
1963	Apr	3-5	12	40mm ctgs, complete, Fused	Projectiles
1963	Apr	3-5	19	40mm projectiles, Fused	Projectiles
1963	Apr	3-5	20	61mm Mortar Rounds, H.E. Fused	60mm Mortar
1963	Apr	3-5	10	M-100 Bomb tail fuses	Fuzes
1963	Apr	3-5	12	M-103 Bomb nose fuses	Fuzes
1963	Apr	3-5	6	MK4 A/C Float lights	Misc
1963	Apr	3-5	1	MK2 Hand grenade, Fused	Grenades
1963	Apr	17	1	500 lb. Incendiary Bombs M-76	Bomb
1967	May	30	2	81mm Mortars	81mm Mortar
1967	May	30	2	40mm complete rounds	Projectiles
1967	May	30	1	.50 Cal. Round	Small Arms Ammo.
1967	Oct	20	5	81mm Hi Capacity Mortars	81mm Mortar
1967	Oct	20	1	Partial 60mm Mortar	60mm Mortar

TABLE A-1
Munition Descriptions and Types
Former Naval Air Facility, Adak Island, Alaska

Year	Month	Day	Qty[1]	Item Description from EOD Reports[2]	Munition Type
1967	Oct	20	1	Fuse of Unknown Type	Fuzes
1967	Oct	24	1	3.5 inch Rocket Mortar	Projectiles
1971	May	18	1	81mm Mortar M43A1	81mm Mortar
1971	Oct	28	1	Assorted caliber small arms ammo. [3]	Small Arms Ammo.
1972	May	3	2	103 Bomb Fuses	Fuzes
1972	May	3	4	AN-M112 Series Fuses	Fuzes
1972	May	3	75	30 Caliber Rounds	Small Arms Ammo.
1972	May	3	1	40mm fuze and shell	Projectiles
1972	May	3	5	4-lb incendiary bomb, AN-M50A2/6	Bomb
1972	May	3	30	50 Caliber Rounds	Small Arms Ammo.
1973	Jun	1	1	81mm Mortar	81mm Mortar
1973	Jun	1	1	Bomb Tail Fuze	Fuzes
1973	Jun	1	1	Incendiary	Bomb
1975	May	28	1	81mm Mortar Round	81mm Mortar
1979	Apr	4	1	81mm Mortar (WP)	81mm Mortar
1979	Apr	4	1	60mm Mortar (HE)	60mm Mortar
1979	Apr	24	18	Thermite Bomblets	Bomb
1979	Apr	24	1	81mm Mortars	81mm Mortar
1979	Apr	24	2	Bomb Fuzes	Fuzes
1979	Oct	18	1	60mm Mortar	60mm Mortar
1979	Oct	18	2	81mm Mortars	81mm Mortar
1979	Oct	18	2	A/N M52A1 Thermite Bomblets	Bomb
1979	Oct	18	3	40mm powder casings	Projectiles
1979	Oct	18	2	5 inch Bombardment Rocket Head	Projectiles
1979	Oct	18	2	Bomb Fuzes	Fuzes
1979	Oct	18	1	200 rounds of misc. small arms ammo [3]	Small Arms Ammo.
1979	Dec	10	12	MK5 C.S. Carts	Misc
1979	Dec	10	5	5" shell cases	Projectiles
1979	Dec	10	3	75mm shell cases	Projectiles
1979	Dec	10	1	60mm Mortar	60mm Mortar
1979	Dec	10	7	CAD's	Misc
1979	Dec	10	1	Assorted small arms[3]	Small Arms Ammo.
1980	Jun	18	2	81mm Mortars	81mm Mortar
1980	Jun	18	1	Burster Tube	Misc
1980	Jun	18	1	M103 Bomb Fuze	Fuzes
1980	Jun	18	1	Thermite Bomblets	Bomb
1980	Jun	24	1	81mm Mortar WP	81mm Mortar
1980	Jun	24	1	M103 Bomb Fuze	Fuzes
1980	Jun	24	1	Thermite Bomblets	Bomb
1980	Jun	24	2	60mm powder casings	60mm Mortar
1980	Jun	24	1	40mm powder casing	Projectiles
1981	May	6	1	81mm Mortar	81mm Mortar
1981	May	6	2	Grenade Fuzes	Grenades
1981	May	6	3	Thermite Grenades	Grenades
1981	May	6	1	Assorted small arms[3]	Small Arms Ammo.
1982	Jan	7	15	80mm Mortar Round	81mm Mortar
1982	Apr	8	2	105mm Casings	Misc
1982	Apr	8	8	50 Caliber Rounds	Small Arms Ammo.
1982	Apr	8	10	40mm Casings	Projectiles
1982	Jul	7	1	81mm Mortar	81mm Mortar
1982	Jul	7	2	60mm Mortar	60mm Mortar
1982	Jul	7	11	Assorted 60 and 75mm Powder Casings	Projectiles
1982	Jul	7	3	Projectile Fuzes	Fuzes

TABLE A-1
Munition Descriptions and Types
Former Naval Air Facility, Adak Island, Alaska

Year	Month	Day	Qty[1]	Item Description from EOD Reports[2]	Munition Type
1982	Jul	7	1	Misc. small arms[3]	
1988	Feb	1	2	30mm Shell Casings (primers intact)	Projectiles
1992	--	--	2	M52 Incendiary Bombs[4]	Bomb
1992	--	--	1	37mm projectiles[4]	Projectiles
1992	--	--	1	60mm Mortars[4]	60mm Mortar
1992	--	--	1	6" Projectiles[4]	Projectiles
1992	--	--	1	3" Projectiles[4]	Projectiles
1992	--	--	1	Incendiary Firebombs[4]	Bomb
1992	--	--	1	Old Bulk Explosives[4]	Misc
2004	Sept	22-23	238	small arms and various casings	Small Arms Ammo.
2006	Sept	15	8	ordnance items	Misc
2006	Sept	22	30	ordnance items	Misc
2007	Sept	24-25	12	Mortars	81mm Mortar
2007	Sept	24-25	7	Cartridges	Small Arms Ammo.
2007	Sept	24-25	4	Bursters	Misc
2007	Sept	24-25	3	Fuzes	Fuzes
2007	Sept	24-25	16	Rounds of ammo.	Small Arms Ammo.
2007	Sept	24-25	2	Cartridges	Small Arms Ammo.
2007	Sept	24-25	1	Burster	Misc
2007	Sept	24-25	78	Rounds of ammo.	Small Arms Ammo.
2008	Sept	29	15	Mortars	81mm Mortar
2008	Sept	29	54	Casings/cartridges	Small Arms Ammo.
2008	Sept	29	1	Burster	Misc
2008	Sept	29	6	Fuzes	Fuzes
2008	Sept	29	3	Projectiles	Projectiles
2008	Sept	29	1	57mm Ammo.	Projectiles
2008	Sept	29	3	Mortar Tail Booms	81mm Mortar
2008	Sept	29	1	Firing Device	Misc
2009	Sept	10	13	Mortars	81mm Mortar
2009	Sept	10	22	Casings/cartridges	Small Arms Ammo.
2009	Sept	10	1	Burster	Misc
2009	Sept	10	10	Fuzes	Fuzes
2009	Sept	10	35	Small arms ammo.	Small Arms Ammo.
2009	Sept	10	2	Mortar Tail Booms	81mm Mortar

Notes:

[1] Quantities are based off various EOD reports. In some cases quantities were not consistent (i.e. small arms ammo reported by weight).

[2] Description of munition items is taken directly from EOD report even if description is likely inaccurate (i.e. 61mm mortar).

[3] No quantities given for small arms ammunition.

[4] Exact date not available for these items, but they were found in 1992.

TABLE A-2
Specific Munitions within Munition Type
Former Naval Air Facility, Adak Island, Alaska

Munition Type	Munition Specifics
60mm Mortar	60mm Mortar
	60mm Mortar (HE)
	60mm Mortars
	60mm powder casings
	61mm Mortar Rounds, H.E. Fused
	Mortar, 60mm
	Partial 60mm Mortar
81mm Mortar	80mm Mortar Round
	81mm Hi Capacity Mortars
	81mm Mortar
	81mm Mortar (WP)
	81mm Mortar M43A1
	81mm Mortar Round
	81mm Mortar Rounds (heavy) H.E. or W.P Fused
	81mm Mortar Rounds (light) H.E. Fused
	81mm Mortar WP
	81mm Mortars
	Mortar Tail Booms
	Mortar, 81mm, HE and WP M43, Light
	Mortar, 81mm, HE and WP M56, Heavy
	Mortars
Bomb	1000 lb. G.P. Bomb M-65 Unfused
	4-lb incendiary bomb, AN-M50A2/6
	500 lb. Incendiary Bombs M-76
	750 lb., SAP Bomb M-58 Unfused
	A/N M52A1 Thermite Bomblets
	Bomb, Incendiary, 4 lb.
	Fuse, Bomb AN/M-100 A1
	Fuse, Bomb AN/M-103 A1
	Incendiary
	Incendiary Firebombs
	M52 Incendiary Bombs
	Thermite Bomblets
Fuzes	103 Bomb Fuses
	AN-M112 Series Fuses
	Bomb Fuzes
	Bomb Tail Fuze
	Fuse of Unknown Type
	Fuzes
	M-100 Bomb tail fuses
	M103 Bomb Fuze
	M-103 Bomb nose fuses
	Projectile Fuzes
Grenades	Grenade Fuzes
	Grenades, frag.
	Grenades, rifle, HEAT
	Grenades, rifle, HEAT, Fused
	MK2 Hand grenade, Fused
	Thermite Grenades
Misc	105mm Casings
	Burster
	Burster Tube
	Bursters
	CAD's

TABLE A-2
Specific Munitions within Munition Type
Former Naval Air Facility, Adak Island, Alaska

Munition Type	Munition Specifics
	Firing Device
	MK4 A/C Float lights
	MK5 C.S. Carts
	Old Bulk Explosives
	ordnance items
	Parachute Flare MK5
Projectiles	2.36" Rockets HEAT, Fused
	3" Projectiles
	3.5 inch Rocket Mortar
	30mm Shell Casings (primers intact)
	37mm projectiles
	40mm Casings
	40mm complete rounds
	40mm ctgs, complete, Fused
	40mm fuze and shell
	40mm powder casing
	40mm powder casings
	40mm projectiles, Fused
	40mm, HEI (complete round)
	40mm, HEI (projectiles)
	5 inch Bombardment Rocket Head
	5" shell cases
	57mm Ammo.
	6" Projectiles
	75mm shell cases
	Assorted 60 and 75mm Powder Casings
	Projectile, 90mm
	Projectiles
Small Arms Ammo.	.50 Cal. Round
	200 rounds of misc. small arms ammo
	30 Caliber Rounds
	50 Caliber Rounds
	Assorted caliber small arms ammo.
	Assorted small arms
	Cartridges
	Casings/cartridges
	Rounds of ammo.
	Small arms ammo, various cal.
	Small arms ammo.
	small arms and various casings

TABLE A-3
Summary of Ordnance Type Results by Time Frames
Adax Island Andrew Bay

Time Frame	60mm Mortar	81mm Mortar	Bomb	Fuzes	Grenades	Misc	Projectiles	Small Arms Ammo
1962 - 1967	68	363	47	23	14	7	95	4
1971 - 1975	0	3	6	7	0	0	1	106
1979 - 1992	8	24	25	9	5	23	40	11
2004 - 2009	0	45	0	19	0	46	4	452
Totals	76	435	78	58	19	76	140	573

Appendix B
Marine Survey Information

Adak Geophysical Site Survey

Proposed Technologies

Multibeam - Reson 7125

Multibeam sonar systems provide three dimensional bathymetric coverage of the seafloor. The Reson 7125 is an ultra-high-resolution multibeam system providing the highest spatial resolution of any multibeam sonar on the market. This dual frequency system can operate between 0.5 to 500m water depths. At the high frequency setting (400kHz) the system produces 512 beams with an effective angular resolution of .25^{o}. In 50ft of water, the high frequency setting produces an across track resolution of ~.2ft (at nadir). At the low frequency setting (200kHz) the angular resolution of each beam is 0.5^{o}, and the system is capable of recording 256 independent soundings per ping. In 1000ft of water, the lower frequency setting produces an across track resolution of ~9ft (at nadir). The high ping rate of the Reson 7125 (up to 50Hz) yields a very-high along track resolution as well.

In addition to collecting bathymetry data, the Reson 7125 is capable of recording pseudo-sidescan or "Backscatter" data. This feature analyzes the amplitude of the returning signal to give an image similar to that of sidescan.

Deliverables for multibeam surveys include an xyz point set, a chart of the survey color coded by depths (and the pseudo-sidescan amplitude if desired), and a 3d virtual environment that can be viewed and navigated through in the Fledermaus viewing software iView4d (see below).

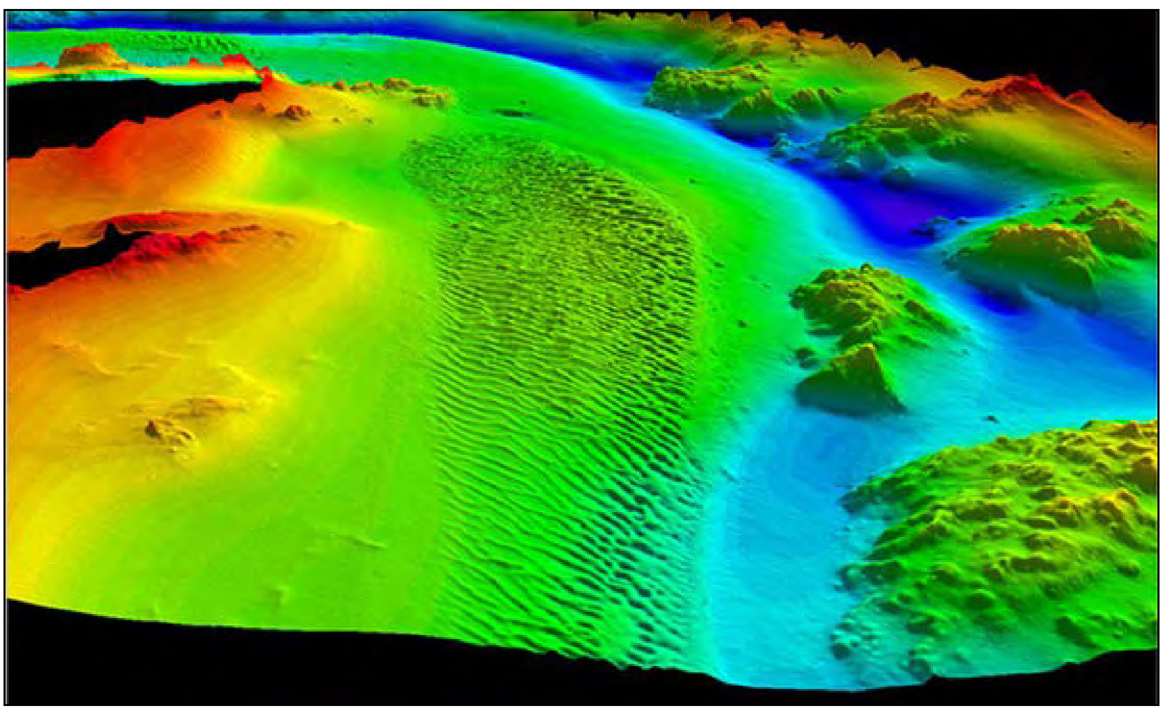

Figure 1: Example of seafloor survey using multibeam sonar. Data is seen in 3d, and color coded by depth. (Imagery courtesy of Reson)

Information Courtesy of TerraSond Limited

Sidescan – Edgetech 4200

The Edge-tech 4200 is a dual frequency (100/500 kHz) towed sidescan sonar that produces a qualitative image of the seafloor. This system works to differentiate between hard and soft materials, and to pick up subtle changes in the seafloor that may not have bathymetric signatures. Sidescan sonar is an effective tool for locating surface lain cables, pipelines and shipwrecks, as well as the locations of disturbed sediments and sediment transitions (mud/clay/sand/gravel etc.). The 4200's multi-pulse feature will allow 100% seafloor coverage at up to 10kts, or provide twice the along track resolution at more typical survey speeds. This system can also be effectively used in conjunction with the Marine Magnetics Explorer magnetometer, which tows 11m directly behind the tow fish.

Sidescan reconnaissance coverage generally starts at 100m range scale (to both port and starboard), covering 200m of the seafloor. Typically surveys are run to collect 200% coverage and to obtain views of objects from multiple directions. For smaller-target identification, a smaller range scale may be necessary. With a smaller range scale, resolution increases; however the tow fish must be towed closer to the bottom.

Products for Sidescan include a 2d chart of the data in plan view, color coded by return amplitude of the signal (seen below). These 2d images can also be draped on top of the 3d bathymetry data in Fledermaus and viewed in iView4d.

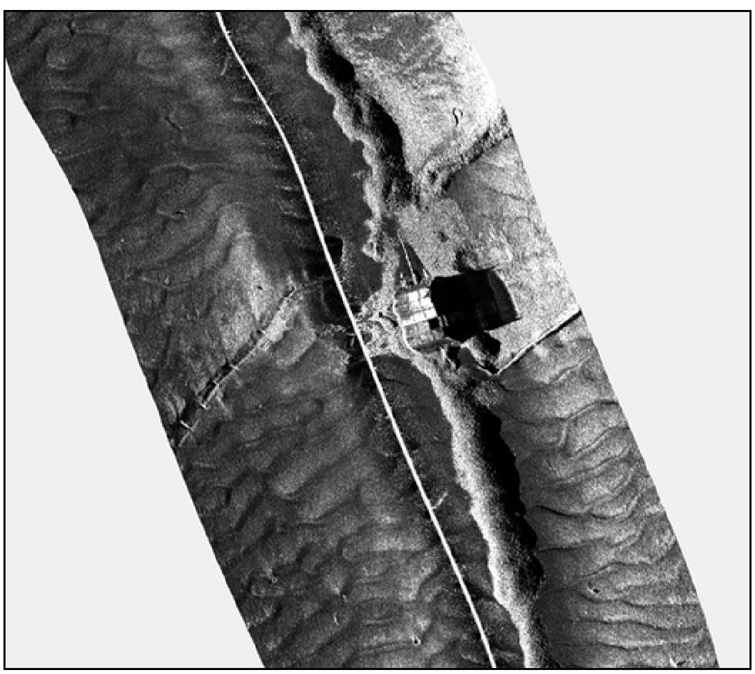

Figure 2: Example of seafloor survey using sidescan sonar. Data is seen in 2d plan view. (Imagery courtesy of Edgetech)

Information Courtesy of TerraSond Limited

Sub-bottom - Edgetech 3200 system w/ tow fish

The Edgetech 3200 is a wideband (Chirp) Frequency-Modulated sub-bottom profiling system. This system adds a qualitative third dimension to the information given by the sidescan sonar. Multiple tow fish are available for the Edgetech 3200 depending on the depth of coverage desired for the survey area. Larger tow fish emit frequencies that can penetrate up to 200m sub-seafloor depending on the sediment type. In practice they will penetrate the upper 5-15m in the higher energy environments found along the coast of Alaska. Tow fish emitting higher frequencies gather higher resolution data in the near sub-surface. The 3200 system can differentiate between bedrock /sediments, identify vertical sediment stratification, and spatial sediment transitions The Edgetech 3200 will additionally show distinct parabolic signatures when passing over point sources such as boulders.

The coverage of the subbottom profiler is a two dimensional along track image slicing vertically into the seafloor. Objects can be seen slightly off track due to the conical nature of the sound footprint on the seafloor, however this system is considered a 2d tool and spatial resolution will depend on the survey line spacing.

Deliverables for subbottom data include 2d images annotated with event markers that can be geo-referenced on a track line map. Additionally these images can be draped vertically in the Fledermaus 3d viewer along track line, displaying underneath the multibeam data.

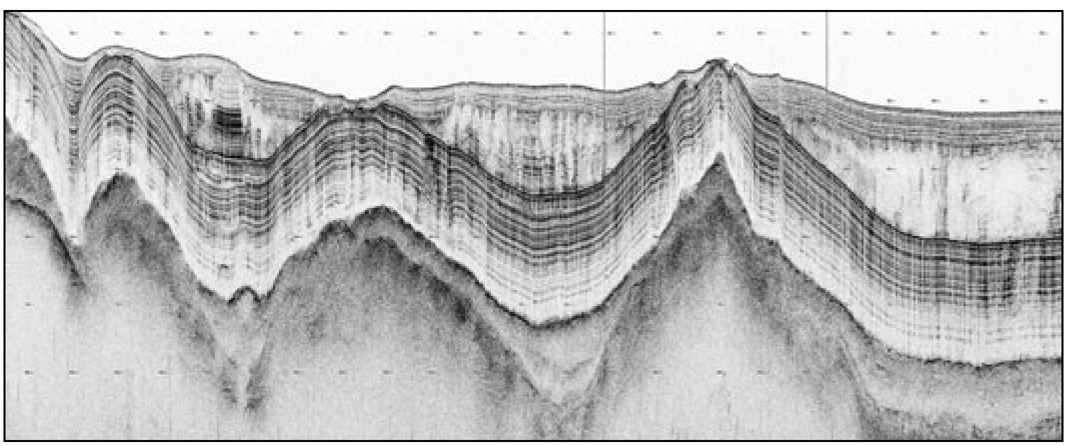

Figure 3: Example of seafloor survey using a Sub-bottom profiler. Data in 2d profile view (Imagery courtesy of Edgetech)

Tide Gauge – SeaBird SBE 26plus

The Seabird SBE 26plus wave and tide recorder combines precision thermometer and pressure sensor to provide wave and tide recording of unprecedented resolution and accuracy, along with high-quality temperature information.

The SBE 26 plus integrates samples over a user defined interval to record tide information independently of wave height. Additionally, wave amplitudes are measured in periodic sampling bursts with samples taken at 4Hz.

Deliverables for Seabird data typically take the form of time series plots of tidal data taken at 6 minute intervals. Wave height data can be collected and reported at user defined intervals that take into account deployment time versus battery life.

ADCP - RDI Workhorse

ADCP data can be collected via bottom moored and vessel mounted “roving” deployments. Current velocity information can be measured with either methodology, however, wave series spectrum and wave height information will only be available when using the seafloor mooring technique. ADCP systems come in a variety of frequencies which enable a significant variation in range, capability, and levels of precision. Instrument frequency selection requires well defined deliverables and project planning in order to achieve the survey goals.

Multiple ADCPs may be necessary to accommodate the precision necessary for the near shore environment and longer frequencies may be necessary when planning for the offshore oceanographic measurements.

Ultimately, both static and roving deployment methods will be required to fully characterize the sea state and current behavior. A well designed wave monitoring array can consist mostly of low cost pressure sensors doped with strategically placed moored ADCPs which will measure the directionality of the wave series. An array of this nature will be capable of describing the wave height, wave period, as well as differentiate multiple, convoluted, diffracted, or interfered wave series. If tidal information is desired, moored ADCPs will be required to measure at minimum one complete lunar cycle.

The roving method can range over extended distance and measure the prevailing currents from the deeper waters which will be forcing or driving the near shore areas. This is typically acquired along predefined linear transects which can be used to spatially identify current focal and peak flow approaches into the project area.

TerraSond has had significant success with the deployment and acquisition of moored ADCPs as well as the acquisition of roving current velocity measurements. We are prepared to acquire in native software and process the current velocity data in MATLab with proprietary scripts and techniques. The deliverables for current vector data typically take the form of velocity-scaled transect graphics or current velocity time series plots. Wave information will be processed and delivered as wave height time series, wave spectrum time series, and directional rose diagram plot. Tidal information will be processed with MATLab and can be interpolated beyond the measurement period. Discussion and interpretation are available within the TerraSond Oceanographic and Geophysical teams within TerraSond typically resulting in a conclusion and recommendation section of the project report.

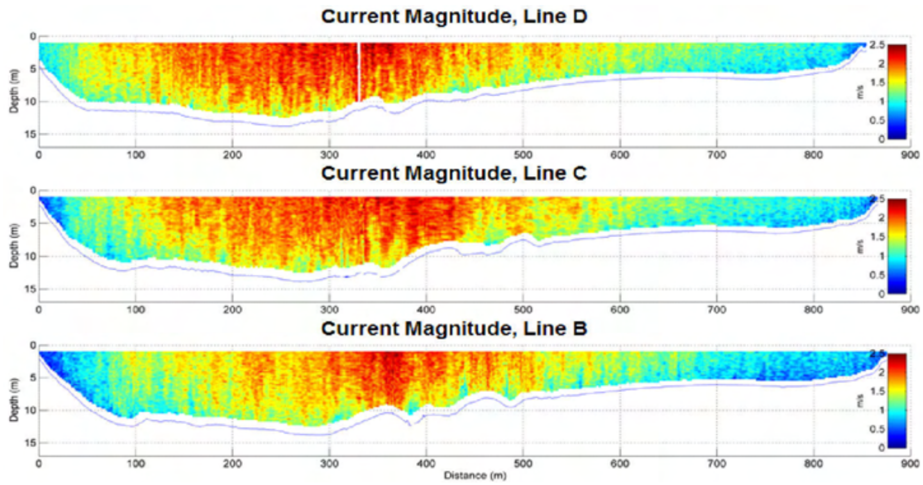

Figure 4: ADCP Transect data from vessel mounted sensor, viewed in profile (courtesy Terrasond Ltd.)

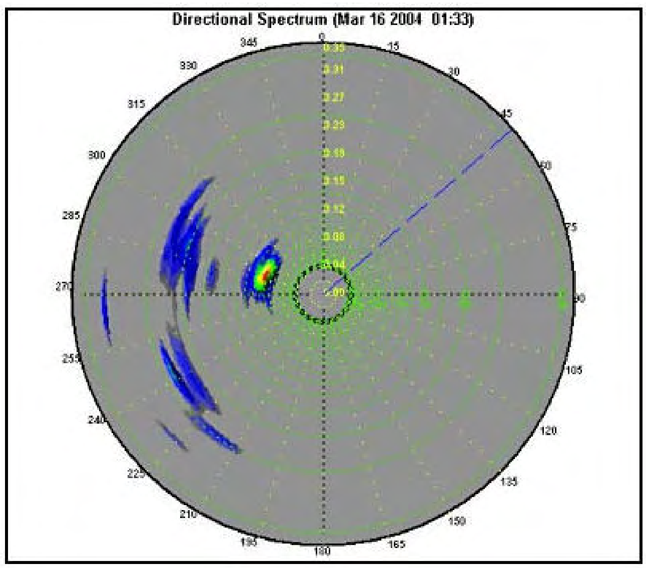

Figure 5: Wave height and directional spectrum from moored ADCP (courtesy RDI instruments)

Magnetometer - Marine Magnetics Sea Spy Explorer

The Marine Magnetics Explorer is highly sensitive towed magnetometer. This is a passive system that measures the regional magnetic field, and will detect any slight deviation from the baseline regional value. The system is ideal for ferrous target detection. The Explorer is used in conjunction with the Edgetech 4200 sidescan sonar, enabling superior depth control and system positioning.

Data can be sampled at up to 4Hz along track; however horizontal resolution, similar to the sub-bottom is determined by line spacing.

Deliverables are typically an area plot showing magnetometer data plotted along track lines. The locations of magnetic spikes are identified and geo-referenced on the chart.

Metal Detector - Geonics EM61S

The Geonics EM61S is a high-power submersible metal detector capable of detecting both ferrous and non-ferrous metals. The system generates a magnetic field which induces currents in nearby magnetic objects, these currents decay with time and the nature of the decay depends on the metallic characteristics of the object. The system is typically mounted to a submersible unit. Used in conjunction with the Marine Magnetics Explorer magnetometer, ferrous and non-ferrous contacts could be differentiated between.

Proposed Vessel

M/V Peregrine
For more info see: http://www.mvperegrine.com/

Figure 6: Proposed survey platform M/V Peregrine

Information Courtesy of TerraSond Limited

Appendix C
Basis of Cost Estimate

Data Collection Cost Estimate: Multi-sensor Marine Survey

Prepared by CH2M HILL

Adak Island Andrew Lake Seawall Marine Area

Purpose

Conduct multi-sensor survey of Andrew Bay (ALSW-01 submerged lands) to define site characteristics and to locate clustered and individual MEC items. Provide sufficient information to determine the nature and extent of the source of munitions that wash up at ALSW-01.

Scope

Provide integrated 3-dimensional electronic representations of site bathymetry, sea bottom properties, and geophysical anomalies. Also gather video, wave and tide, and supplementary information as needed to support identifying the nature and extent of UXO and DMM that wash up on ALSW-01. Deliver data under current DoD-acceptable standards for digital elevation and digital geophysical mapping.

Include multi-beam, side scan sonar, magnetometer, magnetic gradiometer, limited video, wideband frequency-modulated sub-bottom on fixed, surface tow, and submerged tow platforms as appropriate. Deploy acoustic doppler current profiler sensors for wave amplitude, return frequency, and directional data collection (as well as secondary data for tide and current flow) during the site survey and also deploy sensors for data collection over winter season.

Return to collect ADCP data, investigate anomalies, and address data gaps as identified and conduct intrusive survey as determined safe and appropriate. Conduct video survey via ROV to confirm features, and characterize deposits mapped during the previous season. Follow-on magnetometer surveys may be conducted to fill data gaps in areas determined to be accessible.

Assumptions

Survey operating day duration is 16 hours. Survey & oversight crew is staffed to provide 24-hour coverage for data review, equipment maintenance and repair, and other non-operating tasks.

All cost are in present day value.

Base scope survey duration	14	days
Geophysical prove-out control installation	1	days
Limited category investigation duration	3	days
Weather and other delay budget	10	days
Projected duration of each season's field effort	28	days

Phase 1 Conceptual Survey Plan: 1) execute control survey to establish terrestrial geodetic control and MLL tide datum; 2) deploy seed items for geophysical prove-out; 3) conduct multibeam survey for vessel safety, survey planning, and large groupings; 4) conduct side scan sonar, magnetometer, and sub-bottom survey; 5) conduct fixed array ADCP survey ongoing during entire survey phase; 6) deploy two ADCP sensors for 1-year data gathering duration. No intrusive activities planned so as to avoid undefined UXO hazards.

Phase 2 Conceptual Survey Plan: 1) recover ADCP sensors and download wave data; 2) conduct additional site information and UXO/DMM data gap investigation (likely magnetometer only), 3) utilize ROV to investigate anomalies, provide photographic, video, and magnetometer confirmation of bottom conditions, and access limited areas between boulders.

Munitions response safety issues identified during work planning can be resolved by avoidance of underwater bottom areas. Terrestrial survey team safety planning can be addressed with training and avoidance measures and conducted without staking. Vessel landings are not possible in Andrew Bay area. Full redundancy of all instruments is included in costs as 5-10 operating days can be lost at full standby cost should equipment be damaged, lost, or malfunction to a degree beyond repair onsite.

Estimated costs are based on analagous costs from recent project proposals and proposals from UXO investigation and removal contractors.

Data Collection Cost Estimate: Multi-sensor Marine Survey

Prepared by CH2M HILL

Adak Island Andrew Lake Seawall Marine Area

Description	Quantity	Unit	$/Unit	Total Cost	Basis
PHASE 1 INVESTIGATION					
Develop and Implement Site-Specific Plans					
Work Plans, includes extensive technology, QA/QC measures, and contingency plan development, health and safety plan	1	Lump Sum	$150,000	$150,000	Recent and ongoing Navy project effort.
Control Survey					
Control Survey Staff Mobilization	2	Persons	$1,250	$2,500	Vendor budgetary level of effort and recent Navy costs.
Survey Labor, 2 person crew	7	Day	$2,880	$20,160	Vendor budgetary level of effort and recent Navy costs.
Survey Equiment, GPS units	7	Day	$442.71	$3,099	Vendor budgetary level of effort and recent Navy costs.
Onsite Vehicle with Fuel, 2 each (crew operates independently)	7	Day	$120	$840	Vendor budgetary level of effort and recent Navy costs.
Per Diem, Adak, 2 persons	14	Day	$199	$2,786	Vendor budgetary level of effort and recent Navy costs.
Control Survey Staff Demobilization	2	Persons	$1,250	$2,500	Vendor budgetary level of effort and recent Navy costs.
Marine Survey Mobilization					
Vessel Preparation at Origin Port (Homer, Alaska)	4	Day	$14,942.43	$59,770	Vendor budgetary cost estimate.
Vessel Transit from Homer to Adak	7	Day	$12,149.55	$85,047	Vendor budgetary cost estimate.
Survey equipment Transit from Homer to Adak	7	Day	$9,801.50	$68,611	Vendor budgetary cost estimate.
Survey Labor, 4 persons	4	Persons	$1,250	$5,000	Vendor budgetary level of effort and recent Navy costs.
Marine Survey					
Seed items	10	Each	$1,000	$10,000	Allowance
Marine Survey, Vessel Day Rate with Crew	28	Day	$8,036.26	$225,015	Vendor budgetary cost estimate.
Surveying Labor, Per Diem, and Vehicles, 4 persons	28	Day	$6,234	$174,552	Vendor budgetary level of effort and recent Navy costs.
Survey Equipment (multi-beam, side scan sonar, magnetometer, limited video, sub-bottom profiler, ADCP fixed array)	28	Day	$25,227.26	$706,363	Vendor budgetary cost estimate.
ADCP Sensors, deployed for ~1 year data collection, 2 each	1	Lump Sum	$80,000	$80,000	Vendor budgetary cost estimate.

Data Collection Cost Estimate: Multi-sensor Marine Survey

Prepared by CH2M HILL

Adak Island Andrew Lake Seawall Marine Area

Description	Quantity	Unit	$/Unit	Total Cost	Basis
Survey Crew Demobilization					
Survey Labor, 4 persons	4	Persons	$1,250	$5,000	Vendor budgetary level of effort and recent Navy costs.
Vessel Transit from Adak to Homer	7	Day	$12,149.55	$85,047	Vendor budgetary cost estimate.
Equipment Transit from Adak to Homer	7	Day	$9,801.50	$68,611	Vendor budgetary cost estimate.
Vessel Restoration at Origin Port (Homer, Alaska)	4	Day	$14,942.43	$59,770	Vendor budgetary cost estimate.
Survey Deliverables and Reports	1	Lump Sum	$131,003	$131,003	Vendor budgetary cost estimate.
Survey Equipment Risk Budget	Loss Risk		Replacement	Risk Budget	Provision for equipment loss related to kelp, scrap, debris, and other entanglement hazards.
Multibeam and other fixed array	0.0%		$250,000	$0	Vendor risk estimate and rough order-of-magnitude replacement cost.
Side Scan Sonar	7.5%		$75,000	$5,625	Vendor risk estimate and rough order-of-magnitude replacement cost.
Sub-bottom Profile	7.5%		$90,000	$6,750	Vendor risk estimate and rough order-of-magnitude replacement cost.
Magnetometer	7.5%		$30,000	$2,250	Vendor risk estimate and rough order-of-magnitude replacement cost.
Bottom Drag	15.0%		$60,000	$9,000	Vendor risk estimate and rough order-of-magnitude replacement cost.
Project Management and Technical Support Travel During Survey					
Staff Mobilization	2	Persons	$1,250	$2,500	Recent and ongoing Navy project effort.
Staff Labor, 2 persons, for Duration of Control and Marine Surveys	37	Days	$1,972.74	$72,991	Recent and ongoing Navy project effort.
Onsite Vehicle	37	Days	$120	$4,440	Recent and ongoing Navy project effort.
Per Diem, Adak, 2 people	74	Days	$199	$14,726	Recent and ongoing Navy project effort.
Staff Demobilization	2	Persons	$1,250	$2,500	Recent and ongoing Navy project effort.
PHASE 2 INVESTIGATION					
Develop and Implement Site-Specific Plans					
Work Plans, includes review of previous years data and development of conclusions, target lists and data needs.	1	Lump Sum	$100,000	$100,000	Recent and ongoing Navy project effort.
Marine Survey Mobilization					
Vessel Preparation at Origin Port (Homer, Alaska)	4	Day	$14,942.43	$59,770	Vendor budgetary cost estimate.
Vessel Transit from Homer to Adak	7	Day	$12,149.55	$85,047	Vendor budgetary cost estimate.
Equipment Transit from Homer to Adak	7	Day	$9,801.50	$68,611	Vendor budgetary cost estimate.
Survey Labor, 4 persons	4	Persons	$1,250	$5,000	Vendor budgetary level of effort and recent Navy costs.

Data Collection Cost Estimate: Multi-sensor Marine Survey

Prepared by CH2M HILL

Adak Island Andrew Lake Seawall Marine Area

Description	Quantity	Unit	$/Unit	Total Cost	Basis
Marine Survey					
Marine Survey, Vessel Day Rate with Crew	28	Day	$8,036.26	$225,015	Vendor budgetary cost estimate.
Surveying Labor, Per Diem, and Vehicles, 4 persons	28	Day	$6,234	$174,552	Vendor budgetary level of effort and recent Navy costs.
Survey Equipment (multi-beam, magnetometer, video, ROV, ADCP fixed array)	28	Day	$19,254.26	$539,119	Vendor budgetary cost estimate.
Survey Crew Demobilization					
Survey Labor, 4 persons	4	Persons	$1,250	$5,000	Vendor budgetary level of effort and recent Navy costs.
Vessel Transit from Adak to Homer	7	Day	$12,149.55	$85,047	Vendor budgetary cost estimate.
Equipment Transit from Adak to Homer	7	Day	$9,801.50	$68,611	Vendor budgetary cost estimate.
Vessel Restoration at Origin Port (Homer, Alaska)	4	Day	$14,942.43	$59,770	Vendor budgetary cost estimate.
Survey Deliverables, Final Reports, Regulatory Meetings	1	Lump Sum	$250,000	$250,000	Recent and ongoing Navy project effort.
Survey Equipment Risk Budget	Loss Risk		Replacement	Risk Budget	Kelp, scrap, debris, and other entanglement hazards.
Multibeam and other fixed array	0.0%		$250,000	$0	Vendor risk estimate and rough order-of-magnitude replacement cost.
Magnetometer	5.0%		$30,000	$1,500	Vendor risk estimate and rough order-of-magnitude replacement cost.
Bottom Drag	10.0%		$60,000	$6,000	Vendor risk estimate and rough order-of-magnitude replacement cost.
Project Management and Technical Support Travel During Survey					
Staff Mobilization	2	Persons	$1,250	$2,500	Recent and ongoing Navy project effort.
Staff Labor, 2 persons, for Duration of Control and Marine Surveys	28	Days	$0	$0	Recent and ongoing Navy project effort.
Onsite Vehicle	28	Days	$120	$3,360	Recent and ongoing Navy project effort.
Per Diem, Adak, 2 people	56	Days	$199	$11,144	Recent and ongoing Navy project effort.
Staff Demobilization	2	Persons	$1,250	$2,500	Recent and ongoing Navy project effort.
SUBTOTAL				**$3,819,000**	
CONTINGENCY	20%		$3,819,000	$763,800	Per R.S. Means Reference Code #01-21-16.50 - Schematic stage.
SUBTOTAL - FIELD INVESTIGATION COST				**$4,582,800**	

Data Collection Cost Estimate: Multi-sensor Marine Survey

Prepared by CH2M HILL

Adak Island Andrew Lake Seawall Marine Area

Description	Quantity	Unit	$/Unit	Total Cost	Basis
PROJECT MANAGEMENT, ADMINISTRATION, AND DELIVERABLES					
GENERAL REQUIREMENTS	1%		$4,582,800	$45,828	Per R.S. Means Reference Code #01-21-55.50, adjusted downwards from 8% as many items are itemized.
OVERHEAD	5%		$4,582,800	$229,140	Per R.S. Means Reference Code #01-31-13.70.
GENERAL AND ADMINISTRATIVE	11.7%		$4,582,800	$536,188	Per CH2M HILL Forward Pricing Rate Agreement for 2010.
PROJECT MANAGEMENT AND ADMINISTRATIVE	10%		$4,582,800	$458,280	Commonly used budgetary allowance.
STRUCTURAL ENGINEERING, DESIGN, AND REVIEW	2.5%		$4,582,800	$114,570	Per R.S. Means Reference Code #01-11-31-30-1300.
TOTAL COST				**$5,966,805**	
FEE	8%		$5,966,805	$477,344	
BONDING AND INSURANCE	3%		$0	$0	Not applicable to investigation work.
TOTAL				**$6,444,149**	
			Lower Range (-30%)	**$4,510,905**	
			Upper Range (+50%)	**$9,666,224**	
Total Cost				**$6,444,149**	

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APPENDIX D

Remedial Action Alternatives Assessment

This appendix screens the conceptual approaches to underwater munitions and explosives of concern (MEC) remedial actions that could be used in Andrew Bay and evaluates the most likely remedial action that would be implemented in Andrew Bay based on the Project Team's best professional judgment. This appendix was developed in the absence of definitive data on the nature and extent of MEC present and many other topics needed to develop a feasibility study (FS) under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements. However, to develop general level of effort and costing information, remedial alternatives were considered and the most likely method chosen that considers the assumed dispersal of munitions, location, sea and seafloor conditions, and technological capabilities.

D.1 Depositional and Transport Model

The location, content, and extent of the MEC source area are unknown, as are the specific physical conditions that govern MEC movement and deposition across the area of concern (AOC). This lack of information restricts decision-making about the types of remedial action alternatives that might be appropriate to address MEC hazards at Andrew Lake Seawall (ALSW-01). However, based on the information reviewed to date and knowledge of site conditions, the following depositional and transport model can be constructed:

- MEC is present and mobile off the Andrew Lake Seawall out to a depth of 300 feet.
- MEC is assumed to be present in a primary source area of 250 acres with limited quantities at dispersed locations within an area of 2.25 square miles.
- The MEC might be present in piles and is present individually spread along the seafloor, both on and below cobbles, among boulders, and potentially in kelp beds.
- The seafloor consists of cobbles and boulders, with some sandy areas to the center of Andrew Bay and kelp density increasing to the east and west of the bay.
- Sea conditions can be very aggressive, with periods when no on-water work is possible. In addition, no sheltered areas are present on the north side of the island for on-water staging of equipment during periods of foul weather

D.2 Remedial Action Objectives

Remedial action criteria (RACs) as discussed here are based on the requirements of the National Contingency Plan (NCP) to minimize potential exposure to MEC given reasonably anticipated future land use activities. Furthermore, it is U.S. Navy policy in accordance with NAVSEA Ordnance Pamphlet 5 to use all reasonable means possible to protect the public from exposure to hazards from real property contaminated with ammunition, explosives, or chemical warfare materiel (U.S. Navy, 2005). Real property known to be contaminated with ammunition, explosives, or chemical warfare materiel must be decontaminated using the most reasonable and appropriate technology to protect the environment and public consistent with the property's proposed end use.

Remedial action objectives (RAOs) are part of the RACs for a project, which also include remedial action goals and general remedial actions. RAOs define cleanup performance goals and specify contaminants and media of concern, exposure routes and receptors, and acceptable contaminant levels. No explosive safety hazard assessment (ESHA) score has been developed to date for the marine portion of ALSW-01 because human exposure to MEC in the submerged marine environment is not considered in the ESHA methodology.

The RAO pertaining to the explosive safety aspect of MEC is directly related to the relationship among, and the collective evaluation of, the established ESHA hazard factors. This evaluation should, therefore, account for the risk MEC poses to human receptors in the terrestrial areas of the seawall. Accordingly, the following RAO has been developed for tidelands and submerged lands presumed to be the source of MEC hazards present in ALSW-01:

- Provide protection to human health and the environment by reducing and mitigating the explosive hazard to an ESHA score of B or better that is commensurate with the reasonably anticipated future land use of wildlife management\recreation\subsistence for ALSW-01.

Meeting this RAO would facilitate removing existing access restrictions and transferring real property related to ALSW-01, as is currently contemplated by the Navy. For the purposes of this assessment, it is assumed that there are no unacceptable exposure risks to human health and ecological receptors from MC because of the energetic site conditions; inferences that can be made from the risk assessment results in the OU B-2 RI; and also the similar types of contaminants, fate factors, transport factors, and attenuation factors expected at Andrew Bay. Consequently, this appendix does not address assessment and mitigation of such risks.

D.3 Remedial Action Goals

Remedial action goals consist of media- or OU-specific goals for protecting human health and the environment. Given that the anticipated future land use at the site is as a wildlife refuge/subsistence/recreation area, the preliminary overall MEC remedial action goals for ALSW-01 are to implement measures that reduce the potential for exposure to explosive hazards from MEC to site users under the reasonably anticipated future land use scenario. This goal would be met through the following action:

- Remove MEC from the source area so that deposition no longer occurs along the seawall.

In the event that not all transportable MEC is removed from Andrew Bay, annual seawall sweeps would be continued. Furthermore, consistent with Navy goals for all of Adak Island, the Navy would maintain community awareness as to the residual explosive safety risk from MEC and define the response process to be used if MEC were to be encountered by the public. The current institutional and engineering controls, including community outreach and education and restricted site access through fencing and gates, would be continued. Access restriction points may change based on remediation occurring at other parts of the island.

D.4 General Remedial Actions

This section identifies remedial action techniques and technologies that could be used for underwater MEC recovery in Andrew Bay and indicates those that cannot be evaluated at this time or that appear to be inappropriate at a conceptual level. The underwater environment poses additional challenges for MEC removal above that for terrestrial munitions response sites. These challenges include safety issues associated with the generally more unstable underwater environment from factors such as waves, tides, currents, low visibility, and sedimentation. Safety must be of the highest priority in regard to divers and all other personnel for underwater MEC response actions. The subsections below discuss individual approaches for underwater MEC remedial actions.

D.4.1 Divers

Explosive ordnance disposal (EOD) or unexploded ordnance (UXO) qualified divers could be used to conduct visual and handheld instrument-guided searches to detect and remove MEC in water depths of 120 feet or less. As a guide for level of effort, a diver can perform two dives per day of one hour or less in waters 60 feet deep. This depth range would not require decompression diving although barometric chambers would be required onsite. These depth ranges also conform to Navy policies that limit the depth of underwater munitions response actions (U.S. Navy, 2005). These searches could be conducted in clear or turbid waters using a grid pattern technique. If MEC were found, divers could assess the safety and logistical aspects of moving the items, and then remove the appropriate small MEC by hand or other means and bring them to the surface for proper handling.

Using divers is a time-consuming and inherently dangerous operation, especially in waters as remote to medical support infrastructure as Adak Island. The often harsh weather conditions, cold water temperatures, waves, and tides in Andrew Bay would make this approach even more dangerous. The U.S. Navy Diving Manual typically does not allow diving in currents in excess of 1 knot. Diving requires extensive logistical and emergency services support. Divers are only able to remove by hand small MEC located on the seabed floor, although airbags, winched lines, and robotic arms might be used for larger items. Large boulders have been reported as prevalent on the seabed floor. MEC that is partially buried or obscured by poor water visibility, kelp, or large boulders would be difficult to locate and remove from this area.

Close inspection of suspected MEC located within and among boulders or kelp would be necessary to assess the potential for safe removal. This appears to be conceptually difficult and complex in terms of managing safety risks and requirements, and ineffective in producing an efficient rate of clearance operations. The likely source area immediately adjacent to the shoreline depositional portion of ALSW-01 and within the 100-foot depth contour is roughly 250 acres in extent, an exceptionally large area for divers to cover given the short working season in Andrew Bay. The actual extent of MEC may be much larger (on the order of thousands of acres) and in much deeper waters (up to 300 to 600 feet deep), further complicating diving and removal operations and extending the required duration of clearance. The expected safe rate of survey, assessment, and clearance of MEC from among the large-diameter boulders and kelp reported in this area is likely to be very low.

Little is known about the areal density throughout the possible source areas. Reliable estimates of this factor would be needed in addition to establishing a sound estimate of underwater survey and clearance rates. A surface swimmer survey discussed in the Data Collection Assessment TM described the sea bottom adjacent to ALSW-01 in waters about 15 feet deep as “an ordnance rich environment” (U.S. Navy, 2000).

Given the factors discussed above, clearance of the submerged lands that are the source of MEC deposition at ALSW-01 by divers is not considered further in this assessment. Diving surveys and clearances are viewed as an ancillary approach to other techniques in that they could be used to further refine surveys and augment clearance operations. Clearance with trained divers could be reevaluated should future developments indicate a relatively confined source area grouping in shallow water allowing for safe inspection and handling, or should other information become known that contradicts the extent of MEC presence indicated at the time of this assessment.

D.4.2 Magnets and Electromagnets

Large industrial magnets operated by cranes have been used successfully by dredging, salvage, and marine construction companies to remove metal debris and to lift other metallic objects from underwater (motor vehicles). Magnets could be dragged along the bottom surface to recover ferrous objects on or slightly below the seafloor. Crane operator compartments could be hardened to protect operators from an unplanned detonation. Metallic objects collected from the seafloor could be placed in a large shielded area on a barge. UXO technicians could then inspect, sort, and segregate MEC and metallic debris as appropriate.

This approach requires construction of a barge deck for the operation and the transport of the barge, crane, magnet, and very substantial electrical generator to Adak. A limited work window is available for such operations in Andrew Bay because of weather conditions. In addition, the ability of magnets to remove objects is significantly reduced as the depth of the object increases. No case studies were identified that describe the use of magnets or electromagnets for the removal of underwater MEC. Other challenges to implementing this approach include the seafloor composition and aquatic plant life. In the shallower waters of Andrew Bay, the seafloor consists of large-diameter boulders that would make it very difficult to effectively traverse magnets or electromagnets along the seafloor. Kelp beds may also limit the area in which these magnets could be dragged through the water. Scrap metal and other debris are likely to be present given the use of target sleds in the area.

Planning for the handling of the MEC on the barge deck, and, to a lesser extent, during its capture at the bottom of Andrew Bay, must consider the explosive hazard associated with the electromagnetic fuzing on some MEC. Given that no case studies were found for the large scale removal of munitions using magnets, and the specialized equipment required at a remote site that lacks material support, this alternative is not considered further.

D.4.3 Mechanical Rake

A mechanical rake with large tines could be used to scrape sediment in an attempt to recover MEC that is on or shallowly buried in the seafloor. The rake is limited in its ability to recover objects in deep sediment by the length of its tines and the distance between tines. Rakes are most effective where the seafloor is not rocky because the rocks could interfere with the movement of the rake and associated MEC recovery. Objects collected from the seafloor could be placed in a large container located on a barge. UXO technicians could then inspect, sort, and segregate MEC and metallic debris as appropriate.

Use of the mechanical rake technology would involve addressing munitions response safety requirements and protective engineering measures for crew members similar to those for magnetic methods described above.

The effectiveness of this technology depends on the seafloor composition, which precludes it from being useful in all or most of the expected MEC source area. Sediments that contain large-diameter boulders may clog the rake, making it difficult to recover MEC. Mechanical rake technology would remove both metallic and nonmetallic material, which would need to be managed separately. This would include a more robust screening process than with magnetic methods. Finally, the mechanical rake technology would be impractical to execute in areas of Andrew Bay with dense kelp beds.

Ecological damage risk exists for actions that remove contaminated sediments, and would need to be assessed against the expected benefits of achieving the RAO. While the RAO involves mitigating explosive hazards to human receptors, U.S. Environmental Protection Agency (EPA) CERCLA guidance recommends that ecological risk management "…balance (1) residual risks posed by site contaminants before and after implementation of the selected remedy with (2) the potential impacts of the selected remedy on the environment independent of contaminant effects." This alternative is not considered further based on its inability to remove materials from beneath larger cobbles and boulders, the expected continual damage to the rake tines, and the inability to access all portions of the bay.

D.4.4 Entombment

MEC entombment might be an acceptable approach if it could be demonstrated that entombment is a permanent isolation of the MEC source. Entombment may be a conceivable approach to meeting the RAO for ALSW-01, but the size of rock would likely need to be very large due to the relatively high wave heights and frequencies prevalent in the Bering Sea. Detailed and reliable bathymetric, sea-bottom composition, wave, current, and MEC presence data would be required to properly design such a remedy.

Entombment is a remedy that is rarely considered for reducing explosive risks at munitions response sites. Successfully deploying a rock cap over such a large area would involve massive quantities of materials. Minor variations in the deployment of capping materials might allow significant explosive risks to remain active. Deploying rock on top of areas where extensive MEC (and explosive risks) are known to be present is conceptually inadvisable. Furthermore, permitting issues, habitat damage, and wildlife take is likely to be extensive with any entombment or capping approach, given the expected widespread extent of MEC presence in Andrew Bay. Finally, this approach would likely be irreversible in that future removal of entombed materials would likely generate significant risks from the entombed MEC itself because removal of the cap would necessarily impart shock to any entombed MEC. Given the area affected and the quantity of materials required, plus the dynamic nature of the area, this alternative is not considered further in this evaluation.

D.4.5 Dredging

Hydraulic or mechanical dredging is an approach that can be used to remove sediment from designated underwater locations. Dredge spoils could be screened to separate MEC and other metallic debris for handling in an adjacent barge. In general, hydraulic dredges are more productive and mechanical dredges are best suited for removing large amounts of sediment. Dredging would require UXO construction support for inspection and segregation of MEC and metallic debris in the dredge spoils.

There are many variations of dredging approaches used depending on the nature of seafloor composition. Numerous types of dredge buckets (including clamshell buckets, backhoe, hopper, and hydraulic pipeline dredges) and sediment segregation methods are used to maximize the effectiveness of dredging (U.S. Army Corps of Engineers [USACE], 2006). Although a pilot study could be conducted to determine the specific dredging technologies most appropriate for Andrew Bay, a large scale clamshell bucket is believed to be the most effective means to remove the cobbly substrate for sorting on a barge deck. Dredging has been successfully implemented to remove MEC from underwater sources in locations such as the Toussaint River near Toledo, Ohio (USACE, 1998) and pilot studies conducted at Jackson Park Housing Complex in Bremerton, Washington (U.S. Navy, 2010).

One benefit of dredging is the capability of covering a relatively large area. In addition, clamshell dredging has been implemented to depths of 200 feet. Dredging would be very expensive and require mobilization of specialized barges to Adak Island. Significant permitting would also be expected. Increased engineering protective measures would have to be implemented for the safety of crewmembers. Dredging would remove both metallic and nonmetallic material that would need to be managed separately. If the seafloor consists of large boulders, the efficiency of operations would be reduced, given the requirement to handle large quantities of rock mixed with debris and MEC. This would require a yet more robust screening process than is required with magnets or rakes.

Use of dredging methods for MEC clearance would involve addressing munitions response safety requirements and protective engineering measures for crewmembers similar to those for the magnetic methods described above. Furthermore, permitting issues, habitat damage, and wildlife take is likely to be extensive with any dredging approach, given the expected widespread extent of MEC in Andrew Bay. Additionally, any activity that intentionally disturbs potential MEC on the sea bottom would generate the risk of unintentional detonation. The most direct threat from this type of detonation would likely not be blast or fragmentation, but instead would be the generation of a large detonation bubble. This bubble, which could produce an effect similar to that of sea mines, could endanger the dredge platform or support vessels. If suction dredging were implemented, screens could be used to limit the size of potential MEC recovered. This practice would enable the recovery of items such as 81mm mortar projectiles, while reducing the risk of recovering larger items that might require more blast and fragmentation mitigation. This practice would require the use of other methods to address larger MEC.

Of the items discussed, dredging represents the greatest amount of material handling with assessment, sorting, and handling of mixed debris, rock, sediment, and MEC by response personnel required on a barge deck. MEC is likely to be in varying states of corrosion and abrasive damage on the seafloor. The types of MEC include small arms ammunition up to bombs and similarly large munitions. Further handling of these items with mechanical means and with mixed materials is likely to further damage the munitions items. Reliable remote mechanized methods for the inspection and safe handling of hundreds or thousands of cubic yards of sediments and debris-containing munitions items were not identified during research for this assessment. Thus, the safe and efficient processing of recovered MEC and other materials may be infeasible with respect to safety risks.

Given the robustness of the dredge buckets and the non-specialized equipment that would be used (thereby easier to maintain and repair on island), dredging is considered further in this evaluation.

D.5 Case Study: Pilot Test for Dredging in Ostrich Bay

The U.S. Navy conducted a Pilot Feasibility Study (FS) in the Pier Area of Ostrich Bay for potential discarded military munitions (DMM). This Pilot FS included Pilot-scale testing of sediment removal and material processing systems in support of development of FS alternative analysis for remedial actions planned around Pier 1 and Pier 2 portions of Ostrich Bay. The bottom of Ostrich Bay is likely composed of relatively deep, homogeneous silt, or may have exposed outcroppings of bedrock (Environmental Security Technology Certification Program [ETSCP], 2008).

Three sediment dredging techniques were tested:

- Standard clamshell dredge bucket
- Modified clamshell dredge bucket
- Modified skeleton excavator bucket

Prior to conducting the study, a geophysical survey and diver target investigation of the study area was performed in order to detect and recover potential DMM prior to dredge operations and to support evaluation of the dredge techniques. In addition to the sediment removal techniques, three sediment screening or processing methods were also evaluated:

- A hopper and conveyor assembly coupled with an electromagnet and metal detector
- A multistage screening structure coupled with water nozzles
- A floating screen platform coupled with water nozzles

The modified clamshell bucket, or a variation, was determined to be the most efficient dredge method in Ostrich Bay. The modified bucket, as anticipated, allowed a degree of fine sediment to wash from the bucket during recovery. Results of the pilot testing for the modified dredge bucket are inconclusive with respect to recovery of items of interest greater than 0.75 inch in size. The floating screen platform was found to be the most effective sediment screening method. The adhesive nature of the sediments rendered the hopper and magnet assembly unsuitable for continued testing. (U.S. Navy, 2010)

An important consideration when comparing the dredging conducted at Ostrich Bay to the dredging that would be performed in Andrew Bay is the different physical setting and sea energy. Ostrich Bay dredging was conducted in a shallow (<40 feet), low-energy setting that allowed precise depth and position control. Little re-dredging of an area was required to confirm a particular area was accessed. Weather was not a factor and a hospital was available at the location. None of these conditions exist at Andrew Bay, where the harsh sea conditions and climate, requirement to access deeper water, cobbles and boulders comprising the bottom, and remote setting all contribute to performance and quality obstacles, as well as health and safety risk.

D.6 Remedial Alternative Assessment: Dredging

The following section describes the dredging alternative in further detail and the assumptions associated with the approach. The assumptions were developed by examining the effort and related costs associated with analogous activities identified in past projects and other reference sources. Assumptions have been used to set broad boundaries on the conceptual scope of work for the purposes of comparative alternative evaluation.

These assumptions were used to develop a cost estimate as presented in the Conceptual Remedial Action Cost Estimate that follows this narrative. The major assumptions include the following:

- It is assumed that underwater MEC removal will occur in depths ranging from approximately 10 to 200 feet below the surface (the reasonable maximum depth for dredge buckets). This is based on technology limitations and exceeds current Navy policies that limit underwater munitions response actions to water depths of 120 feet or less based on diver access (U.S. Navy, 2005), but does not satisfy the analysis previously described in this assessment, which found that the majority of MEC that washes up on ALSW-01 is likely from depths to 300 feet deep.
- The underwater MEC removal area was assumed to involve removal within a primary source area of 250 acres.
- Using the primary source area (250 acres) and clearing the upper 3 feet of bottom materials, 1.25 million cubic yards of material would require handling and sorting. The actual quantity of dredge spoils to be handled may be much larger.
- A Naval Ordnance Safety and Security Activity (NOSSA)-approved Explosives Safety Submission (ESS) and Project Team-approved Work Plan would be prepared prior to any work being conducted. The requirements for USACE and National Environmental Policy Act (NEPA) permits for dredging would be required to be met.
- EOD or UXO-qualified personnel would conduct all work related to MEC removal. The rate of inspecting, sorting, and removing MEC is highly uncertain and may significantly affect production rates.
- A total of 20 UXO-qualified personnel and professional labor would be involved, including UXO Technician I, II, and III personnel, a Paramedic Class IV, a Senior UXO Supervisor, UXO Quality Control/Safety Officer, Project Engineer, Environmental Scientist/Compliance Specialist, and Geographic Information Systems (GIS) Technician.

- Tugboats, dredging equipment, a work barge, and two sorting barges would be mobilized from Seattle, Washington.
- Dredging equipment would include a variety of ancillary equipment, such as a grizzly screen with two-belt conveyor delivery, and electromagnets for separation. Work barges include front-end loaders to handle materials on barge for sorting and water dumping.
- Dredge contractor would equip barge with spare parts for the soil conveyor, the dredge, and other equipment. Equipment would also include pickup trucks for island transport and smaller support boats.
- 18 miles one-way from Sweeper Cove in Kuluk Bay to the midpoint of the ALSW-01 offshore area, travel between Sweeper Cove and ALSW-01 offshore area at 12 knots.
- Some marine equipment would be moored closer to ALSW-01 area with work crews mobilized each day from Sweeper Cove in tender boats, though there does not appear to be suitable coves adjacent to ALSW-01 offshore area.
- An ROV would be used to inspect dredged areas for residual munitions.
- Fuel would be purchased for dredge ship, barge, transfer tugs, two tender boats, grizzly on the barge, and generator for electromagnets. Fuel purchases for marine operations will be made locally.
- Armoring for working ship around the pilothouse and hull armoring would be required. The crane operator’s cab would also require armoring with Plexiglas sheeting, approximately 6 inches thick.
- Existing on-island munitions bunkers would be used. One hundred pounds net explosive weight (NET)/year donor explosives would be needed for disposing of MEC/material documented as an explosive hazard (MDEH), jet perforators, boosters, detonating cord, and blasting caps.
- Assumption of work time on a 75 percent basis because of weather and sea conditions. Likely would take 7 seasons to complete the work. This would depend on the information gathered during the separate data collection/data gap discovery phase.
- Food and lodging arrangements on Adak would be provided in old Navy buildings operated by local and/or Native corporations.
- Crews for workboats would come from Anchorage or Dutch Harbor. UXO crews would fly in and out of Adak for work rotations on commercial air carriers. Supplies by commercial cargo carriers. Munitions supplies and equipment by military cargo aircraft.

The total 7-year net present value estimated cost for dredging is $136 million. The basis for this cost range is documented in the Conceptual Remedial Action Cost Estimate following this narrative. There is a relatively high uncertainty associated with the costs for this remedial approach because they are dependent on broad assumptions about the nature and extent of MEC source areas in Andrew Bay.

There are feasibility issues associated with this alternative. These issues include the following:

- Weather conditions limiting the amount of work time.
- Logistical challenges associated with getting materials to Adak.
- Time-consuming work likely to take seven seasons.
- Effectiveness of dredging technologies in areas of large boulders and kelp beds.
- Meeting the permitting requirements of USACE/NEPA.
- The effectiveness of mechanical dredging becomes limited at depths greater than about 200 feet. MEC may be located at depths up to about 600 feet, based on current information.
- To maximize the effectiveness of the dredging/raking technologies, it would likely be necessary to perform pilot test studies of specific dredging, raking, and MEC sorting equipment prior to full implementation of the alternative.

Assuming that the extensive technical feasibility issues previously discussed are resolved and the project could be successfully implemented; dredging, while identified as the most effective alternative, may not be fully protective of human health and the environment. Given the practical, technical, and spatial limitations of dredging at Adak Island, individual MEC items may remain in the dredged area. MEC items may also be present outside of the dredging area. Given that explosive hazards may arise from a single MEC item that migrates to the depositional zone, explosive hazards at ALSW-01 would remain.

D.7 References

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Conceptual Remedial Action Cost Estimate

Prepared by CH2M HILL

Adak Andrew Lake Site - Dredging Cost

Assumptions:

Material can be dredged by clamshell or other special bucket.
Area assumed for dredging is 250 acres, depth assumed 3'. Volume is 1,210,000 cy. Nominal Production 100 cy/hr. Nominal work duration of 12,500 crew hours.
Season is 15 weeks, two 10 hour shifts, 6 days per week. 90 days x 20 hrs /day = 1800 crew hours per year.
Required duration = 12,500 crew hours / 1,800 crew hours/year = 7 years of dredging.
One clamshell dredge barge and two work barges for receiving, sorting, and releasing dredge spoils.
Demobilize equipment each season.
Then no further work based on annual count of washup items.
Actual dredging area and downtime for weather and other delays offset each other such that the actual removal area is estimated to be approximately 188 acres.

Description	Quantity	Unit	$/Unit	Total Cost	Basis
CAPITAL COST:					
Develop and Implement Site-Specific Plans	1	LS	$150,000	$150,000	Recent Experience
Develop and Implement an Explosive Safety Submission (ESS)					
Completion of an Explosive Safety Submission	1	LS	$25,000	$25,000	Engineer's estimate based on recent project bid from UXO Contractor
Dredging Work					
Year 1 Dredging					
Safety Modifications to Dredging Equipment	3	LS	$50,000	$150,000	Allowance
Mobilization of Personnel to Anchorage/Adak	40	Persons	$1,250	$50,000	Recent and ongoing Navy project effort.
Mobilization of 3 barges (dredge and two sorting barges)	1	LS	$1,300,000	$1,300,000	Recent and ongoing Navy project effort.
Minor Site Clearing for beach access and shelter	1	LS	$25,000	$25,000	Allowance
Access Road Upgrade/Repair	2,000	LF	$100	$200,000	Recent and ongoing Navy project effort.
Dredging or Raking Operation (barges, equipment, and crews)	3.5	MO	$2,018,044	$7,063,154	From HCSS software detailed crew and equipment cost estimate.
UXO Labor, 20 persons	3.5	MO	$504,000	$1,764,000	Recent and ongoing Navy project effort.
Onsite Vehicle, 6	36	MO	$1,200	$43,200	Shipped on project barges.
Per diem, Adak, 40 persons	4,480	DAY	$199	$891,520	Recent and ongoing Navy project effort.
One Rotation Personnel to Anchorage/Adak	40	Persons	$2,500	$100,000	20 persons, 2 shifts, 2 rotations
Magazine Mob/Demob	2	LS	$2,000	$4,000	Allowance
Magazine Grounding	1	LS	$2,500	$2,500	Allowance
Magazine Fencing	1	LS	$1,500	$1,500	Allowance
Location surveys to document dredged area	5	DAY	$2,520	$12,600	Allowance
Demobilization Personnel to Anchorage/Adak	40	Persons	$1,250	$50,000	17 persons, 2 shifts
Demobilization, 3 barges	1	LS	$1,300,000	$1,300,000	Recent and ongoing Navy project effort.
Disposal of Recovered MEC					
Disposal of Recovered MEC	15	Ea	$6,666.67	$100,000	Engineer's estimate based on pricing from USA Environmental, Inc.
Disposal of Recovered MPPH	20	Tons	$750	$15,000	Engineer's estimate based on pricing from USA Environmental, Inc.
SUBTOTAL				**$13,247,474**	

Conceptual Remedial Action Cost Estimate

Prepared by CH2M HILL

Adak Andrew Lake Site - Dredging Cost

Description	Quantity	Unit	$/Unit	Total Cost	Basis
CONTINGENCY	20%		$ 13,247,474	$2,649,495	Per R.S. Means Reference Code #01-21-16.50 - Schematic stage.
SUBTOTAL - Year 1 Cost				**$15,896,969**	
GENERAL REQUIREMENTS	8%		$ 15,896,969	$1,271,758	Per R.S. Means Reference Code #01-21-55.50.
OVERHEAD	5%		$ 15,896,969	$794,848	Per R.S. Means Reference Code #01-31-13.70.
PERMITTING AND LEGAL	2%		$ 15,896,969	$317,939	Per R.S. Means Reference Code #01-41-26.50.
GENERAL AND ADMINISTRATIVE	11.7%		$ 15,896,969	$1,859,945	Per CH2M HILL Forward Pricing Rate Agreement for 2010.
SERVICES DURING CONSTRUCTION	10%		$ 15,896,969	$1,589,697	Includes project management and construction management cost, commonly used budgetary allowance.
ENGINEERING & DESIGN COST	6%		$ 15,896,969	$953,818	Per R.S. Means Reference Code #01-11-31.30.
SUBTOTAL - Implementation Cost Year 1				**$22,684,974**	
FEE	8%		$ 22,684,974	$1,814,798	Per R.S. Means Reference Code #01-31-13.50.
BONDING AND INSURANCE	3%		$ 22,684,974	$680,549	Per R.S. Means Reference Code #01-31-13.90.
TOTAL - Capital Cost: Year 1				**$25,180,000**	
TOTAL - Reoccuring Annual Dredging Cost				**$24,847,371**	Dredging Work Costs Plus Markup Percentages
Construction Completion Report at End Of Project, Year 7	**1**	**LS**		**$200,000**	
TOTAL - Net Present Value, Years 1 thru 7				**$135,992,379**	
			Lower Range (-30%)	**$95,194,665**	
			Upper Range (+50%)	**$203,988,569**	
			Discount rate	**7%**	

Net Present Value (NPV Calculation):

Year	Total Capital Cost	Total NPV Cost	
1	$25,180,000	$25,180,000	Plans/Dredging Year 1
2	$24,847,371	$21,702,656	Dredging Year 2
3	$24,847,371	$20,282,856	Dredging Year 3
4	$24,847,371	$18,955,940	Dredging Year 4
5	$24,847,371	$17,715,832	Dredging Year 5
6	$24,847,371	$16,556,852	Dredging Year 6
7	$25,047,371	$15,598,244	Dredging/Final Report Year 7
Total Cost		**$135,992,379**	